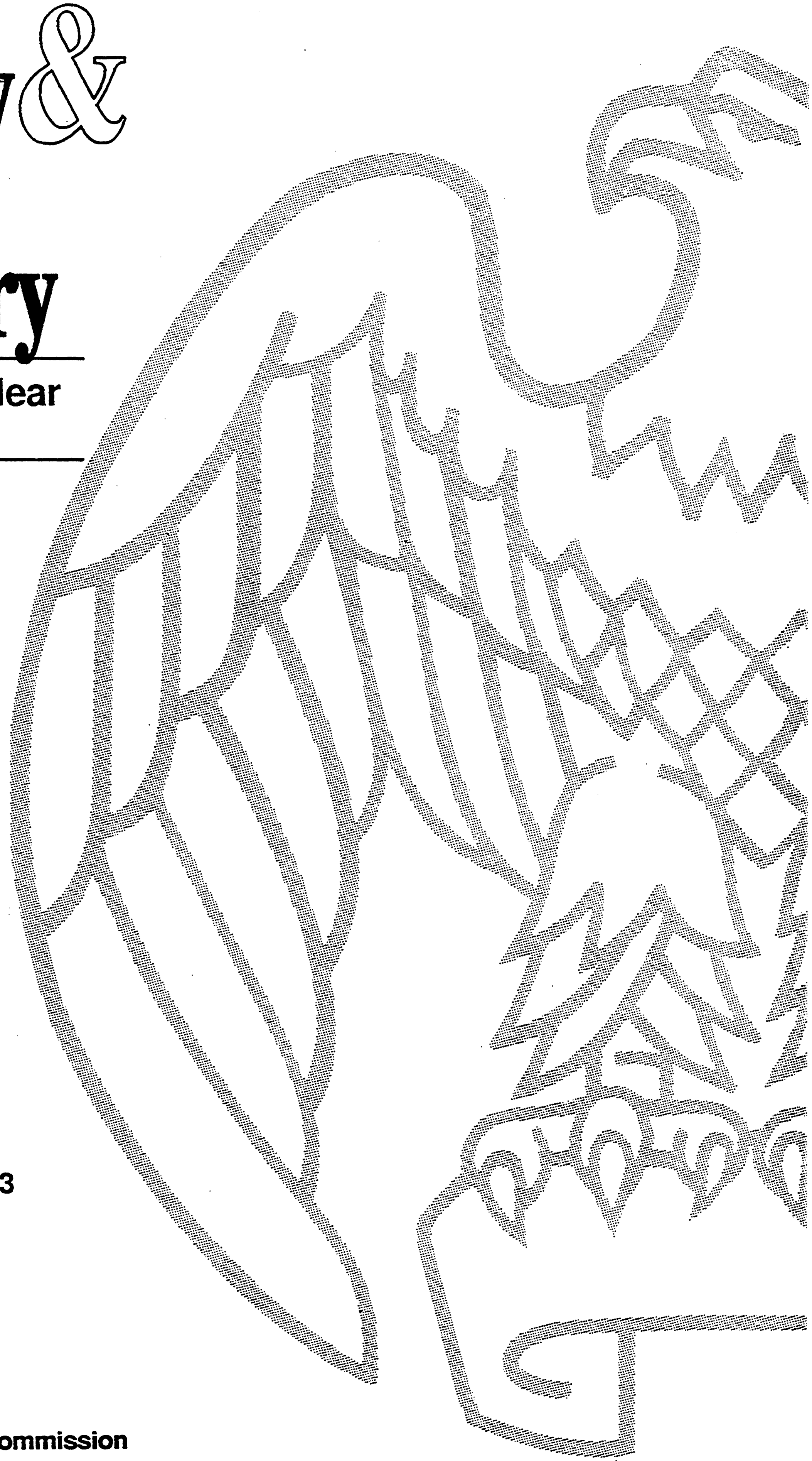
Industry & Trade Summary

Uranium and Nuclear Fuel



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PREFACE

In 1991 the United States International Trade Commission initiated its current *Industry and Trade Summary* series of informational reports on the thousands of products imported into and exported from the United States. Each summary addresses a different commodity/industry area and contains information on product uses, U.S. and foreign producers, and customs treatment. Also included is an analysis of the basic factors affecting trends in consumption, production, and trade of the commodity, as well as those bearing on the competitiveness of U.S. industries in domestic and foreign markets.[1]

This report on uranium and nuclear fuel covers the period 1989 through 1993 with import and export data supplied for 1990-94 and represents one of approximately 250 to 300 individual reports to be produced in this series. Listed below are the individual summary reports published to date on the chemicals, energy, and textiles sectors.

USITC publication number	*Publication date*	*Title*
Energy and Chemicals:		
2458	November 1991	Soaps, Detergents, and Surface-Active Agents
2509	May 1992	Inorganic Acids
2548	August 1992	Paints, Inks, and Related Items
2578	November 1992	Crude Petroleum
2588	December 1992	Major Primary Olefins
2590	February 1993	Polyethylene Resins in Primary Forms
2598	March 1993	Perfumes, Cosmetics, and Toiletries
2736	February 1994	Antibiotics
2739	February 1994	Pneumatic Tires and Tubes
2741	February 1994	Natural Rubber
2743	February 1994	Saturated Polyesters in Primary Forms
2747	March 1994	Fatty Chemicals
2750	March 1994	Pesticide Products and Formulations
2823	October 1994	Primary Aromatics
2826	November 1994	Polypropylene Resins in Primary Forms
2845	March 1994	Polyvinyl Chloride Resins in Primary Forms
2846	December 1994	Medicinal Chemicals, except Antibiotics
2866	March 1995	Hose, Belting, and Plastic Pipe
2943	December 1995	Uranium and Nuclear Fuel
Textiles and Apparel:		
2543	August 1992	Nonwoven Fabrics
2580	December 1992	Gloves
2642	June 1993	Yarn
2695	November 1993	Carpets and Rugs
2702	November 1993	Fur Goods
2703	November 1993	Coated Fabrics
2735	February 1994	Knit Fabric
2841	December 1994	Cordage
2853	January 1995	Apparel

[1] The information and analysis provided in this report are for the purpose of this report only. Nothing in this report should be construed to indicate how the Commission would find in an investigation conducted under statutory authority covering the same or similar subject matter.

CONTENTS

	Page
Preface	i
Introduction	1
Scope	1
Organization of the report	4
U.S. industry profile	4
Industry structure	4
Uranium mining and milling industry	6
Uranium conversion industry	9
Uranium enrichment industry	9
Nuclear fuel fabrication industry	12
Production	12
General characteristics of the uranium and nuclear fuel industry	13
Globalization	14
U.S. market	15
Consumer characteristics and factors affecting demand	15
Market mechanisms	15
Pricing	16
Consumption	17
Foreign dependence	19
U.S. dependence on foreign-origin natural uranium	19
U.S. dependence on foreign suppliers of enrichment services	19
Foreign industry profile	20
Foreign industry structure	20
Supply, demand, and inventories	23
U.S. and foreign trade measures	23
U.S. trade measures	23
U.S. tariff measures	23
U.S. nontariff measures	27
U.S. Government trade-related investigations	27
Foreign trade measures	28
Foreign tariff measures	28
Foreign nontariff measures	29
International trade	30
U.S. imports	30
EIA import data by type of transaction	30
EIA utility purchases data of foreign and domestic uranium	31
Selected DOC data	32
U.S. exports	36
Foreign market profile	36
U.S. export data	36
EIA data	36
Selected DOC data	37
U.S. trade balance	37
Appendixes	
A. Explanation of tariff and trade agreement terms	A-1
B. Glossary of terms	B-1
C. Nuclear fuel materials and processing costs	C-1

CONTENTS—*Continued*

Page

Figures

1. The nuclear fuel cycle 3
2. U.S. uranium and nuclear fuel industry: Principal raw materials, producer types, major products, principal consumers, and end-uses 5
3. Major U.S. uranium reserve areas and status of mills and plants, Dec. 31, 1993 7
4. Utility services contract terminations by U.S. utilities 10
5. Uranium marketing activity during 1993 17
6. Utility inventory drawdown and buildup 24
7. Western uranium supply and demand (assuming 62.1 percent capacity utilization) 25
8. Western uranium supply and demand (assuming 100 percent capacity utilization) 25

Tables

1. Uranium concentrate facilities and nuclear fuel production plants as of Dec. 31, 1993 6
2. World uranium production 1989-93 21
3. Uranium enrichment facilities 24
4. Uranium and nuclear fuel: Harmonized Tariff Schedule subheading; description; U.S. col. 1 rate of duty as of Jan. 1, 1995; U.S. exports, 1994; and U.S. imports, 1994 26
5. Quota allocations for uranium exports to the United States from the FSU in relationship to the domestic price of uranium 29
6. Natural uranium oxide: U.S. imports for consumption, by principal sources, 1990-94 33
7. Natural uranium hexafluoride: U.S. imports for consumption, by principal sources, 1990-94 34
8. Enriched uranium hexafluoride: U.S. imports for consumption, by principal sources, 1990-94 35
9. Enriched uranium hexafluoride: U.S. exports of domestic merchandise, by principal markets, 1990-94 38
10. Enriched uranium oxide: U.S. exports of domestic merchandise, by principal markets, 1990-94 39

INTRODUCTION

Scope

This summary focuses on uranium and processed forms of uranium referred to as nuclear fuel used in the generation of electricity in nuclear power plants and for nuclear propulsion in nuclear submarines and nuclear-powered aircraft carriers. Uranium is also used in the production of nuclear weapons. This summary covers the period 1989-93. Domestic data for the U.S. uranium industry, as reported by the Department of Energy's (DOE) Energy Information Administration (EIA) in its Uranium Industry Annuals, were not available for 1994 at the time of the preparation of this report. However, import and export data compiled by the U.S. Department of Commerce (DOC) for products covered by this summary are supplied for 1990-94. Also, when deemed useful to improve clarity and relevance, references are occasionally made to events before 1989 and after 1993.

In terms of commercial value of consumption, by far the most important products in this summary are such processed forms of uranium ore as natural uranium oxide (also referred to as uranium yellowcake or uranium concentrates or as the chemical compound, triuranium octoxide, U_3O_8) and natural and enriched uranium hexafluoride (UF_6).[1] These products are ultimately fabricated into nuclear fuel and used by nuclear power plants in the generation of electricity. Because the nuclear power industry generates slightly more than 20 percent of the electricity used in the United States, uranium and nuclear fuel are of intense interest to analysts of U.S. energy policy.

In the United States, uranium raw material is obtained from mined ore, leached from uranium-containing deposits (in situ leach (ISL)), recovered as a byproduct of phosphate production, or recovered from mine water. The uranium raw material is then processed into uranium concentrates.[2] The uranium concentrates, like the ore they are derived from, are all in the natural (nonenriched) form because ordinary physical and chemical processing will not affect the isotopic composition of uranium. However, in most nuclear power plants, including all the commercial nuclear power plants in the United States, the uranium used must be in the enriched form to generate electricity.[3]

To prepare the uranium for enrichment, uranium concentrates are shipped to a "converter" that converts the uranium concentrates to UF_6, a form of uranium that, because it can be readily vaporized, is suitable to be enriched. Next, the natural (non-enriched) uranium goes to an "enricher" that enriches the UF_6 product in its isotopic composition of U^{235}. In the enrichment process, the natural UF_6 feed after processing is separated into a product and a coproduct stream. In the product stream the concentration of U^{235} is increased; in the coproduct stream the concentration of U^{235} is reduced. The product is referred to as enriched uranium whereas the coproduct is referred to as depleted uranium or "tails." Although depleted uranium is used in some military applications, it is often considered to be a waste product.

Currently, there are two widely used methods of uranium enrichment. In the first method (gaseous diffusion technology), vaporized UF_6 is passed through a filter that is more permeable to the lighter U^{235} than to the slightly heavier U^{238}. To achieve significant separation of isotopes, this process is repeated many times. In the second method (gaseous centrifuge technology), the vaporized uranium hexafluoride is spun in a centrifuge to achieve separation of the U^{235} and U^{238} isotopes. Upon being spun rapidly, the lighter UF_6 molecules containing U^{235} tend to move toward the center, whereas the heavier UF_6 molecules containing U^{238} tend to move toward the outer walls of the centrifuge.

In most cases, enrichment services, usually expressed as Separative Work Units (SWU), rather than the enriched uranium product are purchased from the enricher. A customer may purchase enrichment services as distinct from enriched uranium by supplying the enricher with natural UF_6 in return for enriched uranium.

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1 See glossary (app. B.) for further information. Although many intermediate products of uranium are produced, these intermediates are usually converted into the uranium products referred to above for transport or sale.

2 Most uranium concentrates contain a minimum of 75 percent U3O8 and average 80 to 85 percent U3O8 on an equivalent basis.

3 Uranium is primarily composed of two isotopes U^{235} and U^{238}. In natural uranium, i.e., uranium found in the ground, the U^{235} composition is only about 0.711 percent; the remainder of the uranium consists almost entirely of U^{238}. However, only the U^{235} component is fissionable; it is able to react with neutrons in a conventional nuclear reactor process to release energy. In the light-water type of nuclear reactors used in the United States and most other countries, the isotopic composition of the U^{235} in the uranium used in these reactors must be "enriched" relative to the isotopic composition of natural uranium in order to achieve a sustainable nuclear reaction. As noted above, ordinary mechanical or chemical processes used in the mining and processing of uranium ore will not appreciably change the isotopic composition of the uranium.

After enrichment, the enriched UF_6 goes to a "nuclear fuel fabricator" that converts the enriched UF_6 to enriched uranium oxide, which is then encapsulated into fuel rods and fuel rods assemblies. Finally, the fuel assemblies are transported to utilities for initial fueling of their nuclear reactors or replacement of spent fuel.

The handling and reprocessing of spent fuel is referred to as the "back end" of the nuclear fuel cycle. In the United States, where the recycling of spent fuel from commercial nuclear power plants is discouraged, the spent fuel is stored. Nuclear fuel for the generation of electricity is produced outside the United States in several countries (including France, the United Kingdom, and Japan) by recycling spent fuel. The recycling of spent fuel permits those countries making use of this method to reduce their purchasing requirements for newly mined uranium. Critics contend, however, that the nuclear fuel produced from recycled spent fuel, which contains plutonium, is susceptible to theft or to misuse (that is, it could be used in the illicit production of nuclear weapons). The processes involved in the production of nuclear fuel are shown schematically in figure 1.

In the nuclear fuel industry, enriched uranium is classified as either Low Enriched Uranium (LEU) or Highly Enriched Uranium (HEU). In LEU, the form of enriched uranium used in commercial nuclear power plants to generate electricity, the uranium is generally enriched to a U^{235} composition of between about 1.5 percent and 5 percent. In HEU, the form of enriched uranium used in nuclear propulsion and nuclear weapons, the uranium is enriched to a U^{235} composition of at least 20 percent U^{235}, and often more than 90 percent.

Both the United States and the former Soviet Union (FSU) amassed large quantities of HEU for military use. Much of this HEU is now considered to be surplus in light of recent arms reduction agreements and reductions of tensions. Surplus HEU can be blended with either natural uranium, slightly enriched LEU,[4] or depleted uranium to produce LEU suitable for use in commercial nuclear power reactors.

The United States has signed an agreement to acquire LEU derived from blended down HEU from Russia to help reduce the amount of surplus Russian material that could be diverted for uses that could pose a threat to national and worldwide security.

International trade in uranium and nuclear fuel is substantial and is a major focus of concern to the industry. Imports of both natural and enriched uranium have increased significantly during the past decade. The domestic uranium industry has attributed many of its problems to the influx of imports. Exports are also a focus of concern, particularly to the enrichment and nuclear fuel segments of the industry, as the economic well-being of some of the industries covered in this summary depends on their maintaining a large export base. In 1993, according to the DOC, U.S. imports of uranium and nuclear fuel amounted to $806 million, whereas U.S. exports amounted to $1.1 billion.[5] Imports, exports, production, and other data for uranium are also reported by the DOE's EIA in the *Uranium Industry Annuals*, as well as in other publications, and are used extensively in this report. Care, however, must be taken when comparing data provided by the EIA with other databases.[6]

In part because of the sensitive nature of nuclear material worldwide, the role of government in the industries producing and marketing these products has been substantial. Although there has been movement toward privatization, many nuclear fuel producers throughout the world remain under government control or influence. Private companies producing nuclear fuel are also heavily influenced by government policies and regulations. In matters not relating to national security, safety, and the environment, the United States Government has probably been less intrusive than the governments of other countries in attempting to formulate commercial nuclear fuel policies.

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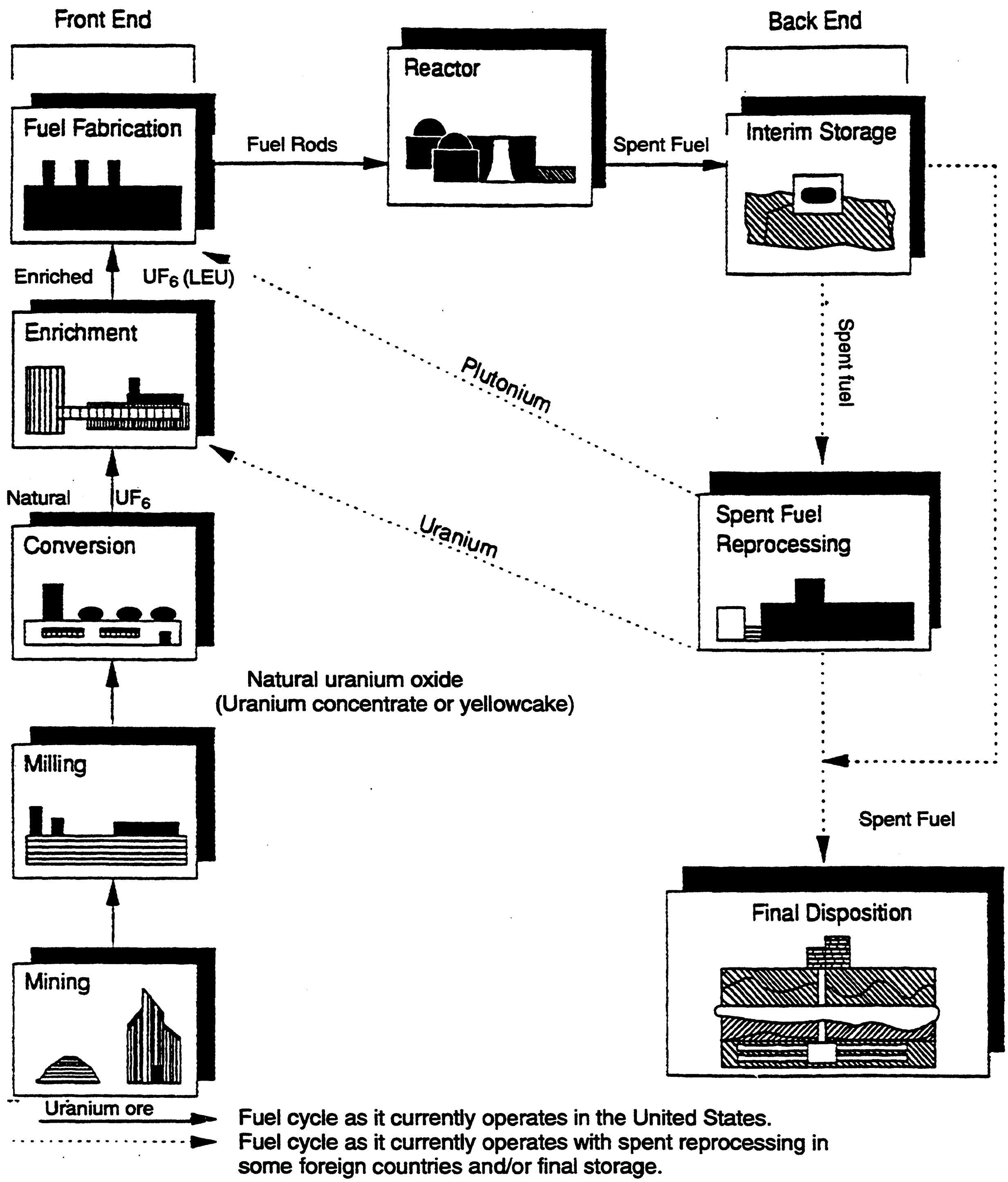
[4] Slightly enriched LEU as defined here is uranium that has been enriched in its U^{235} content relative to natural uranium but the degree of enrichment is insufficient to allow this material to be used in most commercial nuclear power plants unless the material is further enriched. In general, the U^{235} content of slightly enriched LEU is 1.5 percent or less.

[5] The value of U.S. consumption of uranium and nuclear fuel has not been published by sources known to the staff of the Commission. The estimated value of U.S. consumption of uranium and nuclear fuel based on approximations provided by industry sources is probably in the order of $3 billion or more.

[6] The DOE and other analysts of the U.S. industry have adopted the practice of expressing the natural uranium content of uranium concentrates in terms of U_3O_8 equivalent. These units are also widely used in commercial practice. When this terminology is employed, the theoretical amount of uranium in the form of U_3O_8 required to produce the specified uranium product is measured. Unless otherwise specified, uranium data provided by the EIA as reported in this summary includes all commercial forms of uranium in terms of U_3O_8 equivalent. For example, based on a calculation relating the stoichiometry of U_3O_8 and UF_6, about 0.7974 pounds of U_3O_8 are required to produce one pound of UF_6. One million pounds of uranium hexafluoride would, therefore, be expressed as 797,400 pounds U_3O_8 equivalent.

Figure 1
The nuclear fuel cycle



Source: EIA, *World Nuclear Capacity and Fuel Cycle Requirements 1992*. Reprinted with permission of the EIA.

Organization of the Report

This report addresses developments in the uranium and nuclear fuel industry during 1989-93. The first section of this report, *U.S. Industry Profile*, discusses the characteristics of the U.S. uranium and nuclear fuel industry. Topics that are addressed include number and type of producers, competitiveness, production, technology, employment, and inventories.

The market for uranium and nuclear fuel is then described in the second section, *U.S. Market*, focusing on consumer characteristics, market mechanisms, pricing, consumption, and foreign dependence. The foreign industry profile of the world uranium and nuclear fuel industry and trends in world uranium demand, supply, and inventories are addressed in the third section, *Foreign Industry Profile*. The second half of this report focuses on international trade issues. In the first part of this section, (the fourth section, *U.S. and Foreign Trade Measures)* tariff and nontariff measures undertaken by the United States and other countries to regulate imports of uranium and nuclear fuel are addressed including the antidumping investigations conducted by the U.S. Department of Commerce and the U.S. International Trade Commission on uranium from the former Soviet Union as well as subsequent agreements superseding and supplanting these antidumping investigations. The report concludes in the fifth section, *International Trade*, with a description of U.S. imports and U.S. exports of uranium and nuclear fuel during 1989-93 and a discussion of possible reasons for observed trends in international trade for these products.

U.S. INDUSTRY PROFILE[7]

Industry Structure[8]

An overview of the principal raw materials, the major end uses, and the types of producers and principal products of the uranium and nuclear fuel industry appears in figure 2. Compared with other metals, uranium is used in only a few applications, most of which are energy related. The various types of companies producing the products of the nuclear fuel cycle are listed under producer types. Except for the domestic enrichment facilities, which, through June 1993, were owned and operated by the DOE, and are now operated by the United States Enrichment Corp. (USEC), a Government corporation, the remaining domestic facilities producing uranium and nuclear fuel for commercial use are privately owned and operated.

During 1989-93, U.S. uranium production has been increasingly owned and operated by subsidiaries of foreign firms specializing in nuclear fuel, mining, or nuclear power. At year-end 1988, U.S. companies owned 10 of the 15 primary domestic uranium production sites operating in the United States.[9] By the end of 1993, all of the five primary uranium producers that were in commercial operation in the United States were majority foreign owned. These foreign companies had acquired the uranium operations of domestic companies which had exited the business because of reduced income resulting from the expiration of favorable long-term supply contracts and a decline in prices attributed to strong foreign competition and uranium oversupply.[10] Foreign companies also acquired the uranium operations of U.S. utilities which had divested themselves of their uranium business. These utilities' concerns about maintaining security of supply eased as sources of supply grew and uranium prices fell.[11] Although foreign uranium-related companies were subject to similar economic forces as in the United States, they remained interested in acquiring U.S. uranium operations because they were able to acquire such operations (especially relatively efficient ISL operations) on favorable terms. The foreign firms were, therefore, able to gain entry as U.S. producers while ensuring security of supply for their customers.

Three of the five primary domestic uranium production sites as of December 31, 1993, were controlled by the U.S. subsidiaries of a French

[7] Data used in this summary were obtained from several sources, including the EIA, the DOC, and the Commission's own files. The Commission has relied principally on EIA and DOC data because such data are available for the entire period covered by the summary. The Commission prepared a data series of its own in 1993 in connection with an investigation conducted under the U.S. antidumping law, but the report in that investigation contains data only through March 1993 (U.S. International Trade Commission, *Uranium From Tajikistan and Ukraine*, investigations Nos. 731-539-D and 731-539-E (Final), USITC publication 2669, Aug. 1993).

[8] In this summary, the products that are derived from uranium are generally inorganic chemicals or a mixture of inorganic chemicals, such as uranium, nuclear fuel, and inorganic nuclear cores. Establishments producing these nuclear materials, other than mining and milling uranium ore, are generally classified under Standard Industrial

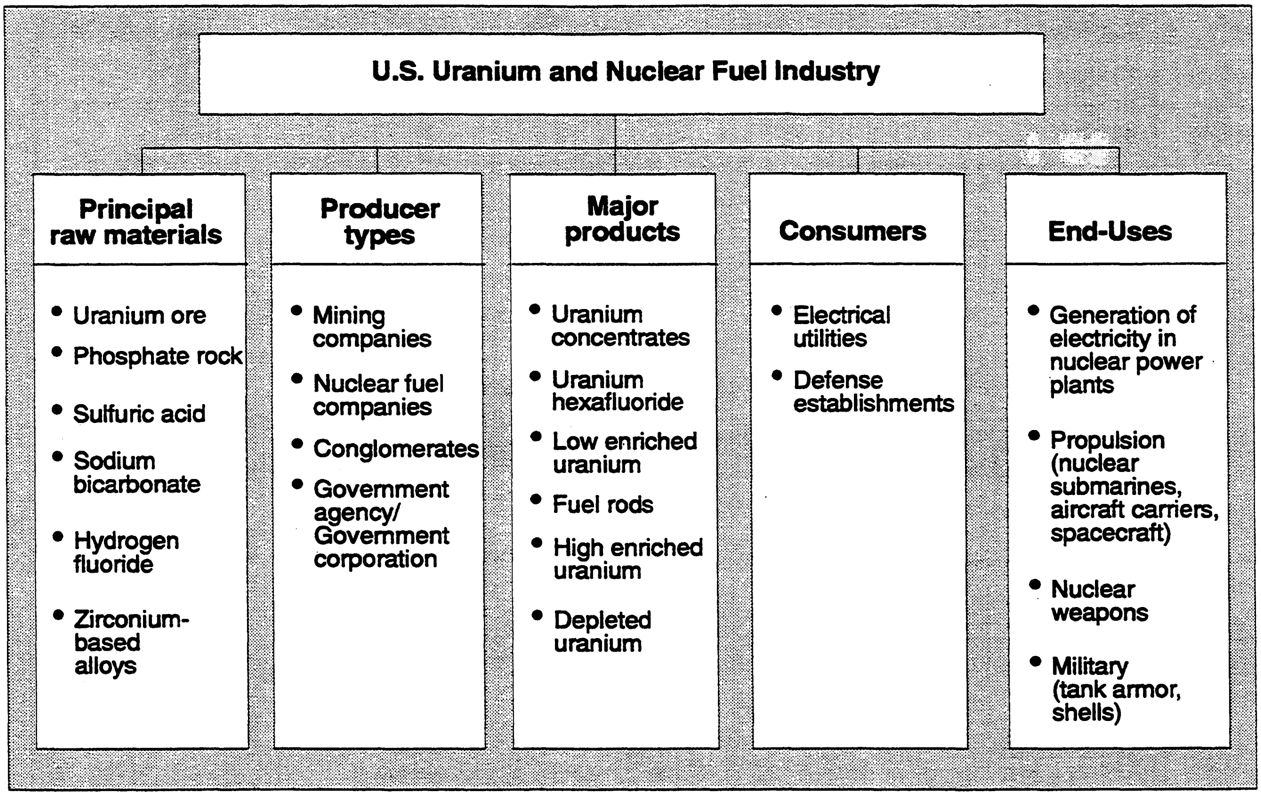
[8] *Continued—*
Classification (SIC) code 2819, the miscellaneous category for industrial inorganic chemicals. Establishments mining uranium ore are classified under SIC code 1094. Because SIC codes are based on the type of establishment, they are not strictly product codes.

[9] A primary uranium production site is a facility that receives most of its revenues from the sale of uranium. Byproduct facilities such as phosphate mines are not considered to be primary uranium production sites.

[10] EIA, *Uranium Industry Annual 1993*, p. xii.

[11] Ibid.

Figure 2
U.S. uranium and nuclear fuel industry: Principal raw materials, producer types, major products, principal consumers, and end-uses



Source: EIA, *Uranium Industry Annual 1993, World Nuclear Outlooks 1994*, and conversations with industry sources.

integrated nuclear fuel cycle company (Cogema). Cogema was also the minority owner of a primary uranium producer (Highland) that was majority owned by U.S. subsidiaries of electrical utilities in the United Kingdom. The fifth primary uranium producer (Crow Butte) was operated by subsidiaries of a German and a Canadian company, Uranerz and Cameco Corp., respectively. These companies specialize in uranium mining and, in the case of Cameco, in nuclear fuel processing also.

In contrast, a significant portion of the private firms responsible for U.S. conversion and fabrication during 1989-93 were well-known U.S. conglomerates (e.g., Allied Corp., Westinghouse Electric Corp., and General Electric Co.) with diversified operations, most of which were not related to nuclear fuel, nuclear power, or mining.

U.S. processors of uranium beyond the uranium concentrate stage (referred to as nuclear fuel producers) experienced overcapacity problems that were similar in some respects to the situation experienced by the natural uranium industry. However, the impact of adverse factors on these processors, such as large utility inventories and increased competition from foreign producers of nuclear fuel, while significant, did not result in as severe a degree of industry downsizing as that experienced by the U.S. uranium mining and milling industry (see the next section). Except for one company involved in conversion services, other nuclear fuel producers did not discontinue their nuclear fuel operations during 1989-93. U.S. nuclear fuel producers did, however, experience other significant changes, including increased foreign ownership and competition.

The number of U.S. facilities producing uranium and nuclear fuel at all stages of the nuclear fuel cycle and their location by state are shown in table 1. Most of the facilities that have been involved in producing uranium concentrates during 1989-93 are located in the Western and Gulf States. The preponderance of

Table 1
Uranium concentrate facilities and nuclear fuel production plants as of Dec. 31, 1993

Uranium Concentrate Facilities

Type of facility	Number	Location
Conventional Production Mills	None	Not Applicable
Phosphate By-product	2	Louisiana
In-Situ Leach	5	Nebraska Wyoming Texas

Nuclear Fuel Production Plants

Type of facility	Number	Location
Uranium Conversion	1	Illinois
Uranium Enrichment	2	Ohio Kentucky
Uranium Fabrication	5	Missouri North Carolina South Carolina Virginia Washington

Source: EIA, *Uranium Industry Annual 1993* and EIA, *World Nuclear Outlook 1994.*

facilities processing uranium beyond the concentrate stage are located in the eastern, southern, and central regions of the United States. Most of the nuclear power plants in the United States are also located in these areas.

Employment data for the nuclear fuel cycle industries are tracked by the DOE's Office of Science/Engineering Education Division.[12] According to an analyst at that office, employment in the nuclear fuel cycle industries (including uranium raw materials employment) declined from 11,221 in 1989 to 9,132 in 1993.[13] In contrast to the decline in employment for workers in the nuclear fuel cycle industries, employment in nuclear waste management rose from 27,332 in 1989 to 50,108 in 1993. Total employment in all nuclear-related sectors[14] increased slightly from 290,248 in 1989 to 299,547 in 1993. Of that increase, however, only about 57 percent (5,300) represented an actual increase in employment. The remainder of that increase has been attributed to a broadening of the scope of coverage in the survey of personnel in 1993.

Uranium Mining and Milling industry[15]

Figure 3 shows the operating U.S. uranium mills and plants producing uranium concentrates, as well as those that were placed on standby or shut down at the end of 1993.[16] The U.S. uranium mining and milling industry contracted sharply relative to 1980, when

[12] Employment data limited to the exploration, mining, milling, and processing of uranium ore to uranium concentrates are discussed in the following subsection titled *Uranium Mining and Milling Industry.*

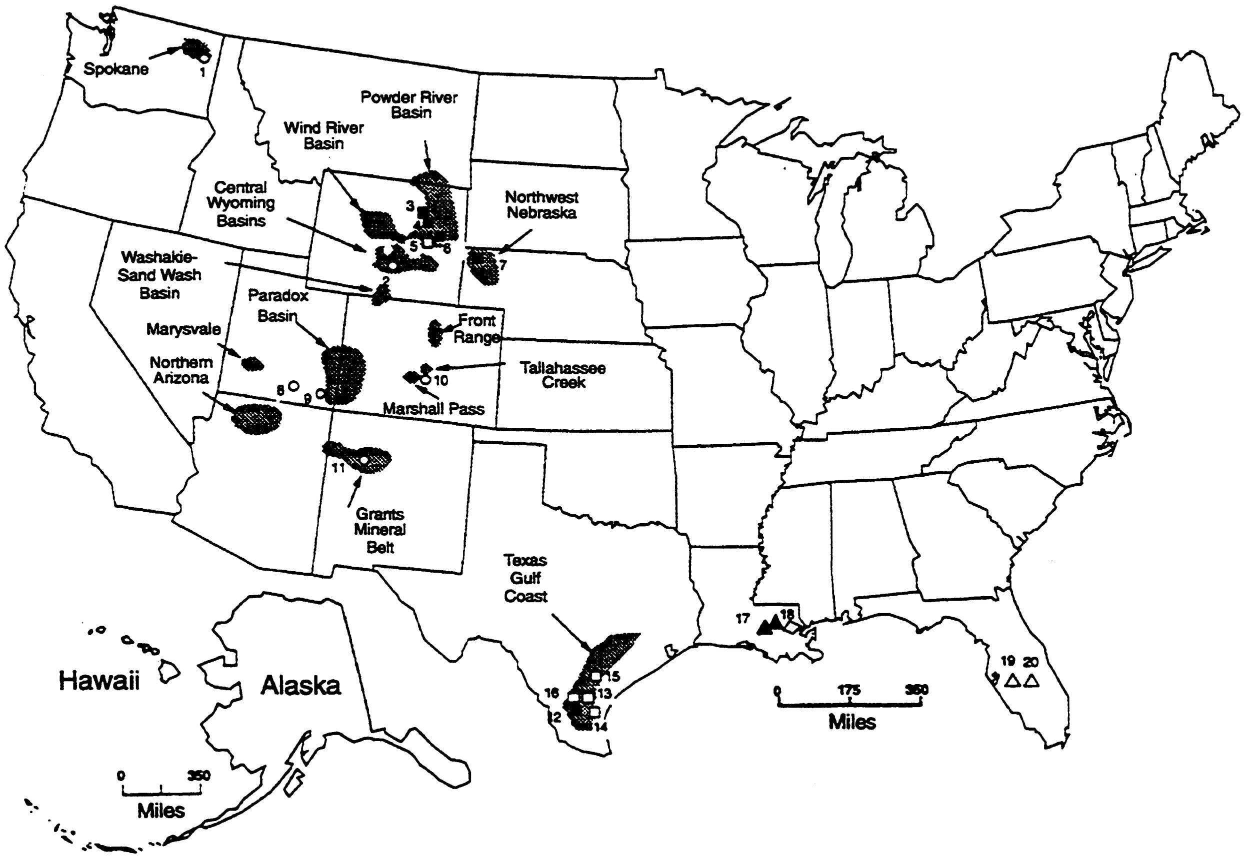
[13] Kathy Olsen, the U.S. Department of Energy, Office of University and Science Education Programs, conversation with USITC staff, Nov. 1994.

[14] These nuclear-related sectors include fuel cycle, waste management, reactor and facility design, operation and maintenance, research, and weapons.

[15] In this report, the term "uranium mining and milling industry" is defined to include all uranium concentrate producers including byproduct producers.

[16] EIA, *Uranium Industry Annual 1992*, p. 43.

Figure 3
Major U.S. uranium reserve areas and status of mills and plants, December 31, 1993



Active at The End of 1993

3. Malapal Resources, Irigaray
4. Malapal Resources, Chistensen Ranch
6. Converse County Mining Venture, Highland
7. Ferret Exploration of Nebraska, Crow Butte
12. Malapal Resources, Holiday-EL Mesquite
17. Imc-Agrico, Sunshine Bridge
18. Imc-Agrico, Uncle Sam

Active	Inactive	
●	○	Conventional Mill
■	□	In Situ Leach Plant
▲	△	Byproduct From Phosphate Processing

← Major Uranium Reserve Areas

Inactive at The End of 1993

1. Dawn Mining, Ford
2. Green Mountain Mining Venture, Sweetwater
5. Rio algom Mining, Smith Ranch
8. Plateau Resources, Shootering
9. Umetco Minerals/Energy Fuels Nuclear, White Mesa
10. Cotter Corp., Canon City
11. Rio Algom Mining, Ambrosia Lake
13. Uranium Resources, Rosita
14. Uranium Resources, Kingsville Dome
15. Everest Minerals, Hobson
16. COGEMA Mining, West Cole
19. IMC-Agrico, Plant City
20. IMC-Agrico, New Wales

Source: EIA, *Uranium Industry Annual 1993.* Reprinted with permission of the EIA.

U.S. domestic production of uranium peaked. This decline was especially sharp for conventional uranium mining and milling operations—that is, open pit and underground mining. Some domestic producers with contractual requirements found it more economical to shut down their high-cost operations and to supply their customers with low-priced uranium purchased in the spot, secondary, or foreign markets. Often the domestic producers were able to purchase uranium at prices that were well below their cost of production.[17] To survive in an increasingly competitive market, producers ". . . in some cases looked more like traders than producers" by diversifying and engaging in cooperative ventures with foreign suppliers.[18]

Another way to adapt to the competitive pressures on the industry was consolidation through acquisitions, mergers, and sales agreements.[19] In 1992, at least four transactions involving consolidation of domestic uranium properties were reported. During 1989-93, the three largest firms increased their share of ownership of the operating uranium mining and milling industry from about 61 percent to about 75 percent.[20]

The consolidation and retrenchment of the domestic uranium industry is reflected in data that compare the domestic natural uranium industry in 1989 and 1993. In 1989, there were 12 principal owners operating 16 active domestic uranium production facilities with a capacity of more than 13.7 million pounds (U_3O_8 equivalent).[21] In 1993, there were 5 principal owners operating 7 active domestic uranium production facilities with a capacity of 3.85 million pounds, a decline in operating plant capacity of more than 72 percent.[22] The number of U.S. uranium mine operations including underground, openpit, and ISL declined from 247 in 1981 to 32 in 1989 and to 12 in 1993. By March 1992, all conventional uranium mines (open pit and underground) in the United States ceased commercial operations. Reflecting the decline in demand for domestically produced uranium, U.S. production of uranium concentrates, which amounted to 43.7 million pounds in 1980, declined to 13.8 million pounds in 1989 and to 3.1 million pounds in 1993.[23] Tracking with the decline in production, U.S. employment in the uranium raw material sector fell from 19,919 in 1980 to 1,583 in 1989 and to 380 in 1993.[24]

As noted in the discussion in the *Industry Structure* section, a number of U.S. companies exited the uranium business to concentrate on their core business because of declining income.[25] These include petroleum, metal mining, and nuclear service companies (e.g., Conoco, Exxon, Kerr-McGee, Mobil, Phelps Dodge, Tenneco, and Westinghouse).[26] The exit of the petroleum companies was accelerated by a decline in profitability following the collapse of petroleum prices that to some extent tracked uranium prices.[27] In 1991, the last multinational oil company (Chevron) exited the uranium business.

Industry analysts attribute the contraction of the domestic mining and milling industry to a steep rise in foreign dependency that not only led to reduced demand for domestic uranium but also facilitated low prices[28] and to continued high, although declining, inventories held by utilities (and other establishments) that reduced the purchasing needs of the utilities.

The decline of commercial inventories has been going on for many years. In 1983, commercial uranium inventories in the United States peaked at 192 million pounds (U_3O_8 equivalent) and has declined since then

[17] In the United States, production costs for conventional uranium mining and milling operations and the more efficient ISL have been estimated to be between \$16-\$30 and \$8-\$11 per pound U_3O_8, respectively. (See *Foreign Industry Profile* section.) Consequently, U.S. conventional uranium mining and milling operations were all shut down or idled in 1993, when the average price of domestic uranium deliveries in that year (\$13.14 per pound U_3O_8, according to the EIA) was well below the cost of production of conventional uranium producers. NUEXCO reported that spot market prices for uranium purchased in the United States in 1993 did not exceed about \$10.25 per pound U_3O_8. (See *NUEXCO 1993 Annual Review*, pp. 3 and 7.) For more information about NUEXCO, see glossary (app. B).

[18] R. Hugh Courtenay, *A Producer's Perspective*, p. 1, presented at the International Uranium Fuel Seminar, Nuclear Energy Institute, Sept. 1994.

[19] Jay M. McMurray, *Impact of Consolidation of the Worldwide Uranium Industry*, p. 3, presented at the International Uranium Fuel Seminar, Nuclear Energy Institute, Sept. 1994.

[20] NUEXCO, 1989 *Annual Review 1989*, table 35, p. 92, and *1993 Annual Review*, fig. 95, p. 97. Data were obtained by adding the operational capacity figures for the top three uranium companies as listed in the NUEXCO tables and comparing that total to the total operational capacity for all uranium producers. For capacities which were specified as being higher than the figures listed, the assumption was made that the listed capacities were approximately equal to the actual capacities.

[21] NUEXCO, *1989 Annual Review*, p. 92.

[22] NUEXCO, *1993 Annual Review*, p. 97.

[23] EIA, *Uranium Industry Annual 1992*, table ES1, p. 16, and *Uranium Industry Annual 1993*, table ES1, p. xxviii.

[24] EIA, *Uranium Industry Annual 1993*, p. 24.

[25] EIA, *Uranium Industry Annual 1993*, p. xii.

[26] Ibid.

[27] Ibid.

[28] Lower production costs of Western foreign producers and the willingness of nonmarket and transitional economies to charge prices that are not related to production costs are two factors that contributed to the increased competitiveness of foreign uranium producers in the U.S. market (see *Foreign Industry Profile* section).

to 104 million pounds in 1993.[29] An important issue relates to when inventories held by domestic utilities become so low that excess stockpiles have essentially disappeared and domestic utilities feel the need to increase their uranium purchases. According to some industry sources, U.S. uranium inventories have declined to the point that, by the end of 1993, the uranium excess had largely disappeared. However, it does not appear that the turning point was reached in 1993 as the decline in inventories continued in 1993 (see *General Characteristics of the Uranium and Nuclear Fuel Industry* section) and utilities did not increase their uranium purchases in that year (see *Consumption* section).

Uranium Conversion Industry

In the United States, before 1992, two privately owned uranium conversion plants located in Metropolis, IL, and in Gore, OK, had a combined annual capacity of about 56.7 million pounds (U_3O_8 equivalent), a capacity substantially greater than the annual level of U.S. consumption of uranium. The U.S. uranium conversion industry has faced stiff competition from conversion plants in Canada and Europe and, like other fuel-cycle producers, has been adversely affected by low capacity utilization. Accordingly, the plant in Gore, OK, was placed on standby indefinitely in 1992, an action that reduced the conversion capacity of the United States to about 33.0 million pounds. A joint marketing venture involving the owners of the two plants has assigned the Illinois plant the responsibility of supplying conversion services to purchasers originally contracted for services at the Oklahoma plant.

Uranium Enrichment Industry

U.S. enrichment facilities, in contrast with the other facilities involved in the processing of uranium, are Government owned and contractor-operated.[30] The DOE operates two gaseous diffusion enrichment plants in Paducah, KY, and in Portsmouth, OH, with a combined annual capacity of about 18.2 million SWU. A third gaseous diffusion enrichment plant in Oak Ridge, TN, closed in late 1987 because demand for nuclear fuel did not meet expectations. To distinguish the enrichment operations of the DOE from its other operations, the term "uranium enrichment enterprise" (UEE) has been used by the industry.

The DOE has produced enriched uranium for both civilian and military applications. In general, civilian nuclear power uses LEU whereas most military applications (including nuclear propulsion and nuclear weapons production) require HEU. In recent years, purchases of enriched uranium for military applications have declined because the DOE has adequate stockpiles of this material. Arms reduction agreements and the easing of tensions between the United States and the FSU were other factors that contributed to a decline in demand for HEU. In November 1991, Energy Secretary James Watkins announced that the DOE's Portsmouth uranium enrichment plant would cease production of HEU, but not of LEU, because inventory levels were more than adequate.[31]

In recent years, the DOE has faced increased foreign competition from uranium enrichers in Western Europe and, especially, from the FSU and, subsequently, from Russia (see *Foreign Industry Profile* section). Although the DOE continues to supply the dominant share of enrichment services in the U.S. market, it had expressed concern in the past that its share of the U.S. market could decline precipitously after 1995, when many long-term contracts with domestic utilities begin to expire. Figure 4 shows that, in recent years, the number of contract terminations for enrichment services with the DOE has increased sharply.[32] Utilities have terminated their enrichment contracts with the DOE primarily because of price considerations, given the fact that concerns about the availability of enriched uranium have eased. Many U.S. utilities are under pressure from their State public utility commissions (PUCs) to seek the lowest-priced supplier of enrichment services regardless of the country of origin. Many of these terminations are not final, but reflect the view of many U.S. utilities that purchasing decisions should be postponed until the best possible deal can be struck.

Despite increased competition from foreign enrichers, DOE's foreign sales of enrichment services remained substantial during 1989-92, amounting to roughly 40 percent of total sales. In fiscal year 1992,

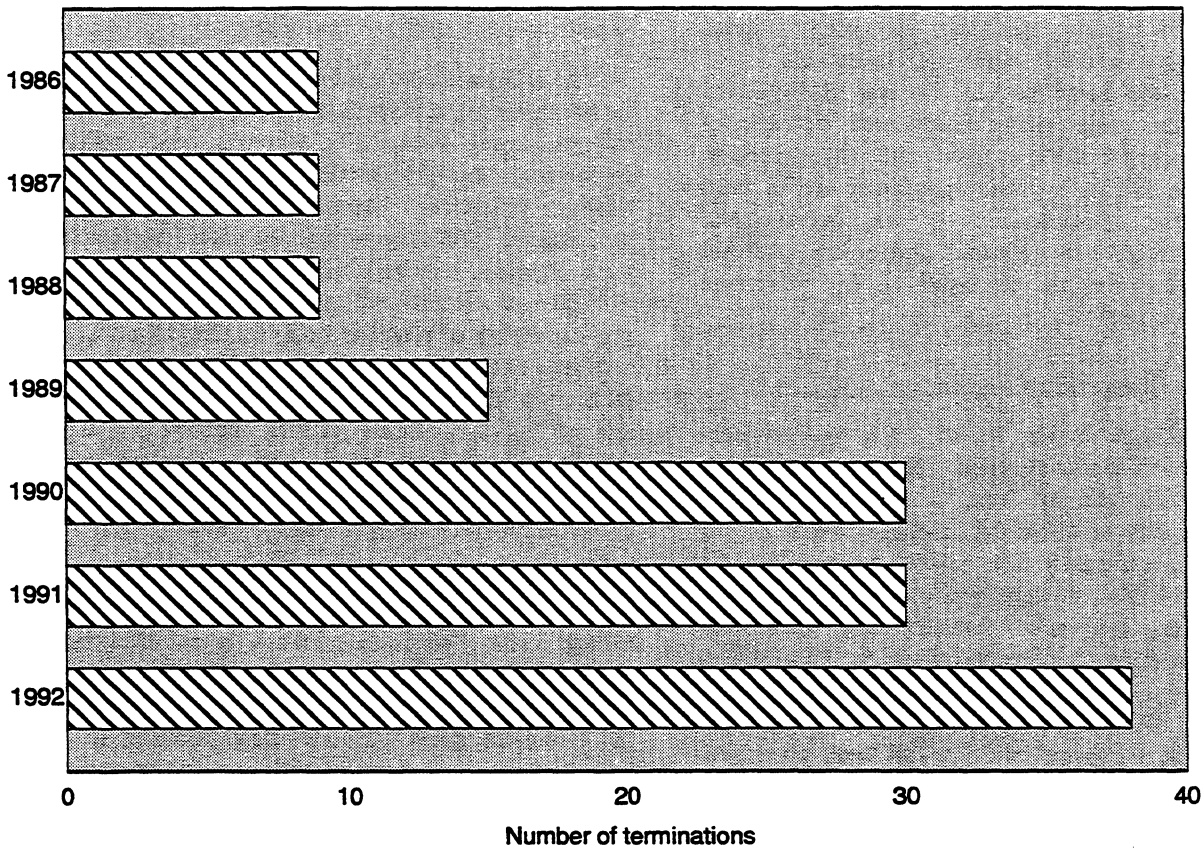
[29] EIA, *Uranium Industry Annual 1993*, p. xxviii. Some industry analysts are hopeful that the decline in uranium inventories, if it were sustained on a world-wide basis, could help lead to at least a partial recovery of the domestic uranium industry, especially for those producers using in-situ leach, considered the most cost-efficient uranium production method in the United States.

[30] The DOE and the USEC have contracted out the operations of the enrichment facilities to a subsidiary of Martin Marietta Corp. In March 1995, Martin Marietta Corp. and Lockheed Corp. merged to form Lcckheed-Martin Corp.

[31] DOE, *Uranium Enrichment 1991*, pp. 3 and 5.

[32] NUEXCO, *1992 Annual Review*, Fig. 6, p. 12. According to a fact sheet issued by the U.S. Enrichment Corp., the contract terminations during 1984-1990 amounted to more than $5 billion of potential lost revenue.

Figure 4
Utility services contract terminations by U.S. utilities, 1986-92



Source: *NUEXCO Review 1992*. Reprinted with permission of Trade Tech.

for example, almost $600 million of the $1.48 billion gross revenue derived from sales of enrichment services by the DOE were foreign sales.[33]

The DOE, despite intense and largely successful efforts to reduce costs, has had to contend with rising costs due to environmental factors, especially cost-projections associated with the eventual decommissioning of its enrichment facilities (the DOE must include such costs in its charges). The General Accounting Office estimated that the costs incurred by the DOE in the decontaminating and decommissioning (D&D) of its uranium enrichment facilities would cost about $16.1 billion, but could be as much as 50 percent more or 30 percent less.[34] This cost would not be borne solely by the DOE. A provision of the Energy Policy Act of 1992 enacted on October 24, 1992, requires U.S. utilities that have purchased enrichment services from the DOE to pay $150 million annually for D&D for at least 15 years.[35]

Other environmental costs the DOE must bear relate to air quality control. According to a trade journal, the passage of the Clean Air Act Amendments of 1990 is expected to increase the cost of enrichment services by about $11 to $15 per SWU by 1997.[36] Another environmental problem that the DOE must contend with is the large volumes of depleted uranium produced as a byproduct of uranium enrichment, which are currently stored in DOE facilities and primarily considered to be waste products.

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[33] DOE, *Uranium Enrichment FY 1992*, Exhibit II, p. 4. For the DOE, the fiscal year ends on Sept. 30th.

[34] "GAO Says D&D Work at GDPs Would Cost $500-Million Annually, Plus Inflation," *Nuclear Fuel*, Nov. 25, 1991, p. 7. D&D work has already begun on the DOE's oldest gaseous diffusion plant in Oak Ridge, TN, which was shut down in 1987. Two other gaseous diffusion plants are still operational in Paducah, KY, and Portsmouth, OH.

[35] "Outlook on USEC," *Nuclear Fuel*, Oct. 11, 1993, p. 9.

[36] NUEXCO, *1990 Annual Review*, p. 13.

Some depleted uranium is, however, used principally for military applications because of its high density and penetrating ability. (During the Gulf War, depleted uranium was used both in armor and in shells.) At least two private companies transform depleted UF_6 produced by the DOE into depleted uranium metal. Some industry observers believe that consumption of depleted uranium will decline because of concerns about its radioactivity.

In another effort aimed at improving its competitiveness, the DOE was allowed to spin off its enrichment enterprise into a Government corporation that could act in many ways as a commercial business enterprise relieved of the restrictions of a Government agency.[37] After several unsuccessful attempts to enact such legislation, Congress passed the Energy Policy Act of 1992, which authorized the establishment of such a Government corporation, the United States Enrichment Corporation (USEC). The USEC officially took over the uranium enrichment business operations from the DOE in July 1993. The USEC leases the uranium enrichment plants from the DOE, which continues to own the facilities and, therefore, still maintains some responsibility for uranium enrichment.[38] Eventually the USEC is to become a private corporation. Legislation privatizing the USEC has been drafted and, as of September 1995, is part of the Congressional agenda.

To become more competitive, the DOE and USEC have been engaged in research to develop a new laser-based technology termed AVLIS (atomic vapor laser isotopic separation) that could sharply reduce uranium enrichment production costs. There are critics, however, who question AVLIS' commercial feasibility.[39] Moreover, AVLIS faces competition from other countries, especially from France and Japan, which are attempting to commercialize an alternative laser-based uranium-separation technology.

An issue of great concern to the United States is the large amount of HEU and plutonium accumulated in the FSU, which was produced in response to Soviet military programs.[40] The primary concern is that these materials will be diverted for the production of nuclear weapons. To address these concerns, on August 31, 1992, President Bush announced that the United States had initialed an agreement with Russia to buy HEU derived from dismantled nuclear weapons.[41] The HEU is to be blended down in Russia before the United States takes ownership of the material. The initialed agreement was signed on January 14, 1994.

The USEC will be able to use the LEU blended down from the HEU to reduce production from their enrichment plants and thereby reduce their electricity costs.[42] The possible impact of the delivery of HEU from Russia and other nations of the FSU, especially Ukraine, to the United States could be substantial. The USEC estimates, that in the first year alone after the agreement is in effect, the HEU delivered from Russia would be sufficient to service 15 nuclear reactors and to provide electricity for 10 million households. Overall, the purchase, which is equivalent to about 3-year worldwide demand for enriched uranium, is valued at about $11.9 billion.[43]

An issue that as of September 1995 has yet to be resolved relates to the sale of the uranium component of Russian HEU in the U.S. market. According to the provisions of the antidumping suspension agreement, uranium sales from Russia to the United States are restricted (see *U.S. Government Trade-Related Investigations* section). The proposed legislation privatizing the USEC also seeks to address the HEU issue by imposing strict conditions on how Russian weapons uranium is to be disposed of in the U.S. market.[44]

Although there has been only one U.S. producer supplying enrichment services in the United States, this could change in the foreseeable future. A joint venture between certain U.S. utilities and a Western European consortium specializing in uranium enrichment has filed an application with the Nuclear Regulatory Commission (NRC) to set up the nation's first fully private enrichment company, Louisiana Energy Services, that will operate a plant in Clairborne Parish, LA. The facility, which, when fully operational, should satisfy between 10 and 15 percent of U.S. demand for uranium enrichment services, is expected to be licensed by the NRC in late 1995. The facility would use gas centrifuge enrichment technology, which some observers believe is more adaptable to smaller scale uses than is gaseous diffusion enrichment technology.

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[37] For example, the USEC will attempt to customize contracts rather than rely on standard contracts. Also, the USEC will not release information on the prices that it charges.

[38] For example, according to an agreement between the DOE and the USEC, the disposition of depleted uranium produced before July 1, 1993, is the responsibility of the DOE, whereas the disposition of depleted uranium produced after July 1, 1993, is the responsibility of the USEC.

[39] "Outlook on USEC," *Nuclear Fuel*, pp. 11-13, Oct. 11, 1993.

[40] *Nuclear Fuel*, Sept. 2, 1992.

[41] Ibid.

[42] Ibid.

[43] United States Enrichment Corp., *U.S. Purchase of Russian HEU*, not dated.

[44] *Nuclear Fuel*, Sept. 25, 1995, pp. 1-5.

Nuclear Fuel Fabrication Industry

In the United States, there are five companies producing fabricated fuel rods assemblies, the final product in the nuclear fuel manufacturing process. These companies convert enriched UF_6 supplied by the enrichers to enriched uranium oxide that is then encapsulated into fuel rods and fuel-rods assemblies for insertion in commercial nuclear reactors. Nuclear fuel fabrication facilities are located in Hematite, MO; Wilmington, NC; Columbia, SC; Lynchburg, VA; and Richland, WA. In the past decade, Western European companies acquired three of the five fuel-fabricating companies operating in the United States. Fabricated fuel-rods assemblies, unlike the nonfabricated forms of uranium discussed in previous sections, are not considered to be a commodity because the fuel-rod-assembly design must be adapted to the geometry of the nuclear reactor in which the fuel-rods assemblies are placed. Consequently, each fabricator maintains rigorous customized specifications for the fuel-rods assemblies it produces.

According to industry sources, in recent years, because fabricators have been able to match the customized specifications of their competitors, customers do occasionally switch suppliers after the initial contract period (typically about 10 years). International competition in fabrication is reportedly increasing since fabricators faced with excess capacity seek to increase their customer base.

Production

Natural uranium concentrates, the product of uranium mills, are produced by a variety of methods, including conventional mining and milling (open pit and underground mining and milling), ISL, and as byproducts of phosphate fertilizer production. However, after the concentrates are formed, they are no longer distinguishable by processing method. Uranium concentrates are the first downstream product of uranium ore that is commercially shipped from the mill to other processors (uranium converters). Thus it is natural that uranium production is generally reported in terms of concentrate production even though there are several other distinct forms of uranium. In the United States, uranium production data reported by the EIA and trade journals have typically been for uranium concentrates in terms of pounds of U_3O_8 equivalent.[45] Comparable publicly reported production data are not available for other forms of uranium, for example, natural UF_6.

As discussed in the *Uranium Mining and Milling Industry* section, U.S. production of natural uranium concentrates during 1989-93 declined precipitously relative to the peak year 1980, when domestic uranium concentrate production, according to the EIA, amounted to 44 million pounds U_3O_8 equivalent. In contrast to 1980, during 1989-93, annual domestic uranium concentrate production did not exceed 14 million pounds throughout the period, although electricity generation from nuclear power in the United States more than doubled during 1980-93.[46]

U.S. production and shipments of uranium during 1989-93, as compiled by the EIA in terms of mine production, concentrate production, and concentrate shipments, in millions of pounds U_3O_8 equivalent, are shown in the following tabulation.[47] Production and shipment data for 1994 were not available at the time of preparation of this report.

Year	Mine production[1]	Concentrate production[1]	Concentrate shipments[1]
1989 . .	9.7	13.8	14.8
1990 . .	5.9	8.9	13.0
1991 . .	5.2	8.0	8.4
1992 . .	1.0	5.6	6.9
1993 . .	2.0	3.1	3.4

[1] During 1989-93, according to EIA data, U.S. concentrate production of natural uranium declined by 78 percent, from 13.8 million pounds to 3.1 million pounds. Uranium mine production and shipments tracking the decline in concentrate production also declined precipitously during this period.

As noted previously, industry sources attribute the precipitous decline in production to high imports, continued large, although declining, inventories, and low market prices, which were often well below the cost of production of many domestic uranium producers. Although all sectors of the domestic uranium raw materials industry were adversely affected by deteriorating market conditions during 1989-93, ISL and byproduct production, with their lower capital and maintenance costs, increased their share of total uranium production at the expense of conventional mining methods. The following tabulation, which contains data obtained from NUEXCO and is therefore not necessarily the same as the EIA data shown above, shows U.S. production of

[45] Outside the United States, production data are generally reported in units of kilograms or metric tons of uranium (U) equivalent. The EIA has recently begun to report some domestic uranium data in terms of both pounds of U_3O_8 equivalent and kilograms U.

[46] EIA, *Annual Energy Review 1993*, table 9.2, p. 257. Nuclear electricity net generation rose from 251.1 billion kilowatthours in 1980 to an estimated 610.3 billion kilowatthours in 1993.

[47] EIA, *Uranium Industry Annual 1993*, table ES1, p. xxviii.

uranium by type of operation in million of pounds U_3O_8 and by share of total for 1989 and 1993.[48]

	1989—		1993—	
	(million pounds)	(percent)	(million pounds)	(percent)
Conventional .	7.7	56	0	0
Byproduct	3.7	27	1.4	39
In situ leach ..	2.4	17	2.2	61
Total	13.8	100	3.6	100

In 1993, conventional uranium production ceased and byproduct uranium production declined by 62 percent relative to 1989. However, uranium produced by ISL, the most efficient form of uranium production, declined by only about 8 percent in quantity relative to 1989 and became the dominant form of production.

General Characteristics of the Uranium and Nuclear Fuel Industry

In the United States most nuclear fuel companies confine their activities to only one stage of the nuclear fuel cycle. Uranium mining companies do not, for example, operate conversion, enrichment, or fuel-fabrication plants, nor do these firms generally have any corporate relationship with companies that operate these facilities. Consequently, the domestic uranium and nuclear fuel industries are characterized by a lack of vertical integration. On a global scale, however, several U.S. uranium mining and milling companies are subsidiaries of large multinational companies or are engaged in joint ventures with such firms. At least one of these multinational companies (Cogema), which has operated uranium mining and milling facilities in the United States, operates facilities globally at all levels of the nuclear fuel cycle.

The uranium and nuclear fuel industries are, in general, considered to utilize a high degree of advanced technology. Moreover, even in the more established technological areas, such as uranium mining and milling, new technologies have been developed particularly in the area of in situ leach mining. Much of the "high-tech" character of the nuclear fuel industry is concentrated in the Government. Perhaps the area of most extensive research and development (R&D) in the nuclear fuel industry is the AVLIS program and similar R&D programs conducted in France and Japan.

The level of inventories of uranium held by utilities declined during 1989-93, and some firms have indicated that they intend to keep inventories to a bare minimum, or a level only sufficient to meet processing needs.[49] This decision by U.S. utilities to consume "excess" inventories has been facilitated by an easing of concern by these utilities about maintaining security of supply, as will be discussed in the *Market Mechanisms* section. In the meantime, rather than letting their inventories sit, some producers and even utilities have loaned out some of their inventories to other utilities. After the period of the loan has expired, the borrower will return an equivalent amount of uranium to the lender.

U.S. end-of-year uranium inventories for 1989-93, for utilities, domestic suppliers, and the U.S. Government, as compiled by the EIA, are shown in the tabulation at the bottom of the page (in millions of pounds U_3O_8 equivalent).[50]

Total inventories of uranium in the United States (including commercial and Government inventories), which amounted to 338 million pounds U_3O_8 equivalent at year-end 1984, declined steadily to 240 million pounds at year-end 1989 and to 178 million pounds at year-end 1993. Decline of inventories occurred for stocks held by utilities as well as for stocks held by the Government, except in 1993 when Government stocks rose slightly. The decline in inventories did not necessarily result in an improvement of the economic conditions of the U.S. uranium industry (see discussion on the *Uranium Mining and Milling Industry*).

[48] NUEXCO, *1993 Annual Review*, p. 97.

[49] Uranium Institute, *Uranium in the New World Market: Supply and Demand 1990-2010*, pp. 65-68.

[50] EIA, *Uranium Industry Annuals 1989-1993.* Government inventories are for end of fiscal year, September 30. In the *Uranium Industry Annual 1993*, relevant tables were table 39, p. 43, and table 40, p. 44.

Year	Utilities	Domestic suppliers	Government	Total
1989	115.8	22.2	102.2	240.2
1990	102.7	26.4	92.6	221.7
1991	98.0	20.7	83.5	202.2
1992	92.1	25.2	68.9	186.2
1993	80.7	23.7	73.6	178.0

According to the Uranium Institute, "excess" utility inventories of uranium in North America as of Dec. 31, 1992 (defined to be uranium that is not held in the processing pipeline and that is not held for strategic purposes, i.e., security of supply reasons) amounted to an estimated 18.2 million pounds U_3O_8 equivalent.[51] Presumably, when these "excess" inventories are depleted, North American utilities (which are predominantly located in the United States) will increase their uranium purchases. Strategic inventories in North America were estimated to be 36.4 million pounds. Total inventories in North America at year-end 1992 were estimated to be sufficient to meet forward requirements of about 14 months.[52]

Globalization

The uranium and nuclear fuel industries are highly globalized. The globalization of the industries is demonstrated by the important role that multinational companies play in the uranium and nuclear fuel industries and by the growth of joint ventures between firms from different countries, including electric companies as well as uranium producers. An advantage of globalization, according to industry sources, is that it enables a producer to enter a uranium market anywhere in the world. Globalization also permits firms to share resources and reduce investment risks. The presence of active brokers and traders and of such international organizations as the Uranium Institute, whose meetings bring together world specialists in uranium, nuclear fuel, and nuclear power, have fostered the globalization of the uranium and nuclear fuel industries.

Six examples of joint ventures are cited below:

- NUEXCO, a Denver-based, fuel-trading organization (the firm recently declared bankruptcy) and Tenex, the Russian export agency, had been involved in a joint venture, Global Nuclear Services and Supply, Ltd., (GNSS) to market Russian-origin uranium in the United States.

- Louisiana Energy Services, a joint venture involving U.S. utilities and Urenco, a Western European consortium specializing in uranium enrichment, is attempting to set up the first fully private uranium enrichment facility in the United States.

- Energy Fuels Exploration Co., a U.S. company specializing in uranium mining and milling, is involved in a joint venture with Priargunsky Mining and Chemical Integrated Works in Eastern Russia and Tenex, the Russian export company, for the mining, processing, and marketing of uranium in that country.[53]

- Uranerz and Cameco Corp., a German and a Canadian multinational uranium mining company, respectively, are involved in a joint venture with Korean Electrical Power Corp. and Ferret Partners, a domestic uranium mining partnership, for the production of uranium in Crow Butte, NE. Crow Butte is the second largest operating ISL facility in terms of production capacity in the United States.[54]

- Highland, as noted in the *Industry Structure* section, the largest operating domestic ISL facility located in Wyoming, is operated by a joint venture principally owned by electric power companies in the United Kingdom and Cogema, the French Government-owned integrated uranium and nuclear fuel producer.[55]

- IMC Fertilizer group and Freeport-McMoRan Resource Partners, formed a joint venture, IMC-Agrico, to manage their phosphate and uranium byproduct operations.[56] The company operates two uranium byproduct facilities in Louisiana.

The global nature of the uranium and nuclear fuel industry is shown also by the high percentage of foreign-based companies that operate in the United States, especially in the U.S natural uranium industry and in the U.S. nuclear fuel-fabrication industry. As noted previously, as of late 1993, all of the five primary uranium producers that were in commercial operation in the United States were majority foreign owned and foreign-based companies currently operate three of the five operations for the fabrication of nuclear fuel. Previously, the U.S. nuclear fuel fabrication industry was managed exclusively by domestic companies.

[51] Uranium Institute, *Uranium in the New World Market: Supply and Demand 1992-2010*, table 23, p. 68.
[52] Ibid.

[53] NUEXCO, *1992 Annual Review*, p. 17.
[54] EIA, *Uranium Industry Annual 1993*, pp. x-xiv.
[55] Ibid.
[56] NUEXCO, *1993 Annual Review*, p. 97.

U.S. MARKET

Consumer Characteristics and Factors Affecting Demand

Electrical utilities operating nuclear power plants are the only significant consumers of uranium outside the defense industries. In 1993, the U.S. nuclear power industry consisted of about 43 lead utilities (main utility owners) or fuel buyers, which operated 109 nuclear reactors.

In recent years, purchases of uranium for military applications, most of which is in the form of HEU, has reportedly declined because the DOE has large stockpiles of this material.[57] Arms reduction agreements and the easing of tensions between the United States and the FSU, especially Russia, were other factors that contributed to a decline in demand for HEU. Defense applications of uranium include its use as a fuel in nuclear submarines and aircraft carriers, as well as its well-known use in nuclear weapons.

Market Mechanisms

Two key factors contributed to the dominant characteristics of the U.S. uranium market during the period covered by this summary: (1) U.S. utilities' fears that they would run out of uranium eased as the supply of uranium became more plentiful because of high imports and surplus inventories;[58] and (2) utilities came under increased pressure from their customers and PUCs to keep their power costs low (including inputs such as uranium). Factors that accounted for this increased price pressure include increased competition and more stringent oversight of prices by some PUCs that previously had been more tolerant of requests for rate increases.[59] For example, legislative moves to deregulate the purchase of electrical power encouraged independent power producers to produce electricity through such alternate methods as cogeneration.[60] Thus utilities came under intense pressures to purchase the various forms of uranium and enrichment services at the most competitive prices feasible.[61]

Partly because utilities accumulated large amounts of uranium, middlemen and brokerage firms have been particularly active in the uranium industry, facilitating foreign purchases and permitting excess inventories to reenter the market. Often these transactions were brokered in the secondary market through transactions such as exchanges and loans.[62]

Because of the uranium oversupply, suppliers of uranium were not limited to producers but included any party with excess quantities of uranium (including utilities). Many of the transactions facilitated by brokers and traders were spot market transactions.[63]

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[57] A "ballpark" estimate of the size of the national security market for uranium relative to the civilian sector can be derived from data provided by the DOE's Office of Uranium Enrichment in their annual reports. This data also show that defense expenditures for enrichment likely declined during fiscal years 1989-1992. In FY 1989, DOE revenues for uranium enrichment services from Government sources (believed to be primarily defense related) amounted to $162 million, whereas domestic non-Government revenues (believed to be primarily sales to domestic utilities) amounted to $748 million. Defense revenues, therefore, made up about 18 percent of DOE's domestic revenues for uranium enrichment services in FY 1989. In FY 1991, DOE revenues for uranium enrichment services from Government sources amounted to $116 million compared with domestic non-Government revenues of $754 million. Defense revenues in FY 1991, therefore, declined to an estimated 13 percent of the DOE's domestic revenues for uranium enrichment services. In FY 1992, no Government revenues to the DOE for uranium enrichment services were reported.

[58] According to industry sources, by the end of 1993, uranium inventories had declined to the point that much of the "excess" had disappeared.

[59] Jim Hewlett, economist, EIA, conversation with USITC staff, July 5, 1995. According to Mr. Hewlett, the probability that a utility would receive a disallowance for a rate increase from a state PUC roughly doubled from one-third to two-thirds in the recent past.

[60] The National Regulatory Research Institute, *Current PGA and FAC Practices: Implications for ratemaking in Competitive Markets*, Nov. 1991, p. 5; and Mark de Michelle, *Insights into a Changing U.S. Electric Utility Industry*, presented before the U.S. Council for Energy Awareness, Oct. 1993.

[61] A characteristic of the uranium market is that utilities tend to purchase natural uranium and uranium-processing services from different suppliers and processors at each stage of the nuclear fuel cycle rather than relying on one supplier to supply finished fabricated nuclear fuel. Uranium, both natural and enriched, is a commodity and can be purchased in various forms from a wide variety of sources, both domestic and foreign.

[62] According to the EIA's *Uranium Industry Annual*s for 1990-93, during that period (comparable data were not reported for 1989), transactions in the secondary market consisting of intersupplier sales, exchanges, and loans ranged between 35.0 million and 43.8 million pounds annually. These figures approximate total annual consumption of uranium during that period (see *Consumption* section) demonstrating that transactions in the secondary market were substantial.

[63] The following data, reported by NEUXCO in the *Market Developments* section of its annual reviews, illustrate the importance of brokers and traders in facilitating global sales of uranium (including concentrates, uranium hexafluoride and enriched uranium) especially in the short-term market during the period covered by this summary. According to NUEXCO, intermediaries, that is brokers and traders, were the largest sellers of uranium reported for spot and near-term sales accounting for 46 percent of sales volume in 1993, although down from 72 percent in 1991. In 1993, sales by intermediaries exceeded sales by producers by

Spot market transactions had increased at the expense of long-term transactions during the past decade.[64] In anticipation of lower prices, especially on the spot market, utilities have allowed long-term contracts with some of their suppliers, including the DOE, to lapse. The tendency to negotiate shorter term contracts also has reduced the average duration of new long-term contracts that were signed.

A summary of U.S. primary market and secondary market activity in terms of trade flows is provided annually by the EIA. Figure 5 summarizes uranium market activity in 1993.[65] This summary demonstrates how in recent years imports and secondary market transactions accounted for a substantial portion of transactions in the U.S. uranium market.

Pricing

As noted in the previous section, the period 1989-93 was a buyer's market for uranium because of an abundant supply of uranium owing to high imports and high inventories. The various processed forms of uranium are considered to be commodities; that is, quality is not usually a factor in influencing purchasing and pricing decisions. Uranium prices generally declined during 1989-93, despite declining inventories, increased generation of nuclear power, and reduced domestic and worldwide production of uranium concentrates. These price declines contributed to the downsizing of the U.S. uranium industry and to the decision by U.S. uranium producers to cease all conventional uranium mining and milling in 1992.[66]

Although fluctuations in the price of uranium have had a profound impact on the economic status of the domestic uranium industry, price fluctuations for uranium and nuclear fuel have not significantly affected U.S. demand for nuclear power, according to industry sources. Relative to the total cost of nuclear power, nuclear fuel costs have remained relatively low and have not escalated, unlike other cost factors for nuclear power.[67]

The average price of uranium delivered by U.S. suppliers to domestic utilities (in dollars per pound U_3O_8 equivalent) during 1989-93 is shown in the following tabulation as well as the average price paid for imported uranium delivered to U.S. utilities and suppliers; their percent ratios are also shown.

Item	1989	1990	1991[1]	1992	1993
	(dollars per pound)				
Domestic deliveries	19.56	15.70	13.66	13.45	13.14
Imports ...	16.75	12.55	15.55	11.34	10.53
Ratio (percent)	86	80	114	84	80

[1] In 1991, according to industry sources, an unusually high percentage of imports were delivered under older longterm contracts that originated during a period when the price of uranium was relatively high. Consequently, the average price of uranium imports in 1991 was relatively high.

In 1988, the average price of delivered uranium per pound U_3O_8 equivalent from domestic suppliers was $26.15, down from $38.37 in 1982. During 1989-93, the average price of delivered uranium continued to fall; however, the rate of decline was much slower during 1991-93 than during 1989-91.[68] During the period covered by this summary, except for 1991, the average price of uranium imports also declined continuously. Except for 1991, the average price of uranium imports was at least 14 percent less than the average price of uranium delivered by domestic suppliers.

63—*Continued*
39 percent. Intermediaries concluded spot and near-term purchasing agreements accounting for 47 percent of uranium purchases in 1989 and 42 percent in 1993, in both of those years exceeding purchases made by utilities. (A spot market contract is defined by NUEXCO to be a contract in which all deliveries are completed within a year after the contract is signed; a nearterm market contract is defined by NUEXCO to be a contract in which all deliveries are completed in more than a year but less than 3 years after the contract is signed. Other industry observers such as the EIA may define these terms differently (see glossary)).

64 The following tabulation, in millions of pounds U_3O_8 equivalent, compiled from data provided by the EIA in its *Uranium Industry Annual 1993*, table 24, p. 29, shows how delivery of uranium under new short-term contracts signed by U.S. utilities increased during 1989-92 relative to a period about 7-10 years earlier, 1982-83, when security of supply was of greater concern. In contrast, the amount of uranium delivered under new long-term contracts (other than fluctuating) did not appear to show an obvious increasing or declining trend.

Year[1]	Short-term Contracts	Long-term Contracts	Total
1982	0.5	9.1	9.6
1983	2.7	15.5	18.2
1989	6.9	11.0	17.9
1990	12.0	15.4	27.4
1991	9.9	2.7	12.6
1992	9.4	13.9	23.3

[1] Data for 1993 were withheld to avoid disclosure of business proprietary information.

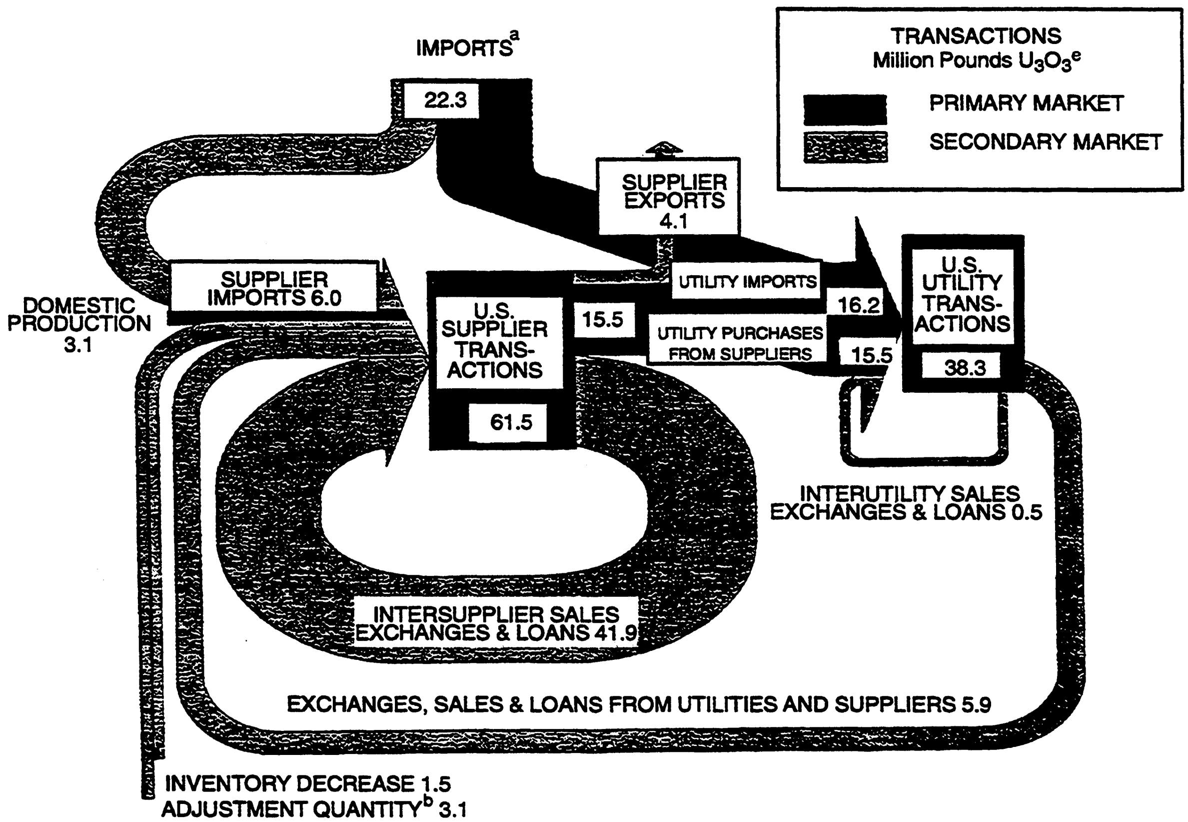
65 EIA, *Uranium Industry Annual 1993*, fig. 11, p. 27.

66 EIA, *Uranium Industry Annual 1993*, p. ix.

67 EIA, *Monthly Energy Review*, "Commercial Nuclear Electric Power in the United States," Aug. 1994.

68 EIA, *Uranium Industry Annual 1993*, p. xxviii.

Figure 5
Uranium marketing activity during 1993



Source: EIA, *Uranium Industry Annual 1993.* Reprinted with permission of the EIA.

Factors that may have accounted for the continued low prices of uranium on the supply side include the following: (1) the large inventories of uranium that accumulated in the 1970s and early 1980s in anticipation of an explosive growth of nuclear power that grew but not at the rate anticipated;[69] (2) the discovery and exploitation of large deposits of uranium especially in Canada, with low production costs that was exported to the United States and other countries; (3) the emergence of the FSU (after 1991, Russia, Kazakhstan, and Uzbekistan) as a major supplier of low-priced natural and enriched uranium on the world market; and (4) the presence of large quantities of HEU in nuclear warheads in Russia and the United States and well-publicized moves to convert this material into LEU suitable for use in nuclear power plants. Although there were, in fact, no U.S. imports of Russian LEU produced from Russian HEU during the period covered by this summary (1989-93), anticipation of a major new source of uranium supply could have influenced uranium buyers and sellers not to raise prices.

Another factor that may have contributed to the continued low prices of uranium during the period covered by this summary on the demand side was the increasingly aggressive attempts by utilities, pressed by their PUCs and customers, to purchase uranium at the most competitive prices. On the other hand, declining levels of inventories and trade restrictions imposed on uranium imports from the FSU may have had the effect of slowing the decline of uranium prices during 1989-93.

Consumption

In this report, uranium consumption will be measured in terms of two variables for the period 1989-93. Data for 1994 were not available at the time of preparation of this report. The first measure of

[69] In 1974, nuclear power was expected to account for approximately 40 percent of U.S. electrical capacity by 1990, about double the actual percentage realized (NUEXCO communication, March 1994). As a result of overbuilding, more than 120 nuclear power units that were ordered were either cancelled or indefinitely deferred. (EIA, *Commercial Nuclear Power 1991*, table E1, pp. 105-109.)

consumption assesses the amount of uranium delivered to U.S. utilities by suppliers and is a measure of uranium demand by U.S. utilities. These deliveries include all forms of uranium delivered expressed as U_3O_8 equivalent. The second measure of consumption assesses the amount of uranium physically required in nuclear power plants (reactor requirements) and is an approximate measure of U.S. demand for nuclear power.[70] These two sets of data points, which were compiled by the EIA, and the ratios of deliveries to reactor requirements are shown in the following tabulation.

Year	Uranium deliveries to utilities[1]	Reactor require-ments[2]	Ratio of utility uranium deliveries to reactor requirements
	— (*millions of pounds U_3O_8 equivalent*) —		(*percent*)
1989	28.0	37.4	75
1990	32.2	38.9	83
1991	40.9	41.8	98
1992	35.4	42.9	83
1993	31.2	45.1	69

[1] Uranium deliveries in 1993 to U.S. utilities are obtained by adding 1993 domestic deliveries in table 23 and 1993 imports in table 30 of the EIA's *Uranium Industry Annual 1993*. This is equivalent to data for total utilities' purchases provided in table 35 of the *U.S. Industry Annual 1993* and to the totals for 1993 in tables 1 and 2 of the *Uranium Purchases Report 1993*. Data for 1989-92 were obtained using the same method. Before 1991, total uranium deliveries could only be obtained using the method described in the first sentence of this footnote.

[2] William Liggett, project manager, Energy Information Center, conversation with USITC staff, Nov. 29, 1994. Data were derived from tables in the *World Nuclear Capacity and Fuel Cycle Requirements* and *Uranium Industry Annual* series.

Because reactor requirements exceeded uranium deliveries to U.S. utilities during 1989-93, utility inventories of uranium were probably being depleted. This inference is supported by data provided by the EIA and discussed in previous sections showing that U.S. utility stocks had declined during 1989-93.[71]

The growth in the use of uranium in nuclear power plants during 1989-93 appears to be primarily attributable to the increased generation of electricity by nuclear power plants during that period. This increase was attributable primarily to an increase in the average amount of electricity generated by nuclear power plants, rather than to an increase in the number of nuclear power plants.

The tabulation at the bottom of the page shows how nuclear power generation changed during 1989-93.[72] Although the number of operational nuclear power plants actually declined slightly during 1989-93 and the total nuclear power capacity of the industry increased only slightly, the nuclear electricity output rose significantly (by 15 percent), except for a slight downturn in 1993. This increase was due primarily to an increase in the average capacity utilization rate of the nuclear power industry.[73]

The reduction in the number of nuclear power units during 1991-93 is attributed to the shutdown of three nuclear reactors in 1992-93, well in advance of their scheduled operational lives.[74] Advocates of nuclear

[70] The assumption that U.S. uranium requirements are directly proportional to U.S. nuclear-powered electricity generation is only an approximation. Factors that will change the proportionality constant include the "burnup rate" (the efficiency of the nuclear reactor) and the U235 assays of the enriched uranium product and the depleted uranium byproduct.

[71] According to the EIA, *Uranium Industry Annual 1991*, table 40, p. 60, and *Uranium Industry Annual 1993*, table 40, p. 44; during 1989-93, utility stocks of natural uranium in terms of U_3O_8 equivalent declined irregularly from 67.3 million pounds to 57.6 million pounds while utility stocks of enriched uranium declined from 48.5 million pounds to 23.1 million pounds.

[72] The capacity utilization rate of a nuclear power plant, termed the capacity factor, is the ratio of electricity produced over a given period, compared to the electricity that could have been produced during that period were the reactor operating at continuous full-power operation.

[73] EIA, *Annual Energy Review, 1993*, table 9.2, p. 257.

[74] In August 1993, a nuclear power unit operated by Texas Utilities Electric Company became operational. Consequently during 1991-93, the number of nuclear power units operating in the United States actually declined by two.

Nuclear power variable	1989	1990	1991	1992	1993[1]
Number of units	110	111	111	109	109
Electricity output[2]	529	577	613	619	610
Capacity factor	62.2	66.0	70.2	70.9	70.5
Total capacity[3]	98.2	99.6	99.6	99.0	99.1

[1] 1993 figures are preliminary.

[2] Units of electricity generation are in billion of kilowatthours.

[3] The total capacity of the U.S. nuclear power industry is the steady hourly output of domestic plants in units of million kilowatts during peak summer demand.

power have expressed concern about the possible implications of these premature shutdowns on the prospects for nuclear power.

Despite the continued increase in use of nuclear power in recent years, the future of commercial nuclear power is uncertain (and by extension, the future of the domestic uranium and nuclear fuel industry).[75] This uncertainty is demonstrated by the fact that no new nuclear power plant has been ordered in the United States since 1978. Moreover, all nuclear power plants ordered since 1973 have either been canceled or face rejection from State governments. According to projections submitted by the DOE, unless new nuclear power plants are ordered and built, the domestic nuclear power industry will become virtually extinct by about the year 2030, as aging nuclear power plants are decommissioned.

The problems facing the nuclear industry include large cost overruns, loss of confidence in the economic viability of the nuclear power industry, and public resistance to nuclear power from a safety and environmental viewpoint.[76] Also of great concern to the electric utilities is the problem of the long-term disposal of highly radioactive nuclear waste that is accumulating in the vicinity of the nuclear power plants.[77] Although the DOE has designated the Yucca Mountain site in Nevada as a prime possible location for the long-term storage of highly radioactive wastes, implementation of this project on schedule may be affected by criticism of the technical feasibility of the project,[78] as well as by opposition from the State of Nevada.[79]

In the meantime, efforts are being made to establish an interim site for the storage of spent fuel. According to the Nuclear Waste Policy Act of 1982, the DOE is required to take title to spent fuel from U.S. reactors as expeditiously as possible after the commencement of repository operations and to begin disposal by Jan. 31, 1998.[80] By that year about 25 nuclear power reactors will have run out of spent fuel storage capacity.[81] About $9 billion, including interest, has been already paid by U.S. electricity consumers to fund this program.[82]

[75] EIA, *World Nuclear Outlook 1994*, p. ix.
[76] EIA, *World Nuclear Outlook 1993*, p. 6.
[77] Ibid.
[78] *Nuclear Fuel*, Mar. 13, 1995, pp. 9-10.
[79] *Nuclear Fuel*, Feb. 27, 1995, p. 15 and Apr. 10, 1995, p. 8.
[80] Christopher A. Couts, Director of Planning Division, Office of Civilian Radioactive Waste Management, conversation with USITC staff, July 20, 1995.
[81] Ibid.
[82] Ibid.

Foreign Dependence

U.S. Dependence on Foreign-origin Natural Uranium

During 1989-93, U.S. utilities seeking lower prices and diversification increased their dependence on foreign suppliers for natural and enriched uranium. The following tabulation, derived from data provided by the EIA summarizes the share of deliveries to domestic utilities under purchase contracts of U.S. and non-U.S. origin uranium (further broken out by Canadian origin) in terms of the natural uranium component (in percent):[83,84]

Year	U.S. origin	Foreign origin	Canadian origin
1989	56	44	([1])
1990	44	56	([1])
1991	30	70	36
1992	22	78	35
1993	12	88	45

[1] Data for Canada are not available for 1989 and 1990.

U.S. utility dependence on foreign-origin uranium rose steadily from 44 percent to 88 percent during 1989-93. By 1993, only 12 percent of total deliveries of uranium to U.S. utilities were of U.S. origin. During 1991-93, Canadian-origin uranium accounted for about half of foreign-origin deliveries to U.S. utilities and between 35 and 45 percent of total deliveries.

U.S. Dependence on Foreign Suppliers of Enrichment Services

The tabulation on the next page is based on data provided by U.S. utilities to the EIA, summarizes their annual shipments of uranium feed to the DOE (supplanted by the USEC in July 1993) and to foreign enrichers as a percentage of U.S. utility feed deliveries to all enrichers:

[83] The origin of the uranium refers to where the natural uranium component was mined.
[84] Deliveries by domestic suppliers to U.S. utilities include both U.S. and foreign origin material. To obtain total deliveries of foreign origin uranium to U.S. utilities, foreign origin uranium delivered by domestic suppliers must be added to imports.
Domestic and foreign-origin uranium deliveries to U.S. utilities for 1991-1993 were obtained from tables 1 and 2 of the EIA's *Uranium Purchases Report 1993*. Data for 1989 for domestic-origin uranium deliveries to U.S. utilities were obtained from table 32, and data for foreign-origin uranium deliveries were obtained from table 32 and table 40 of the EIA's *Uranium Industry Annual 1989*. Data for 1990 were obtained using the same method.

Year	Domestic (DOE)	Foreign
1989[1]	93	6
1990	95	5
1991	89	11
1992	86	14
1993	92	8

[1] Because of rounding, total percentage did not add to 100.

The tabulation shows that, during 1989-93, the domestic enricher (DOE/USEC) remained the principal supplier of enrichment services to domestic utilities in contrast to the situation for natural uranium. However, during 1989-92, utilities increased the percentage of uranium that they shipped to foreign enrichers (from 6 to 14 percent). In 1993, the trend was reversed. In 1993, U.S. utilities increased their share of uranium feed deliveries to the domestic enricher while reducing their share of deliveries to foreign enrichers (from 14 percent) to 8 percent.[85]

FOREIGN INDUSTRY PROFILE

Foreign industry structure

Almost all of the uranium that is marketed internationally is sold either as natural uranium oxide, natural UF_6, or as enriched UF_6, enriched uranium oxide or fabricated fuel. Major suppliers of enriched uranium services are generally industrialized countries that use nuclear power that requires enriched uranium. Several countries that have worldclass facilities that provide enrichment services, such as the United Kingdom and the Netherlands, are not major producers of natural uranium concentrates. Conversely, several leading producers of natural uranium, such as Canada and Australia, do not have any uranium enrichment capacity.[86]

The following tabulation shows selected countries that were significant producers of natural uranium, providers of enrichment services, or both during the period covered by this summary.

Country	Natural uranium	Enrichment services
Australia	X	
Canada	X	
China	X	X
France	X	X
Gabon	X	
Germany[1]		X
Kazakhstan	X	
Namibia	X	
Netherlands		X
Niger	X	
Russia	X	X
South Africa	X	
United States	X	X
Uzbekistan	X	

[1] The Wismut mining enterprise in the former German Democratic Republic was a major uranium concentrate producer. Following unification, the enterprise was shut down in 1991 because of major environmental problems associated with the facility and high production costs.

Estimates of uranium production during 1989-93 are shown in table 2.[87] During 1989-93, virtually all uranium producers experienced some decline in production, and some foreign mining operations (including some Canadian and FSU operations with relatively low-ore grades) were shut down.

Although many nations have reserves of uranium, most uranium marketed commercially is derived from uranium ore mined and milled in only a handful of countries, including the United States, Canada, Australia, South Africa, Namibia, France, and Niger, as well as the leading uranium-producing republics of the FSU: Russia, Kazakhstan, and Uzbekistan.

Although the United States was the world's largest producer of uranium in 1980, U.S. uranium production has declined since then, both absolutely and relatively. U.S. production declined, largely, because U.S. uranium producers, which have higher production costs than many of their foreign counterparts (especially Canada and Australia that have higher quality reserves that can be mined at lower costs than those of the United States), lost market share to these lower-cost producers, including byproduct producers such as South Africa which produces uranium as a byproduct of gold and, to a lesser extent, copper production.[88] In addition, U.S. uranium producers, faced increased competition from uranium producers in nonmarket or transitional economy countries that did not necessarily enjoy resource advantages but that were willing to sell at prices far below that which a U.S. producer could afford in order to gain foreign currency and to maintain employment in their uranium and nuclear fuel industries.[89]

[85] EIA, *Uranium Industry Annual 1989*, table 43, p. 49; *Uranium Industry Annual 1990*, table 40, p. 58; *Uranium Industry Annual 1991*, table 37, p. 57; *Uranium Industry Annual 1992*, table 37, p. 60; and *Uranium Industry Annual 1993*, table 37, p. 42.

According to the EIA, *Uranium Purchases Report 1992*, p. 4, in 1992, U.S. utilities signed three new long-term uranium enrichment service contracts with foreign enrichers (Eurodif, Tenex, and Urenco), but none with the DOE. In 1993, U.S. utilities signed two new enrichment service contracts with unidentified organizations (*Uranium Purchases Report 1993*, p. 4).

[86] Canada does not require enriched uranium in its nuclear power plants that use heavy water. There are no nuclear power plants in Australia.

[87] NUEXCO, *1993 Annual Review*, fig. 14, p. 13. NUEXCO's figure for U.S. uranium production in 1993 (3.3 million pounds) is slightly above the number provided by the EIA of 3.1 million pounds (see section on *Production*).

[88] EIA, *Uranium Industry Annual 1993*, p. ix.

[89] EIA, *Uranium Industry Annual 1991*, p. 11; William N. Szymanski, Geologist at the EIA, conversation with USITC staff, July 6, 1995.

Table 2
World uranium production 1989-93

	Production (million pounds equivalent U_3O_8)					1993 Relative to 1992
	1989	1990	1991	1992	1993	
						Percent
Australia	9.5	9.2	9.8	6.1	5.9	-3.4
Canada	29.5	22.8	21.3	24.2	23.9	-1.2
France	8.4	7.4	6.8	5.5	4.5	-18.2
Gabon	2.3	1.8	1.6	1.4	1.4	0.0
Namibia	8.0	8.3	6.4	4.3	4.3	0.0
Niger	8.0	7.4	7.7	7.7	7.5	-2.6
South Africa	7.7	6.4	4.4	4.4	4.5	-2.3
USA	13.6	8.9	8.0	5.6	3.3	-41.1
Major Eastern Producers[1]	59.8	50.4	40.1	32.5	29.2	-10.2
Other[2]	2.4	1.9	1.6	1.8	1.8	0.0
Total[3]	149.0	124.5	107.5	93.5	86.3	-7.7

[1] Major Eastern Producers = Bulgaria, China, Czech Republic, former E. Germany, Hungary, Kazakhstan, Russia, Ukraine, and Uzbekistan.

[2] Other = Argentina, Belgium, Brazil, India, Mongolia, Pakistan, Portugal, Slovenia, and Spain.

[3] Because of rounding, columns may not add to totals shown.

Source: *NUEXCO 1993 Annual Review.*

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A comparison of estimated production costs (in dollars per pound U_3O_8) for leading Western producing nations for 1992 are shown in the following tabulation.[90]

Country	Conventional operations	ISL operations
United States	16-30	8-11
Canada	7-25	(1)
Australia	10-12	(1)

[1] ISL facilities are not commercially active in these countries.

The global uranium mining and milling industry experienced consolidations similar to that experienced by the U.S. industry (see the *Uranium Mining and Milling Industry* section). The percentage of non-FSU uranium production owned by the top three Western companies rose from 28 percent in 1980 to 31 percent in 1989 and then surged to 52 percent in 1993.[91] Among the world's largest Western firms producing uranium concentrates (U_3O_8) are Cameco (Canada), Cogema (France), and Uranerz (Germany). Cameco is regarded as one of the world's lowest cost producers of uranium because it partially owns and has developed mines that extract some of the highest quality uranium ore grades in the world.[92] The company has been jointly owned by Canadian shareholders, by the Provincial Government of Saskatchewan and by the Federal Government of Canada.[93] It is scheduled to be privatized when market conditions permit. Cameco is an integrated nuclear fuel producer with both refining

[90] Estimated by staff of the U.S. International Trade Commission based on information gathered from industry sources.

[91] Jay M. McMurray, *Impact of Consolidation of the Worldwide Uranium Industry*, Fig. 1, International Uranium Fuel Seminar, Nuclear Energy Institute, Sept. 1994.

[92] For example, Cameco owns 48.75 percent of Cigar Lake Mining Corp (CLMC). CLMC is responsible for developing the richest known uranium ore body in the world; much of the ore has an average ore grade of about 14 percent U_3O_8 (See *NUEXCO 1992 Annual Review*, p. 104). More typically, ore that had been extracted from Key Lake in Canada in 1992 and 1993 had an average mill head grade of between 2.22 and 2.45 percent (Cameco, *Cameco 1988-1993: 5 Years of Growth*) and when that ore is depleted it will be replaced by ore from the McArthur River deposit which contains 260 million pounds at an average ore grade of 5 percent U_3O_8 (*NUEXCO 1993 Annual Review*, p. 14). In contrast, in 1992, the average ore grade of uranium feed sent to conventional uranium mills in the United States was 0.23 percent (EIA, *Uranium Industry Annual 1993*, table 17, p. 18) about one-tenth the concentration of ore extracted from Key Lake in Canada.

[93] The Federal Government of Canada divested itself of its stocks in Cameco in Feb. 1995.

and conversion capabilities but not with enrichment capabilities. In 1994, it accounted for more than 10 percent of Western world uranium consumption requirements.[94]

Cogema, owned by the French Commission for Atomic Energy, accounts for about 20 percent of world uranium production with mines in France, Niger, Gabon, Canada, the United States, and Australia either directly or through subsidiaries and shareholdings. Cogema has a controlling interest in several dozen firms that participate in various aspects of the nuclear fuel cycle, including uranium exploration, mining and milling, conversion, enrichment, fuel fabrication, and spent fuel reprocessing.

Uranerz is controlled by two large German industrial concerns, C. Deilmann AG and Rheinbaum AG. It is involved in uranium production primarily in Canada, but also has an operation in the United States. In 1994, it accounted for about 21 percent of Western low-cost uranium production capacity.[95] Uranerz manages exploration, mining, and milling operations in these countries and is not integrated downstream in the nuclear fuel cycle (for example, conversion, enrichment, and fabrication). Other important Western uranium producers include Western Mining corporation which owns the Olympic Dam uranium enterprise in Australia that may be the world's largest deposit;[96] Rössing, a large open-pit uranium project in Namibia; and Energy Resources of Australia, which operates the Ranger mine in Northern Australia. The uranium-producing republics of the FSU have become international players in the world uranium market although they do not possess especially rich ore bodies.[97] As transitional economies, these countries have been willing to charge low prices to obtain hard currency and maintain employment in their uranium industries; however, these countries have also attempted to reduce costs by switching to ISL and by shutting down some of their more costly conventional uranium mines.[98] In addition, as noted in previous sections, the FSU, especially Russia, amassed a large inventory of natural and enriched uranium (including HEU in nuclear weapons) for defense purposes; much of this inventory is no longer needed and is currently available for commercial use.[99]

Natural and enriched uranium production in Russia are under the control of Minatom, the Russian (formerly the Soviet) Ministry of Atomic Energy. Tenex is the export arm of Minatom. With the breakup of the Soviet Union in late 1991, Kazakhstan and Uzbekistan have emerged as competitors with Russia in providing significant amounts of natural uranium to world markets. Although Kazakhstan and Uzbekistan have been dependent on the old Soviet uranium infrastructure, they are displaying a growing sense of economic independence, facilitated, in part, by Western companies' technical and business know-how.[100]

Uranium enrichment plants outside the United States are located in a relatively small number of countries, including France, the United Kingdom, Germany, the Netherlands, South Africa, Japan, Russia, and China. The largest of the producers in these countries in terms of commercial output are EURODIF in France; Urenco, a Western European consortium specializing in uranium enrichment with

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[94] Cameco Corp., *Information Summary*, 1994.

[95] Jay M. McMurray, *Impact of Consolidation of the Worldwide Uranium Industry*, Fig. 11, presented at the International Uranium Fuel Seminar, Nuclear Energy Institute, Sept. 1994. In Fig. 11, low-cost production capacity is defined to have full production cost of less than $15 per pound U_3O_8. Production capacity is defined to include all facilities that are able to produce uranium within 1 year (Jay McMurray, telephone conversation, Mar. 21, 1995).

[96] Ibid.; p. 3.

[97] The average ore grades of uranium ore bodies in the FSU do not exceed about 0.2-0.3 percent which is typical of the average ore fed to conventional uranium mills in the United States during 1992, the last year that these mills operated domestically. (EIA, *Uranium Industry Annual 1991*, table FE4, p. 8; EIA, *Uranium Industry Annual 1992*, table 18, and staff conversation with William Szymanski, geologist at the EIA.)

[98] EIA, *Uranium Industry Annual 1991*, pp. 10-11; staff conversation with William N. Szymanski, Geologist at the EIA, July 6, 1995.

[99] EIA, *Uranium Industry Annual 1991*, p. 11; Estimated FSU inventories as of 1994 (Steyn, J., in a paper presented at the Nuclear Energy Institute, Sept. 1994) are 300 million pounds U_3O_8 equivalent in civilian inventories (U and LEU) of which about 50 million pounds are possibly stored in Western Europe and 680 million pounds U_3O_8 equivalent in HEU. According to industry sources, a major portion of the uranium obtained by the FSU was extracted from mines in Eastern Europe especially from Czechoslovakia and the German Democratic Republic.

[100] William Szymanski, geologist at the EIA, conversation with USITC staff, Jul. 6, 1995. For example, KATEP (Kazakh State Corporation for Atomic Energy and Industry) is involved with a joint venture with Cameco and Uranerz for the exploration, development, and expansion of uranium facilities and for marketing uranium outside the FSU. KATEP also concluded a sales agreement with Energy Resources of Australia. Kazakhstan, however, still maintains special ties with Russia on nuclear fuel and on other nuclear matters. In 1993, Kazakhstan and Russia agreed to cooperate in the production and marketing of uranium. *(NUEXCO, 1993 Annual Review*, pp. 39-40) Kazakhstan continues to play an important role in the nuclear fuel cycle production process of Russia and Eastern Europe. A facility located at Ust-Kamenogorsk converts natural uranium oxide and uranium hexafluoride into uranium dioxide pellets that are then shipped to Russia for fabrication into nuclear fuel rods.

facilities in the United Kingdom, the Netherlands, and in Germany; and Tenex in Russia.

The uranium enrichment plants that are currently operating in South Africa, China, and Japan are fairly small; as a result, these countries do not export large amounts of enriched uranium. Japan is still heavily dependent on foreign suppliers for enriched uranium needs and will likely remain so because of growing demand for nuclear power and, consequently, nuclear fuel, even after a new enrichment facility comes on stream in Japan in the mid-1990s. The FSU emerged as a major exporter of enriched uranium for reasons that are similar to the emergence of the FSU as a major exporter of natural uranium. Because all the uranium enrichment facilities in the FSU had been located in territories that are now Russian, Russia is the only significant producer and exporter of enriched uranium among the countries that were formed from the break-up of the Soviet Union. However, several other FSU republics possess HEU, which they inherited from the Soviet era.[101] A listing of the major uranium enrichment facilities and their capacities or estimated capacities is provided in table 3.[102]

Supply, Demand, and Inventories

During 1989-93, U.S. uranium inventories declined as discussed in the *Uranium Mining and Milling Industry* section. Figure 6 shows that inventory drawdown is not confined to the United States but is the dominant trend throughout the world.[103]

Some industry observers caution that, because of declining inventories, it is not certain that uranium prices will remain low indefinitely. These observers point out that Western inventories of uranium have been declining in recent years despite an influx of imports from the FSU because reactor requirements have exceeded world uranium production. These industry observers believe that the excess in the world natural uranium market could turn into a shortage in the foreseeable future.

Figure 7 represents the Uranium Institute's estimates and projections for Western uranium supply and demand assuming that the capacity utilization for Western operational and planned mines would continue at estimated 1991 weighted average levels (62.1 percent).[104] The figure shows that the gap between supply and demand will likely grow once excess inventory is depleted. Figure 8 shows that even if Western mines had been operating at 100 percent of capacity, eventually (by about the year 2004) uranium demand would have outpaced supply.[105] The gap could be narrowed temporarily, because the world's major nuclear powers are engaged in activities, as noted in the body of this report, to convert some of their HEU used for defense purposes into LEU suitable for use in nuclear power plants.

U.S. AND FOREIGN TRADE MEASURES

U.S. Trade Measures

U.S. Tariff Measures

Table 4 shows the column 1 rates of duty as of January 1, 1995, for imports of uranium, plutonium, fuel elements (cartridges), spent fuel, and other radioactive elements and their isotopes and compounds under the *Harmonized Tariff Schedule* (*HTS*). This table includes duties assessed on imports from countries that have most-favored-nation (MFN) status, as well as rates of duty for countries qualifying for special tariff preferences. The major articles of trade for these nuclear materials, including natural uranium compounds, enriched uranium compounds, and other radioactive elements and their isotopes and compounds, enter the United States duty free. Those items in this grouping that are dutiable are relatively minor items of international trade, especially when compared with natural and enriched uranium. The column 1-general duty rate for natural and depleted uranium metal and for other forms of natural and depleted uranium that are not in a compound form, such as dispersions of nonenriched uranium including cermets and ceramic products, is 5 per cent ad valorem.[106] The general duty rate for fuel cartridges

[101] Ukraine possesses an estimated 1,200 to 1,400 nuclear warheads that are to be dismantled in Russia. The HEU in these nuclear warheads are to be converted into LEU in Russia for use in commercial nuclear power plants, according to "Ukraine Joins Treaty Curbing Nuclear Arms," *Washington Post*, Nov. 17, 1994, pp. A1, A34.

[102] EIA, *World Nuclear Capacity and Fuel Cycle Requirements 1993*, app. I, p. 149. An MTSWU corresponds to a metric ton of separative work units and is equal to 1,000 SWU.

[103] The Uranium Institute, *Uranium in the New World Market*, Fig. 11, Oct. 1992, p. 32. The unit of measure, the tonne, is defined as 1,000 kilograms of elemental uranium equivalent and is equal to about 2,600 pounds U_3O_8 equivalent.

[104] The Uranium Institute, *Uranium in the New World Market*, fig. 12-c, Oct. 1992, p. 35.

[105] Ibid., figure 12-a, p. 34.

[106] A cermet is a ceramic material bonded with metal and used in applications involving high- temperature and strength.

Table 3
Uranium enrichment facilities

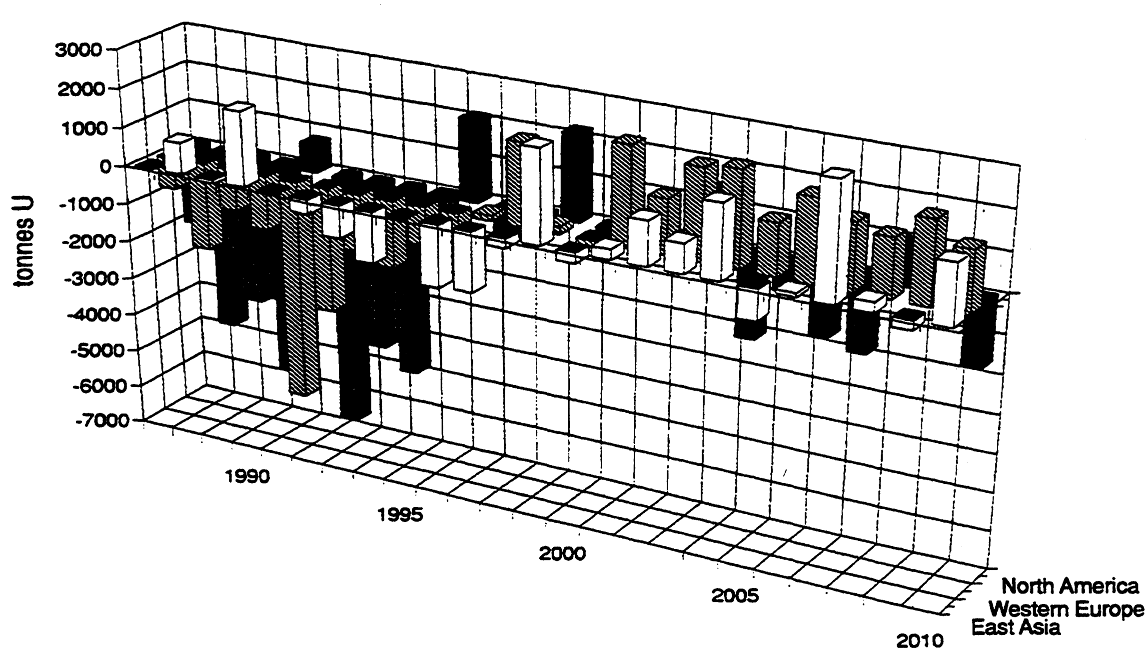
United States	U.S. Department of Energy	Oak Ridge, Tennessee	([1])	
	U.S. Department of Energy	Paducah, Kentucky	11,300	MTSWU/year[2]
	U.S. Department of Energy	Portsmouth, Ohio	7,000	MTSWU/year
France	EURODIF	Tricastin	10,800	MTSWU/year
West Germany	Urenco	Gronau	520	MTSWU/year
Japan	PNC	Ningyo Toge	260	MTSWU/year
	JNFI	Rokkashomura	150	MTSWU/year
Netherlands	Urenco	Almelo	1,410	MTSWU/year
South Africa	AEC	Pelin daba	300	MTSWU/year
United Kingdom	Urenco	Capenhurst	820	MTSWU/year
Russia	Tenex	Ekaterinburg, Angarsk Tomsk, Krasnoyarsk	12,000	MTSWU/year
People's Republic of China	China Nuclear Energy Industry Corporation	Lanzhou, Xi' an	500	MTSWU/year

[1] Shut down.

[2] One MTSWU = 1,000 SWU.

Source: EIA, *World Nuclear Capacity and Fuel Cycle Requirements 1993, NUEXCO 1993 Annual Review,* and staff conversation with an industry source

Figure 6
Utility inventory drawdown and build up



(Negative figure means inventory drawdown)

East Asia Western Europe North America

Source: Uranium Institute: *Uranium in the New World Market,* Oct. 1992.
Reprinted with permission of the Uranium Institute.

Figure 7
Western uranium supply and demand

(Assuming 62.1% capacity utilization for "Western operational and planned mines")

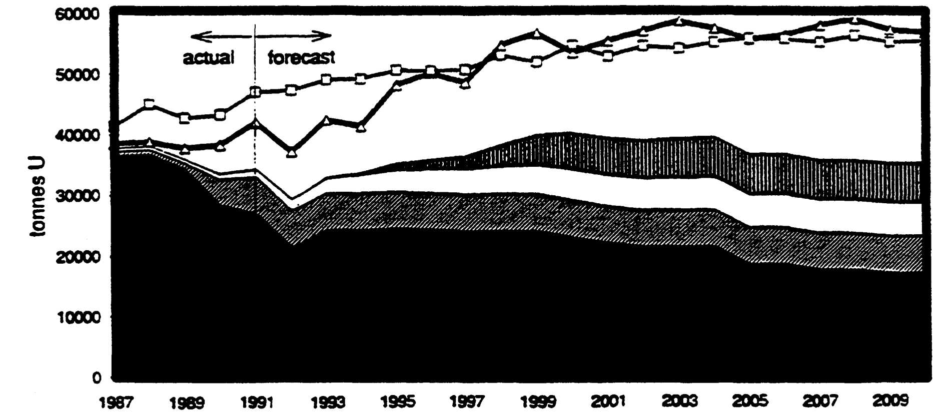
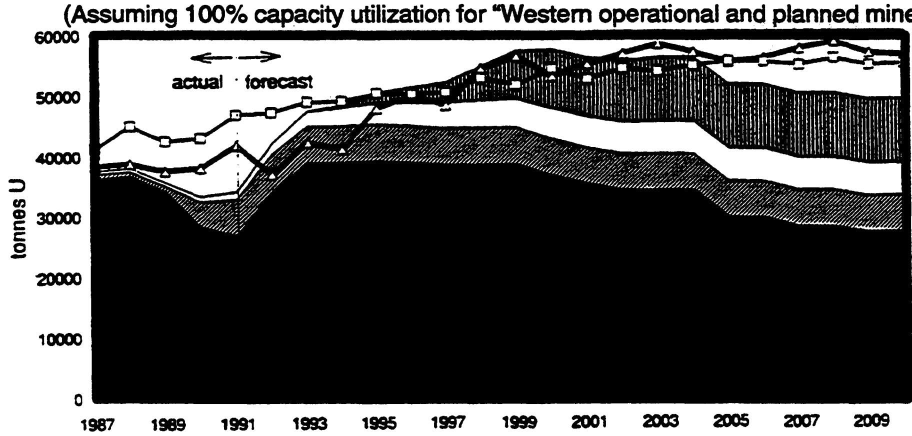
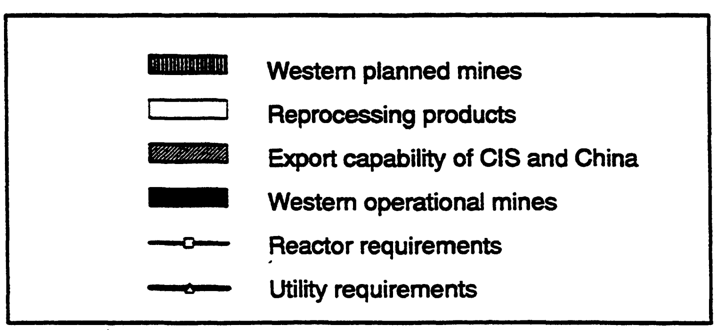


Figure 8
Western uranium supply and demand

(Assuming 100% capacity utilization for "Western operational and planned mines")





Source: *Uranium Institute: Uranium in the New World Market*, Oct. 1992.
Reprinted with permission of the Uranium Institute.

Table 4
Uranium and Nuclear Fuel: Harmonized Tariff Schedule subheading; description; U.S. col. 1 rate of duty as of Jan. 1, 1995; U.S. exports, 1994; and U.S. imports, 1994

HTS subheading	Description	Col. 1 rate of duty as of Jan. 1, 1995		U.S. exports, 1994	U.S. imports, 1994
		General	Special[1]		
				— Million dollars	—
2612.10	Uranium ores and concentrates	Free		1.5	([3])
2844	Radioactive chemical elements and radioactive isotopes (including the fissile or fertile chemical elements and isotopes) and their compounds; mixtures and residues containing these products:				
2844.10	Natural uranium and its compounds; alloys, dispersions (including cermets), ceramic products and mixtures containing natural uranium or natural uranium compounds:				
2844.10.10	Uranium metal	5%	Free (A*[2], CA, E, IL, J, MX)	([3])	([3])
2844.10.20	Uranium compounds	Free		19.3	432.6
2844.10.50	Alloys, dispersions (including cermets), ceramic products and mixtures containing natural uranium or natural uranium compounds	5%	Free (CA, E, IL, J) 3% (MX)	16.0	([3])
2844.20.00	Uranium enriched in U^{235} and its compounds; plutonium and its compounds; alloys, dispersions (including cermets), ceramic products and mixtures containing uranium enriched in U^{235}, plutonium or compounds of these products	Free		1,053.5	524.1
2844.30	Uranium depleted in U^{235} and its compounds; thorium[4] and its compounds; alloys, dispersions (including cermets), ceramic products and mixtures containing uranium depleted in U^{235}, thorium[4], or compounds of these products:				
2844.30.20	Uranium compounds	Free		5.0	([3])
2844.30.50	Alloys, dispersions (including cermets), ceramic products and mixtures containing uranium depleted in U^{235}, depleted uranium metal, thorium, or compounds of these products,	5%	Free (A*[2], CA, E, IL, J, MX)	0.7	0.5
2844.50.00	Spent (irradiated) fuel elements (cartridges) of nuclear reactors	Free		([3])	([3])
8401.30	Fuel elements (cartridges), non-irradiated and parts thereof	6.5%	Free (A, CA, E, IL, J, MX)	82.6	1.7

[1] Programs under which special tariff treatment may be provided and the corresponding symbols for such programs as they are indicated in the "Special" subcolumn are as follows: Generalized System of Preferences (A or A*); North American Free Trade Agreement, eligible goods of Canada (CA); Caribbean Basin Economic Recovery Act (E); United States–Israel Free–Trade Agreement (IL); the Andean Trade Preference Act (J); and the North American Free Trade Agreement, eligible goods of Mexico (MX).

[2] India is currently (1995) ineligible to receive duty concessions under the Generalized System of Preferences for this HTS subheading.

[3] Less than $50,000.

[4] Thorium and thorium compounds are not covered in this summary.

Source: USITC, Harmonized Tariff Schedule of the United States 1995. Exports and imports compiled from official statistics of the U.S. Department of Commerce.

(fuel rods) is 6.5 percent ad valorem. These general duty rates do not reflect the special rates granted to some countries. Imports of uranium metal and fuel cartridges from Canada, for example, enter the United States duty free. On the other hand, imports from the FSU were assessed column 2 duty rates for products that the FSU exported to the United States. Russia became eligible for most-favored-nation treatment on June 17, 1992; most of the other FSU republics subsequently did so as well. During the Uruguay Round, no concessions were made by the United States for the HTS subheadings covered by this summary except for HTS 8401.30. During 1996-2000, duties for this HTS subheading will be staged down from 6.5 to 3.3 percent ad valorem.[107]

U.S. Nontariff Measures

Because of uranium's special role in the manufacture of nuclear weapons, trade in uranium has been subject to a level of scrutiny that exceeds the level applied to most other commodities.[108] However, except for specific cases cited in this section, imports of uranium and nuclear fuel have, in recent years, been relatively free of trade restrictions.[109]

In general, the U.S. uranium market is not only the largest in the world but also among the world's most open. As noted above, rate pressures imposed on utilities by regulators and customers have encouraged utilities to seek the lowest cost source of supply, whether domestic or imported.

During 1989-91, the United States imposed restrictions on uranium originating from South Africa. The Comprehensive Anti-Apartheid Act of 1986 prohibited the importation of South African origin uranium ore or uranium oxide. Although industry sources indicate that there was confusion about the scope of the law[110]—for example, whether it applied to UF_6 or to re-exports—imports of uranium from South Africa plummeted following passage of the bill. In 1991, as a result of the implementation of political reforms in South Africa, the ban on importing uranium from South Africa was lifted.

U.S. Government Trade-Related Investigations

In recent years, at least three U.S. Government agencies, including the USITC, have conducted investigations related to imports of the materials covered in this summary.

Section 170b of the Atomic Energy Act of 1954, as added by section 23(b) of the U.S. Nuclear Regulatory Commission Authorization Act of 1983 (Public Law 97-415), required the Secretary of Energy to conduct an annual assessment of the viability of the domestic uranium mining and milling industry for the years 1983 through 1992.[111] The Secretary is required to consider four criteria—resource capability, supply response capability, financial capability, and import commitment dependency.[112] In the first annual assessment for calendar year 1983, the Secretary found the industry to be viable. Since then, in annual assessments through calendar year 1992, the Secretary has found that the industry was nonviable.[113] A section of the Energy Policy Act of 1992,[114] which superseded the above requirements, requires that the DOE, through the EIA, provide an annual report to the Congress with information on nuclear utility purchases and imports, including the country of origin of uranium, enriched uranium, and enrichment services.[115]

In 1988, the Secretary of Energy requested the Secretary of Commerce to conduct an investigation under section 232 of the Trade Expansion Act of 1962 (19 U.S.C. 1862) to determine whether imports of uranium threaten to impair the national security. In 1989, the DOC made a negative determination.[116]

In September 1991, the U.S. International Trade Commission (USITC), at the request of the Senate Finance Committee, initiated an investigation under section 332(g) of the Tariff Act of 1930 (19 U.S.C. 1332(g)) on the impact on the domestic industry of

107 Presidential Proclamation 6763, "To Implement the Trade Agreements Resulting From the Uruguay Round of Multilateral Trade Negotiations, and for Other Purposes," Dec. 23, 1994.

108 For example, the DOE and the NRC share a database that tracks all movement of uranium that enters or leaves any U.S. location.

109 The United States did not always have relative freedom of import trade in uranium. From the mid-1960s to the mid-1970s, the U.S. Government's uranium enrichment facilities were prohibited from enriching foreign origin uranium for use in domestic nuclear commercial reactors. During 1977-83, these restrictions were phased out and lifted entirely in 1984.

110 *Nuclear Fuel*, Jan. 12, 1987, pp. 9-10.

111 EIA, *Domestic Uranium Mining and Milling Industry 1992*, p. 1.

112 Ibid.

113 Ibid.; Howard Huie, nuclear engineer, Office of Planning and Analysis, DOE, conversation with USITC staff, Jul. 10, 1995.

114 Public Law 102-486, (Oct. 24, 1992), Subtitle B, 42 USC § 2296b-4 Section 1015 of P.L. 102- 486.

115 EIA, *Uranium Purchases Report 1993*, p. ii.

116 DOC, Bureau of Export Administration, Office of Industrial Resource Administration, Strategic Analysis Division, *The Effects of Imports of Uranium on the National Security*, Sept., 1989.

imports of enriched and nonenriched uranium and uranium enrichment services from nonmarket economy countries including the Soviet Union and the People's Republic of China.[117] In December 1992, at the request of the Committee, the Commission terminated the investigation without issuing a report.[118]

On November 8, 1991, a petition was filed with the USITC and the DOC under the U.S. antidumping law (19 U.S.C. 1673 et seq.) on behalf of the Ad Hoc Committee of Domestic Uranium Producers and the Oil, Chemical and Atomic Workers International Union alleging that imports of uranium from the U.S.S.R. were sold at less than fair value.[119] The petition encompassed all forms of uranium. Although the Soviet Union was dissolved at the end of 1991, the DOC determined that the investigation would continue against the FSU's newly independent countries. In June 1992, DOC made preliminary affirmative determinations concerning the countries that had produced or processed uranium in the FSU: Kazakhstan, Kyrgyzstan, Russia, Tajikistan, Ukraine, and Uzbekistan, and negative determinations concerning the other countries.

In October 1992, the USITC and the DOC suspended their investigations following successful negotiations between the DOC and the republics of Kazakhstan, Kyrgystan, Russia, Tajikistan, Ukraine and Uzbekistan. Those newly independent countries which were uranium producers agreed to limit the maximum volume of their exports to the United States to a specified number through October 15, 2000 that is derived from a formula that depends on the market price of uranium: FSU material could only enter the United States, if the U.S. market price for uranium were to rise above $13 per pound U_3O_8 equivalent. This formula was determined by the DOC as shown in table 5.[120]

The Governments of Ukraine and Tajikistan terminated their suspension agreements effective April 12, 1993, and April 26, 1993, respectively. Consequently, the antidumping investigations on uranium from Ukraine and Tajikistan were resumed. Both DOC and USITC reached affirmative final determinations concerning uranium other than high-enriched uranium from Ukraine; antidumping duties of 129.29 percent were imposed effective August 30, 1993. Because USITC reached a negative final determination concerning uranium from Tajikistan, no antidumping duties were imposed against the product.[121]

On March 11, 1994, after consultations requested by Russia, the antidumping suspension agreement with Russia was amended to allow the importation for 1994 (April 1, 1994-March 31, 1995) and for 1995 (April 1, 1995-March 31, 1996) of up to 3,000 metric tons (about 6.6 million pounds) of uranium (U_3O_8 equivalent) annually and up to 2 million SWU of enrichment services per year provided that this imported material was matched with uranium and enrichment services that was newly produced in the United States.[122] The parties signed the amended agreement in recognition of the fact that the antidumping suspension agreement had not generated the anticipated increase in the price of U.S.-origin natural uranium that would have permitted renewed sales of Russian uranium (above $13 per pound of uranium (U_3O_8 equivalent)) under the price-tied quota mechanism nor had that agreement generated increased sales of U.S.-origin uranium or employment in the U.S. uranium industry.[123] A principal objective of the amended agreement was to restore the competitive position of the domestic uranium industry.[124] Subsequently, some U.S. uranium producers and the Governments of Canada and Australia expressed reservations about some aspects of the amended agreement. Concern about the amended agreement centered on whether it conflicted with U.S. antitrust laws, the North American Free Trade Agreement, and the General Agreement on Tariffs and Trade.[125]

Foreign Trade Measures

Foreign Tariff Measures

Most major industrialized countries that are importers of uranium impose no duty on imports of natural uranium and enriched uranium, which are the major articles of trade in this industry. For example, imports of natural and enriched uranium compounds currently enter the European Union (EU) and Japan duty free, even from countries not eligible for MFN

[117] 56 F.R. 49905-49906.
[118] 57 F.R. 59843.
[119] 56 F.R. 58397-58398; 56 F.R. 63711-63712.
[120] DOC, International Trade Administration, *Antidumping: Uranium from Kazakhstan, Kyrgyzstan, Russia, Tajikistan, Ukraine, and Uzbekistan*, 57 F.R. 49220.

[121] International Trade Administration, *Final Determination of Sales at Less than Fair Value: Uranium from Ukraine and Tajikistan*, 58 F.R. 36640-36653, and U.S. International Trade Commission, *Uranium from Tajikistan and Ukraine*, investigations Nos. 731-TA-539-D (final) and 731-TA-539-E (final), Publication 2669, August 1993, pp. 3-4.
[122] 59 F.R. 15373-15377.
[123] Ibid.
[124] Ibid.
[125] *Nuclear Fuel*, June 6, 1994, pp. 2-3.

Table 5
Quota Allocations for Uranium Exports to the United States from the FSU in Relationship to the Domestic Price of Uranium

(Million pounds equivalent U_3O_8)

Price level[1]	Russia	Kazakhstan	Uzbekistan	Ukraine	Total
$13.00	0.0	0.0	0.0	0.0	0.0
$13.00-$13.99	0.5	1.0	1.0	0.4	2.9
$14.00-$14.99	0.7	1.2	1.2	0.4	3.5
$15.00-$15.99	1.0	1.4	1.4	0.5	4.3
$16.00-$16.99	1.4	1.8	1.8	0.5	5.5
$17.00-$17.99	2.0	2.5	2.5	0.7	7.7
$18.00-$18.99	3.3	3.5	3.5	0.7	11.0
$19.00-$19.99	3.8	4.0	4.0	0.9	12.7
$20.00-$20.99	4.8	5.0	5.0	1.0	15.8
$21.00[2]	(2)	(2)	(2)	(2)	(2)

[1] Price is measured in U.S. $/lbs. and is an observed price in the U.S. market as defined in the suspension agreement and reviewed every six months for adjustment.

[2] Unlimited U_3O_8. Russia may only export a quantity of LEU which contains a maximum of 10 percent to 12 percent of the U.S. enrichment market's annual demand under the sum of this quota plus the long-term contract mechanism quota.

Source: DOC, *Suspension of Investigations and Amendments of Preliminary Determinations* (57 F.R. 49220-49261).

rates.[126] Some industrialized countries impose duties on items with relatively minor trade, such as cermets made from depleted uranium. For example, the EU currently imposes a 7.1-percent duty on imports of cermets made from depleted uranium from countries eligible for the conventional (MFN) rate.[127]

Foreign Nontariff Measures

The Euratom Supply Agency[128] has sought to limit imports into the EU of natural uranium from the FSU to about 20 percent of average annual net EU utility requirements.[129] The Euratom Supply Agency has sought to limit uranium and enrichment imports from the FSU to ensure that the EU does not become overly dependent on one source and to ensure that prices reflect the cost of production and producers' offers in market economy countries.[130] The approach used by Euratom is not rigid but pragmatic and, to the extent possible, relies on dialogue and consensus to ensure that reasonable limits are maintained.[131]

Some trade barriers in foreign countries are implicit. Utilities in countries that have nuclear fuel capacity may be informally obliged to limit imports of nuclear fuel and enrichment so as to ensure an adequate market for their national nuclear fuel industries. On the other hand, some foreign utilities, even those with national nuclear fuel production capacity, import some nuclear fuel if only to ensure diversification of supply.[132]

In the Far East, the United States appeared to have enjoyed an advantage in its ability to supply these markets with uranium because of the special relations, military as well as economic, that have developed between the United States and those countries that have signed nuclear cooperation agreements.

[126] EU, *Official Journal of the European Communities*, L 345, vol 37, (Dec. 31, 1994); Japan Tariff Association, *Customs Tariff Schedule of Japan (1995).*

[127] EU, *Official Journal of the European Communities*, L 345, vol. 37 (Dec. 31, 1994).

[128] Euratom, the atomic energy agency of the EU, is responsible for decisions relating to atomic and nuclear matters. The Euratom Supply Agency, a division of Euratom, is responsible for decisions relating to the supply and demand of nuclear materials including imported materials.

[129] *Nuclear Fuel*, Jan. 18, 1993, p. 16.

[130] Euratom Supply Agency, *Annual Report 1993*, pp. 1-3.

[131] Ibid.

[132] Roger Gagne, Production Planning Associate, USEC, conversation with USITC staff, July 7, 1995. Mr. Paleit, Finance and Commercial Director for Urenco Ltd., indicates in a paper entitled *Urenco's View of the Western World Enrichment Market*, presented at the World Nuclear

According to an industry observer, however, the Far Eastern countries are increasingly opening their uranium markets to suppliers other than the United States.[133]

Conversely, political difficulties may work to adversely affect trade in uranium and nuclear fuel between trading partners. For instance, industry observers reported that political tensions between Japan and the Soviet Union (Russia after 1991) over the territorially disputed Kurile Islands had a negative impact on trade in uranium and nuclear fuel between these countries.[134]

An industry association representing several U.S. uranium producers believes that the U.S. industry is competitively handicapped because other countries (including market economies) have subsidized their uranium industries. This source alleged, for example, that the uranium industry in Canada received government support which assisted in refinancing and guaranteeing loans and funding investments. The industry association also alleged that long-term high-priced contracts were used to prop up low-grade and high-cost uranium mines in Ontario that would have been targeted for closure and that stringent restrictions were imposed on U.S. investments in Canadian uranium resources.[135]

INTERNATIONAL TRADE

U.S. Imports

In this summary, U.S. import and export data for the various forms of uranium by the EIA and the DOC, Bureau of the Census, are presented. DOC data differ substantially from EIA data in that the latter combine the various forms of uranium into one generic category, uranium, in terms of pounds of U_3O_8 equivalent and does not specify country breakouts. Because of new reporting requirements, the EIA has recently provided data for utility purchases by country breakouts, which are discussed in the following section. EIA data are based on contracts reported to that agency, whereas DOC data are based on U.S. Customs Service data derived from the physical movements of goods into the United States. In DOC trade statistics, trade data are broken down by product type (based on the product code in the Harmonized System (see appendix A)), by value, by quantity (units are in gross weight, not U_3O_8 equivalent), and by country of origin.[136] Some industry analysts believe that reporting problems associated with these data occasionally exist.[137]

EIA Import Data by Type of Transaction

U.S. imports of all forms of uranium, acquired under purchases, loans, and exchange contracts as compiled by the EIA, are shown in the following tabulation (in units of millions of pounds U_3O_8 equivalent):

Year	Purchase	Loans	Exchanges	Total
1989 ..	13.1	0.3	0.3	13.7
1990 ..	23.7	0.1	2.8	26.6
1991 ..	16.3	5.7	1.1	23.1
1992 ..	23.3	2.4	0.8	26.5
1993 ..	21.0	(1)	(1)	(1)

1 Withheld to avoid disclosure of individual company data.

U.S. imports of uranium for purchases, loans, and exchanges rose from 13.7 million pounds in 1989 to 26.6 million pounds in 1990 and then remained relatively steady at between 23.1 million pounds and 26.5 million pounds during 1991-92.[138]

In the *Uranium Industry Annual 1992*, the EIA added a new import category for transactions that were not previously reported as imports. This category included "uranium shipped under transactions involving custody/storage siting, conversion, enrichment, and/or fuel fabrication facilities at U.S.

132—*Continued*
Fuel Market Conference, May 12-14, 1991, that countries that have nuclear power capacity but have no indigenous enrichment capacity are more inclined to stress diversification of supply than countries that have an indigenous enrichment capacity.

133 Roger Gagne, Production Planning Associate, USEC, conversation with USITC staff, July 7, 1995.

134 Ibid.

135 DOE, Office of Nuclear Energy, *A Response to 1014(b) of the Energy Policy Act of 1992: Recommendations to Promote the Export of Domestic Uranium*, Apr. 1993, p. 12.

136 The DOC and the EIA treat imports differently in many ways other than those shown above. For example, according to the EIA, the specified country of origin is based on where the uranium was extracted; according to the DOC, the specified country of origin is based on where the uranium product was last substantially transformed. For example, according to the U.S. Customs Service, which monitors the data that are then forwarded to and compiled by the DOC, enrichment is considered to be a substantial transformation. Consequently, Russian-origin uranium that was enriched in France is specified as Russian-origin uranium by the EIA but as French-origin material by Customs and the DOC.

137 For example, import data for enriched uranium hexafluoride reported by the DOC show Australia, Brazil, and Canada as sources. None of these countries is known to have enrichment capacity.

138 EIA, *Uranium Industry Annual 1993*, p. 34. According to the EIA's, *Uranium Industry Annual 1992*, pp. 51-52, "Purchase-contract imports include domestic utility, supplier, and trader/broker purchases reported as imports of foreign-origin uranium materials into the United States." These data do not include ". . purchases of foreign-origin uranium by U.S. companies to be delivered to foreign companies."

facilities."[139] Uranium imports under these new categories in 1992 and 1993 were substantial, amounting to 18.8 million pounds and 19.6 million pounds (U_3O_8 equivalent), respectively.[140]

Cumulative U.S. imports for purchase contracts during 1989-93, which amounted to 97.4 million pounds, rose by 42 percent relative to the previous 5-year period, 1984-88 (68.6 million pounds). This is consistent with information noted previously in this report: that in recent years, the U.S. dependence on foreign uranium has increased significantly.

EIA Utility Purchases Data of Foreign and Domestic Uranium

In the Energy Policy Act of 1992, the DOE was authorized to seek additional information on utility purchase contracts (including utility imports) and on country of origin.[141] This new information was incorporated in the EIA publication, *Uranium Purchases Report*. Utility purchases of uranium by selected countries of origin or country groupings from both domestic and foreign suppliers, as well as the share of utility purchases, are shown in the tabulation at the bottom of the page.[142]

Because of a steady decline in utility purchases of U.S.-origin uranium, the percentage of utility uranium purchases that were of foreign origin rose from 70 percent in 1991 to 88 percent in 1993. During 1991-93, more Canadian-origin uranium was purchased by U.S. utilities from domestic and foreign suppliers than uranium of any other origin including that of the United States. As noted previously, Canadian producers own some of the lowest-production cost uranium ore deposits in the world.

During 1991-93, the FSU was the second largest foreign source of uranium. In 1993, U.S. utility purchases of FSU-origin uranium amounted to 6.2 million pounds, of which 3.7 million pounds were from Russia and 1.6 million pounds from Kazakhstan.[143] China has emerged as another significant supplier of uranium to the United States. In 1993, U.S. utility purchases of Chinese origin uranium accounted for about 9 percent of U.S. utility purchases. Another significant foreign supplier of uranium to the U.S. utilities was Australia, which supplied 1.8 million pounds in 1993, a figure that is, however, only a

[139] EIA, *Uranium Industry Annual 1993*, p. 34.

[140] For example, Canadian-origin natural uranium imported into the United States that is subsequently enriched by the DOE/USEC would fall under this category.

[141] As defined by the EIA, a utility purchase of uranium from a foreign supplier is considered to be an import but a utility purchase of foreign-origin uranium from a domestic supplier is not considered to be an import. In fact, most of the uranium purchased by U.S. utilities from domestic suppliers during 1991-93 was also of foreign origin. (EIA, *Uranium Purchases Report 1993*, table 2, p. 3.)

[142] EIA, *Uranium Purchases Report 1993*, table 2, p. 3. Utility purchases by country of origin were determined by summing the utility purchases from domestic suppliers by country of origin and the purchases from foreign suppliers. Information for some of these data points was withheld because of confidentiality requirements.

[143] EIA, *Uranium Purchases Report 1993*, table 1, p. 2.

Country of Origin	**1991**	**1992**	**1993**	**1993 Share of Purchases**
	(1,000 pounds U_3O_8 equivalent)			*(percent)*
Australia	2,075	≥[1] 2,245	1,777	6
Canada	14,736	12,377	14,019	45
China	≥[1]1,146	≥[1] 920	2,922	9
FSU	≥[1]6,824	6,954	6,230	20
Namibia	917	≥[1] 1,333	392	1
All other foreign	≤[2]2,806	23,620	1,948	6
Total foreign	28,504	27,449	27,288	[3]88
United States	12,443	7,934	3,896	12
Total	40,947	35,383	31,184	100

[1] The symbol ≥ stands for equal or greater than.

[2] The symbol ≤ stands for equal or less than.

[3] Because of rounding, column does not add to total shown.

fraction (about 13 percent) of U.S. utility purchases from Canada in that year. Although Australian reserves of uranium are considered to be on a par with those of Canada, U.S. utility purchases of uranium from Australia have lagged behind those from Canada. According to industry sources, this is partly because of long-standing Australian Government policies that limit uranium production to three mines.[144]

The average price of uranium delivered to U.S. utilities originating in the United States and the top five foreign sources for 1993 are shown in the following tabulation (in dollars per pound U_3O_8 equivalent):[145]

	1993 Average price
Canada	$13.02
Russia	10.02
China	9.31
Australia	10.65
Kazakhstan	9.56
United States	15.53

Although Canada is believed to contain some of the lowest production-cost uranium ore bodies in the world, Canadian origin uranium was associated with the highest foreign prices. Australian-origin uranium was ranked second highest in terms of foreign price, but the average price for Australian origin uranium was substantially less (18 percent) than the average Canadian price. Uranium originating in Kazakhstan and China was the least expensive. Canadian uranium was priced at an average 40 percent more than the Chinese material. The average uranium price of even the most expensive foreign supplier, Canada, was below the minimum estimated production cost of U.S. conventional uranium producers, which, for 1992, was estimated to range from $16 to $30 per pound U_3O_8 equivalent (see *Foreign Industry Profile* section). Relative to average Canadian and Chinese prices (the highest and lowest priced foreign suppliers, respectively), the average price for U.S.-origin uranium averaged 19 percent and 67 percent higher, respectively, in 1993.

[144] *NUEXCO Review, 1993 Annual*, p. 51. According to industry sources, because of the relatively high unit value of uranium concentrates, even in the depressed market of the early 1990s, competitive purchasing decisions are usually not dependent on transportation costs; for example, the relative distance between the United States and Canada compared with the United States and Australia.

[145] EIA, *Uranium Purchases Report 1993*, p. 1. The average price for U.S. origin uranium reported above differs from the average domestic price reported in the pricing section, in that the average domestic price includes uranium of foreign origin that had been imported to the United States, but that was delivered to U.S. utilities by domestic suppliers in 1993.

Selected DOC Data

The dollar value, quantity (reported as gross weight), and average unit value of U.S. imports for consumption of the most commercially important uranium products, including natural uranium oxide, natural UF_6, and enriched UF_6,[146] as compiled by the DOC for 1990-94 are shown in tables 6-8.[147] Relative to the total value of imports of the products in this summary for 1994 ($959 million), natural uranium oxide accounted for 21 percent; natural UF_6, for 24 percent; and enriched UF_6, for 54 percent. Together, these three products accounted for virtually all imports (98 percent) of the products in this summary.

According to table 6, U.S. imports of natural uranium oxide rose from 11.2 million kilograms in 1990 to 14.0 million kilograms in 1991 and then fluctuated between 7.8 and 10.7 million kilograms during 1992-94.[148] Except for 1991, Canada and Australia were the leading sources of natural uranium oxide imports. In 1991, the FSU, reportedly motivated by a need to obtain foreign currency and possessing large inventories of uranium, became the largest foreign supplier of natural uranium oxide to the United States. In that year, imports of natural uranium oxide from the FSU amounted to 5.6 million kilograms, accounting for about 40 percent of total imports. The Republic of South Africa did not export natural uranium oxide to the United States during 1989-91, but it did become a significant supplier beginning in 1992 presumably because of the lifting of the U.S. trade embargo against South Africa.

[146] U.S. import and export trade data for this category are reported as enriched uranium fluorides, not as uranium hexafluoride (UF_6). However, although there is more than one fluoride of uranium (e.g., natural uranium tetrafluoride (UF_4) is produced as an intermediate in the production of natural uranium hexafluoride), enriched uranium fluoride that is shipped is virtually exclusively in the hexafluoride form.

[147] In this summary, DOC imports-for-consumption data are used. In the *Guide to Foreign Trade Statistics* issued by the DOC in December 1992, imports for consumption are defined as follows:

"'Imports for Consumption' measure the total of merchandise that has physically cleared through Customs either entering consumption channels immediately or entering after withdrawal for consumption from bonded warehouses under Customs custody or from Foreign Trade Zones."

[148] The decline in imports of natural uranium oxide during 1991-93 is not reflected in EIA data, which appear to indicate that uranium purchases rose irregularly during that period. Definitional differences may account for the apparent inconsistency of the data.

Table 6
Natural uranium oxide: U.S. imports for consumption, by principal sources, 1990-94

Source	1990	1991	1992	1993	1994
			Quantity (*kilograms*)		
Canada	2,484,345	3,148,352	4,366,730	4,761,619	3,635,145
Australia	3,340,754	3,663,908	2,578,169	947,441	2,708,263
Kazakhstan[1]	0	0	0	0	629,272
Tajikistan[1]	0	0	0	0	631,967
Germany	237,467	0	619,193	0	849,224
China	1,433,854	595,663	591,709	531,456	393,240
Namibia	584,323	697,324	0	183,820	241,320
Republic of South Africa	0	0	1,044,595	749,492	241,320
Soviet Union	1,859,266	5,563,558	1,323,892	0	0
All other	1,283,100	306,555	152,796	649,153	181,255
Total	11,223,109	13,975,360	10,677,084	7,822,981	9,640,981
			Value (*1,000 dollars*)		
Canada	74,316	73,226	141,666	108,444	72,324
Australia	96,928	156,356	81,232	24,915	63,868
Kazakhstan[1]	0	0	0	0	12,582
Tajikistan[1]	0	0	0	0	11,905
Germany	5,500	0	9,581	0	11,136
China	36,353	11,163	10,436	10,544	10,377
Namibia	14,556	21,479	0	3,210	10,307
Republic of South Africa	0	0	25,436	17,422	6,490
Soviet Union	35,555	110,358	24,927	0	0
All other	28,768	7,496	3,158	13,786	3,120
Total	291,975	380,077	296,436	178,320	202,108
			Unit value (*per kilogram*)		
Canada	29.91	23.26	32.44	22.77	19.90
Australia	29.01	42.67	31.51	26.30	23.58
Kazakhstan[1]	(2)	(2)	(2)	(2)	19.99
Tajikistan[1]	(2)	(2)	(2)	(2)	18.84
Germany	23.16	(2)	15.47	(2)	13.11
China	25.35	18.74	17.64	19.84	26.39
Namibia	24.91	30.80	(2)	17.46	27.76
Republic of South Africa	(2)	(2)	24.35	23.25	26.89
Soviet Union	19.12	19.84	18.83	(2)	(2)
All other	22.42	24.45	20.67	21.24	17.21
Total	26.02	27.20	27.76	22.79	20.96

[1] Before 1994, imports from this country may have been included under Soviet Union.

[2] Not applicable.

Source: Compiled from official statistics of the U.S. Department of Commerce.

During 1990-94, except for 1992 when imports dipped to 5.9 million kilograms, U.S. imports of natural UF_6 ranged between 8.1 and 10.8 million kilograms (table 7). Canada, which has both uranium conversion and low-cost uranium mining capacity, was the dominant supplier of natural UF_6 to the United States throughout 1990-94.

U.S. imports of enriched UF_6 rose from 599,000 kilograms in 1990 to 1,062,000 kilograms in 1994 (table 8). These are believed to be imports of enriched uranium from foreign enrichers. The growth in imports may be related to reports that U.S. utilities are seeking to diversify purchases of enriched uranium and enrichment services rather than to rely solely on the DOE or USEC. During 1990-1994, the leading suppliers of enriched UF_6 to the United States were the FSU/Russia, France, China, the Netherlands, Germany and the United Kingdom. All these countries are known to have uranium enrichment capacity.

Table 7
Natural uranium hexafluoride: U.S. imports for consumption, by principal sources, 1990-94

Source	1990	1991	1992	1993	1994
			Quantity *(kilograms)*		
Australia	0	0	0	347,977	457,172
Belgium	0	0	0	5	49
Canada	8,464,464	7,156,984	5,139,717	7,050,381	8,946,031
France	69,309	582,315	174,390	0	0
Germany	15,010	0	12,116	0	0
Namibia	0	0	0	179,295	35,784
Netherlands	0	42,145	6,265	0	6,675
Republic of South Africa	0	0	32,156	0	0
Soviet Union	33,902	25	0	0	0
United Kingdom	849,785	327,933	497,388	3,250,128	144,633
Total	9,432,470	8,109,402	5,862,032	10,827,786	9,590,344
			Value *(1,000 dollars)*		
Australia	0	0	0	6,661	8,959
Belgium	0	0	0	1	4
Canada	152,174	145,545	96,264	132,925	213,457
France	6,810	57,588	16,625	0	0
Germany	9,751	0	5,480	0	0
Namibia	0	0	0	3,120	541
Netherlands	0	17,805	4,832	0	1,855
Republic of South Africa	0	0	734	0	0
Soviet Union	15,707	2	0	0	0
United Kingdom	45,141	7,490	24,100	54,880	2,138
Total	229,583	228,430	148,035	197,587	226,954
			Unit value *(per kilogram)*		
Australia	(1)	(1)	(1)	19.14	19.60
Belgium	(1)	(1)	(1)	270.00	82.24
Canada	17.98	20.34	18.73	18.85	23.86
France	98.26	98.90	95.33	(1)	(1)
Germany	649.66	(1)	452.29	(1)	(1)
Namibia	(1)	(1)	(1)	17.40	15.11
Netherlands	(1)	422.46	771.25	(1)	277.89
Republic of South Africa	(1)	(1)	22.83	(1)	(1)
Soviet Union	463.31	60.00	(1)	(1)	(1)
United Kingdom	53.12	22.84	48.45	16.89	14.79
Total	24.34	28.17	25.25	18.25	23.66

[1] Not applicable.

Source: Compiled from official statistics of the U.S. Department of Commerce.

Table 8
Enriched uranium hexafluoride: U.S. imports for consumption, by principal sources, 1990-94

Source	1990	1991	1992	1993	1994
			Quantity *(kilograms)*		
China	0	0	103,490	82,767	122,753
France	125,969	301,840	195,795	158,930	259,911
Germany	135,038	320,684	115,959	70,745	49,720
Netherlands	1,143	41,095	78,473	135,124	108,064
Republic of South Africa	0	0	0	218,307	28,198
Russia	0	0	63,491	132,627	354,771
Soviet Union	130,753	0	0	0	0
United Kingdom	96,386	113,459	305,542	150,219	123,642
All other	109,474	85,187	0	22,714	15,220
Total	598,763	862,265	862,750	971,433	1,062,279
			Value *(1,000 dollars)*		
China	0	0	30,080	25,185	50,468
France.	64,923	121,208	127,701	93,500	174,793
Germany	73,111	125,438	41,245	25,856	8,894
Netherlands	549	27,435	42,053	92,340	44,722
Republic of South Africa	0	0	0	5,203	7,176
Russia	0	0	12,229	56,691	160,393
Soviet Union	71,086	0	0	0	0
United Kingdom	36,997	63,830	170,369	66,452	62,616
All other	2,416	7,017	0	14,578	5,269
Total	249,081	344,929	423,678	379,804	514,331
			Unit value *(per kilogram)*		
China	(1)	(1)	290.66	304.29	411.14
France	515.39	401.56	652.22	588.31	672.51
Germany	541.41	391.16	355.69	365.48	178.88
Netherlands	480.05	667.60	535.90	683.37	413.85
Republic of South Africa	(1)	(1)	(1)	23.83	254.48
Russia	(1)	(1)	192.61	427.45	452.10
Soviet Union	543.67	(1)	(1)	(1)	(1)
United Kingdom	383.84	562.59	557.60	442.37	506.43
All other	22.07	82.38	(1)	641.80	346.20
Total	415.99	400.03	491.08	390.97	484.18

[1] Not applicable.

Source: Compiled from official statistics of the U.S. Department of Commerce.

U.S. Exports

Foreign Market Profile

U.S. exports of uranium, much of which are in the enriched form, are shipped primarily to the Far Eastern countries of Japan, Taiwan, and South Korea and secondarily to Western European countries, especially Germany, the United Kingdom, and France.[149] The United States has nuclear cooperation agreements with all those countries and has assisted them in their nuclear programs. Some of these countries have special relations with the United States, including military relations that have broadened into business relations.

U.S. exports of enriched uranium and enrichment services are largely concentrated in the Far East, especially Japan, because countries in this area are major users of nuclear power but have little or no enrichment capacity. Japan has launched a major effort to expand its nuclear power capacity. This action is considered likely to more than offset Japan's limited expansion of its indigenous enrichment program in the next few years; net world exports of enriched uranium and enrichment services to Japan could, therefore, increase.[150]

The Far-East (also including India) is likely to emerge as an even more important nuclear fuel market in the foreseeable future as projected growth in the use of nuclear power is largely concentrated in this area.[151] According to one industry source, the United States faces increased competition from other uranium enrichment suppliers in the Far East as political considerations are increasingly being replaced by business considerations.[152]

U.S. exports of uranium and nuclear fuel are limited to countries that have signed a bilateral nuclear cooperation agreement with the United States. A license must be obtained for the export of nuclear fuel, nuclear reactors, and reactor components. Although the nuclear agreement reached between European countries that are members of Euratom and the United States is considered to fall short of meeting the full requirements of the Nuclear-Non-Proliferation Act of 1985 (NNPA), a provision in the NNPA permits the President to annually waive export requirements until a renewal of the agreement is reached between Euratom and the United States. The Nuclear-Non-Proliferation Treaty is set to be extended by the end of 1995. A major problem that must be resolved relates to U.S. proliferation concerns about U.S-origin uranium and nuclear fuel that are reprocessed in Europe.[153] Were the treaty not extended, the legal basis for trade in uranium and nuclear fuel could be undermined.[154] In November 1995, a new accord between the United States and Euratom was signed and was submitted to Congress.[155]

U.S. Export data

EIA data.—U.S. exports of all forms of uranium by contract type during 1989-93, as compiled by the EIA, are shown in the following tabulation (in millions of pounds U_3O_8 equivalent):

Year	Sales	Loans	Exchanges	Total
1989	2.1	0	0.4	2.5
1990	2.0	0.4	0	2.4
1991	3.5	0	0	3.5
1992	2.8	0	0	2.8
1993	3.0	(1)	(1)	(1)

1 Withheld to avoid disclosure of proprietary information.

During 1989-92, annual U.S. exports of U.S.-origin uranium, including sales, loans, and exchanges, fluctuated between 2.4 million and 3.5 million pounds U_3O_8 equivalent.[156] Because most U.S.-origin natural uranium is more expensive to produce than foreign-origin natural uranium, U.S. uranium exports during 1989-92 were smaller than imports. In 1992, a new category was added that included uranium shipped from conversion, enrichment, and/or fuel fabrication facilities in the United States. Uranium exports under these new categories in 1992 were substantial (18.1 million pounds), indicative of the large amount

149 A distinction must be made between U.S. exports of natural uranium originating in the United States and exports of enrichment services by the DOE/USEC. As most of the uranium used in the United States has recently not been of U.S. origin, most of the enriched uranium exported from the United States has likely been foreign-origin uranium that was enriched by the DOE/USEC. According to the EIA, 76 percent of U.S. utility enrichment feed deliveries to the DOE/USEC in 1993 consisted of foreign uranium. (EIA, *Uranium Industry Annual 1993*, table 37, p. 42.)

150 As of early 1994, eight nuclear power plants in Japan were under construction, and sixteen others were planned. (NUEXCO, *1993 Annual Review*, p. 32.)

151 According to the Uranium Institute based on 1993 projections, East Asia is expected to account for about 76 percent of world growth in nuclear power generating capacity during 1995-2010. (The Uranium Institute, *The Global Uranium Market Supply and Demand 1992-2010*, table 4, p. 26.)

152 Staff conversation with an industry source, Oct. 25, 1994.

153 A mixture of reactor-grade plutonium (produced by recycling spent fuel) and of natural or depleted uranium, known as MOX (mixed-oxide-fuel), has been used in Europe and is planned to be used in Japan in ordinary commercial nuclear reactors. Largely because of security and non-proliferation concerns, U.S. commercial nuclear power plants do not typically use this type of fuel.

154 *Nuclear Fuel*, Oct. 10, 1994, pp. 11-12.

155 *Nuclear Fuel*, Dec. 4, 1995, p. 7.

156 EIA, *Uranium Industry Annual 1993*, p. 34.

of uranium, most of which is of foreign origin, that is processed in the United States (for example, enriched), and then reexported.

Selected DOC Data.—The dollar value, quantity, and average unit value of U.S. exports of enriched UF_6 and enriched uranium oxide as compiled by the DOC for 1990-94 are shown in tables 9 and 10, respectively. Relative to the total value of exports of products in this summary for 1994 ($1,179 million), enriched UF_6 accounted for 64 percent, and enriched uranium oxide accounted for 25 percent. Together, these two products accounted for almost 90 percent of the value of products covered in this summary.

Although the United States is not a major exporter of natural uranium, the United States, through the DOE and USEC, has remained a major exporter of enrichment services.[157] Because of the high value added in providing these services, U.S. exports of enrichment services contribute significantly to the U.S. balance of trade. During 1990-94, the dollar value of U.S. exports of enriched UF_6 (believed to be principally exports of uranium enriched by the DOE or the USEC), ranged between $639 million and $753 million, and the quantity of these exports ranged between 614,000 and 906,000 kilograms (table 9).[158] Japan, which is one of the world's largest importers of enriched uranium because of its large nuclear power capacity and its relatively small enrichment capacity, remained the principal market for these exports throughout the period. Other significant markets for U.S. exports of enriched UF_6 during 1990-94 were South Korea, France, Sweden, and the United Kingdom. All of these countries have nuclear power capacity and are, therefore, consumers of natural and enriched uranium.[159]

During 1990-94, the dollar value of U.S. exports of enriched uranium oxide fluctuated between $126 million and $311 million, and the quantity of these exports ranged between 418,000 and 1.3 million kilograms (table 10). Germany, Japan, and Taiwan were the leading markets for these exports. Germany, Japan, and Taiwan, which are known to have nuclear power capacity and Germany and Japan, which are known to have fuel-fabrication capacity, are purchasers of uranium in its various forms. Some of the exports of enriched uranium oxide to Germany are likely shipments of nuclear fuel pellets from the Siemens Power Corp., a fuel fabricator located in Bellevue, Washington, to their European affiliate, Siemens A.G., in Germany, for further processing into nuclear fuel assemblies for use in nuclear power plants in Europe.[160]

U.S. Trade Balance

Although DOC export and import data in terms of value may in principle be used to calculate the trade balance for products associated with uranium and nuclear fuel, obtaining the total trade balance for uranium and nuclear fuel products simply by subtracting total imports from total exports would likely not yield meaningful figures. Trade balance figures would not be meaningful given the highly complex nature of many nuclear fuel transactions involving loans, exchanges, imports for storage in U.S. facilities, and extensive imports of nuclear materials for further processing and re-exporting. Although meaningful quantitative data are not available, qualitatively, the United States is likely a net exporter of enrichment services but a net importer of natural uranium, as noted previously in this report.

157 According to a DOE source, in most cases, the customer provides the natural uranium to the DOE for enrichment. Thus the DOE is principally involved in providing enrichment services and not in selling enriched uranium.

158 The value of the enriched uranium is the sum of the feed value of the natural uranium that is provided by the customer and the enrichment services that has been provided by the DOE/USEC. (See app. C for a typical calculation of material and processing costs.)

159 The annual revenues obtained by the DOE from its sales of enrichment services to foreign markets during fiscal years 1990-92, as reported in its annual enrichment reports, amounted to $391 million, $457 million, and $595 million, respectively. These figures have been consistently smaller than the figures reported by the DOC of the value of U.S. exports of enriched UF_6 during the same approximate period. According to the DOC, during calendar years 1990-92, U.S. exports of enriched UF_6 amounted to $664 million, $753 million, and $639 million, respectively (see table 9). According to an industry source, the higher value for DOC data may be attributable to the fact that the DOC data (but not the DOE data) include the feed value of the uranium in enriched uranium.

160 Wayne Baker, Manager, Public Relations, Siemens Power Corp., letter to the staff of the USITC, Mar. 9, 1995.

Table 9
Enriched uranium hexafluoride: U.S. exports of domestic merchandise, by principal markets, 1990-94

Market	1990	1991	1992	1993	1994
			Quantity *(kilograms)*		
Argentina	0	7	0	2,000	0
France	27,295	15,010	66,151	140	26,033
Germany	456	101	0	18	23,116
Japan	647,117	750,506	610,616	590,548	708,865
Korea, South	73,270	85,483	0	0	52,297
Spain	0	10,886	10	3,556	0
Sweden	35,765	11,017	18,573	0	9,014
United Kingdom	17,039	33,247	37,415	18,037	41,278
All other	34	24	177	91	2
Total	800,976	906,281	732,942	614,390	860,605
			Value *(1,000 dollars)*		
Argentina	0	4	0	1,000	0
France	12,363	16,498	37,999	114	34,000
Germany	84	29	0	3	6,025
Japan	529,535	657,522	574,289	653,271	654,160
Korea, South	76,433	52,302	0	0	22,650
Spain	0	2,548	3	2,206	0
Sweden	28,987	8,602	7,113	0	6,133
United Kingdom	17,074	15,414	19,282	9,709	25,642
All other	10	9	38	141	4
Total	664,486	752,928	638,725	666,445	748,614
			Unit value *(per kilogram)*		
Argentina	([1])	579.14	([1])	500.00	([1])
France	452.93	1,099.12	574.43	811.16	1,306.03
Germany	184.74	289.56	([1])	190.44	260.65
Japan	818.30	876.10	940.51	1,106.21	922.83
Korea, South	1,043.17	611.84	([1])	([1])	433.11
Spain	([1])	234.06	280.00	620.49	([1])
Sweden	810.48	780.77	382.98	([1])	680.41
United Kingdom	1,002.06	463.62	515.35	538.27	621.21
All other	287.79	383.54	217.12	1,553.62	1,835.00
Total	829.60	830.79	871.45	1,084.73	869.87

[1] Not applicable.

Source: Compiled from official statistics of the U.S. Department of Commerce.

Table 10
Enriched uranium oxide: U.S. exports of domestic merchandise, by principal markets, 1990-94

Market	1990	1991	1992	1993	1994
			Quantity *(kilograms)*		
Germany	748,917	731,239	377,638	322,675	239,634
Japan	400,165	149,274	229,758	144,358	39,837
Mexico	0	16,462	20,707	829	0
Spain	55,358	179,348	35,920	20,501	52,700
Sweden	549	38,442	728	566	1,145
Switzerland	0	20	544	0	0
Taiwan	40,341	103,575	337,742	24,343	82,903
United Kingdom	0	120	0	0	0
Canada	0	0	17,281	54,354	2,030
Netherlands	10,869	0	0	0	0
All other	0	0	0	3	3
Total	1,256,199	1,218,480	1,020,318	567,629	418,252
			Value *(1,000 dollars)*		
Germany	97,387	101,087	91,508	141,614	147,264
Japan	61,558	15,546	62,973	33,197	27,590
Mexico	0	4,850	14,272	829	0
Spain	858	2,202	1,962	11,747	21,172
Sweden	290	2,241	469	249	579
Switzerland	0	63	110	0	0
Taiwan	48,239	259	138,609	22,428	99,879
United Kingdom	0	60	0	0	0
Canada	0	0	762	6,068	524
Netherlands	1,649	0	0	0	0
All other	0	0	0	16	3
Total	209,981	126,309	310,665	216,148	297,011
			Unit value *(per kilogram)*		
Germany	130.04	138.24	242.32	438.88	614.54
Japan	153.83	104.15	274.09	229.96	692.57
Mexico	([1])	294.62	689.24	999.87	([1])
Spain	15.50	12.28	54.63	573.02	401.75
Sweden	528.28	58.30	644.13	439.59	506.07
Switzerland	([1])	3,168.20	202.21	([1])	([1])
Taiwan	1,195.77	2.50	410.40	921.33	1,204.77
United Kingdom	([1])	500.00	([1])	([1])	([1])
Canada	([1])	([1])	44.08	111.63	257.92
Netherlands	151.68	([1])	([1])	([1])	([1])
All other	([1])	([1])	([1])	5,334.00	1,000.00
Total	167.16	103.66	304.48	380.79	710.12

[1] Not applicable.

Source: Compiled from official statistics of the U.S. Department of Commerce.

APPENDIX A
TARIFF AND TRADE AGREEMENT TERMS

In the ***Harmonized Tariff Schedule of the United States*** (HTS), chapters 1 through 97 cover all goods in trade and incorporate in the tariff nomenclature the internationally adopted Harmonized Commodity Description and Coding System through the 6-digit level of product description. Subordinate 8-digit product subdivisions, either enacted by Congress or proclaimed by the President, allow more narrowly applicable duty rates; 10-digit administrative statistical reporting numbers provide data of national interest. Chapters 98 and 99 contain special U.S. classifications and temporary rate provisions, respectively. The HTS replaced the *Tariff Schedules of the United States* (TSUS) effective January 1, 1989.

Duty rates in the ***general*** subcolumn of HTS column 1 are most-favored-nation (MFN) rates, many of which have been eliminated or are being reduced as concessions resulting from the Uruguay Round of Multilateral Trade Negotiations. Column 1-general duty rates apply to all countries except those enumerated in HTS general note 3(b) (Afghanistan, Cuba, Kampuchea, Laos, North Korea, and Vietnam), which are subject to the statutory rates set forth in ***column 2***. Specified goods from designated MFN-eligible countries may be eligible for reduced rates of duty or for duty-free entry under one or more preferential tariff programs. Such tariff treatment is set forth in the ***special*** subcolumn of HTS rate of duty column 1 or in the general notes. If eligibility for special tariff rates is not claimed or established, goods are dutiable at column 1-general rates. The HTS does not enumerate those countries as to which a total or partial embargo has been declared.

Although the ***Generalized System of Preferences*** (GSP) expired at the close of July 31, 1995, provisions relating thereto continue to appear in the HTS pending possible Congressional renewal. The GSP afforded nonreciprocal tariff preferences to developing countries to aid their economic development and to diversify and expand their production and exports. The U.S. GSP, enacted in title V of the Trade Act of 1974 for 10 years and extended three times thereafter, applied to merchandise imported on or after January 1, 1976 and before the close of July 31, 1995. Indicated by the symbol "A" or "A*" in the special subcolumn, the GSP provided duty-free entry to eligible articles the product of and imported directly from designated beneficiary developing countries, as set forth in general note 4 to the HTS.

The ***Caribbean Basin Economic Recovery Act*** (CBERA) affords nonreciprocal tariff preferences to developing countries in the Caribbean Basin area to aid their economic development and to diversify and expand their production and exports. The CBERA, enacted in title II of Public Law 98-67, implemented by Presidential Proclamation 5133 of November 30, 1983, and amended by the Customs and Trade Act of 1990, applies to merchandise entered, or withdrawn from warehouse for consumption, on or after January 1, 1984. Indicated by the symbol "E" or "E*" in the special subcolumn, the CBERA provides duty-free entry to eligible articles, and reduced-duty treatment to certain other articles, which are the product of and imported directly from designated countries, as set forth in general note 7 to the HTS.

Free rates of duty in the special subcolumn followed by the symbol "IL" are applicable to products of Israel under the ***United States-Israel Free Trade Area Implementation Act*** of 1985 (IFTA), as provided in general note 8 to the HTS.

Preferential nonreciprocal duty-free or reduced-duty treatment in the special subcolumn followed by the symbol "J" or "J*" in parentheses is afforded to eligible articles the product of designated beneficiary countries under the ***Andean Trade Preference Act*** (ATPA), enacted as title II of Public Law 102-182 and implemented by Presidential Proclamation 6455 of July 2, 1992 (effective July 22, 1992), as set forth in general note 11 to the HTS.

Preferential or free rates of duty in the special subcolumn followed by the symbol "CA" are applicable to eligible goods of Canada, and rates followed by the symbol "MX" are applicable to eligible goods of Mexico, under the ***North American Free Trade Agreement***, as provided in general note 12 to the HTS and implemented effective January 1, 1994 by Presidential Proclamation 6641 of December 15, 1993. Goods must originate in the NAFTA region under rules set forth in general note 12(t) and meet other requirements of the note and applicable regulations.

Other special tariff treatment applies to particular ***products of insular possessions*** (general note 3(a)(iv)), goods covered by the ***Automotive Products Trade Act*** (APTA) (general note 5) and the ***Agreement on Trade in Civil Aircraft*** (ATCA) (general note 6), ***articles imported from freely associated states*** (general note 10), ***pharmaceutical products*** (general note 13), and ***intermediate chemicals for dyes*** (general note 14).

The ***General Agreement on Tariffs and Trade 1994*** (GATT 1994), annexed to the Agreement Establishing the World Trade Organization, replaces an earlier agreement (the GATT 1947 [61 Stat. (pt. 5) A58; 8 UST (pt. 2) 1786]) as the primary multilateral system of disciplines and principles governing international trade. Signatories' obligations under both the 1994 and 1947 agreements focus upon most-favored-nation treatment, the maintenance of scheduled concession rates of duty, and national (nondiscriminatory) treatment for imported products; the GATT also provides the legal framework for customs valuation standards, "escape clause" (emergency) actions, antidumping and countervailing duties, dispute settlement, and other measures. The results of the Uruguay Round of multilateral tariff negotiations are set forth by way of separate schedules of concessions for each participating contracting party, with the U.S. schedule designated as Schedule XX.

Pursuant to the **Agreement on Textiles and Clothing** (ATC) of the GATT 1994, member countries are phasing out restrictions on imports under the prior "Arrangement Regarding International Trade in Textiles" (known as the **Multifiber Arrangement** (MFA)). Under the MFA, which was a departure from GATT 1947 provisions, importing and exporting countries negotiated bilateral agreements limiting textile and apparel shipments, and importing countries could take unilateral action in the absence or violation of an agreement. Quantitative limits had been established on imported textiles and apparel of cotton, other vegetable fibers, wool, man-made fibers or silk blends in an effort to prevent or limit market disruption in the importing countries. The ATC establishes notification and safeguard procedures, along with other rules concerning the customs treatment of textile and apparel shipments, and calls for the eventual complete integration of this sector into the GATT 1994 over a ten-year period, or by Jan. 1, 2005.

APPENDIX B
GLOSSARY TERMS

GLOSSARY OF TERMS

AVLIS— The acronym for atomic vapor laser isotope separation, the term for the research program that was undertaken by the U.S. Department of Energy (superseded by the U.S. Enrichment Corp.) to develop a uranium enrichment process based on laser technology that may be substantially less costly than uranium enrichment processes used currently.

Decontamination and Decommissioning (D&D)— The processes involved in cleaning up a facility after it is decommissioned in order to ensure compliance with environmental regulations.

Depleted Uranium— A form of uranium that contains a lesser amount of U^{235} than exists in natural uranium. It is formed as a byproduct in the production of enriched uranium from natural uranium. The term is synonymous with uranium tails. Although generally considered a waste product, depleted uranium, because of its high density, is used in military applications and as counterweights. Typically, the U^{235} assay for depleted uranium is between about 0.2 and 0.3 percent.

U.S. Department of Energy (DOE)— An executive agency of the U.S. Government that is responsible under the President for policy regarding energy-related matters including the production of nuclear weapons. Until July 1993, the DOE was the agency responsible for providing uranium enrichment services to military and civilian sectors.

Energy Information Administration (EIA)— A division within the DOE that is responsible for providing objective information on energy-related matters to that agency, the Congress, the President, and the public. The EIA publishes many recurring publications dealing with energy-related topics including the *Uranium Industry Annuals*.

Enriched Uranium or Enriched Uranium Product— Uranium that has been enriched in its isotopic composition of U^{235} relative to natural uranium as found in the ground. Typically, enriched uranium for commercial nuclear power plants contains about 4 percent U^{235} and about 96 percent U^{238}. In recent years, the concentration of U^{235} used in commercial nuclear power plants has increased. Uranium enrichment is necessary in order to achieve a sustained nuclear reaction for the generation of electricity in light water reactors (reactors using ordinary water), the preponderant type of reactor used commercially in nuclear power plants. Only in a handful of countries, including Canada, India, South Korea, Romania, and Argentina are reactors using heavy water (water composed of heavy isotopes of hydrogen) employed in nuclear power plants. In these reactors, natural uranium may be used to generate electricity.

Enrichment services— The service of increasing (or enriching) the U^{235} composition of uranium feed. In addition to the production of the enriched uranium product, a depleted uranium waste product is also produced as a byproduct. The standard measures of uranium enrichment services are SWU, the acronym for separative work units.

EURODIF— A multinational enrichment consortium that operates a large gas-diffusion plant near Pierralatte, France. Essentially EURODIF is a hybrid government corporation with French majority-ownership. EURODIF is also owned in part by the national fuel supply organizations in Spain, Belgium, and Italy.

Exchange-(EIA definition)— A market business deal wherein title to a specified quantity of uranium of one form is transferred for title of a like or similar quantity of uranium that is of the same or a different form. The term "swap" is an alternative term for an exchange.

Fissile— The property characterizing U^{235} which undergoes splitting or fission when bombarded with neutrons. Because the fission of U^{235} results in the release of neutrons and energy, the reaction is self-sustaining and can be harnessed to serve as a source of power.

Former Soviet Union (FSU)— The area that constituted the former Soviet Republics that dissolved in late 1991.

Fuel rods/fuel rods assemblies— The corrosion-resistant tubes of zirconium alloy or stainless steel containing pellets of enriched ceramic uranium dioxide that are mounted into special assemblies for loading into a nuclear reactor.

Gas Centrifugation— A type of uranium enrichment technology that relies on the difference in pressure diffusion rates between the lighter U^{235} and the heavier U^{238} to achieve isotopic separation when vaporized uranium is spun rapidly in a centrifuge. The spinning force tends to push lighter U^{235} toward the center of the centrifuge and the heavier U^{238} towards the outer walls of the centrifuge.

Gaseous Diffusion— A type of uranium enrichment technology that relies on the difference in diffusion rates between the lighter U^{235} and the heavier U^{238} through a porous barrier to achieve isotopic separation.

Highly Enriched Uranium (HEU)— A form of enriched uranium that contains about 20 percent U^{235} or more. Frequently, the U^{235} content is 90 percent or more. HEU is used primarily in defense applications for propulsion and nuclear weapons; it is not used in ordinary commercial reactors unless it is diluted into low enriched uranium.

In situ leach mining (ISL)— A method of extracting natural uranium from an ore body through a leaching process that does not physically remove the ore and associated waste rock from the ground.

Intersupplier sale, loan, or exchange (EIA definition)— A market business deal wherein title to a specified quantity of uranium is traded or transferred under contract between uranium suppliers in a sale, loan, or exchange transaction.

Isotope— The different components of a chemical element that have nearly identical chemical properties but differ in atomic weight. Different isotopes of the same element differ in their atomic weights because they contain a different number of neutrons. However, the number of protons that they contain is the same.

Long-Term Purchase (EIA definition)—

A purchase contract under which at least one delivery of uranium is scheduled to occur during the second calendar year after the contract-signing year. Other sources may use different definitions to describe this term and other terms associated with the uranium market and industry.

Low Enriched Uranium (LEU)—

Uranium that has been enriched in its isotopic composition of U^{235} relative to natural uranium, but not to the degree that its U^{235} composition is 20 percent or more. The U^{235} composition of LEU used in nuclear power plants typically does not exceed 5 percent.

MTU—metric ton uranium—

1,000 kilograms of elemental uranium equivalent which is equal to about 2,600 pounds U_3O_8 equivalent.

Natural Uranium—

Uranium that has the same isotopic composition of U^{235} and U^{238} as uranium found in nature, that is in the ground. Natural uranium consists of approximately 99.3 percent U^{238} and of only 0.7 percent U^{235}. Ordinary processing steps such as mining, milling, and conversion will not change the isotopic composition of this uranium.

Nuclear reactor—

An apparatus in which a nuclear reaction occurs at a controlled rate leading to the release of controlled amounts of energy.

Nuclear Fuel Cycle—

The processes involved in the production of nuclear fuel from uranium raw material. This consists of recovering uranium from raw materials (for example, from mining and milling uranium ore or leaching or from byproduct recovery), processing the uranium into a form suitable for generating electricity, "burning" the fuel in nuclear reactors, and managing the resulting spent nuclear fuel. The processing steps required to prepare finished nuclear fuel from uranium raw materials are referred to as the "front end of the nuclear fuel cycle." The processing steps required to manage the highly radioactive spent fuel that results after the nuclear fuel is "burnt" in a nuclear reactor, including interim and final waste storage and possible spent fuel reprocessing, are referred to as the "back end of the nuclear fuel cycle."

Nuclear Regulatory Commission (NRC)—

The agency within the U.S. Government that is responsible for regulating nuclear materials and nuclear reactors.

NUEXCO/CONCORD NUEXCO—

Formerly, the world's largest nuclear fuel trading organization, that was part of Concord, a group of companies that was owned by Oren L. Bentson. NUEXCO had been a major trader involved in exporting uranium from the Soviet Union. In conjunction with Tenex, the Soviet trading company, a joint venture with CONCORD was set up in 1991 called Global Nuclear Services and Supply, Ltd. (GNSS) to market uranium from the Soviet Union, especially in the United States and the Far East. NUEXCO also has published a monthly and annual report on developments related to uranium, nuclear fuel and nuclear power and information on uranium prices and transactions. On February 23, 1995, four companies owned by Bentson: NUEXCO Trading Co., Concord Services Inc., Energy Fuels Ltd., and Energy Fuels Exploration Co., filed a Chapter 11 petition in U.S. Bankruptcy Court in Denver. Oren Bentson sold NUEXCO's publication and information services to former employees. The new company was named *Trade Tech.*

Primary market transactions— According to the EIA, these are direct sales or direct imports by suppliers to U.S. utilities. Other types of transactions, including exchanges and loans, are considered to be secondary market transactions.

Public Utility Commission (PUC)— The regulatory agency usually under the control of the States responsible for monitoring the activities of public utilities. Also referred to as state regulatory agency. Many PUCs have become increasingly active, attempting to ensure that the price of electrical power, including such inputs as uranium, are as low as possible.

Secondary Market Transactions— According to the EIA, primary market transactions are defined to be direct sales by suppliers to U.S. utilities or direct imports by U.S. utilities.[1] Other types of transactions including sales, exchanges, and loans are defined to be secondary market transactions. Definitions provided by other sources may differ from that provided by the EIA.

Short-term Purchase (EIA definition)— A purchase contract under which all deliveries of material are scheduled to be completed by the end of the first calendar year following the contract-signing year; otherwise it is a long-term contract.

Spot market— The buying and selling of uranium for immediate or very near-term delivery.

Separative Work Unit (SWU)— A measure of the amount of uranium enrichment services required in enriching a given amount of uranium in its composition of the fissionable isotope U^{235}. The number of SWU that is required is proportional to the amount of material that is enriched and also depends on the U^{235} composition of the starting material, the U^{235} composition of the resulting enriched uranium product, and the U^{235} composition of the depleted uranium (tails) coproduct.

Tenex (Techsnabexport)— The trading organization in the FSU responsible for exports of uranium. It has undergone reorganization as a result of the sweeping changes that have affected the region. Natural and enriched uranium production in Russia are under the control of Minatom, the Russian (formerly the Soviet) Ministry of Atomic Energy. Tenex, also referred to by its official name Techsnabexport, is the export arm of Minatom.

Tonne— See MTU (metric ton uranium).

U^{235}— An isotope of uranium, which is the fissile or active component in nuclear fuel. The "235" in U^{235} refers to its atomic mass, which is the sum of its protons and neutrons, that is 92 + 143 = 235. Because U^{235} contains three less neutrons than U^{238}, the predominant species found in uranium, U^{235} is slightly lighter than U^{238}. Methods currently used for separating U^{235} and U^{238} use processes that are able to distinguish this slight mass difference.

[1] EIA, *Uranium Industry Annual 1993*, p. 45.

U^{238}— An isotope of uranium that is the predominant species found in natural uranium. The "238" in U^{238} refers to its atomic mass, which is the sum of its protons and neutrons, that is $92 + 146 = 238$. Because U^{238} contains three more neutrons than U^{235}, the fissile or active component of uranium, U^{238} is slightly heavier than U^{235}. Although not typically a fissile isotope or an active component in commercial nuclear reactors that use enriched uranium as a feed, U^{238} can absorb neutrons to form plutonium, Pu^{239}, which is a fissile isotope in reactors using reprocessed nuclear fuel as a feed.

U_3O_8 equivalent — Natural uranium oxide equivalent. Natural uranium oxide equivalent is defined to be the theoretical amount of natural uranium oxide in the form of triuranium octoxide (U_3O_8) needed to produce a given amount of uranium, which can be in any form whose quantity is being measured. In the United States, uranium quantities expressed in U_3O_8 equivalent are typically in units of pounds.

UF_6— Uranium hexafluoride. A fluorinated form of uranium. Natural uranium is converted into UF_6 in preparation for uranium enrichment. Both the natural and the enriched forms of UF_6 are major articles of commerce.

Uranium enrichment services— See Enrichment Services, page 88.

Urenco— A tri-national joint venture which operates gas centrifuge uranium enrichment plants in the United Kingdom, the Netherlands, and Germany.

Western countries or Western world— All countries except Eastern Europe, the former Soviet Union, China, Mongolia, North Korea, and Cuba.

APPENDIX C
NUCLEAR FUEL MATERIALS AND PROCESSING COSTS

NUCLEAR FUEL MATERIAL AND PROCESSING COSTS[1]

The tabulation below illustrates material and processing costs for the manufacture of one kilogram of enriched uranium product of product assay 3.5 percent and tails assay 0.3 percent:[2]

Uranium feed ($10/lb. U_3O_8)	$11.80/lb U
Conversion to UF_6	$1.75/lb U
Total	$13.55/lb U
Multiply by 2.2046 (lbs. to kgs.)	$29.87/kg U
Multiply by 7.786 (ratio of feed to product)[1]	$232.56/kg U
Enrichment costs per SWU	$100.
Multiply by 4.339 (the estimated SWU's required for the cost of enrichment).[2]	$433.90/kg U
Estimated fabrication costs	$200./kg U
To obtain the total costs to produce a kilogram of enriched uranium product we add the following:	
Feed costs	$232.56/kg U
SWU costs	$433.90/kg U
Fabrication costs	$200/kg U
Total	$866.46/kg U

[1] See text below for a discussion of how the feed ratio is derived.

[2] See text below for a discussion of how the SWU number is derived.

The ratio of feed to product in terms of uranium equivalent is given by $F = (X_P - X_W) / (X_F - X_W)$, where F is the ratio of quantity of feed to product, X_P, the product assay, is the weight fraction of U^{235} in the product (weight of U^{235} relative to weight of total contained uranium), X_W is the weight fraction of U^{235} in the tails (referred to as W because uranium tails are generally considered to be a waste product), and X_F is the weight fraction of U^{235} in the feed. For a natural uranium feed, about 0.711 percent of the uranium by weight is in the form of U^{235} or $X_F = 0.00711$. In the above example, the product assay of the uranium is 3.5 percent or $X_P = 0.035$ and the tails assay is 0.3 percent or $X_W = 0.003$. Plugging in these numbers in the formula, the value for the feed ratio is 7.786. In other words, it takes about 7.8 kilograms of natural uranium (0.711 percent U^{235}) to produce 1 kilogram of enriched uranium of 3.5 percent product assay and 0.3 percent tails assay.

According to calculations shown above, it takes about 4.339 SWUs to produce 1 kilogram of enriched uranium with a product assay of 3.5 percent U^{235} and a tail assay of 0.3 percent U^{235}. This calculation was derived from the formula $SWU = PV(X_P) + WV(X_W) - FV(X_F)$, where SWU are the separative work units; F, P and W are the weights of the feed, product, and waste (tails) in kilograms of uranium; X_P, X_W, and X_F are the weight fractions (weight of U^{235} relative to weight of total contained uranium) for the product, tails, and feed, respectively; and V is the separative work value function. The separative work value function V(x) is defined to be: $V(x)= a + bx + (2x - 1)L_n (x /(1 - x))$, where a and b are arbitrary constants, L_n is the natural logarithm, and x is the weight of the U_{235} component relative to the total weight of uranium. In practice, SWU calculations are typically obtained through the use of tables or computer spreadsheets based on the formula shown above using convenient normalization parameters for the constants.

In the tabulation shown on the following page, obtained from a spreadsheet program used by the DOE, the feed factor (defined as the ratio of feed to enriched product) and the SWU factor (defined as the ratio of SWUs to enriched product) are shown for enriched uranium having a product assay of 3.5 percent. The tail assays of the associated depleted uranium coproduct vary in increments of .01 percent units from .20 to .30 percent. The SWU calculations in the tabulation at right assume that the quantity of enriched uranium product is expressed in units of kilograms U. Note that this tabulation, in the example shown above, can be used to obtain the factor of 7.786 used to obtain the ratio of feed to enriched uranium product and the factor of 4.339 used to calculate the number of SWUs required for enrichment.

[1] Adopted from U.S. International Trade Commission, Appendix F, *Summary of Trade and Tariff Information, Uranium and Uranium Compounds*, February 1981. Principal author is Louis N. DeToro. Data have been updated to reflect changes in the typical processing specifications and costs for the production of nuclear fuel. The data shown are for illustrative purposes only and are not meant to reflect actual costs in a given situation.

[2] In the enrichment of uranium, a feed (usually natural uranium) is converted into a product (enriched uranium) that contains a higher percentage composition by weight of U235 than the feed and a coproduct (usually considered to be a waste product) referred to as depleted uranium (or as "tails") that contains a lower percentage composition by weight of U235 than the feed. The percentage composition by weight of U235 in the product is referred to as the product assay and the percentage composition by weight of U235 in the tails is referred to as the tails assay.

Tails assay	Feed factor	SWU factor
(percent)		
.2000	6.458	5.414
.2100	6.567	5.280
.2200	6.680	5.153
.2300	6.798	5.033
.2400	6.921	4.919
.2500	7.050	4.811
.2600	7.184	4.708
.2700	7.324	4.610
.2800	7.471	4.516
.2900	7.625	4.426
.3000	7.786	4.339