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Nuclear Power Generation and Fuel Cycle Report 1997

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Contacts

The *Nuclear Power Generation and Fuel Cycle Report* is prepared by the U.S. Department of Energy's Energy Information Administration. Questions and comments concerning the contents of the report may be directed to:

Dr. Zdenek D. (Dan) Nikodem, Branch Chief
Energy Information Administration, EI-531
U.S. Department of Energy
Washington, DC, 20585

Telephone number: (202)426-1179
Internet E-Mail number: ZDENEK.NIKODEM@EIA.DOE.GOV

or the following subject specialists:

Subject	Contact	Phone Number	Internet E-Mail
Nuclear Capacity Status and Projections	Kenneth Chuck Wade	202-426-1248	KENNETH.WADE@EIA.DOE.GOV
Uranium Market Developments and Uranium Market Model Forecasts and Operation . . .	William Szymanski	202-426-1177	WILLIAM.SZYMANSKI@EIA.DOE.GOV
International Nuclear Model Forecasts	Diane L. Jackson	202-426-1176	DIANE.JACKSON@EIA.DOE.GOV
Far East Discussion	John Moens	202-426-1247	JOHN.MOENS@EIA.DOE.GOV
High Level Waste, Spent Fuel	Kathy Gibbard	202-426-1129	KATHY.GIBBARD@EIA.DOE.GOV
World Integrated Nuclear Evaluation System Forecasts	Laura Church	202-586-1494	LAURA.CHURCH@EIA.DOE.GOV

Internet Addresses in earlier publications are also valid.

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Preface

Section 205(a)(2) of the Department of Energy Organization Act of 1977 (Public Law 95-91) requires the Administrator of the Energy Information Administration (EIA) to carry out a central, comprehensive, and unified energy data information program that will collect, evaluate, assemble, analyze, and disseminate data and information on energy resources, reserves, production, demand, technology, and related economic and statistical information.

The legislation that created the EIA vested the organization with an element of statutory independence. The EIA does not take positions on policy questions. Its responsibilities are to provide timely, high-quality information and to perform objective, credible analyses in support of deliberations by both public and private decision makers. Accordingly, this report does not purport to represent the policy position of the U.S. Department of Energy or the Administration. This report was prepared for use by the Congress, Federal and State agencies, the Organization for Economic Cooperation and Development, trade journals, and also for use by the general public.

This report provides information and forecasts important to the domestic and world nuclear and uranium industries. The first chapter presents the current status and projections through 2015 of nuclear capacity and generation for all countries with commercial nuclear power programs. U.S. capacity projections are consistent with those published in the *Annual Energy Outlook 1997*. Because of its robust growth in nuclear power, a special section on the Far East appears on colored sheets at the back of this chapter.

The next chapter contains current information and projections on worldwide uranium requirements, enrichment service requirements and spent fuel discharges from 1997 to 2015. The projections for U.S. spot-market prices, production, and imports are given to 2010. There is also a discussion of the U.S. uranium market analyzing how uranium purchases vary with spot-market prices. Information on deliveries of surplus Russian defense material is also presented in this chapter.

The last chapter compares EIA's projections with those of Energy Resources International, Inc., and NAC International.

The composition of this report differs from earlier versions. Previous reports contained discussions on current interest issues such as nuclear power plant performance and operations lifetime issues (1995) as well as decommissioning U.S. nuclear power plants (1996). In this report we confine our presentation to discussions of worldwide nuclear capacity, generation and the uranium market. New to Appendix A is a brief account of historical events that lead to the first self-sustaining nuclear reactor experiment. Detailed descriptions of the models used to make the fuel cycle projections are found in Appendix B. We have also included in Appendix C, nuclear generating units ordered in the United States from 1953 to 1996. Appendix F contains detailed reference case forecasts of nuclear fuel cycle requirements along with the low and high case capacity projections.

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Overview

Nuclear power is an important source of electric energy and the amount of nuclear-generated electricity continued to grow as the performance of nuclear power plants improved. In 1996, nuclear power plants supplied 23 percent of the electricity production for countries with nuclear units, and 17 percent of the total electricity generated worldwide. However, the likelihood of nuclear power assuming a much larger role or even retaining its current share of electricity generation production is uncertain. The industry faces a complex set of issues including economic competitiveness, social acceptance, and the handling of nuclear waste, all of which contribute to the uncertain future of nuclear power. Nevertheless, for some countries the installed nuclear generating capacity is projected to continue to grow. Insufficient indigenous energy resources and concerns over energy independence make nuclear electric generation a viable option, especially for the countries of the Far East.

Current Status and Recent Developments

Watts Bar 1 May be the Last U.S. Reactor

During 1996, five nuclear reactors worldwide were connected to their respective electricity grid. In the United States, 110 reactors, having a total capacity of 100.7 GWe, were in operation (Figure OV1).[1] Watts Bar 1, connected to the grid in February 1996, could be the last commercial nuclear reactor constructed in the United States within the projected time frame. At year-end 1996, 442 commercial nuclear units with a total capacity of 351 net gigawatts-electric (GWe) were operating in 32 countries, generating 2,300 net terawatthours of electricity (Figure OV2).

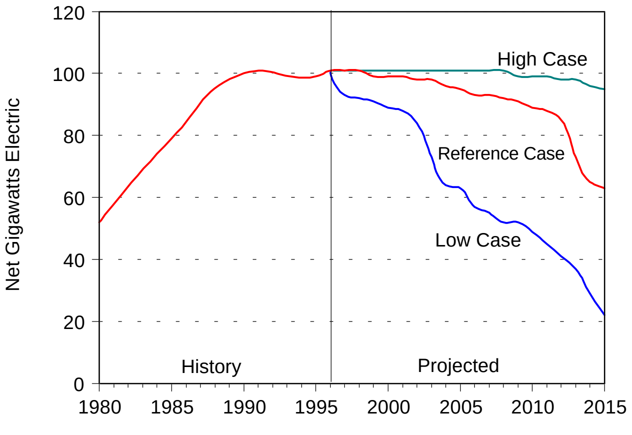


Figure OV1. Historical U.S. Nuclear Capacity and Projected Capacity, 1980-2015

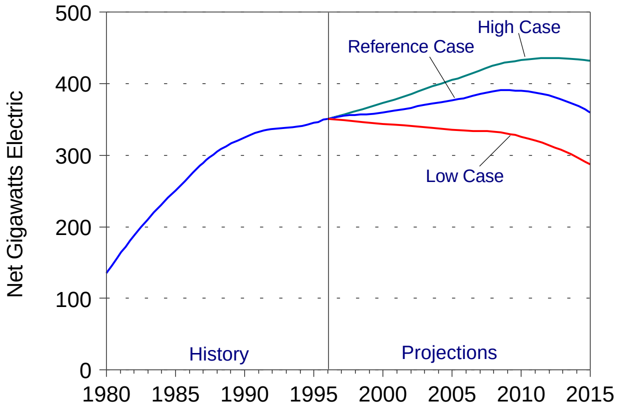


Figure OV2. World Nuclear Capacity, 1980-2015

Russia and South Korea Led in Units Under Construction

As of year-end 1996, 45 nuclear units were under construction. Russia and South Korea each had seven units under construction—the largest number for a single country. Additionally, there were 27 units in the planning stages, and 6 indefinitely deferred units that are not projected ever to be completed. Most of the planned units are located in China and Japan and are scheduled to begin operation between 2002 and 2010.

Record Nuclear Plant Performance Throughout the World

In 1996, record electricity production was reported in several countries, including Bulgaria, Finland, Germany, Hungary, India, Japan, South Korea, Ukraine, and the United States. In the United States, nuclear power accounted for 19.4 percent of the total generated electricity in 1996.[2] Germany's nuclear electricity share was 30 percent with no new nuclear units having come online since 1989.

Reversal in Uranium Spot-Market Prices

The average uranium spot-market price for the unrestricted world market and the restricted U.S. market in 1996 were \$14.17 and \$15.57 per pound U_3O_8, respectively. Both prices had risen from 1995. However, prices began to decline in mid-1996 in response to utilities purchasing uranium in excess of immediate requirements. By May 1997, prices had fallen to \$10.50 per pound U_3O_8

for the unrestricted market and $11.40 per pound U_3O_8 for the restricted market.

Commercialization of Surplus Defense Material

In 1996, a five-year contract was signed between the United States Enrichment Corporation (USEC) and Techsnabexport regarding the sale of low-enriched uranium (LEU), which will be derived from highly enriched uranium (HEU) taken from dismantled Russian nuclear warheads. By 2004, uranium derived from Russian HEU could supply 33 percent of U.S. commercial requirements. In addition, the U.S. Department of Energy announced plans to sell or transfer inventories of HEU, LEU, and natural uranium that have been declared surplus to national defense needs. A total of about 470 million pounds of U_3O_8 and 100 million separative work units (SWU) are expected to be displaced under current plans to commercialize U.S. and Russian inventories formerly held for defense purposes. The penetration of surplus defense material into the U.S. uranium market is restricted by legislation and trade policies.

Yucca Mountain Tunnel Boring Successful

In April 1997, DOE completed its Exploratory Studies Facility (ESF) tunnel at the Yucca Mountain site. Excavation of the ESF began in September 1994. The ESF will serve as an underground laboratory for determining whether the Yucca Mountain site can provide a suitable geologic repository for the long-term storage of spent fuel and other high-level nuclear waste. DOE hopes to complete by 1998 an assessment of the viability of Yucca Mountain to serve as such a repository. Yucca Mountain is scheduled to begin receiving nuclear waste in 2010.

Outlook

World's Nuclear Capacity Begins to Decline by 2010

Nuclear capacity for the reference case is projected to increase from 351.0 net GWe to 390.5 net GWe by 2010 before falling to 359.6 net GWe by 2015. The low growth in projected capacity is attributed to the projected retirement of several U.S. nuclear reactors. In Asia, primarily South Korea, China, Japan, Taiwan, and India, there is a genuine desire for building new plants because these countries, with the exception of China and India, are without an abundance of natural gas or coal and face the alternative of importing fuels at relatively high cost. Over 70 percent of the world's new nuclear capacity is anticipated in these five countries. In the reference case, the nuclear capacity of the Far East and "Other" regions grow at an annual rate of 3.4 and 5.6 percent, respectively, through 2015. In North America, Western Europe, and Eastern Europe, capacities show declining growth rates of 2.3, 0.5, and 0.4 percent, respectively.

Uranium and Enrichment Services Requirements Continue to Grow

For EIA's reference case, the annual worldwide uranium requirements for nuclear power reactors from 1997 through 2015 are projected to range from 140 million to 167 million pounds. Cumulative requirements over the same period are projected to approach 3.0 billion pounds. Reactors in Western Europe account for 30 percent of the cumulative requirements, followed by the United States (26 percent) and the Far East (24 percent). In response to its growing nuclear power capacity, the Far East is anticipated to increase its share of worldwide uranium requirements over time.

Annual worldwide enrichment service requirements are projected in EIA's reference case to range from 32 million SWU to 37 million SWU. Cumulative enrichment requirements over the same period are projected at 661 million SWU. Western Europe, the United States, and the Far East require the largest share of enrichment services. The Far East's share of worldwide requirements will rise in conjunction with the region's increased nuclear power generating capacity in the later years of the projection period.

MOX Fuel Reduces Requirements for both Uranium and Enrichment Services

Mixed oxide (MOX) fuel for nuclear reactors is being utilized in Belgium, France, Japan, Germany, and Switzerland. Although not incorporated in the EIA reference case, EIA projects that the continuing use of MOX fuel in these countries will reduce uranium requirements over the forecast period by around 7 percent and enrichment services by 8 percent.

Spent Fuel Continues to Accumulate

In the EIA reference case, world nuclear reactors are projected to discharge 10,000 metric tons of uranium as spent fuel in 1997, while U.S. reactors are projected to discharge 2,000 metric tons. In the period 1997-2015, world cumulative discharges of spent fuel are projected to total 206 thousand metric tons of uranium, with the U.S. share at 38 thousand metric tons.

Uranium Price to Decline Before Rising to Higher Level

The spot-market price (in constant 1996 dollars) for the U.S. market is projected to decline in 1997 following increased purchases by utilities during previous years. U.S. uranium production in 1997 is projected to decline to 5.9 million pounds U_3O_8 from the 1996 output of 6.3 million pounds. The price is expected to rise in 1998 as the market adjusts to a reduction in excess commercial inventories. The decline in commercial inventories is expected to be offset by increased production, particularly from Australia and Canada, and sales of Government surplus inventories. By 2003, the price is projected to rise above $15.00 per pound U_3O_8 as the rate of introduced Government surplus inventories is stabilized and lower cost reserves are depleted. In 2010, the spot-market price in constant 1996 dollars is projected to be around $16.00 per pound U_3O_8. For most of the forecast period, U.S. production is projected to range from 6.6 to 8.5 million pounds U_3O_8. Over half of U.S. reactor requirements are projected to be filled by imports. In addition to imports, government inventories previously held for defense purposes and commercial inventories will supply uranium to U.S. utilities.

1996 Nuclear Capacity Status and Projections

The projections in the *Nuclear Power Generation and Fuel Cycle Report 1997* are not statements of what will happen, but of what might happen given the assumptions and methodology used. EIA does not propose, advocate, or speculate on future legislative and regulatory changes. All laws are assumed to remain as currently enacted; however, the impacts of emerging regulatory changes, to the extent that they were adequately known, have been incorporated.

The methodologies used to assess the nuclear capacity projections are described in Appendix B.

Because long-range capacity projections are complex and are subject to much uncertainty, two additional scenarios were developed for this report: the Low Growth and High Growth Cases are presented in Appendix F, Table F7. Many events which shape a country's energy mix are difficult to anticipate, including political disruptions, strikes, and technological breakthroughs. Also, assumptions concerning future technology, demographics, and resources cannot be known to an acceptable degree of certainty. The Low and High Case scenarios are attempts to estimate reasonable limits for the energy mix for a given country.

Nuclear Power 1996

Introduction

For the 32 countries that had nuclear generating programs in 1996, nuclear power accounted for 23 percent of their total electricity production and 17 percent of total electricity generated worldwide. In the future, the prospect for nuclear power to assume a larger role or even to continue to retain this current share of the total electricity generation is uncertain in those countries. Nevertheless, for some “nuclear countries,” the application of nuclear electric generation will be increased by completing the nuclear plant projects currently under construction, as well as additional projects planned for the near future. Worldwide, the future of nuclear electric generation is dependant upon favorable economic considerations, societal acceptance of nuclear power technology, and the development and implementation of safe, secure, long-term nuclear waste disposal systems. Through 2015, nuclear capacity is projected to continue to grow in two of the five regions considered, namely the Far East and Other regions,[3] especially in countries where a lack of sufficient indigenous energy resources make nuclear electric generation a viable option (Figure 1). Stagnant or declining capacity is projected for Eastern Europe, North America, and Western Europe.

New Reactors

At the end of 1996, 442 commercial nuclear units with a total capacity of 351 net gigawatts-electric (GWe) were operating in 32 countries throughout the world (Figure 2). During the year, five nuclear units were connected to the grids in four countries. Two units were connected to the grid in Japan: Kashiwazaki Kariwa 6, a 1,315-megawatt-electric (MWe) boiling-light-water reactor (BWR), and Genkai 4, a 1,127-MWe pressurized light-water reactor (PWR). In France, Romania, and the United States, one unit each was connected to the grid. France connected the Chooz B1, a 1,455-MWe PWR in August 1996. Romania’s first nuclear unit, Cernavoda 1, a 650-MWe PWR, was

Figure 1. Regional Groupings for Nuclear Capable Countries

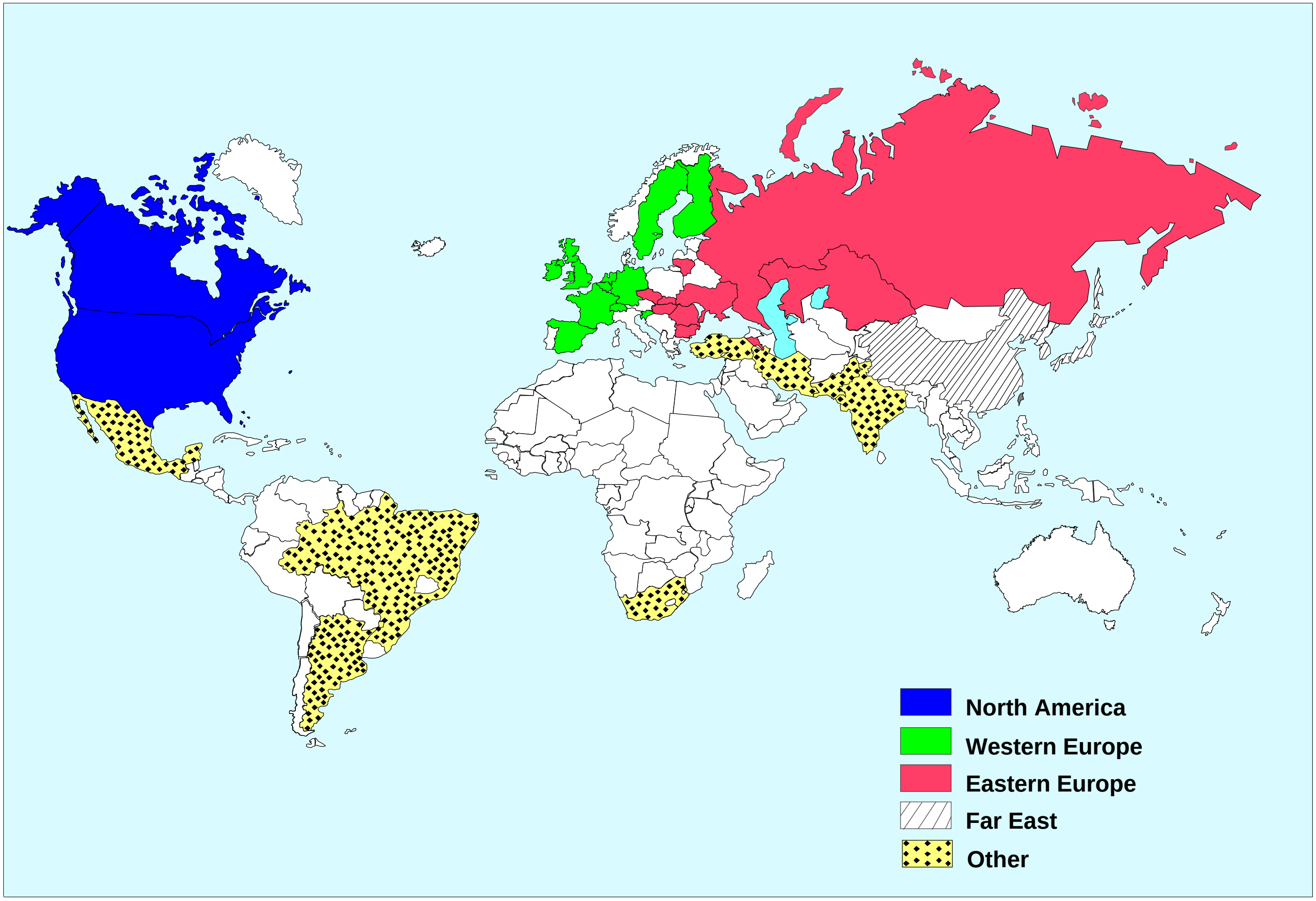
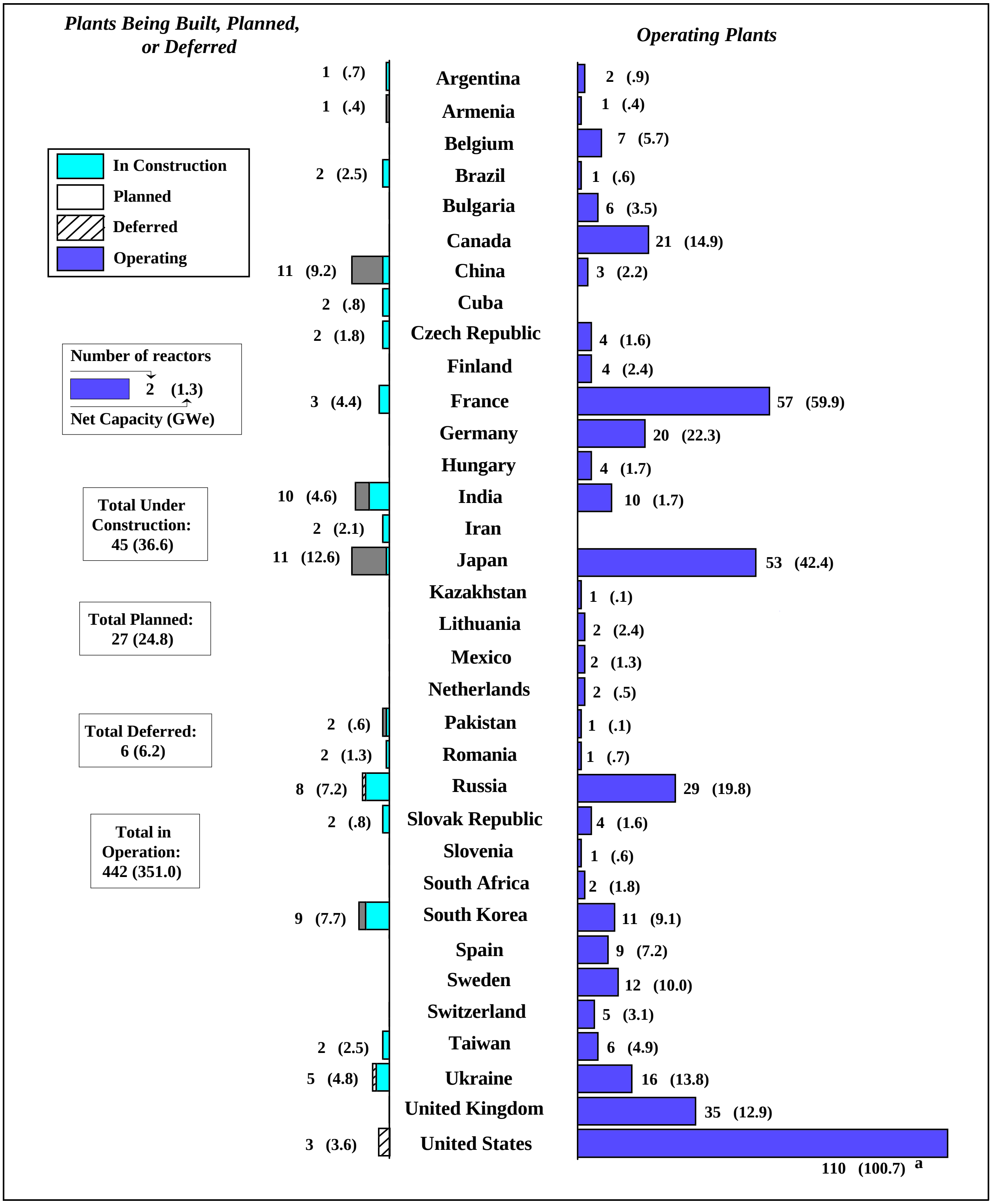


Figure 2. World Nuclear Power Reactors, 1996



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[a] 1996 U.S. capacity is preliminary.

connected in July 1996. In the United States, the Watts Bar 1, a 1,170-MWe PWR, was connected in February 1996.

Western Europe led all regions in electricity generation in 1996 with a nuclear share of 33 percent, followed by North America with 19 percent and the Far East with 18 percent. The nuclear capacity of North America and Western Europe is expected to decline over the projection period, due to the economics of nuclear power construction and operation, the deregulation of electric utilities from a government regulated monopoly to an unregulated competitive market, and issues associated with public acceptance of nuclear power.

Reactors Under Construction, Planned, or Deferred

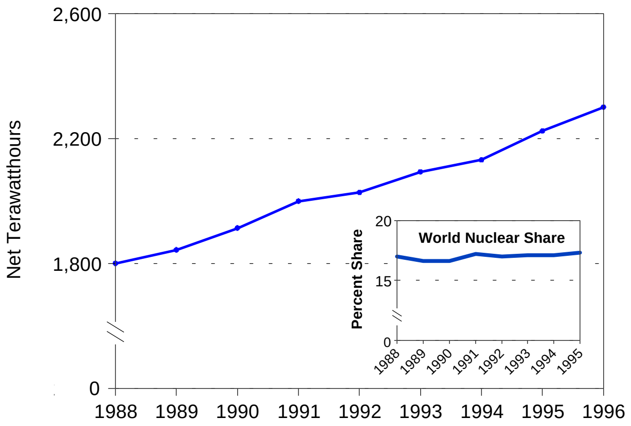
As of December 31, 1996, there were 45 units under construction in the world, with a total capacity of 36.6 GWe. Of the 45 units, 15 units were between 75 and 100 percent complete and 10 were less than 25 percent complete. Russia and South Korea each had seven units under construction, the largest number for a single country. India had six units under construction. Four of India's units are over two-thirds complete and are expected to become operational by 2000.

A total of 33 units is listed as planned or indefinitely deferred with a capacity of 30.9 GWe. Although these plants are dispersed throughout 10 countries, 62 percent of this capacity is in China and Japan. Most of China's and Japan's plants are scheduled to begin operating between 2002 and 2010. In the United States, three units are indefinitely deferred and are not expected ever to come online.

1996 Reactor Performance

The operating nuclear units performed well in 1996, continuing to provide more electricity than in the previous year and retaining a sizable portion of total electricity production. World nuclear-generated electricity was 2,300.0 net terawatthours (TWh) in 1996, eclipsing the generation of 2,223.5 net TWh in 1995 (See Figure 3 and Table D4 in Appendix D).[4] Record electricity production was reported in several countries, including Bulgaria, Finland, Germany, Hungary, India, Japan, South Korea, Ukraine, and the United States. The record generation by U.S. reactors (Appendix D, Table D4) was attributable to the industry's decision to move to longer operating cycles, improved maintenance, and shorter refueling outages. Germany's 20 units generated a record 152.8 net TWh. Seven of that country's large nuclear units turned in the highest electric generation worldwide, with Kernkraftwerk Philippsburg GmbH's Philippsburg 2 unit grossing 11.4 TWh of electricity (See Table D5 in Appendix D). This performance in 1996 kept Germany's nuclear share at 30 percent, although no new nuclear units have come online since 1989.

Figure 3. Total Net Nuclear Electricity Generation Worldwide, 1988-1996



Two Japanese reactors reported the highest capacity factor for the second consecutive year, with Tokyo Electric Power Company's Fukushima Daiichi 2 and Kansai Electric Power's Ohi 3 operating at 100.0 and 99.9 percent capacity, respectively (Table 1).[5] They were followed by Virginia Power's Surry 1, Korea Electric Power Company's Kori 3, and Spain's Asco 1. Shutting down for shorter duration placed five U.S. units among the 10 plants with the highest capacity factors. Electricite de France's units, for which the capacity factors have long been kept lower by extensive load-following, rose three percentage points in 1996 to nearly 74 percent.

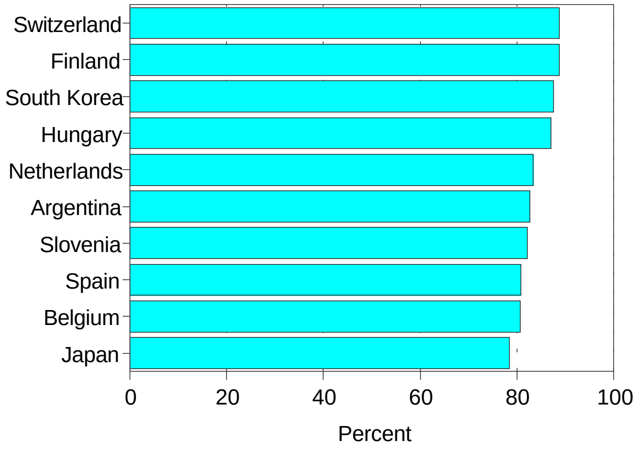
For Spain's nine reactors, the capacity factor averaged 81 percent in recent years, up from the mid-70's, which reflects their efforts to improve reactor performance (Figure 4). Taiwan's six reactors broke through the 80-percentile barrier for the first time while Sweden's reactors were just short of 80 percent.

Table 1. Top 10 Nuclear Units by Capacity Factor, 1996

Unit	Gross MWe	1996 Capacity Factor (Percent)	Nation
Fukushima Daiichi	1,100	100.0	Japan
Ohi 3	1,180	99.9	Japan
Surry 1	847	99.4	United States
Kori 3	950	99.1	South Korea
Asco 1	947	99.0	Spain
Hatch 2	844	98.8	United States
Palo Verde 3	1,307	98.6	United States
Three Mile Island 1	871	98.2	United States
Farley 1	873	98.1	United States
Ohi 2	1,175	98.1	Japan

Plants in the former Soviet Union were operated at capacity factors that ranged from 55 to 70 percent. These plants have been hampered by long shutdowns for retrofits, shortages of spare parts, erratic grid conditions, and chaotic economies. Even with these deficiencies, both Russia and Ukraine increased their electricity generation in 1996. The increased generation in Ukraine was partly due to the startup of the sixth unit at Zaporozhye in October 1995 and also to programsimplemented at various plants to improve overall operating efficiencies.

Figure 4. Ten Countries With the Highest Capacity Factors



The average capacity factor for all Ukrainian nuclear plants increased from 62 percent to 67 percent in 1996.[6]

Outlook

Nuclear capacity is projected to increase slightly from about 351.0 net GWe in 1996 to 359.6 net GWe by 2015 (Table 2). The low growth through 2015 is somewhat misleading. There is growth of about 1.0 percent between 1996 and 2005 as nuclear capacity continues to increase; however, growth occurs at a slower rate of 0.7 percent between 2005 and 2010. After 2010, nuclear capacity declines at an annual rate of 1.6 percent, mostly as a result of the projected retirement of U.S. units. The vast majority of reactors likely to be operating in the world during 2015 are already in use today, unless there is a renewal in reactor orders and those units planned and deferred are completed. Consideration of operating lives of current reactors and estimation of new or replacement reactors are essential factors for assessing future capacity.

Given the uncertainty in projecting nuclear capacity, two additional scenarios, the low and high growth cases, were developed for this report (Figure 5). The reference case reflects a continuation of present trends in the nuclear industry, resulting in minimal growth through 2010 and decline by 2015. The low and high growth cases reflect the uncertainty associated with electricity growth rates and do not reflect other uncertainties associated with nuclear power. The low growth case assumes that capacity will decline at an average annual rate of 1.1 percent. The high growth case reflects a moderate revival in nuclear orders, with net capacity growth of 1.1 percent annually over the forecast period. The methodology used to produce the scenarios is discussed in appendix B. The low and high growth cases data is presented in Appendix F, Table F7.

Given the lack of new orders, the industry must increasingly rely on servicing, replacing, and refueling reactors until an increase in plant orders occurs. There is a great need for modernizing Soviet-designed plants in Eastern Europe, but very little money is available to pay for the work.

In North America and Western Europe, the deregulation of the electricity industry is intensifying competition among all fuel sources. As a result, the low growth in the reference case can be attributed to the expected retirement of U.S. nuclear reactors (Figure 6). Key factors that influence the choice of new and replacement generation include relative costs of fossil fuels, investment costs,

Table 2. 1996 Operable Nuclear Capacities and Projected Reference Case Capacities for 2000, 2005, 2010, and 2015

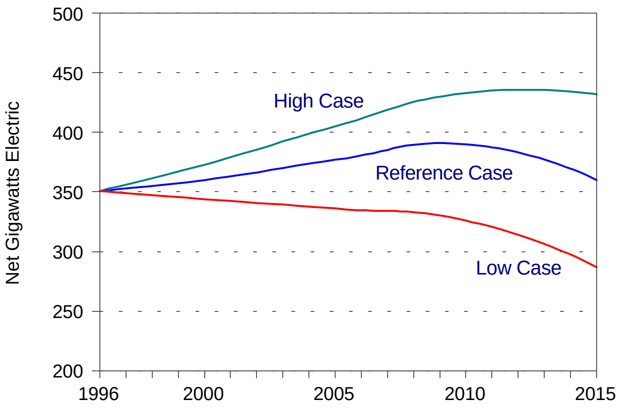
(Megawatts-electric)

Country Name	1996[a]	2000	2005	2010	2015	Growth Rate (1996-2005)	Growth Rate (2005-2010)	Growth Rate (2010-2015)
North America								
United States	[b]100,685	99,382	94,965	89,122	62,960	-0.6	-1.3	-6.7
Canada	14,902	14,054	14,054	14,054	11,994	-0.6	0.0	-3.1
Subtotal	**115,587**	**113,436**	**109,019**	**103,176**	**74,954**	**-0.6**	**-1.1**	**-6.2**
W. Europe								
Belgium	5,712	5,712	5,712	5,712	5,712	0.0	0.0	0.0
Finland	2,355	2,610	2,610	2,610	2,610	1.1	0.0	0.0
France	59,948	64,303	62,870	62,870	62,870	0.5	0.0	0.0
Germany	22,282	21,063	21,063	20,723	18,916	-0.6	-0.3	-1.8
Netherlands	504	449	0	0	0	N/A	N/A	N/A
Slovenia	632	632	632	632	632	0.0	0.0	0.0
Spain	7,207	7,207	7,054	7,054	7,054	-0.2	0.0	0.0
Sweden	10,040	10,040	10,040	10,040	6,685	0.0	0.0	-7.8
Switzerland	3,077	3,077	3,077	2,712	2,000	0.0	-2.5	-5.9
United Kingdom	12,928	11,772	10,518	9,568	7,158	-2.3	-1.9	-5.6
Subtotal	**124,685**	**126,865**	**123,576**	**121,921**	**113,637**	**-0.1**	**-0.3**	**-1.4**
E. Europe								
Armenia	376	376	752	752	752	8.0	0.0	0.0
Bulgaria	3,538	3,538	2,722	2,722	1,906	-2.9	0.0	-6.9
Czech Republic	1,648	3,472	3,472	3,472	3,472	8.6	0.0	0.0
Hungary	1,729	1,729	1,729	1,729	1,729	0.0	0.0	0.0
Kazakhstan	70	70	500	500	500	24.4	0.0	0.0
Lithuania	2,370	2,370	2,370	2,370	1,185	0.0	0.0	-12.9
Romania	650	650	1,300	1,300	1,300	8.0	0.0	0.0
Russia	19,843	19,843	23,618	22,758	18,347	2.0	-0.7	-4.2
Slovak Republic	1,632	2,020	1,592	1,592	1,592	-0.3	0.0	0.0
Ukraine	13,765	14,015	13,090	15,577	11,400	-0.6	3.5	-6.1
Subtotal	**45,621**	**48,083**	**51,145**	**52,772**	**42,183**	**1.3**	**0.6**	**-4.4**
Far East								
China	2,167	2,167	6,737	11,542	17,500	13.4	11.4	8.7
Japan	42,369	43,525	50,176	54,768	59,200	1.9	1.8	1.6
Korea, North	0	0	950	1,900	1,900	N/A	14.9	0.0
Korea, South	9,120	12,990	16,790	20,600	24,600	7.0	4.2	3.6
Taiwan	4,884	4,884	7,384	7,384	7,384	4.7	0.0	0.0
Subtotal	**58,540**	**63,566**	**82,037**	**96,194**	**110,584**	**3.8**	**3.2**	**2.8**
Other								
Argentina	935	935	1,627	1,292	1,292	6.3	-4.5	0.0
Brazil	626	626	1,871	1,871	1,871	12.9	0.0	0.0
India	1,695	2,503	2,653	5,913	7,900	5.1	17.4	6.0
Iran	0	0	1,073	2,146	2,146	N/A	14.9	0.0
Mexico	1,308	1,308	1,308	1,308	1,308	0.0	0.0	0.0
Pakistan	125	425	425	725	600	14.6	11.3	-3.7
South Africa	1,842	1,842	1,842	1,842	1,842	0.0	0.0	0.0
Turkey	0	0	0	1,300	1,300	N/A	N/A	0.0
Subtotal	**6,531**	**7,639**	**10,799**	**16,397**	**18,259**	**5.7**	**8.7**	**2.2**
Total World	**350,964**	**359,589**	**376,576**	**390,460**	**359,617**	**0.3**	**0.7**	**-1.6**

[a] Status as of December 31, 1996.

[b] 1996 U.S. capacity is preliminary.

Figure 5. World Nuclear Capacity and Projected Capacity, 1996-2015



discount rates, transportation costs, and the regulatory environment.

The expected use of natural gas as the preferred fuel for base load power generation is a relatively new phenomenon, arising partly from the development of combined-cycle technology and partly from changing attitudes towards long term investments for electricity production. The competitiveness of gas is, however, dependent on its current low price, which may not last into the longer term. Security of long term supply is also an important concern within gas markets.

In Asia, primarily South Korea, China, Japan, Taiwan, and India, there is a genuine desire to build new nuclear plants because those countries, with the exception of China and India, are without an abundance of natural gas or coal and face the alternative of importing fuels at relatively high cost. Nuclear power has demonstrated that its technology can compete with all alternatives within such a framework and especially if social objectives such as national security are valued in conjunction with concerns over acid rain and greenhouse gas emissions. These projects, however, take time to develop and are often delayed by domestic political debates in which concern focuses increasingly on environmental issues.

In the reference case, the nuclear capacities of the Far East and Other regions are projected to grow at an annual rate of 3.4 and 5.6 percent, respectively, through 2015. In North America, Western Europe, and Eastern Europe, capacity shows declining growth rates of 2.3, 0.5, and 0.4 percent, respectively.

North America

In 1996, North America had 131 operable units generating about one-fifth of the regions' electricity. U.S. plants recorded an average capacity factor of 76.4 percent, resulting in total nuclear generation of 674.7 net TWh. This is an increase of 1.3 TWh over the record 1995 level. One reactor, Watts Bar 1, which is owned by the Tennessee Valley Authority, received its full-power license on February 7, 1996. By 2015, North America's nuclear share of total electricity generation is projected to decline from 19 percent in 1996 to 10 percent (Figure 7).

Figure 6. World Nuclear Capacity by Region, 1980, 1996, and 2015

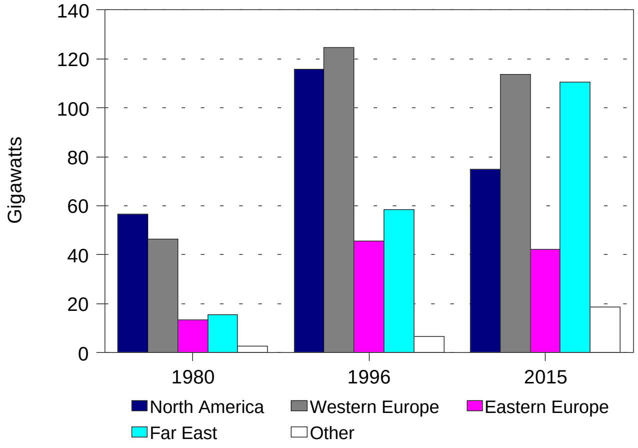


Figure 7. Comparison of Total and Nuclear Net Electricity Generation, North America, 1980-2015

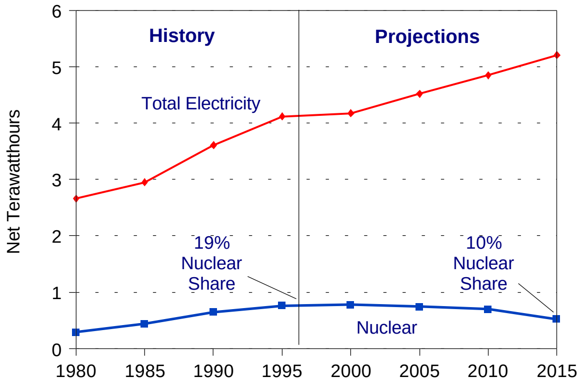


Table 3. U.S. Nuclear Generation by Federal Region, 1996

	Generation (net TWh)	Percent Share[a]
New England	30,255	40.6
New York/New Jersey	46,254	32.3
Middle Atlantic	107,051	29.1
South Atlantic	194,541	26.1
Midwest	132,740	22.9
Southwest	64,888	14.4
Central	30,476	18.1
North Central	0	0
West	62,936	30.2
Northwest	5,588	3.2
Total	**674,729**	**21.9**

[a] Nuclear-generated electricity as a percentage of utility-generated electricity. Nonutility generated electricity is not included.

TWh=Terawatthour.

In the United States, nuclear power accounted for 21.9 percent of the total utility generated electricity in 1996, compared with 22.5 percent generated in 1995 (Table 3). This decline can be attributed to the extended shutdown of several nuclear units such as Northeast Utilities' Millstone station. Nuclear's share of total utility electricity generation was largest in New England (40.6 percent) and New York / New Jersey (32.3 percent).[7] Utilities in 6 of the 10 Federal regions generated more than 20 percent of their electricity from nuclear power plants.

The United States' nuclear capacity is projected to decline from 100.7 net GWe in 1996 to 63.0 net GWe in 2015 because more than one-third of current U.S. nuclear capacity is scheduled for retirement by 2015. The reference case assumes that most U.S. nuclear units will operate to the end of their current 40 year license terms, with 50 units (38 percent of the current nuclear capacity) retiring between 1996 and 2015. Some nuclear units, however, may be retired before their license expiration dates due to operating costs exceeding 4.0 cents per kilowatthour. Given these assumptions, 59 nuclear units are projected to provide 10 percent of the total electricity generation in 2015.[8] No new nuclear units are expected to become operable by 2015.

In the United States, three nuclear units are indefinitely deferred; however, the likelihood of any of these reactors being completed is considered to be low. Nuclear generation is more capital intensive than fossil-fueled generation, and the lead times associated with licensing and building nuclear-powered generation are appreciably longer than they are for fossil-fueled generation. Combined, these two characteristics adversely influence the financing of new or existing nuclear construction so as to burden nuclear power with an immediate handicap in any comparative evaluation. With the electric utility industry moving from a regulated industry to a competitive market, these unfinished units and those units with high operating costs may not operate in the future.

The decision to retire a nuclear power plant is based on a comparison of a plant's operating costs with the cost of alternative power sources. The decision to close early is more complicated. A utility must also consider such factors as how its decontamination and decommissioning cost will be funded and how its underappreciated plant costs will be allocated. High production costs are certainly more likely to prompt a comparative analysis of costs that might result, in turn, in a determination for early shut down.

On August 7, 1997, Maine Yankee Atomic Power Company, owners of the Maine Yankee nuclear unit, announced that it will not reopen the unit, citing the rising costs of safety measures as a major factor. GPU Energy, owner of the Oyster Creek nuclear power unit, has expressed a likelihood that it, too, may shut its plant down before the current operating licenses expire.[9] GPU Energy would offset the generating capacity lost with existing capacity and/or enhancements of the transmission system.

An increase in natural gas reserves—due to improved geophysical techniques for locating gas reserves, and horizontal drilling for opening gas bearing seams—have made gas-fired plants more economical. Currently, natural gas appears to be the fuel of choice for future electricity generation in North America.[10]

Nuclear electricity production in Canada dropped by 5.2 percent in 1996 as the Pickering units continued to post low generation. Ontario Hydro (OH), Canada's largest utility, shut down all eight Pickering reactors last April to modify a malfunctioning valve in the station's centralized emergency cooling system. OH subsequently shutdown several of the Pickering units for extensive maintenance work. OH also decided to close its Bruce 1 unit in 2000 instead of retubing the unit. Surplus generating capacity and higher than expected nuclear production costs were cited as factors contributing to the decision.

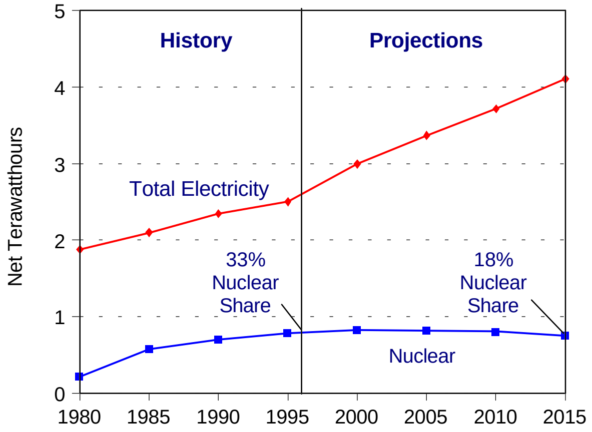
In December 1996, the government of Canada decided to postpone any decision on the privatization of OH and instead decided as its first priority, to restore the utility's nuclear performance. The proposed privatization of OH would create a number of small generating companies and some government-owned nuclear companies that would compete against each other in Ontario. If there isn't a strong electric utility player in Ontario, then the vacuum may be filled by a major utility from the United States, while the Ontario-based generating companies would not have the ability to compete outside the province.

Western Europe

Nuclear capacity in 1996 in Western Europe represented a 36 percent share of the total world nuclear capacity, the largest regional share in the world. Nuclear generation in 1996 was 834.2 net TWh, the largest of any region. The European Union recently passed a directive designed to open the electricity market to competition starting in 1997. Initially, this will affect only a small portion of customers, but will increase to almost one-third of the market by 2003. A freeze in the construction of nuclear power plants is currently in effect in Belgium, Finland, Germany, Netherlands, Spain, Sweden, Switzerland, and the United Kingdom. Utility deregulation and privatization, operating as collateral forces, have undermined the competitive potential of new nuclear power construction. As a result, no new nuclear units are projected to be built after 1998, and the nuclear share of total electricity generation is projected to decline from 33 percent to 18 percent by 2015 (Figure 8). Nuclear capacity is projected to range between 108 and 121 net GWe by 2015 (Appendix F, Table F7).

The United Kingdom has been the most aggressive country in introducing market competition into its electric generation industry. Nuclear capacity in the United Kingdom is projected to decrease from 12.9 net GWe to 7.2 net GWe by 2015. In a recent restructuring of its nuclear industry, all the country's advanced gas-cooled reactors and a single PWR, Sizewell B, were placed in a new company, British Energy Co., which was privatized in July 1996.[11] In advance of the privatization, the government stated that plans to build additional PWR's have been abandoned, at least at the present time. The older plants, which now belong to Magnox Electric Co., will not be privatized.[12]

Figure 8. Comparison of Total and Nuclear Net Electricity Generation, Western Europe, 1980-2015



Of the 10 countries in Western Europe with installed nuclear capacity, only France has units currently under construction. Once these units are complete, most likely by 1998, France, too, will have none remaining in the construction pipeline. The decline in market prices for gas and oil combined with the steadily improved efficiency of both gas- and coal-fired power plants have eroded prospects for nuclear power's competitiveness. A recent study by the general economic studies department of France's government-owned electric utility, Electricite de France (EDF) indicates that the cost of coal-fired stations would be equivalent to those of nuclear power, and combined-cycle gas turbines would have a cost advantage of around 20 percent over nuclear power.[13]

Spain has no plans to build additional nuclear power stations, the country's nine nuclear units accounted for 32 percent of the country's total electricity generation in 1996. Unesa, the Spanish utilities association, is finalizing a five-year plan to coordinate modernization work on the country's nuclear power plants and increase their capacity. The plan envisions extending the service life of the plants beyond the current 25 year limit.[14]

Due to a national referendum in Switzerland in 1990, a decision for a new nuclear plant cannot be made before 2000. Switzerland favors a 10-percent increase in the capacity of its existing five units.

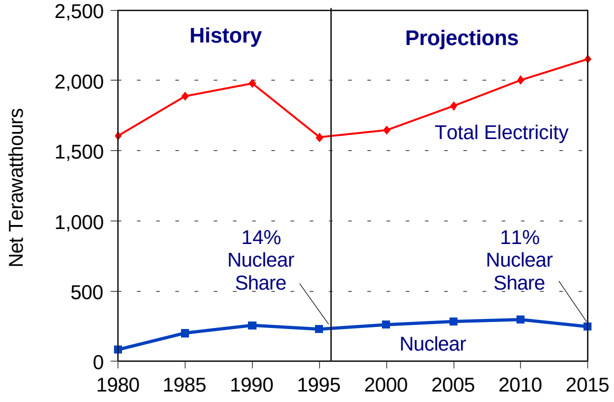
Sweden's 12 nuclear units, with a combined installed capacity of 10 net GWe provided 52 percent of the country's electricity generation in 1996. The Swedish Energy Commission had concluded at the end of 1995 that a complete phaseout of the country's 12 reactors by 2010 was unrealistic, but that it might be possible to close one unit before 2000. Following a February 1997 political agreement, the industrial ministry announced that negotiations would be started with the country's private utility, Sydkraft AB, to close the first of two units at Barseback by 1998 and the second unit by 2001.[15] Sydkraft has indicated that it will strenuously resist any imposed closure and would claim full compensation for an equivalent quantity of electricity at current costs and for the environmental costs of using gas or oil.[16] The threatened units, Barseback 1 and 2, are 615-MWe BWRs. The Barseback 1 unit has been operating for 22 years and Barseback 2 for 20 years.

A government statement on the proposed closures put the likely cost of closing the two units and developing alternative energy sources at around $1.2 billion (current 1996 dollars) spread over seven years. Sydkraft has estimated these actions will cost $2.7 billion.[17]

Eastern Europe

Eleven years after the Chernobyl accident, two of the four units at the Chernobyl plant in Eastern Europe remain in operation. In 1996, 68 nuclear powered units provided a total of 45.6 net GWe, about 14 percent of the total electricity generated in the region. Reliance on nuclear power varies in the region, from 83 percent in Lithuania to 0.2 percent in Kazakhstan. Several countries in the region have ambitious plans for additional nuclear capacity, but there are many challenges that will likely limit new nuclear construction. Consequently, nuclear-generated electricity is projected to decline to 11 percent by 2015 (Figure 9). At the end of 1996, 20 units remained in the construction pipeline, with Russia and Ukraine combined accounting for 13 units. By 2015, nuclear capacity in Eastern Europe is projected to range between 38 and 57 net GWe (Appendix F, Table F7).

Figure 9. Comparison of Total and Nuclear Net Electricity Generation, Eastern Europe, 1980-2015



The Russian nuclear sector is the largest of the former Soviet Union republics, and there are plans to increase it substantially in the next few decades. In 1996, Russia's 29 nuclear power units, with a combined installed capacity of 19.8 net GWe, provided 108.8 net TWh of electricity, equivalent to a nuclear share of 13.1 percent. Russia has other means to generate electricity, unlike other former Soviet republics; however, with its present economic difficulties, it needs to sell most of its natural gas, oil, and coal supplies for required hard currency.[18] Therefore, nuclear power is seen as a key resource for domestic electricity production. Coal, gas, and oil now provide over 70 percent and hydropower provides about 15 percent of the country's energy production.

In early 1993, the Ministry of Atomic Energy (MINATOM), set goals for the development and use of nuclear energy in Russia through 2010. One major goal is to replace older and unsafe nuclear units as they are permanently shutdown. With seven units under construction, MINATOM is aiming for nuclear power to continue to provide about one-eighth of the country's electricity needs.

In August 1996, MINATOM approved the construction of a new advanced reactor, VVER-640, design series V-407. The new reactor is scheduled to begin operation at the existing Leningrad nuclear site by 2003.[19] The continuing financial problems of Rosenergoatom, the government-owned utility, may threaten the construction of the VVER (Soviet designed light-water reactor) plants.

Of the former Soviet republics, Ukraine is the second largest producer of electricity from nuclear-powered plants. The 16 nuclear power units in the Ukraine accounted for 44 percent of all the electrical power in the republic. The operable Chernobyl units still are being utilized to alleviate electricity shortages in the area, although lack of fuel assemblies limited the output for several months during 1996. The government has tentatively agreed to close the plants by 2000, given that replacement power would come from upgraded VVERs.

Ukraine is continuing work to finish the Khmelnitski 2 unit by 1998 as well as Rovno 4, but the work is going slowly because of insufficient funds. Both units were hit by a moratorium on nuclear plant construction imposed in 1989, but the ban was lifted by the Ukrainian Parliament in 1993. The G-7 and associated western partners have proposed funding completion of the two units if the projects are revised to incorporate safety upgrades, which are planned to be designed and implemented by western firms.

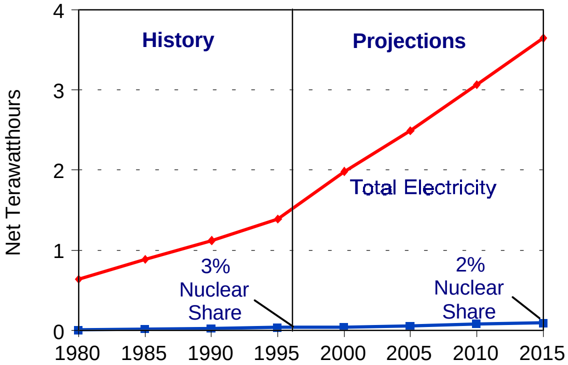
Cernavoda 1, Romania’s first nuclear unit, was connected to the grid in July 1996. This was 16 years after the start of work on this project, which was to have been a five-unit plant. The unit is situated about 170 km east of the country’s capital, Bucharest, at Cernavoda on the river Danube. The unit will generate electricity to meet about 10 percent of the country’s requirements, which should equate to an annual saving of 1.4 million tons of imported oil.[20] The $2 billion project has suffered from financial and organizational problems over the years, but has survived the recent change of regime.

The change of government has put the completion of Cernovoda 2 on hold, however. The former government of Ion Illiescu had announced that Renel, the Romanian electricity authority, could enter into a partnership with Atomic Energy of Canada Limited and Ansaldo. The new national government has not yet determined its policy or stated any position on the project.[21] Romania has called on international institutions, including the World Bank and European Investment Bank, to help finance the project.

Other

The countries of Argentina, Brazil, India, Mexico, Pakistan, and South Africa have relatively small nuclear power programs, compared with the major regions, and they account for only 2 percent of the world’s total nuclear capacity. Currently, these six countries constitute the Other region in this report. Additional countries with the potential to have nuclear programs in place by 2015 are Cuba, Iran, and Turkey. Although the total nuclear capacity of this region is expected to remain small throughout the projection period, it is projected to increase at an annual rate of 5.6 percent through 2015 and to maintain an electrical generation share of 2 percent (Figure 10). Nuclear capacity for the region is projected to range between 15 and 22 net GWe (see Table F7 in Appendix F).

Figure 10. Comparison of Total and Nuclear Net Electricity Generation, Other Region, 1980-2015



Most of the Other countries do not have the capital required for large nuclear programs and, in fact, will likely require financial and technical assistance before undertaking construction of a larger nuclear power electric generation industry. Successful completion of Cuba’s Juragua station will require international assistance. Russia has agreed to complete two units for Iran at the Bushehr site where construction was started in the 1970's. Neither Mexico nor South Africa currently have plans to add additional nuclear electric capacity in the near future. The present plants provide about 5 percent of electricity generation in each country.

The India Atomic Energy Commission had set an ambitious goal of 10 gigawatts-electric of installed nuclear capacity by 2000; however, financial constraints, local political issues and operational problems have played a part in delaying development of the country’s nuclear program. Despite these problems, the country can boast a comprehensive capability for the design and construction of nuclear power plants and the complete fuel cycle. India’s 10 operating reactors are located at five stations: Kakrapar, Kalpakkam, Norora, Rajasthan, and Tarapur. These units generated 7.4 net TWh of electricity in 1996, accounting for sightly over 2 percent of the nation’s total electricity generation.

“Other” Region

Currently, there are six units under construction in India and four more units are projected to go on-line before 2010. When these units are completed, nuclear-powered generation should remain at 2 percent of the country’s electricity share by 2015.

Construction work is continuing at Pakistan’s Chasnupp 1 unit, which is expected to start up in 1998. The PWR is being built by Chinese companies and is modeled after the Chinese-designed Qinshan-1 unit. Pakistan has announced that China is willing in principle to build a second unit, Chasnupp 2, but financing of the project has not yet been worked out. The Pakistan Atomic Energy Commission (PAEC), the utility that operates the country’s sole operable unit, Kanupp-1, is looking to extend the plant life by 10 years, to 2012. PAEC has identified problem areas and has plans to replace obsolete electricity systems as well as instrumentation and control systems.

Far East: 1996 Status and Outlook

At least 30 percent of the World's new nuclear capacity will be located in the Far East. Countries in the Far East that currently operate nuclear power units include China, Japan, South Korea, and Taiwan. At the end of 1996, these four countries had 73 nuclear units with a net capacity of 58.5 GWe that provided 18 percent of the region's electricity production. Growth in electricity demand is projected to be robust in this region with nuclear power projected to provide about 16 percent of this region's demand by 2015 (reference case) (Figure 11). Nuclear capacity is projected to range between 93 and 124 net GWe by the end of the projection period (Appendix F, Table F7).

Although nuclear's share of the electricity market will shrink as it fails to keep pace with demand, nuclear output will significantly increase. The impact of this upward trend extends far beyond the boundaries of Asia. In both East and West, the successes and setbacks of nuclear programs will be of significant interest to developing nations, environmental groups, producers of competing fuels, equipment manufacturers, and nuclear proponents, opponents, and those who are still undecided.

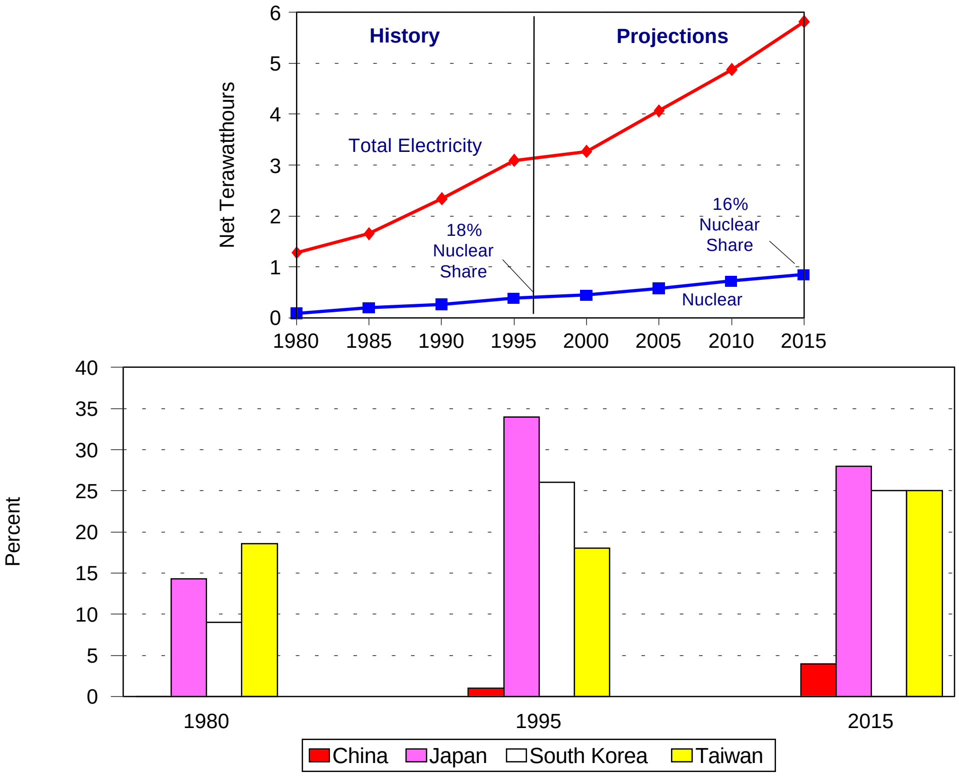
China

China began considering nuclear energy in the late 1970's as an alternative to burning coal. As China modernizes its industry, electricity demand has skyrocketed: from 400 billion kilowatt hours of electricity in 1986 to 823 billion kilowatt hours in 1995.

Nuclear's share of electricity generation, however, seems minuscule—less than 2 percent. The nuclear industry is growing. Nuclear generation increased from less than 3 net TWh in 1993 to over 13 net TWh in 1996 (Figure 12). EIA projects that nuclear output will increase 9-fold over current levels within two decades: from 13 net TWh in 1996 to 112 net TWh in 2015 (Figure 13).[22]

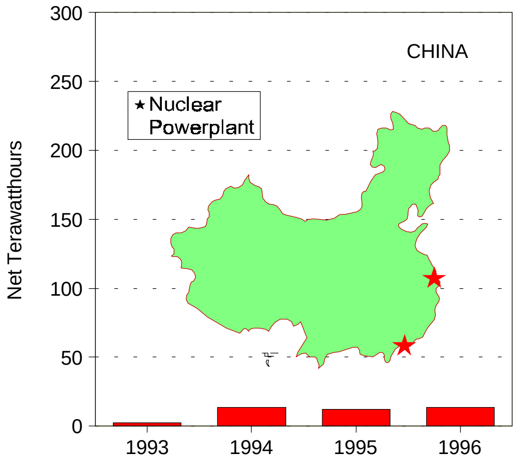
Current Status: China has two commercial nuclear powerplants in operation: one at Guangdong and the other at Qinshan. A third plant, Lingao, is projected to

Figure 11. Comparison of Total and Nuclear Net Electricity Generation, Far East, 1980-2015



Far East: 1996 Status and Outlook

Figure 12. Nuclear Generation in China, 1993-1996



come on line early in the next century. The China National Nuclear Corporation (CNNC) built Qinshan 1, the nation's first commercial nuclear reactor. Framatome, a French company, supplied the two operable units at Guangdong and is building two pressurized light-water-moderated and cooled reactors for Qinshan. Qinshan 2 is projected to be operational in 2002 and Qinshan 3 should be operational in 2003.

Nuclear Share: China has a significant fuel advantage over most of its neighbors. It possesses massive resources of coal: enough coal to provide 70 percent of its electric power. By comparison, nuclear's share of the electricity market, however, is a modest 2 percent.[23]

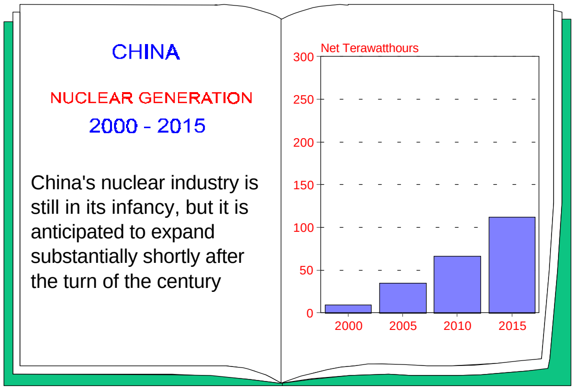
Nuclear Generating Units–1996

Operable Units	3
Capacity (net)	2,167 MWe
In Construction	2
Capacity (net)	1,200 MWe
Planned, Deferred	6
Capacity (net)	8,045 MWe

Although the share is modest, the growth is rampant. In the next century, China could overtake South Korea—which has ambitious industrial expansion plans of its own—to become the second largest commercial nuclear supplier in Asia.

International Focus: CNNC both actively encourages foreign investment and actively promotes its own expansion. China's efforts to build reactors in Pakistan and the Middle East have raised concerns in the West about nuclear proliferation. Pakistan has ordered one reactor from CNNC that is expected to begin operation at the turn of the century. When completed, Pakistan's Chasnupp 1 will be the first Chinese-built nuclear generating unit on foreign soil.

Figure 13. Nuclear Generation in China, Reference Case, 2000-2015



Foreign suppliers play a significant role in China's nuclear program. The many examples of foreign participation include: the involvement of French technology in making fuel for Qinshan and Daya Bay powerplants; the Research Institute for Nuclear Service Operation, a joint venture with Westinghouse; the training in Spain of operators for Qinshan, and the German main cooling pumps and injection pumps at Qinshan.[24]

Concerns: Heavy coal use in the absence of environmental safeguards has brought heavy pollution levels. China currently has the largest volume of carbon emissions from coal in the world (673 million metric tons in 1995). This is 25 percent more than levels in the United States, but China's annual emissions are expected to increase at four times the U.S. rate.

By the year 2015, China's carbon emissions will nearly triple over present levels, rising to 1,675 million metric tons.[25] Nuclear power provides an alternative to coal, but it is only a partial solution.

The Future: Growth in electricity demand is projected to outpace the growth in China's total energy production between 1995 and 2015.[26] Expectations of robust electricity demand are driven by rural electrification and projections of high economic growth. Electricity generation in China remains dominated by coal. Natural gas and oil provide only 5 percent of the generation. Potential hydropower resources in China are large, estimated at 370 gigawatts of generating capacity.[27] The Gorges Dam, the largest hydroelectric project in the world's history (18.2 GWe) is scheduled to be completed around 2010.

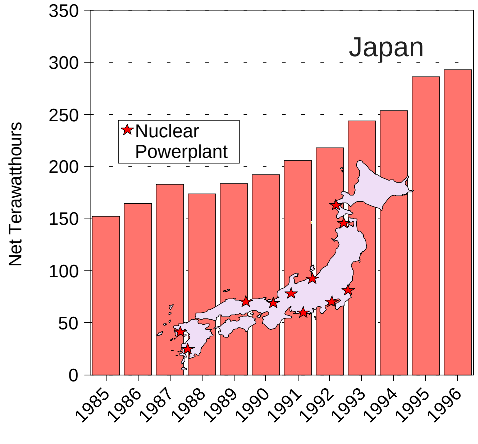
China has aggressive plans for nuclear expansion with nine additional planned units totaling 8.0 GWe. Qinshan 2 and 3 are 10 and 5 percent complete, respectively, and are projected to go online in 2002 and 2003.

In 1996, Canada and China signed a final contract for the construction of two 700 MWe CANDU nuclear reactors at the country's Qinshan site. Construction of these units, Qinshan 5 and 6, is expected to begin in 1997 and will take about six years to complete. Over a 30 year period, the two-unit plant could avert burning about 116 million tons of coal or 500 million barrels of oil, avoiding emissions of more than 250 million tons of carbon dioxide.[28]

Japan

Imported oil fueled Japan's commercial boom in the 1960's and 1970's, but the oil embargo of 1973 wreaked havoc with Japan's economy. Proponents of nuclear power argue that Japan's shift to nuclear fuel was essential. Japan's nuclear output nearly doubled between 1985 and 1996 (Figure 14). Even with the shift to nuclear power, however, the electric power industry will need to maximize the nation's limited resources.

Figure 14. Nuclear Generation in Japan, 1985-1996



Current Status: Japan ranks third in installed nuclear capacity, behind the United States and France. Japan has 11 nuclear generating units in construction or being planned. Japan brought 2 nuclear reactors on-line in 1996: Kashiwazaki Kariwa 6 in January and Genkai 4 in November.

Nuclear Generating Units–1996

Operable Units	53
Capacity (net)	42,369 MW
In Construction	1
Capacity (net)	1,315 MWe
Planned, Deferred	10
Capacity (net)	11,243 MWe

Nuclear Share: In 1996, Japan's 53 nuclear units, with an installed capacity of 42.4 net GWe, provided 287 net TWh of electricity, equivalent to a nuclear share of 33.4 percent. Population growth in Japan, unlike many countries of the Far East, is expected to be low. However, there is a projected increase in per capita electricity consumption.

International Focus: For the U.S. economy, Japan's increasing reliance on nuclear power is simultaneously a cause for concern and a cause for optimism. Nuclear growth could offset coal consumption in Asia. Japan is the second largest importer of U.S. coal and the largest importer of Australian coal. Even with two new nuclear plants coming online in 1996, however, Japanese imports of U.S. steam coal (the type of coal used by electric utilities) increased by 29 percent.[29] Despite rapid nuclear expansion, consumer demand for electricity will continue to outpace nuclear growth.

For nuclear equipment suppliers in the West, Japan is a potential market. Because the Japanese have long ago developed technical expertise, however, it is a difficult market to penetrate. Three fourths of Japan's operating reactors were built by domestic firms. Japan, however, also has 12 reactors built entirely by or in partnership with foreign companies.

Kashiwazaki Kariwa 6, Japan's newest nuclear generating unit, continues the East / West partnership. It was built by Toshiba Corporation and General Electric Company (GE).

The only unit currently under construction, Kashiwazaki Kariwa 7, is also being built in partnership with GE. This time, Hitachi, Ltd., is the Japanese partner.

Concerns: To enhance its energy security, the government advocates uranium and plutonium recovery through reprocessing of spent fuel. The Power Reactor and Nuclear Fuel Development Corporation (PNC) operates a reprocessing plant with an annual capacity of 90 tons but completion of a larger reprocessing plant, Rokkasho-Mura, with a capacity of 800 tons per anum, planned for 2003, is delayed.[30] Reprocessing is an expensive process and the cost can quickly rise with new safety requirements and the development of new technologies. Estimated in 1993 to cost about $8 billion when completed, a more recent estimate for Rokkasho-Mura (January 1996) places the cost at $15 billion.[31]

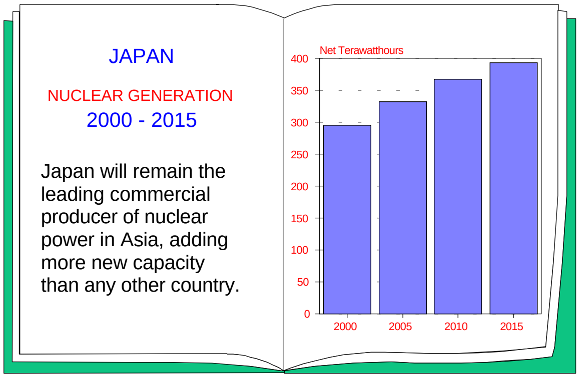
The Japanese Government is committed to nuclear growth, but several recent accidents have aroused public concern. In December 1995, a sodium leak at the Monju plant exposed workers to minor doses of radiation. The government's report was critical of the plant's design, operating procedures, handling of the emergency, and its own safety screening procedures.[32] A fire and explosion at the Tokai Mura vitrification facility in March 1997, followed by a sodium leak at Fugen in April, added to public concern. The PNC, operator of all three facilities, is reviewing its management procedures.[33]

The government may opt for security over costs in fuel choice, but the costs are considerable. Japan's nuclear program is regarded by some analysts as being not cost effective.[34] Consequently, Japanese utilities are having difficulty in meeting government demands to reduce electricity prices.

The Future: Japan is the leading commercial nuclear power in Asia and is likely to remain so for at least two decades. Consumption of nuclear-generated electricity in Japan is expected to increase at an annual rate of 1 percent from 1995 to 2015.[35] Generation is projected to increase from 295 net TWh in 2000 to 393 net TWh in 2015 (Figure 15). In 1995, nuclear-generated electricity consumption in Japan was about one-third the level of consumption in the United States.

With the expansion of the Japanese nuclear industry, and the anticipated decline in the U.S. generation due to plant retirements, Japan is expected to generate three-fourths as much as the United States by 2015.

Figure 15. Nuclear Generation in Japan, Reference Case, 2000-2015



People's Democratic Republic of Korea (North Korea)

In October 1994, the North Korean nuclear program was ended by the signing of a pact with the United States.[36] Under the pact, the International Energy Agency will oversee the dismantling of the North Korean nuclear program. In return, the United States agreed to help arrange financing for two reactors to be built near Pyongyang, the capital of the People's Democratic Republic of Korea. South Korea, Japan, and several other countries are participating in the project.

Current Status: North Korea has no nuclear plants, but in December 1995, the Korean Peninsula Energy Development Organization (KEDO) signed a contract to provide two light water reactors to a site at Pyongyang.[37] KEDO is a multi-national body consisting of three members--Japan, South Korea, and the United States, with the European Union considering active participation.

Nuclear Share: None

International Focus: The International Atomic Energy Agency is monitoring the dismantling of North Korea's domestic nuclear program, but progress had stalled on the two reactors planned for Pyongyang. South Korea, Japan, and several other countries are participating in the project.

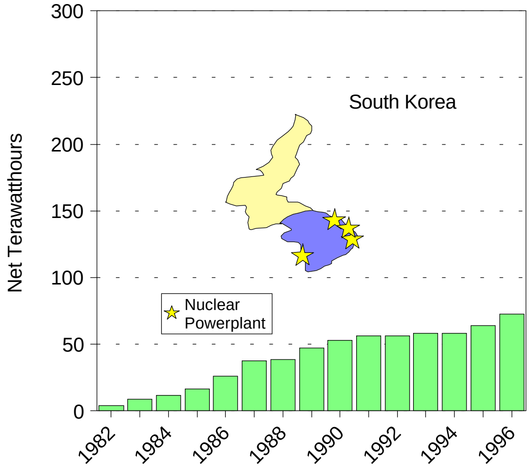
In April 1997, it was announced that a delegation of 54 officials from the United States, Japan, and South Korea will visit North Korea to examine the site and to negotiate matters related to communications, transport, and labor.[38] They will join a 29-member international technical team that has been conducting a geological survey of the site.

Concerns: The gap between the stagnant economy of North Korea and that of the highly industrialized South, is expected to widen in the next century. Even if KEDO supplies both nuclear reactors on schedule, neither unit will be functional until the next century.

Republic of Korea (South Korea)

The economy of the Republic of Korea is booming. To provide the fuel necessary to maintain that economic boom into the next century, the government has shown strong and unflinching support for the nuclear industry. This support has enabled the nuclear industry to increase generation from 0.4 net TWh in 1982 to 70.3 net TWh in 1996 (Figure 16). There are ambitious expansion plans.

Figure 16. Nuclear Generation in South Korea, 1982-1996



South Korea features an electrical supply system dominated by a single state monopoly, Korea Electric Power Company (KEPCO), although Korea has partially privatized the company. South Korea has become virtually self-sufficient in the nuclear construction area, developing its own 1,000 MWe-class Korean Standard Reactor (based on an ABB-CE design), built by the local firm, Hanjun.

Current Status: South Korea ranks 10th in commercial nuclear capacity. In Asia, it ranks second only to Japan. Because South Korea has very limited natural resources, nuclear power was contemplated as a potential resource for electrical power as early at the 1960's.

Nuclear Generating Units–1996

Operable Units	11
Capacity (net)	9,120 MWe
In Construction	7
Capacity (net)	5,770 MWe
Planned, Deferred	2
Capacity (net)	1,900 MWe

Today, 11 nuclear units are in commercial operation. They total 9.1 GWe and account for over one third of the country's total electricity. Seven units are under construction, totaling 5.8 GWe and there is one planned unit. Currently, South Korea intends to add another eight units and have them in operation by 2010. With increasing demand for public participation in key government decisions, however, site selection is likely to become more difficult.

Nuclear Share: Slightly more than a third of South Korea's electricity is supplied by nuclear powerplants.

International Focus: Western technologies have influenced Korea's nuclear industry, since the beginning. The "beginning" was 1969, when Korea ordered a light water pressurized reactor from Westinghouse. Kori 1 was installed at the 442-acre Kori Nuclear Power Plant, northeast of Pusan.[39] By 1987, it was joined by Kori 2, 3, and 4—all supplied by Westinghouse. Also, a Canadian-built unit and 2 more U.S.-built reactors were on-line. The next units to go in operation were provided by a French company.

South Korean industry is influenced by the West, but it is not dependent on the West. By the time Yonggwang 3 (the first Korean-built nuclear generating unit) started up in 1994, Korean manufacturers and designers had more than a decade of experience with various western technologies.

On June 14, 1996, the U.S. Department of Energy and the Korean Ministry of Science and Technology formalized two pacts, expanding U.S./Korean cooperation in nuclear energy and fusion research.[40] One agreement provides for cooperation between five Departmental laboratories and Korea's Energy Research Institute's providing $540,000 to the Princeton Plasma Physics Laboratory for construction of a fusion research facility in Korea.

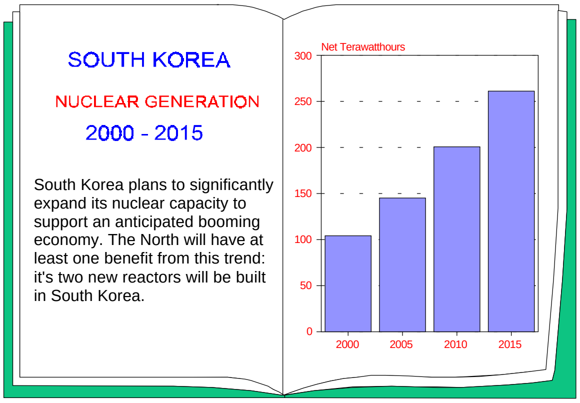
Concerns: With the economic boom in South Korea, annual electricity consumption has increased 15 percent per annum over the last several years.[41] To help supply future demand, South Korea plans to triple its nuclear capacity within a decade. Even if all goes according to plan, this is an expensive undertaking. According to a 1993 estimate, the expansion plan will cost $36 billion.[42]

A more immediate problem than finding the $36 billion, however, is finding a nuclear waste site. The government held firm in the face of stern opposition when it selected the island of Kurrupdo for a waste disposal site. However, when faults were discovered in the seabed near the island, the search for an alternative site began.[43]

The Future: One third of the country's future generating capacity is expected to come from nuclear plants. By the year 2015, South Korea's nuclear capacity is expected to double or possibly triple: from 9.1 gigawatts currently, to between 18.5 and 25 gigawatts.[44] Generation will increase to 104 net TWh in 2000, then to 261 net TWh by 2015, according to EIA projections (Figure 17).

Whether Korea's nuclear market follows a high growth- or a moderate growth-path, the Energy Information Administration projects that South Korea will have only about half as much capacity in 2015 as the current nuclear leader of Asia, Japan.

Figure 17. Nuclear Generation in South Korea, Reference Case, 2000-2015

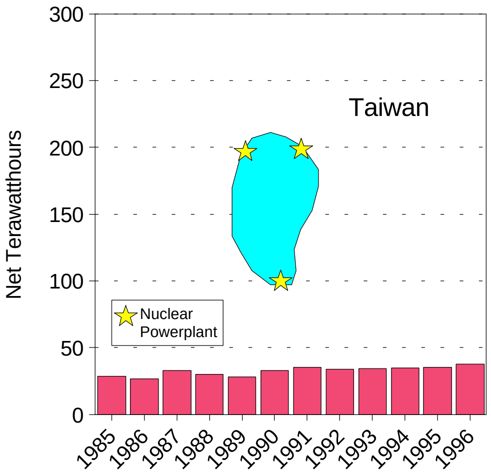


South Korea plans to significantly expand its nuclear capacity to support an anticipated booming economy. The North will have at least one benefit from this trend: it's two new reactors will be built in South Korea.

Taiwan

Since Taiwan is an island and therefore vulnerable to naval blockade, the Taiwanese government has emphasized commercial nuclear power for reasons of national security. Taiwan's nuclear program is relatively small when compared with Asia's two leading commercial nuclear producers, Japan and South Korea. It is, however, a thriving program supported by a government that is committed to nuclear power and an economy that is committed to expansion. Its commitment to nuclear power is reflected in the increased generation from 28.7 net TWh in 1985 to 36.3 net TWh in 1996 (Figure 18).

Figure 18. Nuclear Generation in Taiwan, 1985-1996



Current Status: Taiwan ranks 12th internationally in nuclear capacity, and 3rd in Asia.

Nuclear Share: Almost one-third of Taiwan's electricity is supplied by nuclear powerplants. Taipower determined as early as 1980 that a fourth nuclear station was desirable, and hoped to develop its Lungmen site for that purpose. Due to strong opposition from local residents and nuclear activists, site preparation had to be halted in 1985. This helped delay the two units planned for Lungmen to early next century. A decade of political and financial wrangling ensued during which the project went through a number of transformations. In 1996, General Electric won the bid to build the Lungmen Plant. The plant will be virtually identical to the 1,315-net MWe advance boiling-water reactor (ABWR) Kashiwazaki Kariwa 6 and 7 plant in Japan, which were built by the consortium of General Electric, Hitachi, and Toshiba. Lungmen 1 is scheduled to enter commercial operation in 2003 and unit 2 in 2004.[45]

Nuclear Generating Units–1996

Operable Units	6
Capacity (net)	4,884 MW
In Construction	2
Capacity (net)	2,500 MW
Planned, Deferred	0

International Focus: All six of Taiwan's reactors were supplied by foreign firms. General Electric Company built the reactors for Chinsan 1 and 2 and Kuosheng 1 and 2. Westinghouse provided the reactors for Maanshan 1 and 2. Two General Electric reactors are scheduled to come on line early in the next century (Lungmen 1 and 2).

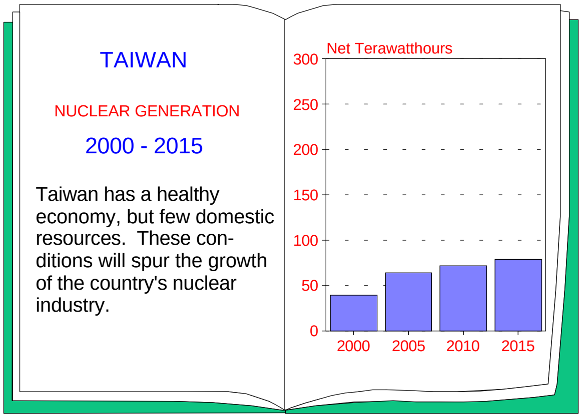
The island nation is dependent on imported uranium. To ensure adequate supplies of uranium, Taiwan signed an agreement with the United States and Canada on March 5, 1994.

Concerns: Plans by Taipower, the State-owned utility, to dispose of low level radioactive waste (LLW) in North Korea have drawn international concern. Under the plan, Taiwan will ship 60,000 barrels in the near future (with possibly as much as 140,000 barrels shipped later).[46] The plan has raised concerns in Korea—not in the People's Republic of Korea, which badly needs the estimated $218 million in fees—but in South Korea which is uncertain about the North's ability to properly handle the stored waste. The issue has also drawn the attention of the United Nations which has similar concerns.

In July 1985, a fire at a nuclear facility near Manshan aroused public concern about nuclear safety. To restore public confidence, the Ministry of Economic Affairs hired a body of international nuclear experts to study management at Taiwan's powerplants.[47] They noted that it is already comparable to other countries and it is improving. Nevertheless, attitudes toward nuclear power—both pro and con—remain strong. In the same year that the study was completed, a police officer and two demonstrators were killed in an anti-nuclear rally.[48] The government, however, appears to remain committed to the nuclear option.

The Future: Taiwan's nuclear expansion plans are limited to the two nuclear units under construction. After their completion the current 4.9 net GWe of nuclear capacity is projected to increase by 66 percent to about 7.4 net GWe. Generation is expected to rise to 39.2 net TWh in 2000 then double to 78.4 net TWh in 2015 (Figure 19).

Figure 19. Nuclear Generation in Taiwan, Reference Case, 2000-2015



Taiwan has a healthy economy, but few domestic resources. These conditions will spur the growth of the country's nuclear industry.

Nuclear Fuel Cycle: Recent Developments; Supply and Demand Projections

The nuclear fuel cycle comprises the steps necessary to prepare uranium ore for use in nuclear power reactors and to manage the spent fuel discharged from reactors. Appendix A contains an overview of these steps and a brief account of historical events that lead to the first self-sustaining nuclear reactor experiment.

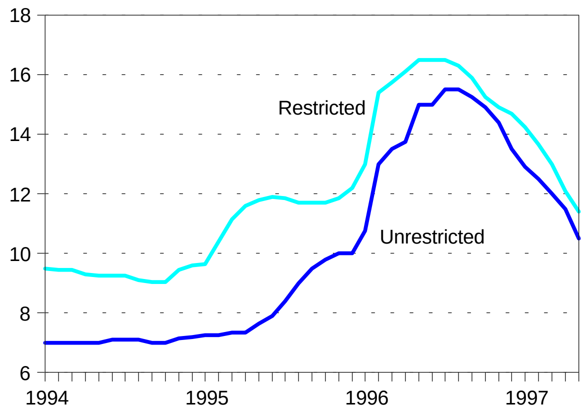
The PC version of the International Nuclear Model and the Uranium Market Model were used to develop the fuel cycle projections in this chapter for the reference case only. Models are simplified representations of real-life activities and therefore can only *estimate* future events. EIA has developed the reference case scenario as a “most-likely” case.

Fuel Cycle Developments

U.S. Uranium Market

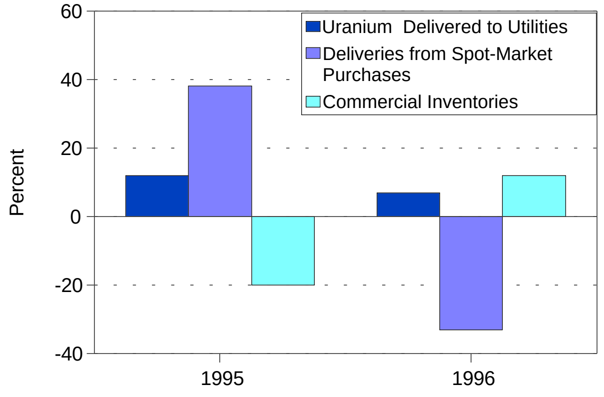
The average unrestricted spot-market price rose to $14.17 per pound U_3O_8 in 1996, an increase of 68 percent from the $8.45 per pound U_3O_8 reported in 1995.[49] For the restricted U.S. uranium market (restrictions apply to U.S. imports of uranium from the republics of the former Soviet Union), the average spot-market price in 1996 was $15.57 per pound U_3O_8, an increase of 36 percent from $11.46 per pound U_3O_8 in 1995.[50] However, the average annual price does not reflect a downward trend in the spot-market price that began in the second half of 1996. After reaching $16.50 per pound U_3O_8 in May 1996, the restricted price retreated to $14.70 per pound U_3O_8 by the end of the year (Figure 20). The downward trend continued during 1997. The restricted price was $11.40 per pound U_3O_8 at the end of May. The unrestricted spot-market similarly declined, reaching $10.50 per pound U_3O_8 at the end of May 1997. Thus, the substantial gains in the uranium spot-market price realized during 1995 and the first half of 1996 have been eliminated.

Figure 20. Restricted and Unrestricted Uranium Spot-Market Prices, January 1994–May 1997
(U.S. Dollars per Pound U_3O_8)



The movement in price over the last several years correlates to the extent to which utilities and other buyers have purchased uranium on the spot market. In 1995, a trading company defaulted on its contractual obligations to deliver uranium. The buyers affected by the default were forced to purchase uranium on the spot market to cover their needs. In addition, uncertainties about the availability of supplies from the former Soviet Union, including uranium derived from the dismantling of nuclear weapons, contributed to a perception that supply might be diminished.[51] As a result, the volume of spot-market transactions rose sharply in 1995. Spot-market purchases contributed 13.6 million pounds of U_3O_8 equivalent delivered to U.S. utilities and suppliers in 1995, compared with 8.5 million pounds delivered in 1994.[52] [53] On a percentage basis, 31 percent of uranium delivered in 1995 was purchased on the spot-market, compared with 22 percent delivered in 1994 (Figure 21). This increased level of transactions served to drive up spot-market prices.

Figure 21. Percent Change from Previous Year in Uranium Delivered to U.S. Utilities, Deliveries to U.S. Utilities from Spot-Market Purchases, and U.S. Commercial Inventories, 1995 and 1996



Spot-market prices continued to rise through the first half of 1996. In response to the rising price, however, buyers began to rely less on spot-market purchases, instead using long-term contracts to lock in more favorable prices. This was achieved by either exercising options on existing contracts to receive additional quantities of uranium, or by signing new long-term contracts. As a result, only 19 percent of the uranium delivered to U.S. utilities and suppliers in 1996 was purchased on the spot market (Table 4).[54] Nevertheless, the total quantity of uranium delivered to U.S. utilities and suppliers in 1996 was greater than that delivered in either 1994 or 1995.[55] This uranium contributed to a 12-percent increase in U.S. commercial inventories at the end of 1996, compared with year-end 1995[56]—the first annual increase since 1983.[57]

Meanwhile, an agreement was reached in November 1996 that eliminated much of the uncertainty over future availability of Russian low-enriched uranium (LEU). The Russian LEU is derived from blending down highly enriched uranium (HEU) taken from dismantled weapons

Table 4. U.S. Uranium Market Data, 1994-1996

	1994	1995	1996
Total Uranium Delivered to Utilities (million pounds U_3O_8)	38.3	43.4	47.3
Spot-Market Purchases Delivered to Utilities (million pounds U_3O_8)	8.5	13.6	9.1
Commercial Inventories (million pounds U_3O_8)	86.9	72.5	81.2
U.S. Uranium Production (million pounds U_3O_8)	3.4	6.0	6.3

(see below). Thus, the combination of adequate supply in the near-term and a reduction of uncertainty over future availability resulted in a significant decline in transactions on the spot market. The volume of spot market transactions worldwide during the first quarter 1997 was only 32 percent of that during the first quarter 1996.[58] Correspondingly, the spot-market price was dramatically reduced.

While less uranium is purchased on the spot market than through term contracts, the price of all purchases is affected by the level of the spot-market price. The rise in the uranium spot-market price during 1995 and 1996 to the highest nominal dollar levels since 1988 supported increased uranium production, and encouraged producers to announce plans for expanding existing capacity or starting up new mines.[59] For example, uranium production, in the United States rose 5 percent to 6.3 million pounds in 1996 compared with 6.0 million pounds in 1995. Furthermore, the quantity of uranium produced in the United States during 1996 was nearly double that produced in 1994. However, the recent sharp reversal in the spot-market price could cause some producers to defer those projects that have relatively higher production costs.

Privatization of the United States Enrichment Corporation

The United States Enrichment Corporation (USEC) was created by the *Energy Policy Act of 1992* (EPACT) as an initial step in transferring to the private sector the uranium enrichment activities formerly held by the U.S. Department of Energy (DOE). As a wholly owned Government corporation, all of USEC's stock issued and outstanding is held by the U.S. Treasury. Similarly, all net revenues not required for operating expenses, investments, or working capital are required to be paid as dividends to the U.S. Treasury. However, USEC's enabling legislation intended that it be operated as a market-oriented business, without many of the constraints faced by Government agencies, while preparing for privatization.

Pursuant to EPACT, USEC's Board of Directors submitted its privatization plan to Congress and President Clinton in June 1995. The privatization plan recommends a "dual-path approach," whereby a negotiated sale to private investors is pursued simultaneously with an initial public offering of common stock. However, privatization will depend on meeting several criteria including the maintenance of a reliable domestic supply of enrichment service and securing the maximum financial return to the U.S. Government. The *United States Enrichment Corporation Privatization Act*, signed in April 1996, provides for certain restrictions on privatization, such as no one person may own more than 10 percent of the corporation within 3 years of privatization. USEC's board of directors are authorized to select the final terms of the sale as well as the purchaser. On July 25, 1997, President Clinton approved the initiation of privatization. However, the Secretary of Treasury is required to approve the terms of the sale.

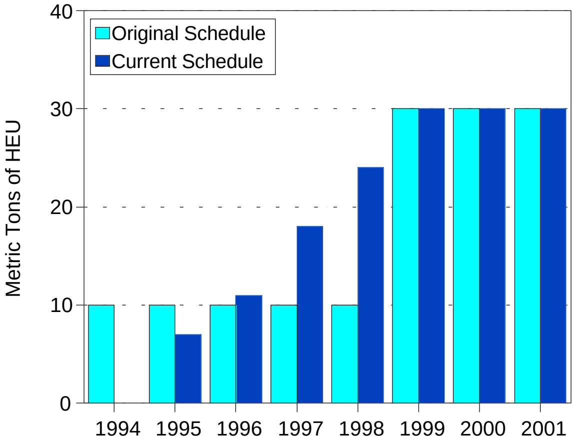
Surplus Defense Material

In 1996, more definitive plans and schedules for disposing of Russian Government surplus HEU and U.S. Government surplus HEU, natural uranium, and LEU were announced. Under current schedules, around 470 million pounds of U_3O_8 and 100 million separative work units (SWU) of enrichment are expected to be displaced by the commercialization of U.S. and Russian Government surplus inventories over the next 15 to 20 years. Over 30 million pounds U_3O_8 and 6 million SWU from these sources could enter the market annually within the next 5 years. The blending down of 500 metric tons of Russian surplus HEU will contribute the largest share; it is equivalent to about 398 million pounds U_3O_8 and 92 million SWU.[60] The USEC Privatization Act established a quota for the sale to the United States end users of uranium derived from Russian HEU: from 2 million pounds U_3O_8 in 1998, to 13 million pounds in 2004, reaching 20 million pounds by 2009. The HEU-derived material represents 4 percent of U.S. reactor requirements (Appendix F, Table F1) in 1998, increasing to 33 percent by 2004, and reaching more than 50 percent in 2009.

As U.S. Executive Agent, the United States Enrichment Corporation(USEC) continued its purchases of LEU from the Russian Federation pursuant to *The Agreement between the Government of the United States and the Government of the Russian Federation Concerning the Disposition of Highly Enriched Uranium Extracted from Nuclear Weapons* (Russian HEU Agreement). However, the quantity of LEU purchased through December 31, 1996, was less than anticipated because the Russians blended down 18 metric tons of HEU, rather than the 30 metric tons that had been specified in the original Russian HEU Agreement. In November 1996, USEC and Techsnabexport, the Russian Executive Agent, amended the original Russian HEU Agreement to provide for prices and quantities over a 5-year period. Under the amended agreement, the Russians would blend down HEU to LEU under the following schedule: (1) 18 metric tons in 1997, (2) 24 metric tons in 1998, and (3) 30 metric tons in 1999 through 2001 (Figure 22). The 5-year contract eliminated considerable uncertainty regarding the availability of uranium from Russian HEU. Previously, USEC and TENEX had to negotiate the details of the contract every year. Adding to the uncertainty, the Russians had indicated that they might not meet the levels of output scheduled for the future.

Under the amended Russian HEU agreement, USEC will pay only for the enrichment content of the LEU. The USEC Privatization Act authorizes that the natural uranium feed component of LEU purchased under the Russian HEU Agreement and delivered after December 31, 1996, be returned to the Russian Executive. USEC accomplishes this by substituting the Russian LEU for the uranium that was delivered by the utilities for enrichment. Prior to January 1, 1997, however, USEC paid the Russian Executive Agent for the natural uranium component. This material, equivalent to approximately 14 million pounds of U_3O_8, was transferred by USEC without cost to the U.S. Department of Energy (DOE) in December 1996. DOE is authorized to sell this uranium by the following means: (1) to the Russian Executive Agent for use in matched sales to U.S. end-users, (2) any time for foreign end use, or (3) to U.S. end-users after 2001.[61] In December 1996, DOE reached an agreement to sell up to 7 million pounds of U_3O_8 to Global Nuclear Services and Supply for the purpose of filling contracts involving matched sales.[62]

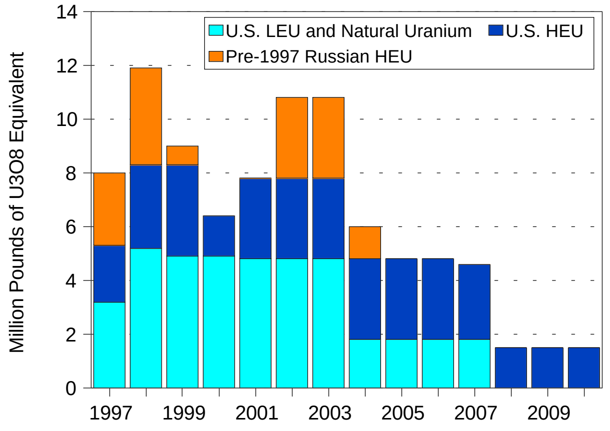
Figure 22. Comparison Between the Original and Current Schedules for Blending Down Highly Enriched Uranium (HEU) from Dismantled Russian Nuclear Weapons (Pursuant to the Russian HEU Agreement), 1994-2001



In July 1996, DOE announced its intention to sell up to 20.3 million pounds U_3O_8 equivalent of natural uranium and 1.2 million pounds U_3O_8 equivalent of LEU (Figure 23).[63] The LEU is also equivalent to about 280,000 SWU. The USEC Privatization Act directed that the Secretary of Energy "determines that the sale of the material will not have an adverse material impact on the domestic uranium mining, conversion, or enrichment industry." On March 12, 1997, the Secretary of Energy issued a determination that the intended sale of 3.2 million pounds of U_3O_8 equivalent during Fiscal Year 1997 would not have an adverse impact on the domestic industry. [64] [65] However, no sales have been made.

In September 1996, DOE released its plan to dispose of approximately 174 metric tons of U.S. surplus HEU.[66] Some of the HEU declared as surplus is not suitable for commercial use without extensive purification; it will be stored for future conversion or disposed of as waste. Approximately 103 metric tons of HEU is considered for commercialization over the next 15 years. This is

Figure 23. Potential Commercial Availability of Uranium from Sales and Transfers by the U.S. Department of Energy, 1997-2010



equivalent to around 33 million pounds U_3O_8 or 8 million SWU.[67] Of this total, DOE had already completed the transfer of 13 metric tons of HEU without cost to USEC. As for the remaining quantity, DOE plans to transfer 50 metric tons of HEU without cost to USEC, and to sell approximately 40 metric tons of HEU to the Tennessee Valley Authority (TVA). The HEU earmarked for TVA does not conform to commercial specifications. It must be purified to remove isotopic impurities before it can be blended down to LEU for use in fuel for TVA's nuclear power plants. TVA would pay for the uranium and enrichment components, but DOE would pay for the purification and blending down the HEU to LEU. Included with the 50 metric tons of HEU, DOE will also transfer without cost to USEC up to 7,000 metric tons of natural uranium—equivalent to about 18 million pounds of U_3O_8.

U.S. High-Level Radioactive Waste Disposal Program

The Nuclear Waste Policy Act of 1982 and the Nuclear Waste Policy Amendments Act of 1987 specify a detailed approach for the disposal of high-level radioactive waste. The Department of Energy is vested with operational responsibility, while the NRC has regulatory responsibility for the transportation, storage, and geologic disposal of the waste. The disposal of high-level radioactive waste requires a determination of acceptable health and environmental impacts over thousands of years. Current plans call for the ultimate disposal of the waste in solid form in a licensed, deep geologic structure.

The Amendments Act redirected DOE to investigate only one potential high-level waste repository—Yucca Mountain in Nevada. As mandated by Congress, the DOE is conducting site characterization studies at Yucca Mountain to determine site suitability. The Revised Program Plan proposes that the DOE will: complete the viability assessment by 1998; publish the final environmental impact statement in 2000; recommend the repository site to the President in 2001, if the site is suitable; submit a license application for repository construction to the Nuclear Regulatory Commission in 2002; and begin emplacement of nuclear waste in a geologic repository in 2010, if the NRC grants the license to proceed with operations.

Excavation of the Exploratory Studies Facility (ESF) began in September 1994 using a custom-designed Tunnel Boring Machine (TBM). The excavation of the five-mile, horseshoe-shaped ESF tunnel at Yucca Mountain was completed on April 25, 1997. The completed ESF tunnel will now serve as an underground laboratory for scientists and engineers to gather data needed to determine if Yucca Mountain will be a suitable site for the geologic disposal of high-level nuclear waste and spent nuclear fuel.

At intervals along the ESF's main tunnel, there are seven alcoves to provide scientists direct access to observe and test Yucca Mountain's geologic features. Some of the tests underway in the ESF involve (1) geomechanical measurement of the rock's response to pressure, (2) radial boreholes to measure water and vapor movement through the rock, and (3) thermal testing to measure the effect of heat on rock-water interactions. These tests will allow scientists to determine how radioactive particles might move through the rock and to explore how rock in the repository system will react in the presence of heat generated by the decay of radioactive materials in waste packages.

All near-term scientific activities at Yucca Mountain are focused on addressing the major unresolved technical questions associated with the overall performance of the repository. This will enable the DOE, by 1998, to make an informed assessment of the viability of licensing and constructing a deep geologic repository at the Yucca Mountain site.[68]

One of the near-term activities includes the development of a market-driven approach that relies on the private sector for waste acceptance, storage, and transportation services; and the conducting of design, engineering, and safety analyses for a non-site specific, phased, interim storage facility. The market-driven approach will allow for the maximum use of private industry capabilities, expertise, and experience in accepting, transporting, and storing commercial spent nuclear fuel. This is needed to expedite the start of interim storage operations when a site is designated and the facility authorized. At the same time, the DOE is involved in pre-licensing discussions for a non-site specific, phased interim storage facility contingency.[69]

U.S. Utility at-Reactor Dry Storage

All of the operating nuclear power reactors are storing used fuel under NRC licenses in spent fuel pools. The nuclear utilities are utilizing a combination of three options for storing their spent fuel: (1) in-pool storage, (2) dry storage in an Independent Spent Fuel Storage Installation (ISFSI), and (3) off-site storage. When a reactor is operating, spent fuel is discharged directly into the spent fuel pool, where it typically remains until the available pool capacity is fully utilized. After efforts to expand in-pool storage, such as reracking, have been exhausted, most utilities have turned to dry cask storage in an ISFSI to expand their on-site spent fuel storage capacity. In 1990, the NRC amended its regulations to authorize licensees to store spent fuel at reactor sites in approved storage casks. Seven cask designs have received certificates of compliance following this rule change. A few utilities have shipped fuel off-site, but the availability of off-site storage locations is limited.

As of the end of 1995, 15 nuclear utilities have ISFSI's either in operation or under construction. The percentages of On-Site Pool Storage Capacity remaining as of December 1995, and the Status of the ISFSI's are presented in Table 5.

Supply and Demand Projections

Uranium

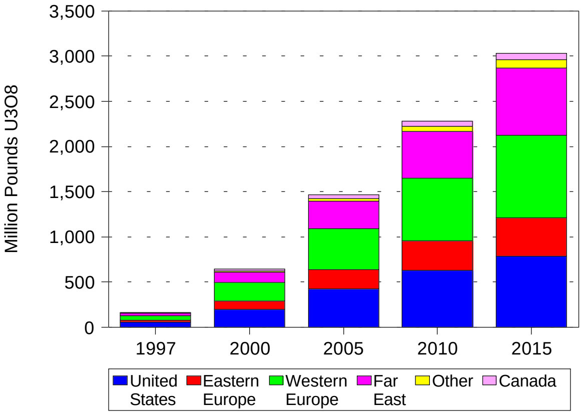
For the reference case, nuclear power plants worldwide are projected to require 3.0 billion pounds U_3O_8 from 1997 through 2015 (Figure 24). The projected annual requirements range from 140 million to 167 million pounds U_3O_8 over the same period (Appendix F, Table F1). However, 2015 requirements are 140 million pounds U_3O_8, the lowest level in the entire forecast period and 15 percent less than the level projected for 1997.

Western Europe is projected to require 914 million pounds U_3O_8 from 1997 through 2015; followed by the United States with 785 million pounds, the Far East with 741 million pounds, and Eastern Europe with 427 million pounds. Projected requirements for the rest of the world are 167.5 million pounds U_3O_8 over the same period (Appendix F, Table F2). The relative share of cumulative requirements for the 3 major consumption regions from 1997 through 2015 is as follows: Western Europe, 30

Table 5. Percent of On-Site Pool Storage Capacity and Status of Independent Spent Fuel Storage Installations as of December 31, 1995

Reactor	Percent Capacity Remaining	Status of ISFSI
Fort St. Vain	Shut down	Operational
Rancho Seco	Shut down	Planned
Trojan	Shut down	Planned
Humboldt Bay	Shut down	
Yankee Rowe	Shut down	Planned
Big Rock Point	Shut down	
Prairie Island	8	Operational
Point Beach	10	Operational
Palisades	16	Operational
Maine Yankee	16	
Surry	20	Operational
Calvert Cliffs	22	Operational
Arkansas Nuclear	22	Operational
Vermont Yankee	22	
Oyster Creek	23	Planned
Ginna	25	
Kewaunee	25	
Haddam Neck	26	
Oconee	27	Operational
North Anna	27	Planned
Davis-Besse	29	Operational
James Fitzpatrick	29	Planned
Hatch	29	
Millstone	32	
Dresden	32	Planned
Peach Bottom	35	
Susquehanna	37	Planned
Zion	37	
Pilgrim	39	
Quad Cities	41	
McGuire	41	
Duane Arnold	41	
Fort Calhoun	42	
H.B. Robinson	47	Operational

Figure 24. Projected Cumulative Uranium Requirements for World Nuclear Power Plants, Reference Case, 1997-2015



percent; United States, 26 percent; and the Far East, 24 percent. However, the Far East is projected to increase its share in later years, relative to Western Europe and the United States. The relative shares of the projected uranium requirements for the 3 major consumption regions from 2010 through 2015 are as follows: Far East, 30 percent; Western, Europe, 29 percent; and the United States, 21 percent. This shift in the relative share of requirements by region reflects the growth in nuclear power generation projected for the Far East, as described in the first chapter. In contrast, no new reactors are planned to replace the reactors expected to be retired in the United States by 2015.

The EIA reference case does not incorporate the use of mixed oxide (MOX) fuel. MOX fuel assemblies contain a mixture of plutonium and uranium dioxides. Burning MOX fuel reduces uranium requirements, enrichment service requirements and inventories of reactor grade plutonium. Their use in light-water reactors is well accepted in France, Germany, Switzerland and Belgium.[70] Japan has a few reactors burning MOX fuel and is planning a major MOX fuel program in the near future. There are no significant technical concerns hampering the use of MOX fuel. The projected savings in uranium requirements average around 8 percent per year when MOX fuel is utilized (Table 6). The savings of enrichment service requirements average around 9 percent per year (Table 7). These projections are made under the following

Table 6. Projected Uranium Requirements, With and Without MOX Fuel, Reference Case, 1997-2015
(Million Pounds U_3O_8 Equivalent)

Year	Western Europe		Far East		Total		
	Without MOX	With MOX	Without MOX	With MOX	Without MOX	With MOX	Percent Savings
1997	54.0	48.3	27.8	24.9	81.8	73.1	10.6
1998	51.7	46.4	28.5	26.7	80.2	73.1	8.9
1999	50.9	45.8	29.5	28.5	80.4	74.3	7.6
2000	49.8	44.9	31.7	29.3	81.5	74.3	8.9
2001	50.2	45.3	33.3	31.0	83.5	76.3	8.6
2002	48.8	44.2	37.3	35.6	86.1	79.8	7.4
2003	50.3	45.6	37.4	36.3	87.7	81.8	6.7
2004	48.8	44.1	38.8	37.4	87.6	81.5	6.9
2005	49.0	44.4	37.4	35.5	86.4	79.9	7.5
2006	47.6	43.0	39.7	38.3	87.3	81.3	6.8
2007	48.2	43.7	42.3	41.1	90.5	84.7	6.4
2008	48.4	43.8	41.2	39.6	89.6	83.5	6.8
2009	48.3	43.9	42.7	40.7	91.0	84.6	7.1
2010	48.4	43.8	43.6	41.9	92.0	85.7	6.9
2011	46.6	42.3	46.2	44.5	92.8	86.8	6.5
2012	45.6	41.2	47.5	45.9	93.1	87.1	6.4
2013	43.8	39.6	45.9	43.9	89.7	83.5	6.9
2014	42.6	38.4	46.3	44.6	88.9	83.0	6.7
2015	41.5	37.4	44.1	42.5	85.6	79.9	6.6

Table 7. Projected Annual Uranium Enrichment Requirements for Western Europe and the Far East, With and Without MOX Fuel, Reference Case, 1997-2015
(Million Separative Work Units)

Year	Western Europe		Far East		Total		
	Without MOX	With MOX	Without MOX	With MOX	Without MOX	With MOX	Percent Savings
1997	12.0	10.8	5.6	5.3	17.6	16.1	8.5
1998	11.7	10.5	6.1	5.8	17.8	16.3	8.6
1999	11.7	10.4	6.2	5.8	17.9	16.2	9.5
2000	11.7	10.4	6.4	5.9	18.1	16.3	9.8
2001	11.6	10.3	6.6	6.2	18.2	16.5	9.5
2002	11.4	10.2	7.2	6.9	18.6	17.2	7.7
2003	11.4	10.2	8.1	7.7	19.5	17.9	8.2
2004	11.6	10.4	8.6	8.2	20.2	18.6	8.1
2005	11.4	10.3	9.0	8.4	20.4	18.7	8.5
2006	11.6	10.4	9.1	8.8	20.7	19.2	7.2
2007	11.4	10.2	9.8	9.5	21.2	19.7	7.1
2008	11.6	10.4	9.7	9.3	21.3	19.7	7.5
2009	11.5	10.3	9.9	9.4	21.4	19.7	7.9
2010	11.1	10.0	9.7	9.2	20.8	19.2	7.9
2011	10.9	9.8	10.6	10.3	21.5	20.0	6.8
2012	10.7	9.6	10.7	10.2	21.4	19.8	7.3
2013	10.8	9.6	10.9	10.4	21.7	20.1	7.5
2014	10.2	9.2	10.9	10.3	21.1	19.5	7.6
2015	9.9	8.9	10.9	10.5	20.8	19.3	7.2

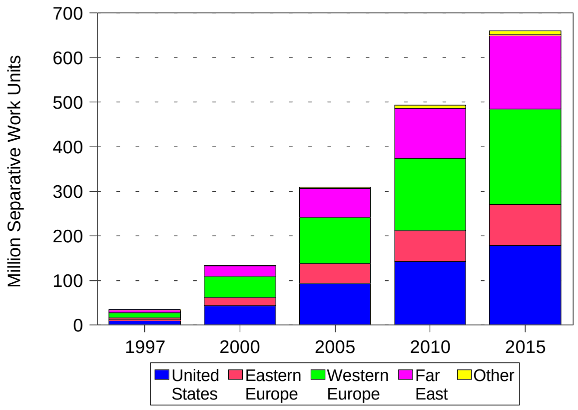
assumptions: (1) countries using MOX fuel will continue to do so and will gradually incorporate the use of MOX fuel into additional reactors; (2) there is sufficient reprocessing capability to satisfy MOX fuel demand over the projection period; and (3) the average cycle length is 12 months with ¼ core reloads with a 30 percent MOX composition in a depleted uranium matrix.

If deployed, the advanced vapor laser isotope separation (AVLIS) enrichment technology could also impact requirements for uranium and other nuclear fuel cycle activities. Although AVLIS has been scheduled by USEC for deployment in 2004, additional work will be required to ensure its commercial operation.[71] As such, an analysis of the effects of AVLIS deployment on the nuclear fuel market is beyond the scope of this report.

Enrichment Services

For the reference case, cumulative total worldwide enrichment service requirements from 1996 through 2015 are projected to be 661 million SWU (Figure 25). On an annual basis, worldwide requirements range from 32 million SWU to 37 million SWU over the same period (Appendix F, Table F3). EIA's analysis of the nuclear fuel

Figure 25. Projected Cumulative Uranium Enrichment Requirements for World Nuclear Power Plants, Reference Case, 1997-2015



market presented in this report does not consider the possible deployment of the AVLIS enrichment technology.

From 1997 through 2015, Western Europe is projected to require 214 million SWU, followed by the United States with 178 million SWU, the Far East with 166 million SWU, and Eastern Europe with 93 million SWU. Projected enrichment service requirements for the rest of the world are 10 million SWU over the same period (Appendix F, Table F4). It should be noted that while Canada requires natural uranium, the CANDU-type reactors operating in that country do not require enrichment services. The relative shares of cumulative requirements for the 3 major consumption regions from 1997 through 2015 are as follows: Western Europe, 32 percent; United States, 27 percent; and the Far East, 25 percent. The Far East is projected to increase its relative share of total projected enrichment services requirements in later years at the expense of Western Europe and the United States. From 2010 through 2015, the relative shares of projected enrichment services requirements for the 3 major consumption regions are as follows: Far East, 31 percent; Western Europe, 31 percent; and the United States, 22 percent.

Projected U.S. Uranium Spot-Market Prices

For the Reference case, the spot-market price for the U.S. uranium market is expected to show both downward and upward movements over the next few years as supply and demand come into balance (Table 8). In 1997, the spot-market price in constant 1996 dollars is expected to decline to \$11.20 per pound U_3O_8 from the previous year's price of \$15.60 per pound. In response to an expected increase in purchases by utilities, the spot-market price is projected to rise to \$12.40 per pound U_3O_8 in 1998. The current level of commercial inventories is projected to decline in the coming years to levels no longer considered as excess. Imports from the republics of the former Soviet Union, a major contributor to excess inventories, are also anticipated to decline. The decline in these supplies is projected to be offset by the addition of production capacity, principally in Canada and Australia, and the introduction of U.S. and Russian Government surplus inventories.

The introduction of uranium derived from both U.S. and Russian Government surplus inventories is expected to

Table 8. Projected U.S. Spot-Market Price, Net Imports, Commercial Inventories, and Production
(Prices in Constant 1996 Dollars per Pound U_3O_8; All Other Projections in Million Pounds U_3O_8 Equivalent)

Year	Spot-Market Price	Net Imports	Commercial Inventories	Production
1997	11.20	40.9	73.3	5.9
1998	12.40	30.4	65.9	6.6
1999	13.10	27.2	59.9	7.6
2000	13.40	26.6	54.9	7.8
2001	13.40	28.6	51.3	8.0
2002	14.40	27.4	48.6	8.0
2003	15.10	30.1	46.6	8.0
2004	15.50	27.7	44.9	8.1
2005	15.40	32.5	43.6	8.2
2006	15.40	29.9	42.6	8.3
2007	15.70	27.6	41.6	8.4
2008	15.50	31.4	40.8	8.5
2009	15.90	28.8	40.1	8.5
2010	15.80	31.2	39.6	8.5

stabilize early in the next decade. The penetration into the market by the natural uranium feed contained in LEU derived from Russian HEU is assumed to reach a maximum annual rate of 24.0 million pounds U_3O_8 equivalent in 2001. Under current plans, the sale of U.S. Government surplus inventories is expected to supply up to 9.5 million pounds U_3O_8 equivalent in 2001, decreasing to 1.5 million pounds U_3O_8 equivalent per year in 2008. Meanwhile, several low-cost uranium mines will be closed due to the depletion of their reserves. As a result, the spot-market price will need to rise further to stimulate increased uranium production to maintain an adequate supply. By 2003, the uranium spot-market price is projected to rise above $15.00 per pound U_3O_8. The spot-market price in constant 1996 dollars is projected to be around $16.00 per pound U_3O_8 in 2010.

Projected Uranium Supply to Meet U.S. Requirements

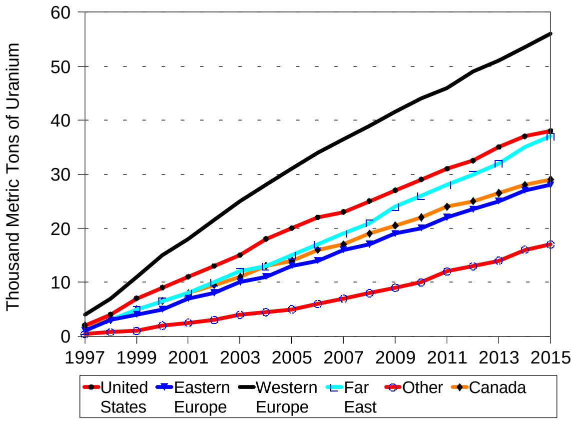
U.S. uranium production is projected to remain around 5.9 million pounds U_3O_8 in 1997, a 6-percent decline from the 6.3 million pounds U_3O_8 produced in the previous year. In response to a gradual increase in prices, U.S. uranium production is projected to increase to 8.5 million pounds in 2008 (Table 8). Lower-cost imports and uranium made available from U.S. and Russian HEU and other Government surplus inventories are expected to limit the growth in U.S. production.

Imports will continue to be the major source of supply for meeting U.S. uranium requirements (Table 8). Over the forecast period, net imports are projected to supply at least 58 percent of annual domestic requirements (Appendix F, Table F1). Government surplus inventories and the draw down of commercial inventories will also be utilized to meet requirements. The quantity projected for 1997 is equivalent to about 1.4 years of reactor requirements. The level of inventories with respect to requirements is projected to further decline to below 1 year during the forecast period. This trend of declining inventories is in response to utility efforts to reduce costs associated with holding excess inventory.

Spent Fuel

The disposal of spent fuel discharged from nuclear reactors is one of the barriers of nuclear energy development. The spent fuel inventory in the United States was 32 thousand metric tons of uranium as of December 1995.[72] EIA projects that in 1997, the reactors in the United States will discharge 2 thousand metric tons and the spent fuel discharged over the next 18 years will amount to 38 thousand metric tons of uranium (Figure 26 and Appendix F, Table F6). Worldwide, nuclear reactors are projected to generate 10 thousand metric tons in 1997. The spent fuel generated over the next 18 years is expected to total 206 thousand metric tons of uranium.

Figure 26. Projected Cumulative Discharges of Spent Fuel from World Nuclear Power Plants, Reference Case, 1997-2015



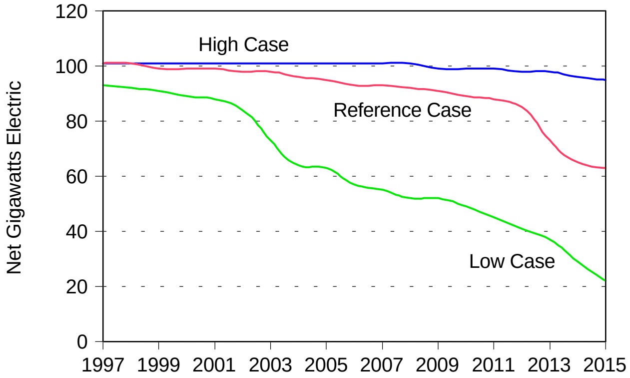
Comparisons

Comparisons

Several organizations associated with the nuclear industry publish annual reports that contain projections of nuclear capacity and fuel cycle requirements. The EIA reference case projections are compared to those for worldwide nuclear capacity, spent fuel discharges, uranium enrichment service requirements, and uranium requirements made by NAC International (NAC) and Energy Resources International, Inc. (ERI), for the period 1997 to 2015.

The EIA has developed three nuclear capacity scenarios for domestic reactors: the low case, the reference case, and the high case (Figure 27). The retirement dates for operating reactors are determined by the expiration date of their licenses that are granted by the U.S. Nuclear Regulatory Commission. The anticipated retirement dates are incorporated in each of the three scenarios. In the low case, on average, all units retire 10 years before the end of their operating license period. The reference case assumes that most nuclear units will operate to the end of their current operating license. In the high case, each unit is given 10 additional years of operation beyond the end of their current operating license.

Figure 27. U.S. Nuclear Capacity Projection Scenarios, 1997-2015



Three nuclear capacity scenarios were also developed for non-U.S. reactors. In the reference case, the reactors operate for about 30 years with new capacity being added as reactors under construction become operable. In some countries, EIA has projected growth beyond the capacity of the nuclear power plants under construction. The World Integrated Nuclear Evaluation System (WINES) was used to determine these capacity additions. The low and high case capacity projections are in Appendix F.

Comparison of Actual Data with EIA Projections

The projections for worldwide nuclear capacity, U.S. nuclear electricity generation, and U.S. cumulative spent fuel discharges from EIA reports from 1993 through 1996 are compared with actual data to show the historical accuracy of EIA's projections (Table 9). The EIA projections for U.S. cumulative spent fuel discharges are in agreement with the actual value for each comparison year. The EIA forecasts for worldwide nuclear capacity are within 5 percentage points of the actual value by year. For the EIA projections of U.S. nuclear electric generation, the projection for 1995 and 1996 show closer agreement (than do 1993 and 1994) with the actual value by year, because the data used for 1995 and 1996 to model improvements in reactor operating efficiencies were more accurate.

Domestic Projections: Comparison with the 1996 EIA Report

The domestic capacity projection for the reference case has all operating reactors retired as their licenses expire except for a few reactors that are projected to retire early. For 1996, this case projected no early retirements; therefore, the current reference case capacity projection is slightly lower than that made last year (Figure 28). Also, last year, the nuclear capacity projection held steady until 2006 before it dropped. The current projection begins its descent in 1999. After 1999, the domestic capacity projection continues to fall until it reaches 63 net gigawatts in 2015.

The projections of domestic uranium requirements for 1997 through 2015 are about 2 percent lower than those published for 1996. EIA is projecting U.S. uranium requirements to be 784 million pounds U_3O_8 for 1997 through 2015 (Figure 29).

EIA is projecting U.S. enrichment service requirements for 1997 through 2015 to be 178 million separative work units (SWU) (Figure 30). This is about 2 percent lower than the value projected last year, 181 million SWU.

The domestic spent fuel projection for 1997 through 2015 is 38 thousand metric tons of initial heavy metal (MTIHM) (Figure 31). The projection last year for that same period was 40 thousand MTIHM, about 4 percent higher.

Table 9. Comparison of Historical Data and EIA Forecasts

Year	Worldwide Nuclear Capacity (Net Gigawatts-Electric)				
	Year Forecast was Made				
	1993	1994	1995	1996	Actual
1993	326	--	--	--	338
1994	327	340	--	--	340
1995	331	343	341	--	344
1996	332	345	349	350	351

Year	U.S. Nuclear Electric Generation (Net Terawatthours)				
	Year Forecast was Made				
	1993	1994	1995	1996	Actual
1993	605	--	--	--	610
1994	610	611	--	--	640
1995	611	618	651	--	673
1996	620	616	651	683	675

Year	U.S. Cumulative Spent Fuel (Thousand Metric Tons Uranium)				
	Year Forecast was Made				
	1993	1994	1995	1996	Actual
1993	28	--	--	--	28
1994	30	30	--	--	30
1995	32	32	32	--	32
1996	34	34	34	34	NA

NA = Not available.
-- = Not applicable.

Foreign Projections: Comparison with the 1996 EIA Report

The foreign nuclear capacity projection grows from 254 net GWe in 1997 to 301 net GWe in 2010, it then falls to 297 net GWe in 2015 (Figure 32). In the 1996 report, the foreign nuclear capacity projection was 271 net GWe in 1997. It grew to 279 net GWe in 2010 before it fell to 270 net GWe in 2015. The capacity projection for South Korea, Japan, Russia, and India are more optimistic this year, thereby raising the capacity projections for foreign countries. The projection of foreign uranium requirements for 1997 through 2015 is 2,250 million pounds U_3O_8. Last year's projection was 2,100 million pounds U_3O_8, which is 7 percent lower. The foreign enrichment service requirement projection for 1997 through 2015 is 483 million SWU. The corresponding projection last year was 449 million SWU. The EIA's projection of spent fuel discharges from foreign reactors for 1997 through 2015 is 168 thousand MTIHM. The 1996 projection was 163 thousand MTIHM. The current projection is 3 percent higher.

Comparison of EIA Projections with Other Projections

All of the domestic nuclear capacity projections follow essentially similar trends except that ERI's reference case is slightly more optimistic than the others near the end of

Figure 28. U.S. Nuclear Capacity Projections, Reference Case, 1997-2015

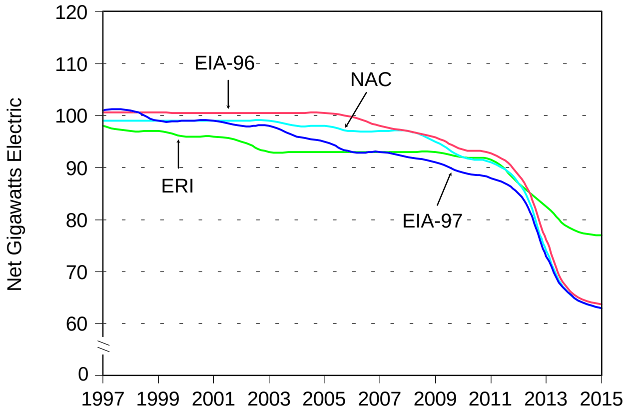


Figure 30. Projections of Total Enrichment Service Requirements, United States and Foreign, Reference Case, 1997-2015

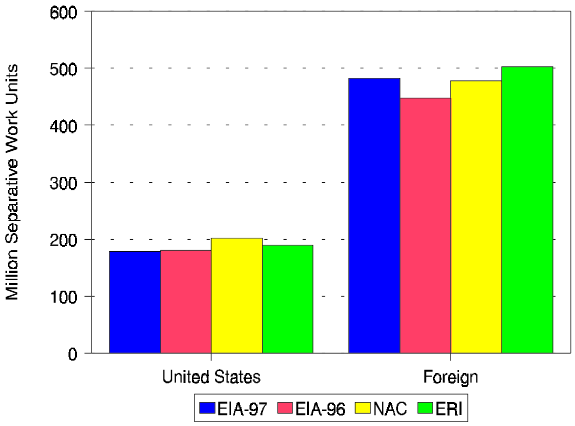


Figure 29. Projections of Total Uranium Requirements, United States and Foreign, Reference Case, 1997-2015

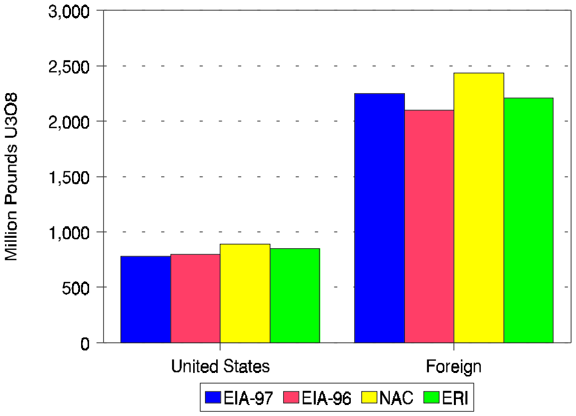
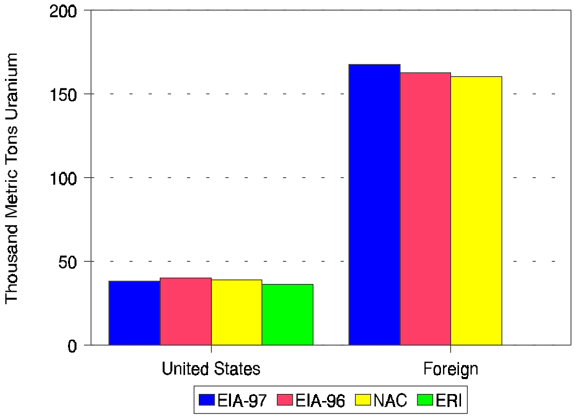


Figure 31. Projections of Total Spent Fuel Discharges, United States and Foreign, Reference Case, 1997-2015

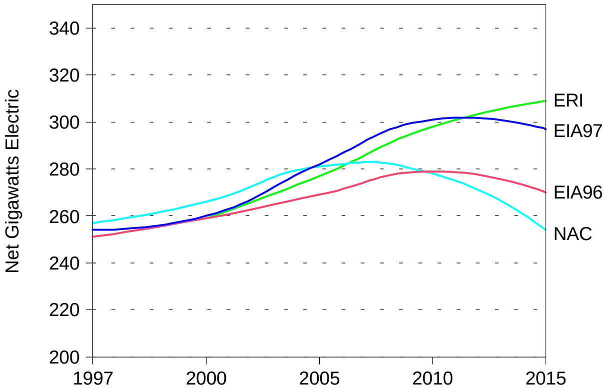


the projection period. The reference case foreign nuclear capacity projections are more divergent. They range, in 2015, from 254 net GWe for NAC to 309 net GWe for ERI. The nuclear capacity projections greatly influence the fuel cycle projections. When the capacity projections are high the fuel cycle projections will be high unless the associated capacity factors are significantly different.

EIA's foreign nuclear capacity projection is less than NAC's until 2005, then it becomes greater. After 2005, EIA projects more growth in the Far East, especially China. ERI's foreign capacity projection is slightly lower than EIA's until 2011, beyond which it remains higher until the end of the projection period. NAC and EIA project about the same nuclear capacity for the United States except between 2004 and 2012, when EIA's projection is about 4 GWe lower. ERI's domestic capacity projection is the lowest of the three until 2007, after which EIA's steadily falling projection becomes the lowest, reaching 63 net GWe by 2015.

The tails assay value influences the enrichment service requirements, but, for the most part, the various tails assay assumptions are similar. ERI's projection of total uranium requirements and enrichment service requirements for the United States for 1997 to 2015 is about 7 percent greater

Figure 32. Foreign Nuclear Capacity, Reference Case, 1997-2015



than EIA's. Even though ERI's U.S. nuclear capacity projection is lower than EIA's until 2012, their projection of uranium requirements and enrichment service requirements is higher. This is because ERI projects higher capacity factors for most countries. NAC's projection of domestic uranium and enrichment service requirements is 13 percent greater than EIA's. NAC projects that foreign uranium requirements for 1997 to 2015 will be 8 percent higher than in EIA's projections. Their projection of foreign enrichment service requirements is about the same as EIA's. ERI projects foreign uranium requirements to be 2,211 million pounds U_3O_8 for 1997 to 2015, which is 2 percent less than EIA's. ERI's foreign enrichment service requirement projection is 4 percent greater than EIA's projection of 483 million separative work units. NAC projects the domestic spent fuel discharges for 1997 to 2015 to be 39 thousand metric tons of uranium and projects the foreign spent fuel discharges to be 160 thousand metric tons of uranium. This is 3 percent more and 4 percent less, respectively, than EIA's projections. ERI projects domestic spent fuel discharges to be 6 percent less than EIA's value of 36 thousand metric tons of uranium.

Text Notes

1. 1996 U.S. capacity is preliminary.

2. Total generated electricity is the sum of utility-generated electricity and the forecasted 1996 gross nonutility generation data, which was obtained from the EIA Projection for the Short-term Energy Outlook Memorandum, July 1997. The nuclear share of utility-generated electricity for the United States was 21.9 percent.

3. Countries included in the "Other" region are: Argentina, Brazil, India, Iran, Mexico, Pakistan, South Africa, and Turkey.

4. International Atomic Energy Agency, *Nuclear Power Reactors in the World* (Vienna, Austria, April 1997), p. 9.

5. Capacity Factor is the ratio of electricity produced by a generating unit, for the period of time considered, to the energy that could have been produced at continuous full-power operation during the same period.

6. "Ukraine" *Nuclear News*, March 1997, p. 54.

7. Energy Information Administration, Form EIA-759, "Monthly Power Plant Report."

8. Energy Information Administration, *Annual Energy Outlook 1997*, DOE/EIA-0383(97) (Washington, DC, December 1997), p. 52.

9. Dave Airazo, "Oyster Creek May Close in 2000, Unless a Buyer Can be Found," *Nuclear News*, April 10, 1997, p. 1.

10. Chauncey Starr, "The Future of Nuclear Power," *Nuclear News*, March 1997, pp. 58-60.

11. "World Nuclear Generating Capacity 1995/96," *NUKEM*, November 1996, p. 24.

12. Ibid.

13. Ibid.

14. "World Nuclear Generating Capacity 1995/96," *NUKEM*, November 1996, p. 34.

15. *Nuclear News*, "First Nuclear Plant Closure Threatened by 1998," March 1997, p. 54.

16. Ibid.

17. Ibid.

18. International Atomic Energy Report, "International Assistance to Upgrade the Safety of Soviet-designed Nuclear Power Plants," December 1993, pp. 33-43.

19. "World Nuclear Generating Capacity 1995/96," *NUKEM*, November 1996, p. 30.

20. *Nucleonics Week*, "Romanian Government Change Puts Cernavoda-2 Completion on Hold," November 28, 1996, pp. 3-4.

21. Uranium Institute, News Briefing, 96.48.

22. Energy Information Administration, *International Energy Outlook 1997* (DOE/EIA-0484(97) (Washington, DC, April 1997), p. 121.

23. Gale Research, Inc., *Nuclear Power Plants Worldwide,* Peter D. Dresser, ed. (Washington, DC, 1993).

24. *News Brief*, Washington, DC, February 1997.

25. Energy Information Administration, *International Energy Outlook 1997* (DOE/EIA-0484(97) (Washington, DC, April 1997), p. 127.

26. Energy Information Administration, *International Energy Outlook 1997* (DOE/EIA-0484(97) (Washington, DC, April 1997), p. 105.

27. Energy Information Administration, *International Energy Outlook 1997* (DOE/EIA-0484(97) (Washington, DC, April 1997), p. 90.

28. Ray Silver, AECL, CNNC INK Contracts.

29. Energy Information Administration, *Quarterly Coal Report*, DOE/EIA-0121 (96/4Q) (Washington, DC, May 13, 1997), p. 20.

30. *NUEXCO Review, 1993 Annual*, p. 32.

31. *NUKEM*, February 1997, p. 21.

32. *Nucleonics Week,* February 25, 1997.

33. Uranium Institute, *Newsbrief*, NB97.16-6, April 1997.

34. "Nuclear Plant Fire in Japan Sets Back Energy Program," *Wall Street Journal* (March 13, 1997).

35. Energy Information Administration, *International Energy Outlook 1997* (DOE/EIA-0484(97) (Washington, DC, April 1997), p. 105.

36. "More Protocols Signed," *Nuclear News,* February 1997, p. 44.

37. Ibid.

38. "U.S., Japan, S. Korea to Open Nuke Talks in North," *Washington Times,* April 5, 1997.

39. Gale Research, Inc., *Nuclear Power Plants Worldwide,* Peter D. Dresser, ed. (Washington, DC, 1993), p. 193.

40. DOE News Release, "United States, Korea Expand Cooperation in Nuclear Energy and Fusion Energy Research," (Washington, DC, June 14, 1996).

41. Energy Information Administration, *International Energy Outlook 1997* (DOE/EIA-0484(97) (Washington, DC, April 1997), p. 105.

42. *NUEXCO Review, 1993 Annual,* p. 36.

43. "Island Site for LLW, Spent Fuel Repository, Dropped," *Nuclear News (*Denver, Colorado, December 1996), p. 44.

44. Energy Information Administration, *International Energy Outlook 1997,* (DOE/EIA-0484(97) (Washington, DC, April 1997), p. 78.

45. "Taiwan: The Little Dragon of the China Sea," *NUKEM, p. 14.*

46. "A Radioactive Hot Potato," *Business Week*, February 17, 1997, p. 52.

47. Gale Research, Inc., *Nuclear Power Plants Worldwide,* Peter D. Dresser, ed. (Washington, DC, 1993), p. 252.

48. Ibid.

49. Historical uranium spot-market prices used in this report are the Exchange Values reported in TradeTech, *The Nuclear Review* (Denver, CO).

50. A two-tier market developed at the end of 1992 as a result of the suspension agreements that restrict U.S. imports from the republics of the former Soviet Union.

51. Energy Information Administration, *Nuclear Power Generation and Fuel Cycle Report 1996*, DOE/EIA-0436(96) (Washington, DC, October 1996), pp. 18, 20-21.

52. Energy Information Administration, *Uranium Industry Annual 1995*, DOE/EIA-0478(95) (Washington, DC, May 1996), Table 16.

53. Energy Information Administration, *Uranium Industry Annual 1994*, DOE/EIA-0478(94) (Washington, DC, July 1995), Table 33.

54. Energy Information Administration, *Uranium Industry Annual 1996*, DOE/EIA-0478(96) (Washington, DC, April 1997), Table 16.

55. Ibid.

56. Ibid., Table 31.

57. Energy Information Administration, *World Nuclear Outlook 1995*, DOE/EIA-0436(95) (Washington, DC, October 1995), p. 27.

58. "First quarter spot U_3O_8 review," *The U_x Weekly*, April 21, 1997, p. 1.

59. Energy Information Administration, *Nuclear Power Generation and Fuel Cycle Report 1996*, DOE/EIA-0436(96) (Washington, DC, October 1996), pp. 19-20.

60. Assumes a HEU feedstock having an enrichment level of 90 percent U-235 and a blendstock with an enrichment level of 1.5 percent U-235.

61. The *Amendment to the Suspension Agreement with the Russian Federation* permits U.S. imports of Russian-origin natural or enriched uranium as long as the quantities specified in the agreement are "matched" with newly produced U.S.-origin natural or enriched uranium.

62. R.M. George, "Status Report on DOE's Surplus Uranium Sales Program," speech presented at the Nuclear Energy Institute's *Nuclear Fuel Supply Forum* (Washington, DC, January 28, 1997).

63. U.S. Department of Energy, "Notice of Intent to prepare an Environmental Assessment on the Proposed Sale of Surplus Natural and Low Enriched Uranium," in *Federal Register*, Vol. 61 (July 9, 1996).

64. U.S. Department of Energy, *Determination Pursuant to the United States Enrichment Corporation Privatization Act for the Sale of Excess Department of Energy Uranium During Fiscal Year 1997* (Washington, DC, March 12, 1997).

65. Fiscal Year 1997: October 1, 1996 through September 30, 1997.

66. U.S. Department of Energy, *Highly Enriched Uranium Disposition Uranium Plan* (Washington, DC, September 1996).

67. U.S. HEU enrichment assays range from 40 percent to 70 percent U-235.

68. DOE Press Release, YNP 97-07, April 25, 1997.

69. Internet, http:\www.rw.doe.gov, 5/13/97.

70. The Recycling of Fissile Nuclear Materials", The Uranium Institute (London, England, November 1996). The Uranium Institute, *The Recycling of Fissile Nuclear Materials* (London, United Kingdom, November 1996).

71. United States Enrichment Corporation, *1996 Annual Report*, p. 7.

72. Energy Information Administration, *Nuclear Power Generation and Fuel Cycle Report 1996*, DOE/EIA-0436(96) (Washington, DC, October 1996), p. 113.

73. A "free neutron" is one that has been released from an atomic nucleus. Atomic nuclei consist of combinations of two types of subatomic particles, protons and neutrons, of about equal mass. The number of electrically charged protons in a nucleus determines which element it is—that is, its chemical properties. The number of protons plus the number of electrically neutral neutrons determines the weight or "atomic mass" of the nucleus.

74. The U.S. reference case projection is discussed in Chapter 1, "1996 Nuclear Capacity Status and Projections," under the North America section.

75. Energy Information Administration, Form RW-859, "Nuclear Fuel Data " (1995).

76. Conversation with Mr. Ray Schmidt, Engineer at General Electric Corp.

77. Z. Incorporated, *International Nuclear Model, Personal Computer (PCINM)* (Silver Spring, MD, 1992).

78. Loans of uranium among the various suppliers and users are not modeled as such. Borrowing and lending activities do not alter the total inventories of uranium, but they do delay the purchase of newly produced uranium. This effect can be modeled by assuming that the inventories of uranium that are not held by utilities or producers remain constant at their current level.

79. In projecting production in the United States and other regions, the modeling system considers only those contract commitments that are tied to specific production centers at firm prices. For this reason, the model in some instances projects production at lower levels than contract commitments.

Figure Notes

Figure 1. Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels.

Figure 2. International Atomic Energy Agency, *Nuclear Power Reactor in the World 1996* (Vienna, Austria, April 1997); *Nuclear News*, "World List of Nuclear Power Plants" (March 1997), pp. 37-52; NAC International, *Nuclear Generation* (February 1997), Section F, pp. 1-43; Energy Information Administration, Form EIA-860, "Annual Electric Generator Report."

Figure 3. International Atomic Agency, *Nuclear Power Reactors in the World* (Vienna, Austria, April 1997); Energy Information Administration, *International Energy Annual 1995*, DOE/EIA-0219(95) (Washington, DC, December 1996).

Figure 4. *Nucleonics Week*, "TEPCO, Kansai, Virginia Power Top 1996 Capacity Factor List," (McGraw-Hill Co.), February 13, 1997, p. 8.

Figure 5. **Historical**–International Atomic Energy Agency, "Nuclear Power Reactors in the World" (Vienna, Austria, April 1997); **Projections**–The projections are based on detailed assessments of country-specific nuclear power plants. For some countries, the "World Intergrated Nuclear Evaluation System," (June 1997 run) was used to supplement the 2015 capacity projection.

Figure 6. **1980-1996**–International Atomic Energy Agency, *Nuclear Power Reactors in the World* (Vienna, Austria, April 1997); **2015**–Table 2.

Figure 7. Energy Information Administration, *International Energy Outlook 1997: with Projections to 2015*, DOE/EIA-0383(97) (Washington, DC, April 1997), Table A6, p. 121.

Figure 8. **1980-1996**–International Atomic Energy Agency, *Nuclear Power Reactors in the World* (Vienna, Austria, April 1997); **2015**–Table 2.

Figure 9. **1980-1996**–International Atomic Energy Agency, *Nuclear Power Reactors in the World* (Vienna, Austria, April 1997); **2015**–Table 2.

Figure 10. **1980-1996**–International Atomic Energy Agency, *Nuclear Power Reactors in the World* (Vienna, Austria, April 1997); **2015**–Table 2.

Figure 11. Energy Information Administration, Monthly Energy Review (Washington, DC, May 1997), Table 10.4d, p. 142.

Figure 12. Energy Information Administration, *International Energy Outlook 1997: with Projections to 2015* (Washington, DC, April, 1997), Table A6, p. 121.

Figure 13. Energy Information Administration, Monthly Energy Review (Washington, DC, May 1997), Table 10.4d, p. 142.

Figure 14. Energy Information Administration, *International Energy Outlook 1997: with Projections to 2015* (Washington, DC, April, 1997), Table A6, p. 121.

Figure 15. Energy Information Administration, Monthly Energy Review (Washington, DC, May 1997), Table 10.4d, p. 142.

Figure 16. Energy Information Administration, *International Energy Outlook 1997: with Projections to 2015* (Washington, DC, April, 1997), Table A6, p. 121.

Figure 17. Energy Information Administration, Monthly Energy Review (Washington, DC, May 1997), Table 10.4d, p. 142.

Figure 18. Energy Information Administration, *International Energy Outlook 1997: with Projections to 2015* (Washington, DC, April, 1997), Table A6, p. 121.

Figure 19. Prices are in nominal dollars. TradeTech, *The Nuclear Review* (February 1997).

Figure 20. Energy Information Administration, Form EIA-858, "Uranium Industry Annual Survey" (1994-1996).

Figure 21. Explanation: Original schedule-Russian HEU Agreement signed between the United States Enrichment Corporation (USEC) and Techsnabexport (TENEX) in January 1994. Current schedule-actual HEU blended down during 1995 and 1996, and the amendment to the Russian HEU Agreement signed between USEC and TENEX in November 1996. United States Enrichment Corporation, *1996 Annual Report*.

Figure 22. Explanation: Availability based on current schedules. U.S. Department of Energy disposition plans; United States Enrichment Corporation, *1996 Annual Report*.

Figure 23. Energy Information Administration, International Nuclear Model, file INM.WK4, 1997.

Figure 24. Energy Information Administration, International Nuclear Model, file INM.WK4, 1997.

Figure 25. Energy Information Administration, International Nuclear Model, file INM.WK4, 1997.

Figure 26. Energy Information Administration, International Nuclear Model, file INM.WK4, 1997.

Figure 27. Energy Information Administration (EIA), International Nuclear Model, File INM.wk4; EIA, *Nuclear Power Generation and Fuel Cycle Report 1996*, DOE/EIA-0436(96) (Washington, DC, October 1996); Energy Resources International, Inc. (ERI), *1997 Nuclear Fuel Cycle Supply and Price Report* (Washington, DC, May 1997), p. 3-34; NAC International (NAC), *Nuclear Megawatt Generation Status Report* (Norcross, GA, February 1997), p. C-43.

Figure 28. Energy Information Administration (EIA), International Nuclear Model, file INM.WK4, 1997; EIA, *Nuclear Power Generation and Fuel Cycle Report 1996*, DOE/EIA-0436(96) (Washington, DC, October 1996); Energy Resources International, Inc., *1997 Nuclear Fuel Cycle Supply and Price Report* (Washington, DC, May 1997), p. 4-40; and NAC International, *U3O8 Status Report* (Norcross, GA, February 1997), pp. F-1, F-13.

Figure 29. Energy Information Administration (EIA), International Nuclear Model, file INM.WK4, 1997; EIA, *Nuclear Power Generation and Fuel Cycle Report 1996*, DOE/EIA-0436(96) (Washington, DC, October 1996); Energy Resources International, Inc. (ERI), *1997 Nuclear Fuel Cycle Supply and Price Report* (Washington, DC, May 1997), p. 6-47; and NAC International (NAC), *Enrichment Status Report* (Norcross, GA, February 1997), pp. F-1, F-13.

Figure 30. Energy Information Administration (EIA), International Nuclear Model, file INM.WK4, 1997; EIA, *Nuclear Power Generation and Fuel Cycle Report 1996*, DOE/EIA-0436(96) (Washington, DC, October 1996); Energy Resources International, Inc. (ERI), *1997 Nuclear Fuel Cycle Supply and Price Report* (Washington, DC, May 1997), p. 8-23; and NAC International (NAC), *Enrichment Status Report* (Norcross, GA, February 1997), pp. F-1, F-13.

Figure 31. Energy Information Administration (EIA), International Nuclear Model, file INM.WK4, 1997; EIA, *Nuclear Power Generation and Fuel Cycle Report 1996*, DOE/EIA-0436(96) (Washington, DC, October 1996); Energy Resources International, Inc. (ERI), *1997 Nuclear Fuel Cycle Supply and Price Report* (Washington, DC, May 1997), p. 3-34; and NAC International (NAC), *Nuclear Megawatt Generation Status Report* (Norcross, GA, February 1997), p. D-1.

Table Notes

Table 1. *Nucleonics Week*, "Top 50 Units By Capacity Factor, 1996," New York:McGraw-Hill (February 13, 1997), pp. 8-9.

Table 2. **1996**—United States, Nuclear Regulatory Commission, "Information Digest, 1997 Edition" NUREG-0380 (May 1997); Foreign International Atomic Energy Agency (IAEA), "Nuclear Power Reactors in the World" (Vienna, Austria, April 1997); **Projections**—The projections are based on a critical assessment of detailed country-specific nuclear power plans. For China, India, Japan, and South Korea, the "World Integrated Nuclear Evaluation System," (WINES) (WINES June 1997 run) was used to supplement the 2015 capacity projection. **Note:** Totals may not equal sum of components due to independent rounding.

Table 3. Energy Information Administration, Form EIA-759, "Monthly Power Plant Report." **Note:** Totals may not equal sum of components due to independent rounding.

Table 4. Energy Information Administration, Form EIA-858, "Uranium Industry Annual Survey," (1994-1996).

Table 5. List includes reactors with less than one-half of their storage pool capacity remaining. ISFSI = Independent Spent Fuel Storage Installation. Energy Information Administration, Form RW-859, "Nuclear Fuel Data" (1995).

Table 6. Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, International Nuclear Model. **Note:** Totals may not equal sum of components due to independent rounding. Data adjusted by three-point smoothing.

Table 7. Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, International Nuclear Model. **Note:** Totals may not equal sum of components due to independent rounding. Data adjusted by three-point smoothing.

Table 8. Energy Information Administration, Uranium Market Model run no. 1997_73.dat, July 18, 1997. **Note:** Adjusted by three-point smoothing.

Table 9. Energy Information Administration: *World Nuclear Capacity and Fuel Cycle Requirements 1993*, DOE/EIA-0436(93) (Washington, DC, November 1993), pp. 141, 143, *World Nuclear Outlook 1994*, DOE/EIA-0436(94) (Washington, DC, December 1994), pp. 8, 106, 107; *Spent Nuclear Fuel Discharges from U.S. Reactors 1993*, SR/CNEAF/95-01 (Washington, DC, February 1995), p. 20; *Spent Nuclear Fuel Discharges from U.S. Reactors 1994*, SR/CNEAF-96-01 (Washington, DC, February 1996), p. 21; Energy Information Administration, Form RW-859, "Nuclear Fuel Data" (1995); *World Nuclear Outlook 1995*, DOE/EIA-0436(95) (Washington, DC, October 1995), pp. 8, 116, 117; *Nuclear Power Generation and Fuel Cycle Report 1996*, DOE/EIA-0436(96) (Washington, DC, October 1996), pp. 112, 113.

Appendix A

Nuclear Power Technology and the Nuclear Fuel Cycle

Appendix A

Nuclear Power Technology and the Nuclear Fuel Cycle

Nuclear Fission

Nuclear fission is the process in which the nucleus of a heavy element, such as uranium, splits when bombarded by a free neutron.[73] The fission process for uranium atoms yields two smaller atoms, one to three free neutrons, plus an amount of energy. Because more free neutrons are released from a uranium fission event than are required to initiate the event, the reaction can become self sustaining—a chain reaction—under controlled conditions.

Uranium in nature consists primarily of two isotopes, ^{238}U and ^{235}U. The numbers refer to the atomic mass for each isotope, or the number of protons and neutrons in the atomic nucleus. Naturally occurring uranium consists of approximately 99.28 percent ^{238}U and 0.71 percent ^{235}U. The atomic nucleus of ^{235}U will nearly always fission when struck by a free neutron, and the isotope is therefore said to be a "fissile" isotope. The nucleus of a ^{238}U atom on the other hand, rather than undergoing fission when struck by a free neutron, will nearly always absorb the neutron and yield an atom of the isotope ^{239}U. This isotope then undergoes natural radioactive decay to yield ^{239}Pu, which, like ^{235}U, is a fissile isotope. The atoms of ^{238}U are said to be fertile, because, through neutron irradiation in the core, some eventually yield atoms of fissile ^{239}Pu.

In the vast majority of the world's nuclear power plants, heat energy generated by burning uranium fuel is collected in ordinary water and is carried away from the reactor's core either as steam in boiling water reactors or as superheated water in pressurized-water reactors. In a pressurized-water reactor, the superheated water in the primary cooling loop is used to transfer heat energy to a secondary loop for the creation of steam. In either a boiling-water or pressurized-water installation, steam under high pressure is the medium used to transfer the nuclear reactor's heat energy to a turbine that mechanically turns a dynamo- electric machine, or electric generator. Boiling-water and pressurized-water reactors are called light-water reactors, because they utilize ordinary water to transfer the heat energy from reactor to turbine in the electricity generation process. In other reactor designs, the heat energy is transferred by pressurized heavy water, gas, or another cooling substance.

Because the water used to remove heat from the core in a light-water reactor absorbs some of the free neutrons normally generated during operation of the reactor, the concentration of the naturally fissionable ^{235}U isotope in uranium used to fuel light-water reactors must be increased above the level of natural uranium to assist in sustaining the nuclear chain reaction in the reactor core: the remainder of the uranium in the fuel is ^{238}U. Increasing the concentration of ^{235}U in nuclear fuel uranium above the level that occurs in natural uranium is accomplished through the process of enrichment, which is explained below.

The fuel core for a light-water nuclear power reactor is can have up to 3,000 fuel assemblies. An assembly consists of a group of sealed fuel rods, each filled with UO_2 pellets, held in place by end plates and supported by metal spacer-grids to brace the rods and maintain the proper distances between them. The fuel core can be thought of as a reservoir from which heat energy can be extracted through the nuclear chain reaction process. During the operation of the reactor, the concentration of ^{235}U in the fuel is decreased as those atoms undergo nuclear fission to create heat energy. Some ^{238}U atoms are converted to atoms of fissile ^{239}Pu, some of which will, in turn, undergo fission and produce energy. The daughter products created by the nuclear fission reactions are retained within the fuel pellets and these become neutron-absorbing products (called "poisons") that act to slow the rate of nuclear fission and heat production. As the reactor operation is continued, a point is reached at which the declining concentration of fissile nuclei in the fuel and the increasing concentration of poisons result in lower than optimal heat energy generation, and the reactor must be shut down temporarily and refueled.

The amount of energy in the reservoir of nuclear fuel is frequently expressed in terms of "full-power days," which is the number of 24-hour periods (days) a reactor is scheduled for operation at full power output for the generation of heat energy. The number of full power days in a reactor's operating cycle (between refueling outage times) is related to the amount of fissile ^{235}U contained in the fuel assemblies at the beginning of the cycle. A higher percentage of ^{235}U in the core at the beginning of a cycle will permit the reactor to be run for a greater number of full power days.

At the end of the operating cycle, the fuel in some of the assemblies is "spent," and it is discharged and replaced with new (fresh) fuel assemblies. The fraction of the reactor's fuel core replaced during refueling is typically one-fourth for a boiling-water reactor and one-third for a pressurized-water reactor.

The amount of energy extracted from nuclear fuel is called its "burnup," which is expressed in terms of the heat energy produced per initial unit of fuel weight. Burnup is commonly expressed as megawatt days thermal per metric ton of initial heavy metal.

The Nuclear Fuel Cycle

The nuclear fuel cycle for typical light-water reactors is illustrated in Figure A1. The cycle consists of "front end" steps that lead to the preparation of uranium for use as fuel for reactor operation and "back end" steps that are necessary to safely manage, prepare, and dispose of the highly radioactive spent nuclear fuel. Chemical processing of the spent fuel material to recover the remaining fractions of fissionable products, ^{235}U and ^{239}Pu, for use in fresh fuel assemblies is technically feasible. Reprocessing of spent commercial-reactor nuclear fuel is not permitted in the United States. The front end of the nuclear fuel cycle commonly is separated into the following steps.

- **Exploration.** A deposit of uranium, discovered by geophysical techniques, is evaluated and sampled to determine the amounts of uranium materials that are extractable at specified costs from the deposit. Uranium reserves are the amounts of ore that are estimated to be recoverable at stated costs.

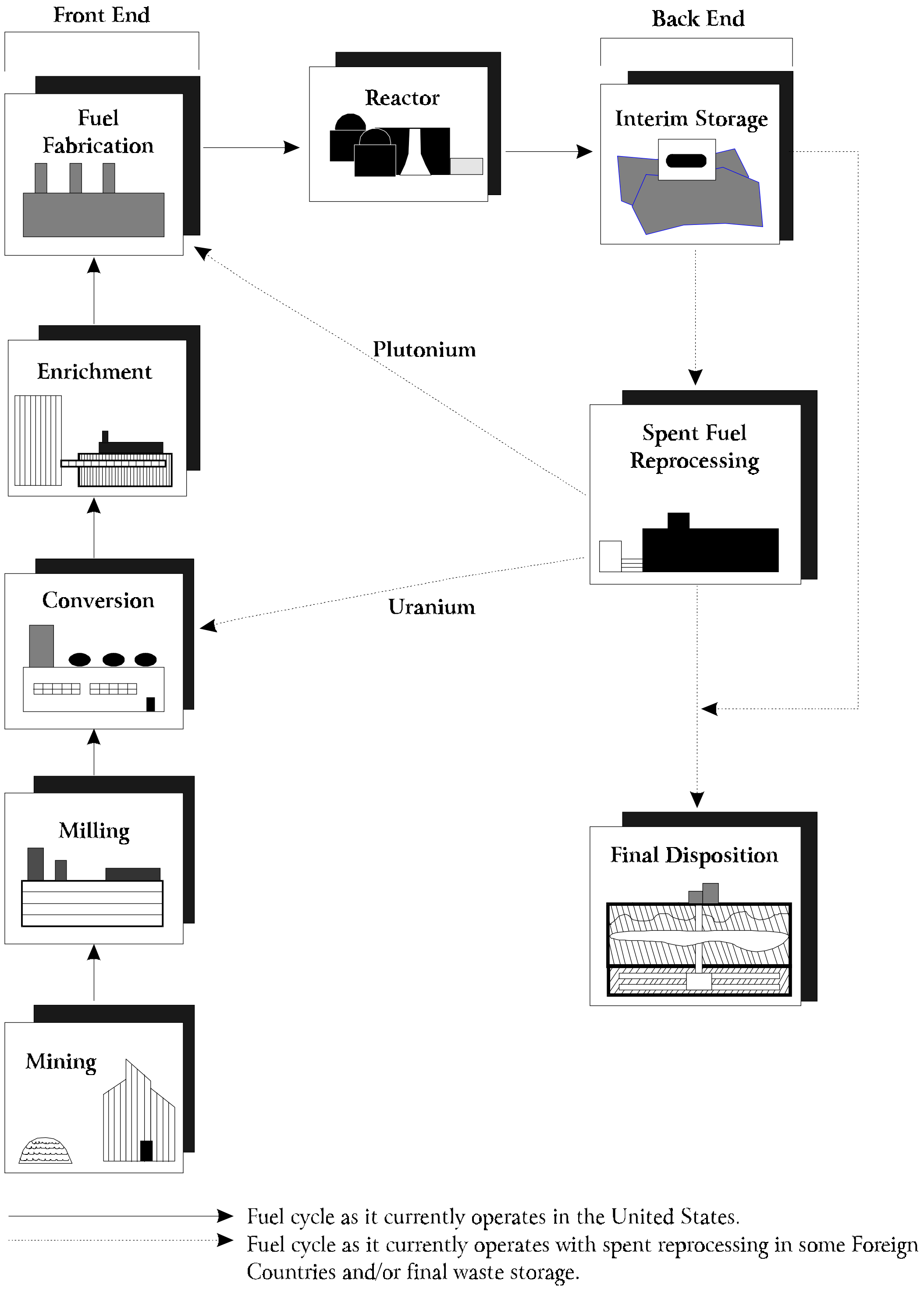
- **Mining.** Uranium ore normally is mined by openpit and underground methods similar to those used for mining other metals. In situ leach mining methods also are used to mine uranium in the United States. In this technology, uranium is leached from the in-place ore through an array of regularly spaced wells and is then recovered from the leach solution at a surface plant. Uranium ores in the United States typically range from about 0.05 to 0.3 percent uranium oxide (U_3O_8). Some uranium deposits developed in other countries are of higher grade and are also larger than deposits mined in the United States. Uranium is also present in very low grade amounts (50 to 200 parts per million) in some domestic phosphate-bearing deposits of marine origin. Because very large quantities of phosphate-bearing rock are mined for the production of wet-process phosphoric acid used in high analysis fertilizers and other phosphate chemicals, at some phosphate processing plants the uranium, although present in very low concentrations, can be economically recovered from the process stream.

- **Milling.** Mined uranium ores normally are processed by grinding the ore materials to a uniform particle size and then treating the ore to extract the uranium by chemical leaching. The milling process commonly yields dry powder-form material consisting of natural uranium, "yellowcake," which is sold on the uranium market as U_3O_8.

- **Uranium conversion.** Milled uranium oxide, U_3O_8, must be converted to uranium hexafluoride, UF_6, which is the form required by most commercial uranium enrichment facilities currently in use. A solid at room temperature, UF_6 can be changed to a gaseous form at moderately higher temperatures. The UF_6 conversion product contains only natural, not enriched, uranium.

- **Enrichment.** The concentration of the fissionable isotope, ^{235}U (0.71 percent in natural uranium) is less than that required to sustain a nuclear chain reaction in light water reactor cores. Natural UF_6 thus must be "enriched" in the fissionable isotope for it to be used as nuclear fuel. The different levels of enrichment required for a particular nuclear fuel application are specified by the customer: light-water reactor fuel normally is enriched up to about 4 percent ^{235}U, but uranium enriched to lower concentrations also is required. Gaseous diffusion and gas centrifuge are the commonly used uranium enrichment technologies. The gaseous diffusion process consists of passing the natural UF_6 gas feed under high pressure through a series of diffusion barriers (semiporous membranes) that permit passage of the lighter $^{235}UF_6$ atoms at a faster rate than the heavier $^{238}UF_6$ atoms. This differential treatment, applied across a large number of diffusion "stages," progressively raises the product stream concentration of ^{235}U relative to ^{238}U. In the gaseous diffusion technology, the separation achieved per diffusion stage is relatively low, and a large number of stages is required to achieve the desired level of isotope enrichment. Because this technology requires a large capital outlay for facilities and it consumes large amounts of electrical energy, it is

Figure A1. The Nuclear Fuel Cycle



Source: Energy Information Administration.

relatively cost intensive. In the gas centrifuge process, the natural UF_6 gas is spun at high speed in a series of cylinders. This acts to separate the $^{235}UF_6$ and $^{238}UF_6$ atoms based on their slightly different atomic masses. Gas centrifuge technology involves relatively high capital costs for the specialized equipment required, but its power costs are below those for the gaseous diffusion technology. New enrichment technologies currently being developed are the atomic vapor laser isotope separation (AVLIS) and the molecular laser isotope separation (MLIS). Each laser-based enrichment process can achieve higher initial enrichment (isotope separation) factors than the diffusion or centrifuge processes can achieve. Both AVLIS and MLIS will be capable of operating at high material throughput rates.

- **Fabrication.** For use as nuclear fuel, enriched UF_6 is converted into uranium dioxide (UO_2) powder which is then processed into pellet form. The pellets are then fired in a high temperature sintering furnace to create hard, ceramic pellets of enriched uranium. The cylindrical pellets then undergo a grinding process to achieve a uniform pellet size. The pellets are stacked, according to each nuclear core's design specifications, into tubes of corrosion-resistant metal alloy. The tubes are sealed to contain the fuel pellets: these tubes are called fuel rods. The finished fuel rods are grouped in special fuel assemblies that are then used to build up the nuclear fuel core of a power reactor.

The back end of the cycle is divided into the following steps:

- **Interim Storage**. After its operating cycle, the reactor is shut down for refueling. The fuel discharged at that time (spent fuel) is stored either at the reactor site or, potentially, in a common facility away from reactor sites. If on-site pool storage capacity is exceeded, it may be desirable to store aged fuel in modular dry storage facilities known as Independent Spent Fuel Storage Installations (ISFSI) at the reactor site or at a facility away from the site. The spent fuel rods are usually stored in water, which provides both cooling (the spent fuel continues to generate heat as a result of residual radioactive decay) and shielding (to protect the environment from residual ionizing radiation).

- **Reprocessing**. Spent fuel discharged from light-water reactors contains appreciable quantities of fissile (U-235, Pu-239), fertile (U-238), and other radioactive materials. These fissile and fertile materials can be chemically separated and recovered from the spent fuel. The recovered uranium and plutonium can, if economic and institutional conditions permit, be recycled for use as nuclear fuel. Currently, plants in Europe are reprocessing spent fuel from utilities in Europe and Japan.

- **Waste Disposal**. A current concern in the nuclear power field is the safe disposal and isolation of either spent fuel from reactors or, if the reprocessing option is used, wastes from reprocessing plants. These materials must be isolated from the biosphere until the radioactivity contained in them has diminished to a safe level. Under the Nuclear Waste Policy Act of 1982, as amended, the Department of Energy has responsibility for the development of the waste disposal system for spent nuclear fuel and high-level radioactive waste. Current plans call for the ultimate disposal of the wastes in solid form in licensed deep, stable geologic structures.

Appendix B

The Analysis Systems

Appendix B

The Analysis Systems

Methodology Used for the Capacity Forecasts

For the reference case projection, EIA uses two methodologies to assess foreign nuclear generating capacity of individual countries.[74] The first approach is to estimate completion dates for units under construction and planned in each country, and to incorporate the capacity upgrades achieved and scheduled retirements of currently operating units. Appendix E list EIA's projected completion dates for units under construction and planned. The estimated dates for unit completion is based on analysis of historical construction performance, regulatory issues, financial constraints, and regional electricity demand.

In the event that a country's total generating capacity will not meet the projected electricity demand during the forecast period, a second approach is to use the World Integrated Nuclear Evaluation System (WINES) model to determine the capacity. The WINES model projects nuclear generating capacity by using assumptions about economic growth, energy consumption, and the proportion of energy to be supplied by nuclear power. WINES forecast were prepared by the Office of Integrated Analysis and Forecasting, Energy Information Administration. This year the WINES model was used to project nuclear capacity for four countries: China, India, Japan, and South Korea. Tables B1 through B3 present economic and energy parameter inputs within the model. Gross Domestic Product (GDP) assumptions are consistent with the values in EIA's, International Energy Outlook 1997. Energy parameter assumptions were derived from statistical studies of historical data for each country and (where available) forecasts from the Organization for International Atomic Energy Agency (IAEA), and analyst's judgment.

The function describing growth in demand for delivered energy uses GDP growth rates plus assumptions regarding growth in the real price of aggregate energy and corresponding price and income elasticities of demand for energy as inputs. The real aggregate energy price is assumed to increase at an average annual rate of 1.5 percent for most countries (Table B2).

Table B1. WINES Gross Domestic Product Growth Rate Assumptions
(Percent)

Country	Gross Domestic Product Growth Rate
China	6.2
India	6.2
Japan[a]	2.3
South Korea[a]	4.6

[a] Member country of the Organization for Economic Cooperation and Development (OECD).

WINES = World Integrated Nuclear Evaluation System.

Note: Values are indicated for those countries where WINES was used to develop the forecasts.

Sources: Decision Analysis Corporation of Virginia, *Final Report: WINES Model Analysis (OECD Countries)*, DOE Contract No. DE-AC01-87EI-19801 (Vienna, VA, November 15, 1991), Volumes 1-3: *WINES Model Analysis (Non-OECD Countries)*, DOE Contract No. DE-AC01-92EI-22941 (Vienna, VA, March 27, 1992); Energy Information Administration, Office of Integrated Analysis and Forecasting.

Price elasticity of aggregate energy demand is assumed to be -0.3 (Table B2) for all countries. The elasticity value is consistent with the aggregate end-use energy price elasticity computed from data for the period 1970 to 1987. Energy price elasticities are generally considered to be greater (in absolute value) for developed countries than for developing countries, reflecting the premise that higher income countries have better opportunities for energy substitution than do countries with relatively lower incomes. Income elasticity of aggregate energy demand for all countries is assumed to be 0.6 (Table B2).

The electrical share of delivered energy and the nuclear share of electricity are derived using market penetration functions. These functions require assumptions regarding long-run asymptotic shares and halving factors. The halving factor determines how fast the share from the base-year value approaches the asymptotic value. The

Table B2. WINES Energy Assumptions for the Reference Case
(Percent)

Country	Aggregate Delivered Energy Real Annual Price Growth Rate	Price Elasticity of Aggregate Delivered Energy Demand	Income Elasticity of Aggregate Delivered Energy Demand
China	1.5	-0.3	0.6
India	1.5	-0.3	0.6
Japan[a]	1.0	-0.3	0.6
South Korea[a]	1.5	-0.3	0.6

[a]Member country of the Organization for Economic Cooperation and Development (OECD).

WINES = World Integrated Nuclear Evaluation System.

Note: Values are indicated for those countries where WINES was used to develop the forecasts.

Source: Decision Analysis Corporation of Virginia, *Final Report: WINES Model Analysis (OECD Countries)*, DOE Contract No. DE-AC01-87El-19801 (Vienna, VA, November 15, 1991), Volumes 1-3: *WINES Model Analysis (Non-OECD Countries)*, DOE Contract No. DE-AC01-92El-22941 (Vienna, VA, March 27, 1992); Energy Information Administration, Office of Integrated Analysis and Forecasting.

base year for electrical nuclear share for the high case is 2010. The asymptotic electrical share of delivered energy ranges from 10 to 30 percent (Table B3). The assumption is based on an analysis of the historical penetration of electricity in the individual countries and by fitting the best logistic curve to the historical data. The electrical halving factor ranges from 10 to 20 years since there are many new end-use technologies on the horizon and the electric industry is a mature one. It is assumed, therefore, that increase in electricity can be achieved relatively quickly.

The asymptotic nuclear share of electrical generation, derived in a manner similar to that used for the asymptotic electrical share, range from 12 to 85 percent (Table B3). France was estimated by analyzing its historical shares and fitting logistic market penetration functions to its historical data. The 1996 average domestic nuclear share of utility-electrical generation was 22.6 percent. Because Far East countries are committed to nuclear power as a means of baseload power, waste disposal and licensing should not create as large a problem as in other countries. Therefore, the nuclear halving factor is assumed to be below 15 years; except for China where financing nuclear projects might require more time (Table B3).

The electrical share of delivered energy and the nuclear share of electricity are derived using market penetration functions. These functions require assumptions regarding long-run asymptotic shares and halving factors. The halving factor determines how fast the share from the base-year value approaches the asymptotic value. The

base year for electrical nuclear share for the high case is 2010. The asymptotic electrical share of delivered energy ranges from 10 to 30 percent (Table B3). The assumption is based on an analysis of the historical penetration of electricity in the individual countries and by fitting the best logistic curve to the historical data. The electrical halving factor ranges from 10 to 20 years since there are many new end-use technologies on the horizon and the electric industry is a mature one. It is assumed, therefore, that increase in electricity can be achieved relatively quickly.

Given the uncertainties regarding nuclear power's future, two additional scenarios were developed for the United States and foreign countries (Appendix F, Table F3).

The U.S. low and high growth cases—show how changing assumptions about the operating lifetimes of nuclear plants affect the reference case forecast of nuclear capacity. The low growth nuclear case assumes that, on average, all units are retired 10 years before the end of their 40 year license periods (93 units by 2015). Early shutdowns could be caused by unfavorable economics, waste disposal problems, or physical degradation of the units. The high growth nuclear case assumes 10 additional years of operation for each unit (4 units retired by 2015), suggesting that license renewals would be permitted. Conditions favoring that outcome could include continued performance improvements, a solution to the waste disposal problem, or stricter limits on emissions from fossil-fired generating facilities.

The foreign low and high capacity growth cases were developed from the low and high nuclear electricity consumption projections supplied by the Office of Integrated Analysis and Forecasting. The foreign capacity cases were developed by taking the ratio of the electricity projection for each year interval then applying that value to the reference case projection for that particular year.

Table B3. WINES Electrical and Nuclear Share Parameter Values Assumed for the Reference Case

Country	Asymptotic Electrical Share of Total Delivered Energy (percent)	Asymptotic Nuclear Share of Total Electricity (percent)	Halving Factor (years)	
	High Case	High Case	Electrical	Nuclear
China	20	20	20	30
India	20	12	15	25
Japan[a]	30	35	10	15
South Korea[a]	20	70	15	8

[a] Member country of the Organization for Economic Cooperation and Development (OECD).

WINES = World Integrated Nuclear Evaluation System.

Note: Values are indicated for those countries where WINES was used to develop the forecasts.

Sources: Decision Analysis Corporation of Virginia, *Final Report: WINES Model Analysis (OECD) Countries)*, DOE Contract No. DE-AC01-87EI-19801 (Vienna, VA, November 15, 1991), Volumes 1-3: *WINES Model Analysis (Non-OECD Countries)*, DOE Contract No. DE-AC01-92EI-22941 (Vienna, VA, March 27, 1992); Energy Information Administration, Office of Integrated Analysis and Forecasting.

Nuclear Fuel Management Plans and Nuclear Fuel Burnup

Fuel management plans for the generic reactor categories were developed from a statistical analysis of projected fuel cycle data starting in 1996. The data include the following: capacity, fuel inserted per cycle (U_3O_8, uranium metal, U-235), requirements for uranium enrichment service, cycle length, capacity factor, full-power days, spent fuel discharges, and fuel burnup.[75]

Equilibrium design burnup levels for U.S. commercial nuclear fuel in the early 1980's were around 28,000 and 33,000 MWDT/MTIHM for boiling-water reactors and pressurized-water reactors, respectively. Engineering advances in fuel integrity and improved fuel management techniques were developed through a joint effort by Government and industry, resulting in higher burnups. In this report, fuel with design burnup above 28,000 MWDT/MTIHM for boiling-water reactors and 33,000 MWDT/MTIHM for pressurized-water reactors is referred to as “extended burnup fuel.” The following pages of this Appendix describe the procedures used to develop fuel plans associated with extended fuel burnup levels.

A fuel plan consists of the following:

- Amount of uranium loaded
- Enrichment assay of the uranium loaded
- Planned number of full-power days
- Design burnup level of the discharged spent fuel.

In an ideal equilibrium cycle, any two of the above parameters determine the other two parameters. The equations relating the parameters are:

$$FB = SD \quad , \tag{1}$$

and

$$E = a + bB\,(1 + F) \quad , \tag{2}$$

where:

F = fraction of the core being replaced in an equilibrium reloading,
B = equilibrium discharge batch average burnup (megawattdays thermal per metric ton of initial heavy metal),
D = equilibrium full-power days (days),
S = core specific power (megawatts thermal per metric ton of initial heavy metal),
E = enrichment assay (percent), and a and b are regression coefficients.

The fraction of the core replaced is functionally equivalent to the amount of enriched uranium loaded. Equation (1) implies that in an equilibrium mode, the core average burnup, SD, equals the discharge batch average burnup, B, times the batch fractional average, F. For example, if $F = 1/3$ and B = 33,000 megawattdays thermal per metric ton of initial heavy metal, then the core average burnup is 11,000 megawattdays thermal per metric ton of initial heavy metal. That is, a batch of fuel stays in the core for three cycles, receiving an exposure of 11,000 megawattdays thermal per metric ton of initial heavy metal during each cycle. The core specific power, *S*, depends on the particular reactor and core configuration being considered. However, there is a high correlation between core specific power and the ratio of the reactor's rated thermal power to core size (uranium content), so that for modeling purposes, *S* can be considered invariant for an individual reactor.

Equation (2) assumes a linear reactivity model: that is, the rate of change of reactivity with fuel burnup is constant. The parameters *a* and *b* are fixed values determined from the analysis of a coupled thermal-hydraulic nuclear fuel cycle; *b* depends on bundle design, and *a* depends on leakage. Both *a* and *b* can be affected by design variables governing the conversion ratio and change in the slope of reactivity versus burnup. In an ideal equilibrium cycle, Equation (2) may be interpreted as relating enrichment assay to total burnup, where total burnup is defined as the sum of the discharge burnup, *B*, and the cycle equilibrium burnup, *BF*. In practice, the assumption of a linear relationship between enrichment assay and total burnup must be tempered because of the incorporation of burnable poisons with the nuclear fuel. Burnable poisons, for example gadolinium, are used in higher burnup fuel to control reactivity and limit power peaking. The addition of burnable poisons to the nuclear fuel requires moderate increases in enrichment assays to obtain a given burnup objective. This additional U-235 requirement introduces an upward concavity in the enrichment-burnup relationship. However, Equation (2) does provide a good estimate of the relationship over a reasonable burnup range. Under the conditions described above, Equations (1) and (2) provide a reasonable approximation for an ideal equilibrium cycle. To obtain generic parameters characterizing a typical boiling-water reactor and pressurized-water reactor, estimates of the coefficients in Equation (2) are obtained using a regression analysis.

The regression parameters in Equations (3) and (4) were estimated by a regression analysis applied to fuel management projections supplied to DOE by utilities on Form RW-859. Separate estimates were made for boiling-water reactors and pressurized-water reactors. Only fuel with zircalloy cladding was considered. Prior to applying the regression analysis, anomalous data were identified and eliminated from the analysis set. The R-squared values were 0.81 and 0.78 for pressurized-water reactors and boiling-water reactors (Table B4), respectively.

The "*t*" test was used to test the regression coefficients against the null hypothesis that they were not significantly different from zero. This test produces a statistical measure for determining whether a variable should be included in the model. In all cases, the coefficients were statistically significant at the 0.0001 level (Table B5).

Substituting the results of the regression analysis in Equation (2) yields the following expressions. For boiling-water reactors:

Table B4. Results of the Regression Analysis of the Enrichment Assay Equations

Reactor Type	Independent Variable	Intercept	Burnup x (1 + Core Fraction)	R-squared
Boiling Water Reactor	Assay	1.018	0.0000457	0.71
Pressurized-Water	Assay	0.756	0.0000526	0.81

Source: Energy Information Administration, Office of Coal, Nuclear, Electric, and Alternate Fuels, Analysis and Systems Division, working papers, April 1997.

Table B5. Results of the Regression Coefficient Tests

Parameter	Reactor Type	
	Boiling Water Reactor	Pressurized-Water Reactor
Intercept		
Value from t Test	10.483	8.411
Significance Level	0.0001	0.0001
Burnup x (1 + Core Fraction)		
Value from t Test	24.337	37.159
Significance Level	0.0001	0.0001

Source: Energy Information Administration, Office of Coal, Nuclear, Electric, and Alternate Fuels, Analysis and Systems Division, working papers, April 1997.

$$E = 1.015 + 0.0000457\, B\, (1 + F)\ . \qquad (3)$$

For pressurized-water reactors:

$$E = 0.756 + 0.0000526\, B\, (1 + F)\ . \qquad (4)$$

The projected discharge burnup data from Form RW-859, “Nuclear Fuel Data Survey,” that was used in this metric ton of initial heavy metal for boiling-water reactors and 65,000 megawattdays thermal per metric ton of initial heavy metal for pressurized-water reactors. Approximately 90 percent of the projected burnup levels are less than 47,000 and 52,000 megawattdays thermal per metric ton of initial heavy metal for boiling-water and pressurized water reactors, respectively. Equations (3) and (4) are analysis peaked at 59,000 megawattdays thermal per not applied to burnup levels exceeding the 90 percent levels, because utilities are only now developing fuel management plans for burnup levels past these limits, and utility-supplied data for fuel management plans associated with these higher burnup goals are sparce. For higher burnup ranges, the following analysis is used to establish the relationship between burnup, enrichment assay, and core replacement fraction.

Estimates of the technical parameters in Equation (2) were supplied by General Electric Corporation.[76] Equation (2) can be written in the following difference format:

$$\Delta E = b\, \Delta[B\, (1 + F\,)]\ , \qquad (5)$$

where Δ indicates the difference operator. This equation is applied to a given fuel management plan consisting of an assay E_1, a burnup B, and a core fraction F_1. If a new fuel management plan has a burnup B_2 and a core fraction F_2, then

$$\Delta[B\, (1 + F\,)] = B_2\, (1 + F_2\,) - B_1\, (1 + F_1\,)\ . \qquad (6)$$

The change in enrichment assay is calculated by $\Delta E = b\, \Delta[B\, (1 + F\,)]$, and the new enrichment assay is given by $E_2 = E_1 + \Delta E$.

General Electric Corporation suggested that an appropriate value of b in the higher burnup ranges is 0.000063. This value of b provides a good approximation for both boiling-water reactors (BWR) and pressurized-water reac tors (PWR). Note that the value of the parameter a in Equation (2) depends on the generic reactor type. Using the General Electric Corporation value for b, Equation (5) becomes

$$\Delta E = 0.000063\, \Delta[B\, (1 + F\,)]\ . \qquad (7)$$

As Equation (1) indicates, for a given discharge burnup and a given number of effective full-power days per cycle, the core fraction depends on the specific power of the reactor. The reactor fuel management plans used in the International Nuclear Model, PC Version are based on the generic reactor types and implicitly incorporate a mean specific power value for a generic boiling-water and pressurized-water reactors, respectively.

Equation (1) is used to calculate the core fraction of a new fuel diet plan,

$$F = (S\, D)\ /\ B\ , \qquad (8)$$

Utilities typically develop fuel management plans to meet effective full-power days and discharge burnup goals. That is, they specify the amount of energy to be produced during the cycle and the desired discharge burnup of the fuel, and use these objectives to determine the amount and enrichment assay of the fresh uranium loaded. The burnup objectives are generally determined by economic and operational considerations.

Domestic and foreign fuel management plans for extended burnup are developed for generic boiling-water reactors and pressurized-water reactors (Tables B6 and B7). Each plan is based on assumptions for the number of effective full-power days for the cycle and a dischargeburnup level. The years the fuel plan is used in the calculation of fuel requirements is noted in Tables B6 and B7. Trends in burnup and number of effective full-power day plans were obtained from utility-supplied data and industry experts.

The following five steps were used to develop fuel models consistent with increases in fuel burnup and the number of effective full-power days per cycle. The procedure was applied separately to generic boiling-water reactors and pressurized-water reactors and for domestic and foreign reactors.

1. The mean core-specific power (ratio of megawatts thermal to core weight in metric tons of uranium) was converted separately for the boiling-water and pressurized-water reactors in the forecast data base.

2. The core fraction associated with a given burnup level and number of effective full-power days was computed by Equation (8).

3. The specified burnup level and the core fraction calculated in step 2 were used to estimate the enrichment assay. In the domestic fuel management plans for years 1994-2004 for BWR's and 1994-2002 for PWR's, Equations (3) and (4) were used to estimate the enrichment assay. For the remaining years, Equation (7) was used to estimate

Table B6. Domestic Fuel Management Plans for Extended Burnup

Year Fuel Plan is Used	Effective Full-Power Days	Core Fraction	Enrichment Assay (percent)	Design Burnup (MWDT/MTIHM)[a]
Boiling-Water Reactors				
1993	450	0.288	3.14	36,000
1996	500	0.288	3.32	40,000
2000	560	0.300	3.47	43,000
2010	580	0.291	3.58	46,000
Pressurized-Water Reactor				
1993	450	0.397	3.84	42,000
1997	480	0.386	4.11	46,000
2001	511	0.378	4.38	50,000
2008	530	0.357	4.74	55,000

[a] MWDT/MTIHM = Megawattdays thermal per metric ton initial heavy metal.

Source: Energy Information Administration, Office of Coal, Nuclear, Electric, and Alternate Fuels, Analysis and Systems Division, working papers, April 1997.

Table B7. Foreign Fuel Management Plans for Extended Burnup

Year Fuel Plan is Used	Effective Full-Power Days	Core Fraction	Enrichment Assay (Percent)	Design Burnup (MWDT/MTIHM)[a]
Europe				
Boiling-Water Reactors				
1995	300	0.206	3.00	36,000
1998	300	0.191	3.09	39,000
2004	300	0.173	3.22	43,000
2009	300	0.161	3.31	46,000
Pressurized-Water Reactor				
1994	300	0.275	3.57	42,000
1998	300	0.251	3.78	46,000
2002	300	0.231	3.99	50,000
2007	300	0.210	4.31	55,000
Far East				
Boiling-Water Reactors				
1995	365	0.241	3.26	36,000
2001	395	0.241	3.38	39,000
2006	420	0.232	3.54	43,000
Pressurized-Water Reactor				
1995	355	0.367	3.47	35,000
1997	365	0.338	3.70	39,000
2001	395	0.332	3.97	43,000
2009	420	0.310	4.33	49,000

[a] MWDT/MTIHM = Megawattdays thermal per metric ton initial heavy metal.

Source: Energy Information Administration, Office of Coal, Nuclear, Electric, and Alternate Fuels, Analysis and Systems Division, working papers, April 1997.

the change in the enrichment assay, based on the increased burnup and change in core fraction.

4. The amount of uranium to be loaded was calculated as the product of the core fraction computed in step 2 and the total core weight.

5. Two types of adjustments were made to the enrichment assays estimated in step 3: (1) boiling-water reactor enrichments were adjusted downward by a small amount in the post-2000 period, to account for anticipated improvements in fuel utilization; (2) an enrichment adjustment of +0.2 percent was made to the Japanese enrichments. Historically, Japanese utilities have been very conservative when ordering nuclear fuel and have typically loaded fuel with higher reactivity levels in their reactors than the fuel customarily loaded in the West to obtain comparable burnup levels. The evidence of this is reflected in the higher U-235 enrichment content of the discharged fuel.

The Models

International Nuclear Model PC Version

The estimates of the nuclear fuel cycle requirements in this report were produced with the International Nuclear Model PC Version (PCINM). This model was developed under contract for the Office of Coal, Nuclear, Electric and Alternate Fuels in the Energy Information Administration (EIA).[77] The PCINM is used to simulate nuclear fuel cycle operations.

The data for the PCINM include the following general categories:

- **Operating Reactor Data**. This is a list of information on nuclear reactors assumed to be operable during the time period being analyzed. For each reactor, the list includes the name, country, start and retirement dates, net summer capability, generic category to which the reactor is assigned, indicators of the fuel management plans to be used, and the applicable dates for the fuel management plans.

- **Generic Reactor Data**. Each operating reactor is classified into one of the generic categories, such as boiling-water reactor and pressurized-water reactor. The data for the generic categories of reactors include capacity factors, thermal efficiency, maintenance priority, and a list of allowable fuel management plans.

- **Fuel Management Data**. The data describing a fuel management plan are used to simulate the internal workings of operating reactors. Fuel management data consist of the following: full-power days, capacity factors, enriched uranium, assays of the fissile isotopes in the fuel loaded and discharged, and fraction of core replaced.

- **Fuel Cycle Parameters**. These data items include lead and lag times from the start of a cycle for the fuel cycle processes (that is, conversion, enrichment, fabrication, spent fuel disposal), enrichment tails assays, and process waste production.

- **Control/Scenario Data**. The user can specify data such as annual capacity factors for all equilibrium cycles.

Annual requirements for uranium concentrate (U_3O_8) and enrichment services, as well as discharges of spent fuel, are a function of the fuel management plan being used by each reactor and the specified tails assay for enrichment services. To calculate the annual requirements, the date for the start of a cycle is determined for each reactor by a formula that uses (a) the number of full-power days specified in the fuel management plan and (b) the capacity factor. A "full-power day" is the equivalent of 24 hours of full-power operation of a reactor. The length of the cycle can then be determined as follows:

Length of cycle = (number of full-power days) / (capacity factor).

The length of the cycle includes the time during which electricity is being generated and the time during which the reactor is not operating (such as during refueling).

The lead times for fuel cycle services must also be incorporated: U_3O_8 is delivered to a conversion plant 15 months before the restart of the nuclear unit, and enrichment services begin 12 months before the restart of the unit. Finally, the quantities of U_3O_8 and enrichment services required are determined from the amount of enriched uranium specified in the fuel management plan and from the enriched product assay and transaction tails assay. For a new reactor, the fuel management data and the lead times for the initial cycles are unique. After a reactor has reached equilibrium, the full-power days in a cycle, the quantity of fuel loaded, and the spent fuel discharged per cycle remain constant for a specific fuel management plan.

The PCINM is used to produce annual summary reports for generic reactor categories and totals for all reactors.

These reports include: annual generation of electricity, annual capacity factors, annual and cumulative requirements for U_3O_8 and enrichment services, annual discharges of spent fuel, and total spent fuel discharges less the spent fuel withdrawn for reprocessing. The uranium concentrate requirements are reported as requirements for U_3O_8 or “yellowcake”; the enrichment service requirements are measured in separative work units; and the discharges of spent fuel are expressed in metric tons of initial heavy metal. The projected discharges of spent fuel exclude discharged fuel that is designated for reinsertion.

Uranium Market Model

Overview

Most of the uranium projections in this report were generated by the Uranium Market Module (UMM). UMM is a microeconomic model in which uranium supplied by the mining and milling industry is used to meet the demand for uranium by electric utilities with nuclear power plants. Uranium is measured on a U_3O_8 concentrate equivalent basis. The input data encompass every major production center and utility in the world. The model provides annual projections for each major uranium production and consumption region in the world. Sixteen regions were used in this study: (1) the United States, (2) Canada, (3) Australia, (4) South Africa, (5) Other Africa, (6) Western Europe, (7) Latin America, (8) the East, (9) Other, (10) Eastern Europe, (11) Russia, (12) Kazakhstan, (13) Uzbekistan, (14) Ukraine, (15) Kyrgyz Republic, and (16) Other Former Soviet Union.

Uranium Demand

Uranium demand is assumed to equal near-term unfilled requirements on the part of utilities. Unfilled requirements are determined by subtracting current contract commitments at firm (non-spot) prices and inventory drawdown from total reactor requirements plus any assumed inventory buildup. Contract commitments calling for price to equal the future spot prices with no firm floor price are thus included in the calculation of uranium demand. In this way, demands may be placed on the market by uranium producers with such contracts when the spot price falls below the production costs of these producers.

The demand for uranium by electric utilities with nuclear power plants is a key parameter. Annual projections of reactor requirements are from EIA forecasts (see Chapter 3 for domestic forecasts). In the model, individual utility requirements were combined into regional totals. These projections are assumed to be inelastic with respect to uranium prices, separative work unit prices, and tails assays. Scenarios with varying demands can be determined by using alternative inputs for projected reactor requirements.

In addition to reactor requirements, most utilities also maintain a uranium inventory as a contingency against possible disruptions in supply. The desired degree of forward inventory coverage varies by country, due to such factors as national policies, contracting approaches, and regulatory treatment of inventory costs. These variations are incorporated in the model. Inventory demand is a function of future reactor requirements and future uranium prices which change annually. This demand is elastic with respect to the spot price and, in line with market behavior, decreases as the price falls and increases as the price rises.

Contract commitments, between both producers and electric utilities and between utilities and enrichment suppliers, are taken into account exogenously. Commitments between producers and electric utilities are considered in two ways. The first is an estimate of the overcommitments by utilities to purchase uranium in excess of their annual reactor requirements. The second represents producer-utility contracts by specifying the commitments made by producers to deliver uranium from a specific production center to a particular utility. Contracts between utilities and enrichment suppliers can also lead to overcommitments in terms of the utility buying uranium for committed deliveries to enrichment plants that exceed the utility's reactor requirements.

Uranium Supply

Uranium supply is represented by an annual short-run supply curve consisting of increments of potential production and the supply of excess inventories which are assumed to be available at different market prices. Production centers are defined as mine-mill combinations, if there is conventional production, and as processing facilities for nonconventional production. Also included are producers in Western countries, Eastern Europe, the Former Soviet Union, and China that are potential net exporters. In general, production centers come on line, produce uranium, and deplete their reserves depending on a number of geological, engineering, market, and political conditions. Producers that are able to produce and sell uranium most cheaply generally occupy the lower portions of the supply curve. Production costs are estimated exogenously, taking the following into account: the size of the reserves; annual production capacity; ore grade; type of production; capital, labor, and other costs;

and taxes and royalty requirements. A fair market rate of return is also assumed. Government subsidies, variations in exchange rates, floor prices, supply disruptions, or other factors may affect the shape of the supply curve each year.

Some excess utility inventories are also treated as sources of potential supply that may be drawn down or sold in the secondary market. The size of these yearly drawdowns and sales depends on the utility's desired level of contingency stocks, spot-market prices, and the utility's general propensity to draw down its stocks or to sell uranium in the secondary market. Thus, each utility's inventory level varies annually depending on its projected reactor requirements, its contract commitments with producers and enrichment suppliers, the trend in market prices, its own inventory planning strategy, and the sales of excess inventories held by suppliers and governments.

Market-Clearing Conditions

Equilibrium is achieved in the forecasts when the supply of uranium meets the demand for uranium. Supply comes from production centers; utilities' inventories, which may already be at levels sufficient to satisfy inventory demand; excess inventories held by suppliers and governments; and utilities' excess inventories which are drawn down or are sold in the secondary market.[78] Demand consists of utility reactor requirements, contingency inventory demand, and any additional market demand resulting from contract over commitments with either producers or enrichment facilities.

The market projections in any given year are determined by activities in previous years, such as market prices and decisions to defer production of reserves. Projected demand levels are affected by reactor requirements in future years. Unanticipated changes in future demand may be introduced exogenously so that market activities in any forecast year may be constrained by actions taken in previous years.

Under free-market conditions with a single world market, utilities may draw down their inventories either for their own use or for sale in the secondary market; production is allocated to satisfy contract commitments; and remaining demand is met by producers with uncommitted reserves and by other suppliers with holdings of uranium. The intersection of this supply curve with the unfilled demand identifies the particular production and other supply increments that are sold in the market and defines the equilibrium spot-market price for that year. These sales, together with those from contract commitments, are tabulated to give projections of production in the United States and in other regions.[79] The equilibrium spot-market price and the 1-year lagged spot-market price are used to compute a projected spot-market price. Projected prices for new contracts are estimated as a function of the projected spot-market price. The net imports of a country are calculated from its utilities' reactor requirements, contingency inventory demand, contract commitments, inventory use, and its producers' sales.

Appendix C

Nuclear Units Ordered in the United States, 1953-1996

Appendix C

Nuclear Units Ordered in the United States, 1953-1996

Table C1. Nuclear Units Ordered in the United States, 1953-1996

Unit Name	Design Capacity (MWe)	Utility	Reactor Supplier[a]	Year of Order	Year of Grid Connection	Current Status and Scheduled Shutdown Date (December 31, 1996)
Allens Creek 1	1,150	Houston Lighting & Power Co.	GE	1973		Canceled, 1982.
Allens Creek 2	1,150	Houston Lighting & Power Co.	GE	1973		Canceled, 1976.
Arkansas Nuclear 1	850	Arkansas Power & Light Co.	B&W	1967	1974	Operating. 5/20/2014.
Arkansas Nuclear 2	912	Arkansas Power & Light Co.	C-E	1970	1978	Operating. 7/17/2018.
Atlantic 1	1,150	Public Service Electric & Gas Co.	W	1972		Canceled, 1978.
Atlantic 2	1,150	Public Service Electric & Gas Co.	W	1972		Canceled, 1978.
Atlantic 3	1,150	Public Service Electric & Gas Co.	W	1973		Canceled, 1978.
Atlantic 4	1,150	Public Service Electric & Gas Co.	W	1973		Canceled, 1978.
Bailly	644	Northern Indiana Public Service Co.	GE	1967		Canceled, 1981.
Barton 1	1,159	Alabama Power & Light	GE	1972		Canceled, 1977.
Barton 2	1,159	Alabama Power & Light	GE	1972		Canceled, 1977.
Barton 3	1,159	Alabama Power & Light	GE	1974		Canceled, 1975.
Barton 4	1,159	Alabama Power & Light	GE	1974		Canceled, 1975.
Beaver Valley 1	835	Duquesne Light Co.	W	1967	1976	Operating. 1/29/2016.
Beaver Valley 2	852	Duquesne Light Co.	W	1971	1987	Operating. 5/27/2027.
Bell	838	New York State Electric & Gas	N/A	1967		Canceled, 1972.
Bellefonte 1	1,235	Tennessee Valley Authority	B&W	1970		Indefinitely deferred.
Bellefonte 2	1,235	Tennessee Valley Authority	B&W	1970		Indefinitely deferred.
Big Rock Point	72	Consumers Power Co.	GE	1959	1962	Operating. 5/31/2000[b]
Black Fox 1	1,150	Public Service Company of Oklahoma	GW	1973		Canceled, 1982.
Black Fox 2	1,150	Public Service Company of Oklahoma	GW	1973		Canceled, 1982.
Blue Hills 1	918	Gulf States Utilities Co.	C-E	1973		Canceled, 1978.

See notes at end of table.

Table C1. Nuclear Units Ordered in the United States, 1953-1996 (Continued)

Unit Name	Design Capacity (MWe)	Utility	Reactor Supplier[a]	Year of Order	Year of Grid Connection	Current Status and Scheduled Shutdown Date (December 31, 1996)
Blue Hills 2	918	Gulf States Utilities Co.	C-E	1974		Canceled. 1978.
Braidwood 1	1,120	Commonwealth Edison Co.	W	1972	1987	Operating. 10/17/2026.
Braidwood 2	1,120	Commonwealth Edison Co.	W	1972	1988	Operating. 12/18/2027.
Browns Ferry 1	1,065	Tennessee Valley Authority	GE	1966	1973	Operating. 12/20/2013.
Browns Ferry 2	1,065	Tennessee Valley Authority	GE	1966	1974	Operating. 6/28/2014.
Browns Ferry 3	1,065	Tennessee Valley Authority	GE	1967	1976	Operating. 7/2/2016.
Brunswick 1	821	Carolina Power & Light Co.	GE	1968	1976	Operating. 9/8/2016.
Brunswick 2	821	Carolina Power & Light Co.	GE	1968	1974	Operating. 12/27/2014.
Byron 1	1,120	Commonwealth Edison Co.	W	1971	1985	Operating. 10/31/2024.
Byron 2	1,120	Commonwealth Edison Co.	W	1971	1987	Operating. 11/6/2026.
Callaway 1	1,188	Union Electric Co.	W	1973	1984	Operating. 10/18/2024.
Callaway 2	1,120	Union Electric Co.	W	1973		Canceled, 1981.
Calvert Cliffs 1	845	Baltimore Gas & Electric Co.	C-E	1967	1974	Operating. 7/31/2014.
Calvert Cliffs 2	845	Baltimore Gas & Electric Co.	C-E	1967	1976	Operating. 8/31/2016.
Carroll County 1	1,120	Commonwealth Edison Co.	W	1978		Canceled, 1988.
Carroll County 2	1,120	Commonwealth Edison Co.	W	1978		Canceled, 1988
Catawba 1	1,145	Duke Power Co.	W	1972	1985	Operating. 12/6/2024.
Catawba 2	1,145	Duke Power Co.	W	1972	1986	Operating. 2/24/2026.
Cherokee 1	1,280	Duke Power Co.	C-E	1973		Canceled, 1983.
Cherokee 2	1,280	Duke Power Co.	C-E	1973		Canceled, 1982.
Cherokee 3	1,280	Duke Power Co.	C-E	1973		Canceled, 1982.
Clinch River Breeder	350	Project Management Co.; DOE; TVA	W	1972		Canceled, 1983.
Clinton 1	950	Illinois Power Co.	GE	1973	1987	Operating. 9/29/2026.
Clinton 2	950	Illinois Power Co.	GE	1973		Canceled, 1983.
Comanche Peak 1	1,150	Texas Utilities Electric Co.	W	1972	1990	Operating. 2/8/2030.
Comanche Peak 2	1,150	Texas Utilities Electric Co.	W	1972	1993	Operating. 2/2/2033.
Cooper 1	778	Nebraska Public Power District	GE	1967	1974	Operating. 1/18/2014.
Crystal River 3	825	Florida Power Co.	B&W	1967	1977	Operating. 12/3/2016.
Crystal River 4	897	Florida Power Co.	W	1971		Canceled, 1972.
Davis-Besse 1	906	Toledo Edison Co.	B&W	1968	1977	Operating. 4/22/2017.
Davis-Besse 2	906	Toledo Edison Co.	B&W	1973		Canceled, 1980.
Davis-Besse 3	906	Toledo Edison Co.	B&W	1973		Canceled, 1980.
Diablo Canyon 1	1,084	Pacific Gas & Electric Co.	W	1966	1984	Operating. 9/22/2021.

See notes at end of table

Table C1. Nuclear Units Ordered in the United States, 1953-1996 (Continued)

Unit Name	Design Capacity (MWe)	Utility	Reactor Supplier[a]	Year of Order	Year of Grid Connection	Current Status and Scheduled Shutdown Date (December 31, 1996)
Diablo Canyon 2	1,084	Pacific Gas & Electric Co.	W	1968	1985	Operating. 4/26/2025.
Donald C. Cook 1	1,030	Indiana/Michigan Power Co.	W	1967	1974	Operating. 10/25/2014.
Donald C. Cook 2	1,100	Indiana/Michigan Power Co.	W	1967	1977	Operating. 10/23/2017.
Douglas Point 1	1,146	Potomac Electric Power Co.	GE	1972		Canceled, 1977.
Douglas Point 2	1,146	Potomac Electric Power Co.	GE	1972		Canceled, 1977.
Dresden 1	200	Commonwealth Edison Co.	GE	1955	1959	Shut down, 1978. SAFSTOR decommissioning plan approved, 1993.
Dresden 2	794	Commonwealth Edison Co.	GE	1965	1969	Operating. 1/10/2006.
Dresden 3	794	Commonwealth Edison Co.	GE	1966	1971	Operating. 1/12/2011.
Duane Arnold 1	538	Iowa Electric Light & Power Co.	GE	1968	1974	Operating. 2/21/2014.
Erie 1	1,267	Ohio Edison Co.	B&W	1976		Canceled, 1980.
Erie 2	1,267	Ohio Edison Co.	B&W	1976		Canceled, 1980.
Fermi 2	1,093	Detroit Edison Co.	GE	1968	1985	Operating. 3/20/2025.
Fermi 3	1,171	Detroit Edison Co.	GE	1972		Canceled, 1974.
Forked River 1	1,070	Jersey Central Power & Light Co.	C-E	1969		Canceled, 1980.
Fort Calhoun 1	478	Omaha Public Power District	C-E	1966	1973	Operating. 8/9/2013.
Fort Calhoun 2	1,136	Omaha Public Power District	W	1974		Canceled, 1977.
Fort St. Vrain	330	Public Service Co. of Colorado	GA	1965	1976	Shut down, 1989. Decommissioning completed. License terminated in 1996.
Fulton 1	1,160	Philadelphia Electric Co.	GA	1971		Canceled, 1975.
Fulton 2	1,160	Philadelphia Electric Co.	GA	1971		Canceled, 1975.
Grand Gulf 1	1,250	System Energy Resources Inc.	GE	1972	1984	Operating. 6/16/2022.
Grand Gulf 2	1,250	System Energy Resources Inc.	GE	1972		Canceled, 1990.
Greene County	1,212	Power Authority of the State of New York	B&W	1974		Canceled, 1979.
Greenwood 2	1,264	Detroit Edison Co.	B&W	1972		Canceled, 1980
Greenwood 3	1,264	Detroit Edison Co.	B&W	1972		Canceled, 1980.
Haddam Neck (Connecticut Yankee)	582	Connecticut Yankee Atomic Co.	W	1962	1967	Operating. 12/1996.[d]
Hanford-N	850	U.S. Department of Energy	GE	1963	1966	Shut down.[e]
Hartsville A1	1,205	Tennessee Valley Authority	GE	1972		Canceled, 1984.
Hartsville A2	1,205	Tennessee Valley Authority	GE	1972		Canceled, 1984.
Hartsville B1	1,233	Tennessee Valley Authority	GE	1972		Canceled, 1982.
Hartsville B2	1,233	Tennessee Valley Authority	GE	1972		Canceled, 1982.

See notes at end of table

Table C1. Nuclear Units Ordered in the United States, 1953-1996 (Continued)

Unit Name	Design Capacity (MWe)	Utility	Reactor Supplier[a]	Year of Order	Year of Grid Connection	Current Status and Scheduled Shutdown Date (December 31, 1996)
Hatch 1	777	Georgia Power Co.	GE	1967	1974	Operating. 8/6/2014.
Hatch 2	784	Georgia Power Co.	GE	1970	1978	Operating. 6/13/2018.
Haven 1	900	Wisconsin Electric Power Co.	W	1973		Canceled, 1980.
Haven 2	900	Wisconsin Electric Power Co.	W	1973		Canceled, 1978.
Hope Creek 1	1,067	Public Service Electric & Gas Co.	GE	1969	1986	Operating. 4/11/2026.
Hope Creek 2	1,067	Public Service Electric & Gas Co.	GE	1969		Canceled, 1981.
Humboldt Bay	65	Pacific Gas & Electric Co.	GE	1958	1962	Shut down, 1976. SAFSTOR decommissioning plan approved, 1988.
H.B. Robinson 2	700	Carolina Power & Light Co.	W	1966	1970	Operating. 7/31/2010.
Indian Point 1	265	Consolidated Edison Co.	B&W	1955	1962	Shut down, 1974. Submitted decommissioning plan in 1980. NRC review is ongoing.
Indian Point 2	873	Consolidated Edison Co.	W	1965	1973	Operating. 9/23/2013.
Indian Point 3	965	Power Authority of the State of New York	W	1967	1976	Operating. 12/15/2015.
James A. Fitzpatrick	821	Power Authority of the State of New York	GE	1968	1974	Operating. 10/17/2014.
Jamesport 1	1,150	Long Island Lighting Co.	W	1973		Rejected by New York State, 1980.
Jamesport 2	1,150	Long Island Lighting Co.	W	1974		Rejected by New York State, 1980.
Joseph M. Farley 1	829	Alabama Power Co.	W	1969	1977	Operating. 6/25/2017.
Joseph M. Farley 2	829	Alabama Power Co.	W	1970	1981	Operating. 3/31/2021.
Kewaunee	535	Wisconsin Public Service Co.	W	1967	1973	Operating. 12/21/2013.
La Crosse	50	Diaryland Power Coop.	A-C	1962	1968	Shut down, 1987. SAFSTOR decommissioning plan approved.
LaSalle 1	1,078	Commonwealth Edison Co.	GE	1970	1982	Operating. 5/17/2022.
LaSalle 2	1,078	Commonwealth Edison Co.	GE	1970	1984	Operating. 12/16/2023.
Limerick 1	1,065	Philadelphia Electric Co.	GE	1967	1985	Operating. 10/26/2024.
Limerick 2	1,065	Philadelphia Electric Co.	GE	1967	1989	Operating. 6/22/2029.
Maine Yankee	825	Maine Yankee Atomic Power	C-E	1967	1973	Operating. 10/21/2008.
Malibu	462	Los Angeles Department of Water & Power	W	1963		Canceled, 1972.
Marble Hill 1	1,130	Public Service of Indiana	W	1974		Canceled, 1985.
Marble Hill 2	1,130	Public Service of Indiana	W	1974		Canceled, 1985.
McGuire 1	1,180	Duke Power Co.	W	1969	1981	Operating. 6/12/2021.
McGuire 2	1,180	Duke Power Co.	W	1969	1983	Operating. 3/3/2023.

See notes at end of table

Table C1. Nuclear Units Ordered in the United States, 1953-1996 (Continued)

Unit Name	Design Capacity (MWe)	Utility	Reactor Supplier[a]	Year of Order	Year of Grid Connection	Current Status and Scheduled Shutdown Date (December 31, 1996)
Midland 1	492	Consumers Power Co.	B&W	1968		Canceled, 1986.
Midland 2	818	Consumers Power Co.	B&W	1968		Canceled, 1986.
Millstone 1	660	Northeast Nuclear Energy Co.	GE	1965	1970	Operating. 10/6/2010.
Millstone 2	870	Northeast Nuclear Energy Co.	C-E	1967	1975	Operating. 7/31/2015.
Millstone 3	1,156	Northeast Nuclear Energy Co.	W	1973	1986	Operating. 11/25/2025.
Montague 1	1,150	Northeast Nuclear Energy Co.	GE	1974		Canceled, 1980.
Montague 2	1,150	Northeast Nuclear Energy Co.	GE	1974		Canceled, 1980.
Monticello	545	Northern States Power Co.	GE	1966	1971	Operating. 9/8/2010.
New England 1	1,150	New England Power Co.	W	1974		Canceled, 1979.
New England 2	1,150	New England Power Co.	W	1974		Canceled, 1979.
Nine Mile Point 1	620	Niagra Mohawk Power Co.	GE	1963	1969	Operating. 8/22/2009.
Nine Mile Point 2	1,080	Niagara Mohawk Power Co.	GE	1971	1987	Operating. 10/13/2026.
North Anna 1	907	Virginia Electric & Power Co.	W	1967	1978	Operating. 4/1/2018.
North Anna 2	907	Virginia Electric & Power Co.	W	1970	1980	Operating. 8/21/2020.
North Anna 3	907	Virginia Electric & Power Co.	B&W	1971		Canceled, 1982.
North Anna 4	907	Virginia Electric & Power Co.	B&W	1971		Canceled, 1980.
North Coast 1	583	Puerto Rico Water Resources Authority	W	1970		Canceled, 1978.
NYSE&G 1	1,250	New York State Electric & Gas Co.	C-E	1977		Rejected by New York State, 1980.
NYSE&G 2	1,250	New York State Electric & Gas Co.	C-E	1977		Rejected by New York State, 1980.
Oconee 1	887	Duke Power Co.	B&W	1966	1973	Operating. 2/6/2013.
Oconee 2	887	Duke Power Co.	B&W	1966	1973	Operating. 10/6/2013.
Oconee 3	887	Duke Power Co.	B&W	1967	1974	Operating. 7/19/2014.
Orange 1	1,300	Florida Power Corporation	C-E	1974		Canceled, 1975.
Orange 2	1,300	Florida Power Corporation	C-E	1974		Canceled, 1975.
Oyster Creek	650	GPU Nuclear Corp.	GE	1963	1969	Operating. 12/15/2009.
Palisades	805	Consumers Power Co.	C-E	1966	1972	Operating. 3/14/2007.
Palo Verde 1	1,304	Arizona Public Service Co.	C-E	1973	1985	Operating. 12/31/2024.
Palo Verde 2	1,304	Arizona Public Service Co.	C-E	1973	1986	Operating. 12/9/2025.
Palo Verde 3	1,304	Arizona Public Service Co.	C-E	1973	1987	Operating. 3/25/2027.
Palo Verde 4	1,270	Arizona Public Service Co.	C-E	1977		Canceled, 1979.
Palo Verde 5	1,270	Arizona Public Service Co.	C-E	1977		Canceled, 1979.
Peach Bottom 2	1,065	Philadelphia Elec./Public Serv.	GE	1966	1973	Operating. 8/8/2013.
Peach Bottom 3	1,065	Philadelphia Elec./Public Serv.	GE	1966	1974	Operating. 7/2/2014.

See notes at end of table

Table C1. Nuclear Units Ordered in the United States, 1953-1996 (Continued)

Unit Name	Design Capacity (MWe)	Utility	Reactor Supplier[a]	Year of Order	Year of Grid Connection	Current Status and Scheduled Shutdown Date (December 31, 1996)
Pebble Springs 1	1,260	Portland General Electric Co.	B&W	1973		Canceled, 1982
Pebble Springs 2	1,260	Portland General Electric Co.	B&W	1974		Canceled, 1982.
Perkins 1	1,280	Duke Power Co.	C-E	1973		Canceled, 1982.
Perkins 2	1,280	Duke Power Co.	C-E	1973		Canceled, 1982.
Perkins 3	1,280	Duke Power Co.	C-E	1973		Canceled, 1982.
Perry 1	1,205	Cleveland Electric Illum. Co.	GE	1972	1986	Operating. 3/18/2026.
Perry 2	1,205	Cleveland Electric Illum. Co.	GE	1972		Canceled, 1994.
Perryman 1	845	Baltimore Gas & Electric Co.	C-E	1972		Canceled, 1972.
Perryman 2	845	Baltimore Gas & Electric Co.	C-E	1972		Canceled, 1972.
Phipps Bend 1	1,233	Tennessee Valley Authority	GE	1974		Canceled, 1982.
Phipps Bend 2	1,233	Tennessee Valley Authority	GE	1974		Canceled, 1982.
Pilgrim 1	655	Boston Edison Co.	GE	1965	1972	Operating. 6/8/2012.
Pilgrim 2	1,150	Boston Edison Co.	C-E	1972		Canceled, 1981.
Point Beach 1	497	Wisconsin Electric Power Co.	W	1966	1970	Operating. 10/5/2010.
Point Beach 2	497	Wisconsin Electric Power Co.	W	1967	1973	Operating. 3/8/2013.
Prairie Island 1	530	Northern States Power Co.	W	1967	1974	Operating. 8/9/2013.
Prairie Island 2	530	Northern States Power Co.	W	1967	1974	Operating. 10/29/2014.
Quad Cities 1	789	Commonwealth Edison Co.	GE	1966	1972	Operating. 12/14/2012.
Quad Cities 2	789	Commonwealth Edison Co.	GE	1966	1972	Operating. 12/14/2012.
Quanicassee 1	1,150	Consumers Power Co.	W	1972		Canceled, 1974.
Quanicassee 2	1,150	Consumers Power Co.	W	1972		Canceled, 1974.
Rancho Seco 1	918	Sacramento Municipal Utility District	B&W	1967	1974	Shut down, 1989. SAFSTOR decommissioning plan approved in 1995.
River Bend 1	934	Gulf States Utilities Co.	GE	1972	1985	Operating. 8/29/2025.
River Bend 2	934	Gulf States Utilities Co.	GE	1973		Canceled, 1984.
Robert E. Ginna	470	GPU Nuclear Corp.	W	1965	1969	Operating. 9/18/2009.
Salem 1	1,090	Public Service Electric & Gas Co.	W	1966	1976	Operating. 8/13/2016.
Salem 2	1,115	Public Service Electric & Gas Co.	W	1967	1981	Operating. 4/18/2020.
San Onofre 1	436	Southern California Edison Co.	W	1963	1967	Shut down, 1992. Decommissioning plan submitted in 1994.
San Onofre 2	1,070	Southern California Edison Co.	C-E	1970	1982	Operating. 10/18/2013.
San Onofre 3	1,080	Southern California Edison Co.	C-E	1970	1983	Operating. 10/18/2013.
Seabrook 1	1,198	Public Service Co. of New Hampshire	W	1972	1990	Operating. 10/17/2026.

See notes at end of table

Table C1. Nuclear Units Ordered in the United States, 1953-1996 (Continued)

Unit Name	Design Capacity (MWe)	Utility	Reactor Supplier[a]	Year of Order	Year of Grid Connection	Current Status and Scheduled Shutdown Date (December 31, 1996)
Seabrook 2	1,198	Public Service Co. of New Hampshire	W	1972		Canceled, 1988.
Sears Isle	1,150	Central Maine Power	W	1974		Canceled, 1977
Sequoyah 1	1,148	Tennessee Valley Authority	W	1968	1980	Operating. 9/17/2020.
Sequoyah 2	1,148	Tennessee Valley Authority	W	1968	1981	Operating. 9/15/2021.
Shearon Harris 1	915	Carolina Power & Light Co.	W	1971	1987	Operating. 10/24/2026.
Shearon Harris 2	915	Carolina Power & Light Co.	W	1971		Canceled, 1983.
Shearon Harris 3	900	Carolina Power & Light Co.	W	1971		Canceled, 1981.
Shearon Harris 4	900	Carolina Power & Light Co.	W	1971		Canceled, 1981.
Shippingport	60	Atomic Energy Agency	W	1953	N/A	Shut down, 1974. Resumed operation in 1977 as a light-water breeder reactor. Retired in 1982.
Shoreham	820	Long Island Lighting Co.	GE	1967	1989	Shut down, 1989. Decommissioning completed and license terminated in 1995.
Skagit-Hanford 1	1,277	Puget Sound Power & Light Co.	GE	1973		Canceled, 1983.
Skagit-Hanford 2	1,277	Puget Sound Power & Light Co.	GE	1974		Canceled, 1983.
Somerset 1	1,200	New York State Electric & Gas	GE	1974		Canceled, 1975.
Somerset 2	1,200	New York State Electric & Gas	GE	1974		Canceled, 1975.
South Dade 1	1,100	Florida Power & Light Co.		1975		Canceled, 1977.
South Dade 2	1,100	Florida Power & Light Co.	W	1975		Canceled, 1977.
South River 1	1,150	Carolina Power & Light Co.	B&W	1973		Canceled, 1978.
South River 2	1,150	Carolina Power & Light Co.	B&W	1973		Canceled, 1978.
South River 3	1,150	Carolina Power & Light Co.	G&W	1973		Canceled, 1978.
South Texas 1	1,250	Houston Light & Power Co.	W	1973	1988	Operating. 3/1/2016.
South Texas 2	1,250	Houston Light & Power Co.	W	1973	1989	Operating. 4/6/2023.
Stanislaus 1	1,200	Pacific Gas & Electric	GE	1971		Canceled, 1979.
Stanislaus 2	1,200	Pacific Gas & Electric	GE	1971		Canceled, 1979.
Sterling	1,150	Rochester Gas & Electric Co.	W	1973		Canceled, 1980.
St. Lucie 1	830	Florida Power & Light Co.	C-E	1967	1976	Operating. 3/1/2016
St. Lucie 2	804	Florida Power & Light Co.	C-E	1972	1983	Operating. 4/6/2023.
St. Rosalie 1	1,160	Louisiana Power & Light	GA	1974		Canceled, 1975.
St. Rosalie 2	1,160	Louisiana Power & Light	GA	1974		Canceled, 1975.
Summer 1	900	South Carolina Electric & Gas Co.	W	1971	1982	Operating. 8/6/2022.
Summit 1	770	Delmarva Power & Light Co.	GA	1971		Canceled, 1975.
Summit 2	770	Delmarva Power & Light Co.	GA	1971		Canceled, 1975.

See notes at end of table

Table C1. Nuclear Units Ordered in the United States, 1953-1996 (Continued)

Unit Name	Design Capacity (MWe)	Utility	Reactor Supplier[a]	Year of Order	Year of Grid Connection	Current Status and Scheduled Shutdown Date (December 31, 1996)
Sundesert 1	974	San Diego Gas & Electric Co.	W	1975		Canceled, 1978.
Sundesert 2	974	San Diego Gas & Electric Co.	W	1975		Canceled, 1978.
Surry 1	788	Virginia Electric & Power Co.	W	1966	1972	Operating. 5/25/2012.
Surry 2	788	Virginia Electric & Power Co.	W	1966	1973	Operating. 1/29/2013.
Surry 3	859	Virginia Electric & Power Co.	B&W	1972		Canceled, 1977.
Surry 4	859	Virginia Electric & Power Co.	B&W	1972		Canceled, 1977.
Susquehanna 1	1,065	Pennsylvania Power & Light Co.	GE	1968	1982	Operating. 7/17/2022.
Susquehanna 2	1,052	Pennsylvania Power & Light Co.	GE	1968	1984	Operating. 3/23/2024.
Three Mile Island 1	819	GPU Nuclear Corp.	B&W	1966	1974	Operating. 4/19/2014.
Three Mile Island 2	906	GPU Nuclear Corp.	B&W	1967	1978	Shut down due to 1979 accident. License amended to possession only status in 1993.
Trojan	1,130	Portland General Electric	W	1968	1975	Shut down, 1992. Decommissioning plan approved in 1996.
Turkey Point 3	693	Florida Power & Light Co.	W	1965	1972	Operating. 7/19/2012.
Turkey Point 4	693	Florida Power & Light Co.	W	1967	1973	Operating. 4/10/2013.
Tyrone 1	1,100	Northern States Power Co.	W	1973		Canceled, 1979.
Tyrone 2	1,150	Northern States Power Co.	W	1973		Canceled, 1974.
Vandalia (Iowa 1)	1,270	Iowa Power & Light Co.	B&W	1976		Canceled, 1982.
Vermont Yankee	514	Vermont Yankee Nuclear Power Co.	GE	1966	1973	Operating. 3/21/2012.
Verplanck 1	1,115	Consolidated Edison Co.	GE	1968		Canceled, 1972.
Verplanck 2	1,115	Consolidated Edison Co.	GE	1968		Canceled, 1972.
Vidal 1	770	Southern California Edison Co.	GA	1972		Canceled, 1974.
Vidal 2	770	Southern California Edison Co.	GA	1972		Canceled, 1974.
Vogtle 1	1,210	Georgia Power Co.	W	1971	1987	Operating. 1/16/2027.
Vogtle 2	1,210	Georgia Power Co.	W	1971	1989	Operating. 2/9/2029.
Vogtle 3	1,113	Georgia Power Co.	W	1973		Canceled, 1974.
Vogtle 4	1,113	Georgia Power Co.	W	1973		Canceled, 1974.
Waterford 3	1,151	Louisiana Power & Light Co.	C-E	1970	1985	Operating. 12/18/2024.
Watts Bar 1	1,165	Tennessee Valley Authority	W	1970	1996	Operating. 11/9/2035.
Watts Bar 2	1,165	Tennessee Valley Authority	W	1970		Indefinitely deferred.
WNP 1	1,266	Washington Public Power Supply System	B&W	1972		Canceled, 1995.
WNP 2	1,100	Washington Public Power Supply System	GE	1971	1984	Operating. 12/20/2023.

See notes at end of table

Table C1. Nuclear Units Ordered in the United States, 1953-1996 (Continued)

Unit Name	Design Capacity (MWe)	Utility	Reactor Supplier[a]	Year of Order	Year of Grid Connection	Current Status and Scheduled Shutdown Date (December 31, 1996)
WNP 3	1,242	Washington Public Power Supply System	C-E	1973		Canceled, 1995.
WNP 4	1,218	Washington Public Power Supply System	B&W	1974		Canceled, 1982.
WNP 5	1,240	Washington Public Power Supply System	C-E	1974		Canceled, 1982.
Wolf Creek	1,150	Wolf Creek Nuclear Operating Co.	W	1973	1985	Operating. 3/11/2025.
Yankee Rowe 1	175	Yankee Atomic Electric	W	1956	1960	Shut down, 1991. SAFSTOR/DECON decommissioning plan approved, 1995.
Yellow Creek 1	1,285	Tennessee Valley Authority	C-E	1974		Canceled, 1984.
Yellow Creek 2	1,285	Tennessee Valley Authority	C-E	1974		Canceled, 1984.
Zimmer 1	810	Cincinnati Gas & Electric Co.	GE	1969		Canceled, 1984.
Zimmer 2	1,170	Cincinnati Gas & Electric Co.	GE	1974		Canceled, 1978.
Zion 1	1,040	Commonwealth Edison Co.	W	1967	1973	Operating. 4/6/2013.
Zion 2	1,040	Commonwealth Edison Co.	W	1967	1973	Operating. 11/14/2013.

Operable . . . . **110**[c]

Indefinitely Deferred **3**

Shut down **13**

Canceled **123**

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[a] Reactor Suppliers: A-C, Allis-Chalmers; B&W, Babcock & Wilcox Co.; C-E, Combustion Engineering, Inc.; GA, General Atomic Company; GE, General Electric Co.; W, Westinghouse Corp.

[b] Big Rock Points utility, Consumers Power Co., announced that the unit will permanently cease operation on August 30, 1997.

[c] Brown's Ferry 1 retains an operating license; however, there are no plans to restart it.

[d] Haddam Neck's operator Connecticut Yankee Atomic Co., brought the unit down for refueling in September 1996, but then announced in December 1996 that it would not bring the unit back on line.

[e] Unit placed in cold standby status by the Department of Energy, February 1988.

N/A = Not available.

Notes: *DECON* is immediate dismantlement and decontamination, the equipment, structure, and portions of the facility containing radioactive contaminants are removed to a level that permits the site to be released for unrestricted use and termination of the license. *SAFSTOR* is often considered "delayed DECON," a nuclear facility maintained in a condition that allows the decay of radioactivity to reduce radiation levels at a facility; afterwards, the same procedure is followed as under DECON.

Sources: Energy Information Administration (EIA), *U.S. Commercial Nuclear Power*, DOE/EIA-0315 (Washington, DC, November 1984); EIA, *Nuclear Plant Cancellations: Causes, Costs, and Consequences*, DOE/EIA-0392 (Washington, DC, April 1983); EIA, *Nuclear Power Generation and Fuel Cycle Report 1996*, DOE/EIA-0436 (Washington, DC, October 1996); Nuclear Regulatory Commission, *1997 Information Digest*, NUREG-0350, (Washington, DC, July 1997).

Appendix D

World Nuclear Units Operable as of December 31, 1996

Appendix D

World Nuclear Units Operable as of December 31, 1996

Table D1. Roster of Nuclear Units Operable as of December 31, 1996

Country	Unit Name[a]	Location	Capacity (net MWe)[b]	Utility[c]	Reactor Type[d]	Reactor Supplier[e]	Date of Operation[f]
Argentina	Atucha 1	Lima, Buenos Aires	335	CN	PHWR	SIEM	03/74
	Embalse	Rio Tercero, Cordoba	600	CN	PHWR	AECL	04/83
	Total: 2 Units		**935**				
Armenia	Medzamor 2	Metsamor, Armenia	376	MA	PWR	AEE	11/95
	Total: 1 Unit		**376**				
Belgium	Doel 1	Doel, East Flanders	392	EL	PWR	ACW	08/74
	Doel 2	Doel, East Flanders	392	EL	PWR	ACW	08/75
	Doel 3	Doel, East Flanders	1006	EL	PWR	FRAM/ACW	06/82
	Doel 4	Doel, East Flanders	985	EL	PWR	ACW	04/85
	Tihange 1	Huy, Leige	962	EL	PWR	ACLF	03/75
	Tihange 2	Huy, Leige	960	EL	PWR	FRAM/ACW	10/82
	Tihange 3	Huy, Leige	1,015	EL	PWR	ACW	06/85
	Total: 7 Units		**5,712**				
Brazil	Angra 1	Itaorna, Rio de Janeiro	626	FN	PWR	WEST	04/82
	Total: 1 Unit		**626**				
Bulgaria	Kozloduy 1	Kozloduy, Vratsa	408	EA	PWR	AEE	07/74
	Kozloduy 2	Kozloduy, Vratsa	408	EA	PWR	AEE	10/75
	Kozloduy 3	Kozloduy, Vratsa	408	EA	PWR	AEE	12/80
	Kozloduy 4	Kozloduy, Vratsa	408	EA	PWR	AEE	05/82
	Kozloduy 5	Kozloduy, Vratsa	953	EA	PWR	AEE	11/87
	Kozloduy 6	Kozloduy, Vratsa	953	EA	PWR	AEE	08/91
	Total: 6 Units		**3,538**				
Canada	Bruce 1	Tiverton, Ontario	848	OH	PHWR	OH/AECL	01/77
	Bruce 3	Tiverton, Ontario	848	OH	PHWR	OH/AECL	12/77
	Bruce 4	Tiverton, Ontario	848	OH	PHWR	OH/AECL	12/78
	Bruce 5	Tiverton, Ontario	860	OH	PHWR	OH/AECL	12/84
	Bruce 6	Tiverton, Ontario	860	OH	PHWR	OH/AECL	06/84
	Bruce 7	Tiverton, Ontario	860	OH	PHWR	OH/AECL	02/86
	Bruce 8	Tiverton, Ontario	860	OH	PHWR	OH/AECL	03/87
	Darlington 1	Newcastle Township, Ontario	881	OH	PHWR	OH/AECL	12/90
	Darlington 2	Newcastle Township, Ontario	881	OH	PHWR	OH/AECL	01/90
	Darlington 3	Newcastle Township, Ontario	881	OH	PHWR	OH/AECL	12/92

See notes at end of table.

Table D1. Roster of Nuclear Units as of December 31, 1996 (Continued)

Country	Unit Name[a]	Location	Capacity (net MWe)[b]	Utility[c]	Reactor Type[d]	Reactor Supplier[e]	Date of Operation[f]
Canada (continued)	Darlington 4	Newcastle Township, Ontario	881	OH	PHWR	OH/AECL	04/93
	Gentilly 2	Becancour, Quebec	635	HQ	PHWR	AECL	12/82
	Pickering 1	Pickering, Ontario	515	OH	PHWR	OH/AECL	04/71
	Pickering 2	Pickering, Ontario	515	OH	PHWR	OH/AECL	10/71
	Pickering 3	Pickering, Ontario	515	OH	PHWR	OH/AECL	05/72
	Pickering 4	Pickering, Ontario	515	OH	PHWR	OH/AECL	05/73
	Pickering 5	Pickering, Ontario	516	OH	PHWR	OH/AECL	12/82
	Pickering 6	Pickering, Ontario	516	OH	PHWR	OH/AECL	11/83
	Pickering 7	Pickering, Ontario	516	OH	PHWR	OH/AECL	11/84
	Pickering 8	Pickering, Ontario	516	OH	PHWR	OH/AECL	01/86
	Point Lepreau	Bay of Fundy, New Brunswick	635	NB	PHWR	AECL	09/82
	Total: 21 Units		**14,902**				
China	Guangdong 1	Shenzhen, Guangdong	944	GV	PWR	FRAM	09/93
	Guangdong 2	Shenzhen, Guangdong	944	GV	PWR	FRAM	02/94
	Qinshan 1	Haiyan, Zhejiang	279	QN	PWR	CNNC	12/91
	Total: 3 Units		**2,167**				
Czech Republic	Dukovany 1	Trebic, Jihomoravsky	412	ED	PWR	SKODA	02/85
	Dukovany 2	Trebic, Jihomoravsky	412	ED	PWR	SKODA	01/86
	Dukovany 3	Trebic, Jihomoravsky	412	ED	PWR	SKODA	11/86
	Dukovany 4	Trebic, Jihomoravsky	412	ED	PWR	SKODA	06/87
	Total: 4 Units		**1,648**				
Finland	Loviisa 1	Loviisa, Uusimaa	445	IV	PWR	AEE	02/77
	Loviisa 2	Loviisa, Uusimaa	445	IV	PWR	AEE	11/80
	TVO 1	Olkiluoto, Turku Pori	755	TV	BWR	A-A	09/78
	TVO 2	Olkiluoto, Turku Pori	710	TV	BWR	A-A	02/80
	Total: 4 Units		**2,355**				
France	Belleville 1	Loire, Cher	1,310	EF	PWR	FRAM	10/87
	Belleville 2	Loire, Cher	1,310	EF	PWR	FRAM	07/88
	Blayais 1	Blaye, Gironde	910	EF	PWR	FRAM	06/81
	Blayais 2	Blaye, Gironde	910	EF	PWR	FRAM	07/82
	Blayais 3	Blaye, Gironde	910	EF	PWR	FRAM	08/83
	Blayais 4	Blaye, Gironde	910	EF	PWR	FRAM	05/83
	Bugey 2	Loyettes, Ain	920	EF	PWR	FRAM	05/78
	Bugey 3	Loyettes, Ain	920	EF	PWR	FRAM	09/78
	Bugey 4	Loyettes, Ain	900	EF	PWR	FRAM	03/79
	Bugey 5	Loyettes, Ain	900	EF	PWR	FRAM	07/79
	Cattenom 1	Cattenom, Moselle	1,300	EF	PWR	FRAM	11/86
	Cattenom 2	Cattenom, Moselle	1,300	EF	PWR	FRAM	09/87
	Cattenom 3	Cattenom, Moselle	1,300	EF	PWR	FRAM	07/90
	Cattenom 4	Cattenom, Moselle	1,300	EF	PWR	FRAM	05/91
	Chinon B1	Chinon, Indre-et-Loire	905	EF	PWR	FRAM	11/82
	Chinon B2	Chinon, Indre-et-Loire	870	EF	PWR	FRAM	11/83
	Chinon B3	Chinon, Indre-et-Loire	905	EF	PWR	FRAM	10/86

See notes at end of table.

Table D1. Roster of Nuclear Units as of December 31, 1996 (Continued)

Country	Unit Name[a]	Location	Capacity (net MWe)[b]	Utility[c]	Reactor Type[d]	Reactor Supplier[e]	Date of Operation[f]
France	Chinon B4	Chinon, Indre-et-Loire	905	EF	PWR	FRAM	11/87
(continued)	Chooz B1	Chooz, Ardennes	1,455	EF	PWR	FRAM	08/96
	Creys-Malville	Bouvesse, Isere	1,200	CR	FBR	NOVA	01/86
	Cruas 1	Cruas, Ardeche	915	EF	PWR	FRAM	04/83
	Cruas 2	Cruas, Ardeche	915	EF	PWR	FRAM	09/84
	Cruas 3	Cruas, Ardeche	880	EF	PWR	FRAM	05/84
	Cruas 4	Cruas, Ardeche	880	EF	PWR	FRAM	10/84
	Dampierre 1	Ouzouer, Loiret	890	EF	PWR	FRAM	03/80
	Dampierre 2	Ouzouer, Loiret	890	EF	PWR	FRAM	12/80
	Dampierre 3	Ouzouer, Loiret	890	EF	PWR	FRAM	01/81
	Dampierre 4	Ouzouer, Loiret	890	EF	PWR	FRAM	08/81
	Fessenheim 1	Fessenheim, Haut-Rhin	880	EF	PWR	FRAM	04/77
	Fessenheim 2	Fessenheim, Haut-Rhin	880	EF	PWR	FRAM	10/77
	Flamanville 1	Flamanville, Manche	1,330	EF	PWR	FRAM	12/85
	Flamanville 2	Flamanville, Manche	1,330	EF	PWR	FRAM	07/86
	Golfech 1	Valence, Tarn et Garonne	1,310	EF	PWR	FRAM	06/90
	Golfech 2	Valence, Tarn et Garonne	1,310	EF	PWR	FRAM	06/93
	Gravelines 1	Gravelines, Nord	910	EF	PWR	FRAM	03/80
	Gravelines 2	Gravelines, Nord	910	EF	PWR	FRAM	08/80
	Gravelines 3	Gravelines, Nord	910	EF	PWR	FRAM	12/80
	Gravelines 4	Gravelines, Nord	910	EF	PWR	FRAM	06/81
	Gravelines 5	Gravelines, Nord	910	EF	PWR	FRAM	08/84
	Gravelines 6	Gravelines, Nord	910	EF	PWR	FRAM	08/85
	Nogent 1	Nogent sur Seine, Aube	1,310	EF	PWR	FRAM	10/87
	Nogent 2	Nogent sur Seine, Aube	1,310	EF	PWR	FRAM	12/88
	Paluel 1	Veulettes, Seine-Maritime	1,330	EF	PWR	FRAM	06/84
	Paluel 2	Veulettes, Seine-Maritime	1,330	EF	PWR	FRAM	09/84
	Paluel 3	Veulettes, Seine-Maritime	1,330	EF	PWR	FRAM	09/85
	Paluel 4	Veulettes, Seine-Maritime	1,330	EF	PWR	FRAM	04/86
	Penley 1	St.-Martin-en, Seine-Maritime	1,330	EF	PWR	FRAM	05/90
	Penley 2	St.-Martin-en, Seine-Maritime	1,330	EF	PWR	FRAM	02/92
	Phenix	Marcoule, Gard	233	CE/EF	FBR	CNIM	12/73
	Saint-Alban 1	Auberives, Isere	1,335	EF	PWR	FRAM	08/85
	Saint-Alban 2	Auberives, Isere	1,335	EF	PWR	FRAM	07/86
	Saint-Laurent B1	St-Laurent-des-Eaux, Loir-et-Cher	915	EF	PWR	FRAM	01/81
	Saint-Laurent B2	St-Laurent-des-Eaux, Loir-et-Cher	880	EF	PWR	FRAM	06/81
	Tricastin 1	Pierrelatte, Drome	915	EF	PWR	FRAM	05/80
	Tricastin 2	Pierrelatte, Drome	915	EF	PWR	FRAM	08/80
	Tricastin 3	Pierrelatte, Drome	915	EF	PWR	FRAM	02/81
	Tricastin 4	Pierrelatte, Drome	915	EF	PWR	FRAM	06/81
	Total: 57 Units		**59,948**				
Germany	Biblis A	Biblis, Hessen	1,167	RW	PWR	KWU	08/74
	Biblis B	Biblis, Hessen	1,240	RW	PWR	KWU	04/76
	Brokdorf (KBR)	Brokdorf, Schleswig-Holstein	1,326	BK	PWR	KWU	10/86

See notes at end of table.

Table D1. Roster of Nuclear Units as of December 31, 1996 (Continued)

Country	Unit Name[a]	Location	Capacity (net MWe)[b]	Utility[c]	Reactor Type[d]	Reactor Supplier[e]	Date of Operation[f]
Germany (continued)	Brunsbuettel (KKB)	Brunsbuettel, Schleswig-Holstein	771	KG	BWR	KWU	07/76
	Emsland (KKE)	Lingen, Niedersachsen	1,290	KN	PWR	SIEM/KWU	04/88
	Grafenrheinfeld (KKG)	Grafenrheinfeld, Bayem	1,275	BY	PWR	KWU	12/81
	Grohnde (KWG)	Emmerthal, Niedersachsen	1,360	GG	PWR	KWU	09/84
	Gundremmingen B	Gundremmingen, Bayem	1,284	KE	BWR	KWU	03/84
	Gundremmingen C	Gundremmingen, Bayem	1,288	KE	BWR	KWU	11/84
	Isar 1 (KKI)	Essenbach, Bayem	870	KI	BWR	KWU	12/77
	Isar 2 (KKI)	Essenbach, Bayem	1,365	KJ	PWR	SIEM/KWU	01/88
	Kruemmel (KKK)	Geesthacht, Schleswig-Holsten	1,260	KK	BWR	KWU	09/83
	Muelheim-Kaerlich	Rheinland, Pfalz	1,219	RW	PWR	BBR	03/86
	Neckarwestheim (GKN) 1	Neckarwestheim, Baden-Wuerttemberg	785	GK	PWR	KWU	07/76
	Neckarwestheim (GKN) 2	Neckarwestheim, Baden-Wuerttemberg	1,269	GK	PWR	SIEM/KWU	01/89
	Obrigheim (KWO)	Obrigheim, Baden-Wuerttemberg	340	KO	PWR	SIEM/KWU	10/68
	Philippsburg 1 (KKP)	Philippsburg, Baden-Wuerttemberg	890	KP	BWR	KWU	05/79
	Philippsburg 2 (KKP)	Philippsburg, Baden-Wuerttemberg	1,358	KP	PWR	KWU	12/84
	Stade (KKS)	Stade, Niedersachsen	640	KS	PWR	SIEM/KWU	01/72
	Unterweser (KKU)	Rodenkirchen, Niedersachsen	1,285	KU	PWR	KWU	09/78
	Total: 20 Units		**22,282**				
Hungary	Paks 1	Paks, Tolna	430	PK	PWR	AEE	12/82
	Paks 2	Paks, Tolna	433	PK	PWR	AEE	09/84
	Paks 3	Paks, Tolna	433	PK	PWR	AEE	09/86
	Paks 4	Paks, Tolna	433	PK	PWR	AEE	08/87
	Total: 4 Units		**1,729**				
India	Kakrapar 1	Kakrapar, Gujarat	202	NP	PHWR	DAE/NPCIL	11/92
	Kakrapar 2	Kakrapar, Gujarat	202	NP	PHWR	DAEC/NPCIL	03/95
	Kalpakkam 1	Kalpakkam, Tamil Nadu	155	NP	PHWR	DAE	07/83
	Kalpakkam 2	Kalpakkam, Tamil Nadu	155	NP	PHWR	DAE	09/85
	Narora 1	Narora, Uttar Pradesh	202	NP	PHWR	DAE/NPCIL	07/89
	Narora 2	Narora, Uttar Pradesh	202	NP	PHWR	DAE/NPCIL	01/92
	Rajasthan 1	Kota, Rajasthan	90	NP	PHWR	AECL	11/72
	Rajasthan 2	Kota, Rajasthan	187	NP	PHWR	AECL/DAE	11/80
	Tarapur 1	Tarapur, Maharashtra	150	NP	BWR	GE	04/69
	Tarapur 2	Tarapur, Maharashtra	150	NP	BWR	GE	05/69
	Total: 10 Units		**1,695**				
Japan	Fugen ATR	Tsuruga, Fukui	148	PF	HWLWR	HIT	07/78
	Fukushima-Daiichi 1	Ohkuma, Fukushima	439	TP	BWR	GE	11/70
	Fukushima-Daiichi 2	Ohkuma, Fukushima	760	TP	BWR	GE	12/73
	Fukushima-Daiichi 3	Ohkuma, Fukushima	760	TP	BWR	TOS	10/74

See notes at end of table.

Table D1. Roster of Nuclear Units as of December 31, 1996 (Continued)

Country	Unit Name[a]	Location	Capacity (net MWe)[b]	Utility[c]	Reactor Type[d]	Reactor Supplier[e]	Date of Operation[f]
Japan	Fukushima-Daiichi 4	Ohkuma, Fukushima	760	TP	BWR	HIT	02/78
(continued)	Fukushima-Daiichi 5	Ohkuma, Fukushima	760	TP	BWR	TOS	09/77
	Fukushima-Daiichi 6	Ohkuma, Fukushima	1,067	TP	BWR	GE	05/79
	Fukushima-Daini 1	Naraha, Fukushima	1,067	TP	BWR	TOS	07/81
	Fukushima-Daini 2	Naraha, Fukushima	1,067	TP	BWR	HIT	06/83
	Fukushima-Daini 3	Naraha, Fukushima	1,067	TP	BWR	TOS	12/84
	Fukushima-Daini 4	Naraha, Fukushima	1,067	TP	BWR	HIT	12/86
	Genkai 1	Genkai, Saga	529	KY	PWR	MHI	02/75
	Genkai 2	Genkai, Saga	529	KY	PWR	MHI	06/80
	Genkai 3	Genkai, Saga	1,127	KY	PWR	MHI	06/93
	Genkai 4	Genkai, Saga	1,127	KY	PWR	MHI	11/96
	Hamaoka 1	Hamaoka-cho, Shizuoka	515	CB	BWR	TOS	08/74
	Hamaoka 2	Hamaoka-cho, Shizuoka	806	CB	BWR	TOS	05/78
	Hamaoka 3	Hamaoka-cho, Shizuoka	1,056	CB	BWR	TOS	01/87
	Hamaoka 4	Hamaoka-cho, Shizuoka	1,092	CB	BWR	TOS	01/93
	Ikata 1	Ikata-cho, Ehime	538	SH	PWR	MHI	02/77
	Ikata 2	Ikata-cho, Ehime	538	SH	PWR	MHI	08/81
	Ikata 3	Ikata-cho, Ehime	846	SH	PWR	MHI	06/94
	Kashiwazaki Kariwa 1	Kashiwazaki, Niigata	1,067	TP	BWR	TOS	02/85
	Kashiwazaki Kariwa 2	Kashiwazaki, Niigata	1,067	TP	BWR	TOS	02/90
	Kashiwazaki Kariwa 3	Kashiwazaki, Niigata	1,067	TP	BWR	TOS	12/92
	Kashiwazaki Kariwa 4	Kashiwazaki, Niigata	1,067	TP	BWR	HIT	12/93
	Kashiwazaki Kariwa 5	Kashiwazaki, Niigata	1,067	TP	BWR	HIT	09/89
	Kashiwazaki Kariwa 6	Kashiwazaki, Niigata	1,315	TP	BWR	TOS/GE	01/96
	Mihama 1	Mihama-cho, Fukui	320	KA	PWR	WEST	08/70
	Mihama 2	Mihama-cho, Fukui	470	KA	PWR	WEST/MHI	04/72
	Mihama 3	Mihama-cho, Fukui	780	KA	PWR	MHI	02/76
	Monju	Tsuruga, Fukui	246	PF	FBR	MHI	02/94
	Ohi 1	Ohi-cho, Fukui	1,120	KA	PWR	WEST	12/77
	Ohi 2	Ohi-cho, Fukui	1,120	KA	PWR	WEST	10/78
	Ohi 3	Ohi-cho, Fukui	1,127	KA	PWR	MHI	06/91
	Ohi 4	Ohi-cho, Fukui	1,127	KA	PWR	MHI	06/92
	Onagawa 1	Onagawa, Miyagi	498	TC	BWR	TOS	11/83
	Onagawa 2	Onagawa, Miyagi	796	TC	BWR	TOS	12/94
	Sendai 1	Sendai, Kagoshima	846	KY	PWR	MHI	09/83
	Sendai 2	Sendai, Kagoshima	846	KY	PWR	MHI	04/85
	Shika 1	Shika-machi, Ishikawa	513	HU	BWR	HIT	01/93
	Shimane 1	Kashima-cho, Shimane	439	CK	BWR	HIT	12/73
	Shimane 2	Kashima-cho, Shimane	791	CK	BWR	HIT	07/88
	Takahama 1	Takahama-cho, Fukui	780	KA	PWR	WEST	03/74
	Takahama 2	Takahama-cho, Fukui	780	KA	PWR	MHI	01/75
	Takahama 3	Takahama-cho, Fukui	830	KA	PWR	MHI	05/84
	Takahama 4	Takahama-cho, Fukui	830	KA	PWR	MHI	11/84
	Tokai 1	Tokai Mura, Ibaraki	159	JP	GCR	GEC	11/65
	Tokai 2	Tokai Mura, Ibaraki	1,080	JP	BWR	GE	03/78
	Tomari 1	Tomari-mura, Hokkaido	550	HD	PWR	MHI	12/88
	Tomari 2	Tomari-mura, Hokkaido	550	HD	PWR	MHI	08/90
	Tsuruga 1	Tsuruga, Fukui	341	JP	BWR	GE	11/69
	Tsuruga 2	Tsuruga, Fukui	1,115	JP	PWR	MHI	06/86
	Total: 53 Units		**42,369**				

See notes at end of table.

Table D1. Roster of Nuclear Units as of December 31, 1996 (Continued)

Country	Unit Name[a]	Location	Capacity (net MWe)[b]	Utility[c]	Reactor Type[d]	Reactor Supplier[e]	Date of Operation[f]
Kazakhstan	BN 350	Aktau, Mangyshlak	70	KZ	FBR	N/A	07/73
	Total: 1 Unit		**70**				
Korea, South	Kori 1	Kori, Kyongnam	556	KR	PWR	WEST	06/77
	Kori 2	Kori, Kyongnam	605	KR	PWR	WEST	04/83
	Kori 3	Kori, Kyongnam	895	KR	PWR	WEST	01/85
	Kori 4	Kori, Kyongnam	895	KR	PWR	WEST	11/85
	Ulchin 1	Ulchin, Kyongbuk	920	KR	PWR	FRAM	04/88
	Ulchin 2	Ulchin, Kyongbuk	920	KR	PWR	FRAM	04/89
	Wolsong 1	Kyongju, Kyongbuk	629	KR	PHWR	AECL	12/82
	Yonggwang 1	Yonggwang, Chonnam	900	KR	PWR	WEST	03/86
	Yonggwang 2	Yonggwang, Chonnam	900	KR	PWR	WEST	11/86
	Yonggwang 3	Yonggwang, Chonnam	950	KR	PWR	KHIC/KAE	10/94
	Yonggwang 4	Yonggwang, Chonnam	950	KR	PWR	KHIC/KAE	07/95
	Total: 11 Units		**9,120**				
Lithuania	Ignalina 1	Snieckus, Lithuania	1,185	IN	LGR	MTM	12/83
	Ignalina 2	Snieckus, Lithuania	1,185	IN	LGR	MTM	08/87
	Total: 2 Units		**2,370**				
Mexico	Laguna Verde 1	Laguna Verde, Veracruz	654	FC	BWR	GE	04/89
	Laguna Verde 2	Laguna Verde, Veracruz	654	FC	BWR	GE	11/94
	Total: 2 Units		**1,308**				
Netherlands	Borssele	Borssele, Zeeland	449	PZ	PWR	KWU	07/73
	Dodewaard	Dodewaard, Gelderland	55	GN	BWR	GE	10/68
	Total: 2 Units		**504**				
Pakistan	Kanupp	Karachi, Sind	125	PA	PHWR	CGE	10/71
	Total: 1 Unit		**125**				
Romania	Cernavoda 1	Cernavoda, Constanta	650	RE	PHWR	AECL	07/96
	Total: 1 Unit		**650**				
Russia	Balakovo 1	Balakovo, Saratov	950	RC	PWR	MTM	12/85
	Balakovo 2	Balakovo, Saratov	950	RC	PWR	MTM	10/87
	Balakovo 3	Balakovo, Saratov	950	RC	PWR	MTM	12/88
	Balakovo 4	Balakova, Saratov	950	RC	PWR	MTM	04/93
	Beloyarsky 3 (BN600)	Zarechnyy, Sverdlovsk	560	RC	FBR	MTM	04/80
	Bilibino A	Bilibino, Chukotka, Russia	11	RC	LGR	MTM	01/74
	Bilibino B	Bilibino, Chukotka, Russia	11	RC	LGR	MTM	12/74
	Bilibino C	Bilibino, Chukotka, Russia	11	RC	LGR	MTM	12/75
	Bilibino D	Bilibino, Chukotka, Russia	11	RC	LGR	MTM	12/76
	Kalinin 1	Udomlya, Tver	950	RC	PWR	MTM	05/84
	Kalinin 2	Udomlya, Tver	950	RC	PWR	MTM	12/86
	Kola 1	Polyarnyye Zori, Murmansk	411	RC	PWR	MTM	06/73
	Kola 2	Polyarnyye Zori, Murmansk	411	RC	PWR	MTM	12/74

See notes at end of table.

Table D1. Roster of Nuclear Units as of December 31, 1996 (Continued)

Country	Unit Name[a]	Location	Capacity (net MWe)[b]	Utility[c]	Reactor Type[d]	Reactor Supplier[e]	Date of Operation[f]
Russia	Kola 3	Polyarnyye Zori, Murmansk	411	RC	PWR	MTM	03/81
(continued)	Kola 4	Polyarnyye Zori, Murmansk	411	RC	PWR	MTM	10/84
	Kursk 1	Kurchatov, Kursk	925	RC	LGR	MTM	12/76
	Kursk 2	Kurchatov, Kursk	925	RC	LGR	MTM	01/79
	Kursk 3	Kurchatov, Kursk	925	RC	LGR	MTM	10/83
	Kursk 4	Kurchatov, Kursk	925	RC	LGR	MTM	12/85
	Leningrad 1	Sosnovyy Bor, St. Petersburg	925	LN	LGR	MTM	12/73
	Leningrad 2	Sosnovyy Bor, St. Petersburg	925	LN	LGR	MTM	07/75
	Leningrad 3	Sosnovyy Bor, St. Petersburg	925	LN	LGR	MTM	12/79
	Leningrad 4	Sosnovyy Bor, St. Petersburg	925	LN	LGR	MTM	02/81
	Novovoronezh 3	Novovoronezhskiy, Voronezh	385	RC	PWR	MTM	12/71
	Novovoronezh 4	Novovoronezhskiy, Voronezh	385	RC	PWR	MTM	12/72
	Novovoronezh 5	Novovoronezhskiy, Voronezh	950	RC	PWR	MTM	05/80
	Smolensk 1	Desnogorsk, Smolensk	925	RC	LGR	MTM	12/82
	Smolensk 2	Desnogorsk, Smolensk	925	RC	LGR	MTM	05/85
	Smolensk 3	Desnogorsk, Smolensk	925	RC	LGR	MTM	01/90
	Total: 29 Units		**19,843**				
Slovak Republic	Bohunice 1	Trnava, Zapadoslovensky	408	EB	PWR	AEE	12/78
	Bohunice 2	Trnava, Zapadoslovensky	408	EB	PWR	AEE	03/80
	Bohunice 3	Trnava, Zapadoslovensky	408	EB	PWR	SKODA	08/84
	Bohunice 4	Trnava, Zapadoslovensky	408	EB	PWR	SKODA	08/85
	Total: 4 Units		**1,632**				
Slovenia	Krsko	Krsko, Vrbina	632	NR	PWR	WEST	10/81
	Total: 1 Unit		**632**				
South Africa	Koeberg 1	Melkbosstrand, Capetown	921	EK	PWR	FRAM	04/84
	Koeberg 2	Melkbosstrand, Capetown	921	EK	PWR	FRAM	07/85
	Total: 2 Units		**1,842**				
Spain	Almaraz 1	Almaraz, Caceres	940	CS	PWR	WEST	05/81
	Almaraz 2	Almaraz, Caceres	900	CS	PWR	WEST	10/83
	Asco 1	Asco, Tarragona	917	AN	PWR	WEST	08/83
	Asco 2	Asco, Tarragona	936	AN	PWR	WEST	10/85
	Cofrentes	Cofrentes, Valencia	955	IB	BWR	GE	10/84
	Jose Cabrera 1 (Zorita)	Zorita, Guadalajara	153	UE	PWR	WEST	07/68
	Santa Maria de Garon	Santa Maria de Garona, Burgos	440	NU	BWR	GE	03/71
	Trillo 1	Trillo, Guadalajara	1,000	UE/IB/HC	PWR	KWU	05/88
	Vandellos 2	Vandellos, Tarragona	966	AV	PWR	WEST	12/87
	Total: 9 Units		**7,207**				

See notes at end of table.

Table D1. Roster of Nuclear Units as of December 31, 1996 (Continued)

Country	Unit Name[a]	Location	Capacity (net MWe)[b]	Utility[c]	Reactor Type[d]	Reactor Supplier[e]	Date of Operation[f]
Sweden	Barsebaeck 1	Barsebaeck, Malmohus	600	SY	BWR	A-A	05/75
	Barsebaeck 2	Barsebaeck, Malmohus	600	SY	BWR	A-A	03/77
	Forsmark 1	Forsmark, Uppsala	968	FK	BWR	A-A	06/80
	Forsmark 2	Forsmark, Uppsala	969	FK	BWR	A-A	01/81
	Forsmark 3	Forsmark, Uppsala	1,158	FK	BWR	A-A	03/85
	Oskarshamn 1	Oskarshamn, Kalmar	445	OK	BWR	A-A	08/71
	Oskarshamn 2	Oskarshamn, Kalmar	605	OK	BWR	A-A	10/74
	Oskarshamn 3	Oskarshamn, Kalmar	1,160	OK	BWR	A-A	03/85
	Ringhals 1	Varberg, Halland	830	VA	BWR	A-A	10/74
	Ringhals 2	Varberg, Halland	875	VA	PWR	WEST	08/74
	Ringhals 3	Varberg, Halland	915	VA	PWR	WEST	09/80
	Ringhals 4	Varberg, Halland	915	VA	PWR	WEST	06/82
	Total: 12 Units		**10,040**				
Switzerland	Beznau 1	Doettingen, Aargau	365	NK	PWR	WEST	07/69
	Beznau 2	Doettingen, Aargau	357	NK	PWR	WEST	10/71
	Goesgen	Daeniken, Solothurn	970	GP	PWR	KWU	02/79
	Leibstadt	Leibstadt, Aargau	1,030	LK	BWR	GETSCO	05/84
	Muehleberg	Muehleberg, Bern	355	BR	BWR	GETSCO	07/71
	Total: 5 Units		**3,077**				
Taiwan	Chinshan 1	Chinshan, Taipei	604	TW	BWR	GE	11/77
	Chinshan 2	Chinshan, Taipei	604	TW	BWR	GE	12/78
	Kuosheng 1	Kuosheng, Wang-Li, Taipei	948	TW	BWR	GE	05/81
	Kuosheng 2	Kuosheng, Wang-Li, Taipei	948	TW	BWR	GE	06/82
	Maanshan 1	Herng Chuen	890	TW	PWR	WEST	05/84
	Maanshan 2	Herng Chuen	890	TW	PWR	WEST	02/85
	Total: 6 Units		**4,884**				
Ukraine	Chernobyl 1	Pripyat, Kiev	725	GT	LGR	MTM	09/77
	Chernobyl 2	Pripyat, Kiev	925	GT	LGR	MTM	12/78
	Chernobyl 3	Pripyat, Kiev	925	GT	LGR	MTM	11/81
	Khmelnitski-1	Neteshin, Khmelnitski	950	GT	PWR	MTM	12/87
	Rovno 1	Kuznetsovsk, Rovno	363	GT	PWR	MTM	12/80
	Rovno 2	Kuznetsovsk, Rovno	377	GT	PWR	MTM	12/81
	Rovno 3	Kuznetsovsk, Rovno	950	MA	PWR	MTM	12/86
	South Ukraine 1	Konstantinovka, Nikolae	950	GT	PWR	MTM	12/82
	South Ukraine 2	Konstantinovka, Nikolae	950	GT	PWR	MTM	01/85
	South Ukraine 3	Konstantinovka, Nikolae	950	GT	PWR	MTM	09/89
	Zaporozhe 1	Energodar, Zaporozhe	950	GT	PWR	MTM	12/84
	Zaporozhe 2	Energodar, Zaporozhe	950	GT	PWR	MTM	07/85
	Zaporozhe 3	Energodar, Zaporozhe	950	GT	PWR	MTM	12/86
	Zaporozhe 4	Energodar, Zaporozhe	950	GT	PWR	MTM	12/87
	Zaporozhe 5	Energodar, Zaporozhe	950	GT	PWR	MTM	08/89
	Zaporozhe 6	Energodar, Zaporozhe	950	GT	PWR	MTM	10/95
	Total: 16 Units		**13,765**				

See notes at end of table.

Table D1. Roster of Nuclear Units as of December 31, 1996 (Continued)

Country	Unit Name[a]	Location	Capacity (net MWe)[b]	Utility[c]	Reactor Type[d]	Reactor Supplier[e]	Date of Operation[f]
United Kingdom	Bradwell 1	Bradwell, Essex	123	NE	GCR	TNPG	07/62
	Bradwell 2	Bradwell, Essex	123	NE	GCR	TNPG	07/62
	Calder Hall 1	Seascale, Cumbria	50	BF	GCR	UKAE	08/56
	Calder Hall 2	Seascale, Cumbria	50	BF	GCR	UKAE	02/57
	Calder Hall 3	Seascale, Cumbria	50	BF	GCR	UKAE	03/58
	Calder Hall 4	Seascale, Cumbria	50	BF	GCR	UKAE	04/59
	Chapelcross 1	Annan, Dumfriesshire	50	BF	GCR	UKAE	02/59
	Chapelcross 2	Annan, Dumfriesshire	50	BF	GCR	UKAE	07/59
	Chapelcross 3	Annan, Dumfriesshire	50	BF	GCR	UKAE	11/59
	Chapelcross 4	Annan, Dumfriesshire	50	BF	GCR	UKAE	01/60
	Dungeness A1	Lydd, Kent	220	NE	GCR	TNPG	09/65
	Dungeness A2	Lydd, Kent	220	NE	GCR	TNPG	11/65
	Dungeness B1	Lydd, Kent	555	NE	AGR	APC	04/83
	Dungeness B2	Lydd, Kent	555	NE	AGR	APC	12/85
	Hartlepool A1	Hartlepool, Cleveland	605	NE	AGR	NPC	08/83
	Hartlepool A2	Hartlepool, Cleveland	605	NE	AGR	NPC	10/84
	Heysham A1	Heysham, Lancashire	575	NE	AGR	NPC	07/83
	Heysham A2	Heysham, Lancashire	575	NE	AGR	NPC	10/84
	Heysham B1	Heysham, Lancashire	625	NE	AGR	NPC	07/88
	Heysham B2	Heysham, Lancashire	625	NE	AGR	NPC	11/88
	Hinkley Point A1	Hinkley Point, Somerset	235	NE	GCR	EBT	02/65
	Hinkley Point A2	Hinkley Point, Somerset	235	NE	GCR	EBT	03/65
	Hinkley Point B1	Hinkley Point, Somerset	610	NE	AGR	TNPG	10/76
	Hinkley Point B2	Hinkley Point, Somerset	610	NE	AGR	TNPG	02/76
	Hunterston B1	Ayrshire, Strathclyde	595	SC	AGR	TNPG	02/76
	Hunterston B2	Ayrshire, Strathclyde	595	SC	AGR	TNPG	03/77
	Oldbury 1	Oldbury, Avon	217	NE	GCR	TNPG	11/67
	Oldbury 2	Oldbury, Avon	217	NE	GCR	TNPG	04/68
	Sizewell A1	Sizewell, Suffolk	210	NE	GCR	EBT	01/66
	Sizewell A2	Sizewell, Suffolk	210	NE	GCR	EBT	04/66
	Sizewell B	Sizewell, Suffolk	1,188	NE	PWR	PPP	02/95
	Torness 1	Dunbar, East Lothian	625	SC	AGR	NNC	05/88
	Torness 2	Dunbar, East Lothian	625	SC	AGR	NNC	02/89
	Wylfa 1	Anglesey, Wales	475	NE	GCR	EBT	01/71
	Wylfa 2	Anglesey, Wales	475	NE	GCR	EBT	07/71
	Total: 35 Units		**12,928**				
United States	3 Mile Island 1	Middletown, Pennsylvania	786	GU	PWR	B&W	04/74
	Arkansas Nuclear 1	Russellville, Arkansas	836	AK	PWR	B&W	05/74
	Arkansas Nuclear 2	Russellville, Arkansas	858	AK	PWR	C-E	09/78
	Beaver Valley 1	Shippingport, Pennsylvania	810	DL	PWR	WEST	07/76
	Beaver Valley 2	Shippingport, Pennsylvania	820	DL	PWR	WEST	08/87
	Big Rock Point	Charlevoix, Michigan	67	CC	BWR	GE	08/62
	Braidwood 1	Braidwood, Illinois	1,090	CM	PWR	WEST	07/87
	Braidwood 2	Braidwood, Illinois	1,090	CM	PWR	WEST	05/88
	Browns Ferry 1	Decatur, Alabama	1,065	TN	BWR	GE	12/73
	Browns Ferry 2	Decatur, Alabama	1,065	TN	BWR	GE	08/74

See notes at end of table.

Table D1. Roster of Nuclear Units as of December 31, 1996 (Continued)

Country	Unit Name[a]	Location	Capacity (net MWe)[b]	Utility[c]	Reactor Type[d]	Reactor Supplier[e]	Date of Operation[f]
United States	Browns Ferry 3	Decatur, Alabama	1,065	TN	BWR	GE	08/76
(continued)	Brunswick 1	Southport, North Carolina	767	CA	BWR	GE	11/76
	Brunswick 2	Southport, North Carolina	754	CA	BWR	GE	12/74
	Byron 1	Byron, Illinois	1,120	CM	PWR	WEST	02/85
	Byron 2	Byron, Illinois	1,120	CM	PWR	WEST	01/87
	Callaway 1	Fulton, Missouri	1,125	UU	PWR	WEST	10/84
	Calvert Cliffs 1	Lusby, Maryland	835	BG	PWR	C-E	07/74
	Calvert Cliffs 2	Lusby, Maryland	840	BG	PWR	C-E	11/76
	Catawba 1	Clover, South Carolina	1,129	DP	PWR	WEST	01/85
	Catawba 2	Clover, South Carolina	1,129	DP	PWR	WEST	05/86
	Clinton 1	Clinton, Illinois	930	IP	BWR	GE	04/87
	Comanche Peak 1	Glen Rose, Texas	1,150	TX	PWR	WEST	04/90
	Comanche Peak 2	Glen Rose, Texas	1,150	TX	PWR	WEST	04/93
	Cooper 1	Brownville, Nebraska	778	ND	BWR	GE	01/74
	Crystal River 3	Red Level, Florida	812	FF	PWR	B&W	01/77
	Davis Besse 1	Oak Harbor, Ohio	873	TO	PWR	B&W	04/77
	Diablo Canyon 1	Avila Beach, California	1,073	PG	PWR	WEST	11/84
	Diablo Canyon 2	Avila Beach, California	1,087	PG	PWR	WEST	08/85
	Donald C. Cook 1	Bridgman, Michigan	1,000	IM	PWR	WEST	10/74
	Donald C. Cook 2	Bridgman, Michigan	1,060	IM	PWR	WEST	12/77
	Dresden 2	Morris, Illinois	772	CM	BWR	GE	12/69
	Dresden 3	Morris, Illinois	773	CM	BWR	GE	03/71
	Duane Arnold	Palo, Iowa	528	IE	BWR	GE	02/74
	Fermi 2	Newport, Michigan	1,100	DE	BWR	GE	07/85
	Fort Calhoun 1	Fort Calhoun, Nebraska	476	OP	PWR	C-E	08/73
	Grand Gulf 1	Port Gibson, Mississippi	1,173	SR	BWR	GE	11/84
	H.B. Robinson 2	Hartsville, South Carolina	683	CA	PWR	WEST	09/70
	Haddam Neck	Haddam Neck, Connecticut	560	CY	PWR	WEST	06/67
	Hatch 1	Baxley, Georgia	759	GA	BWR	GE	10/74
	Hatch 2	Baxley, Georgia	813	GA	BWR	GE	06/78
	Hope Creek 1	Salem, New Jersey	1,031	PS	BWR	GE	07/86
	Indian Point 2	Buchanan, New York	931	CO	PWR	WEST	09/73
	Indian Point 3	Buchanan, New York	980	PW	PWR	WEST	04/76
	James Fitzpatrick 1	Scriba, New York	800	PW	BWR	GE	10/74
	Joseph M. Farley 1	Dothan, Alabama	815	AP	PWR	WEST	06/77
	Joseph M. Farley 2	Dothan, Alabama	825	AP	PWR	WEST	03/81
	Kewaunee	Carlton, Wisconsin	526	WS	PWR	WEST	12/73
	LaSalle 1	Seneca, Illinois	1,048	CM	BWR	GE	08/82
	LaSalle 2	Seneca, Illinois	1,048	CM	BWR	GE	03/84
	Limerick 1	Pottstown, Pennsylvania	1,055	PE	BWR	GE	08/85
	Limerick 2	Pottstown, Pennsylvania	1,115	PE	BWR	GE	08/89
	Maine Yankee	Wiscasset, Maine	870	MY	PWR	C-E	06/73
	McGuire 1	Cowens Ford, North Carolina	1,129	DP	PWR	WEST	07/81
	McGuire 2	Cowens Ford, North Carolina	1,129	DP	PWR	WEST	05/83
	Millstone 1	Waterford, Connecticut	641	NN	BWR	GE	10/70
	Millstone 2	Waterford, Connecticut	873	NN	PWR	C-E	09/75

See notes at end of table.

Table D1. Roster of Nuclear Units as of December 31, 1996 (Continued)

Country	Unit Name[a]	Location	Capacity (net MWe)[b]	Utility[c]	Reactor Type[d]	Reactor Supplier[e]	Date of Operation[f]
United States	Millstone 3	Waterford, Connecticut	1,120	NN	PWR	WEST	01/86
(continued)	Monticello	Monticello, Minnesota	544	NS	BWR	GE	01/71
	Nine Mile Point 1	Oswego, New York	617	NM	BWR	GE	08/69
	Nine Mile Point 2	Oswego, New York	1,026	NM	BWR	GE	07/87
	North Anna 1	Mineral, Virginia	893	VE	PWR	WEST	04/78
	North Anna 2	Mineral, Virginia	897	VE	PWR	WEST	08/80
	Oconee 1	Seneca, South Carolina	846	DP	PWR	B&W	02/73
	Oconee 2	Seneca, South Carolina	846	DP	PWR	B&W	10/73
	Oconee 3	Seneca, South Carolina	846	DP	PWR	B&W	07/74
	Oyster Creek 1	Forked River, New Jersey	619	GU	BWR	GE	08/69
	Palisades	South Haven, Michigan	762	CC	PWR	C-E	10/72
	Palo Verde 1	Wintersburg, Arizona	1,270	AZ	PWR	C-E	06/85
	Palo Verde 2	Wintersburg, Arizona	1,270	AZ	PWR	C-E	04/86
	Palo Verde 3	Wintersburg, Arizona	1,270	AZ	PWR	C-E	11/87
	Peach Bottom 2	Lancaster, Pennsylvania	1,093	PL	BWR	GE	12/73
	Peach Bottom 3	Lancaster, Pennsylvania	1,093	PL	BWR	GE	07/74
	Perry 1	North Perry, Ohio	1,169	CI	BWR	GE	11/86
	Pilgrim 1	Plymouth, Massachusetts	669	BE	BWR	GE	09/72
	Point Beach 1	Two Creeks, Wisconsin	493	WE	PWR	WEST	10/70
	Point Beach 2	Two Creeks, Wisconsin	441	WE	PWR	WEST	03/73
	Prairie Island 1	Red Wing, Minnesota	514	NS	PWR	WEST	04/74
	Prairie Island 2	Red Wing, Minnesota	513	NS	PWR	WEST	10/74
	Quad Cities 1	Cordova, Illinois	769	CM	BWR	GE	12/72
	Quad Cities 2	Cordova, Illinois	769	CM	BWR	GE	12/72
	River Bend 1	St. Francisville, Louisiana	936	GS	BWR	GE	11/85
	Robert E. Ginna	Rochester, New York	470	RG	PWR	WEST	09/69
	Salem 1	Salem, New Jersey	1,106	PS	PWR	WEST	12/76
	Salem 2	Salem, New Jersey	1,106	PS	PWR	WEST	05/81
	San Onofre 2	San Clemente, California	1,070	SL	PWR	C-E	09/82
	San Onofre 3	San Clemente, California	1,080	SL	PWR	C-E	09/83
	Seabrook 1	Seabrook, New Hampshire	1,155	NH	PWR	WEST	03/90
	Sequoyah 1	Daisy, Tennessee	1,111	TN	PWR	WEST	09/80
	Sequoyah 2	Daisy, Tennessee	1,106	TN	PWR	WEST	09/81
	Shearon Harris 1	New Hill, North Carolina	860	CA	PWR	WEST	01/87
	South Texas 1	Bay City, Texas	1,251	HL	PWR	WEST	03/88
	South Texas 2	Bay City, Texas	1,251	HL	PWR	WEST	03/89
	St Lucie 1	Ft. Pierce, Florida	839	FP	PWR	C-E	03/76
	St Lucie 2	Ft. Pierce, Florida	839	FP	PWR	C-E	06/83
	Summer 1	Jenkinsville, South Carolina	885	SE	PWR	WEST	11/82
	Surry 1	Surry, Virginia	801	VE	PWR	WEST	05/72
	Surry 2	Surry, Virginia	801	VE	PWR	WEST	01/73
	Susquehanna 1	Berwick, Pennsylvania	1,090	PV	BWR	GE	11/82
	Susquehanna 2	Berwick, Pennsylvania	1,094	PV	BWR	GE	06/84
	Turkey Point 3	Florida City, Florida	666	FP	PWR	WEST	07/72
	Turkey Point 4	Florida City, Florida	666	FP	PWR	WEST	04/73
	Vermont Yankee 1	Vernon, Vermont	496	VY	BWR	GE	02/73
	Vogtle 1	Waynesboro, Georgia	1,164	GA	PWR	WEST	03/87
	Vogtle 2	Waynesboro, Georgia	1,164	GA	PWR	WEST	03/89

See notes at end of table.

Table D1. Roster of Nuclear Units as of December 31, 1996 (Continued)

Country	Unit Name[a]	Location	Capacity (net MWe)[b]	Utility[c]	Reactor Type[d]	Reactor Supplier[e]	Date of Operation[f]
United States	Waterford 3	Taft, Louisiana	1,075	LP	PWR	C-E	03/85
(continued)	Watts Bar 1	Spring City, Tennessee	1,170	TN	PWR	WEST	02/96
	WNP 2	Richland, Washington	1,107	WP	BWR	GE	04/84
	Wolf Creek	Burlington, Kansas	1,167	WC	PWR	WEST	06/85
	Zion 1	Zion, Illinois	1,040	CM	PWR	WEST	10/73
	Zion 2	Zion, Illinois	1,040	CM	PWR	WEST	11/73
	Total: 110 Units		**100,685**				
Total World:	**442 Units**		**350,964**				

[a] EIA's review of the latest data sources may have resulted in revisions of names, capacities, and operation dates. For the United States, revisions are based on the Energy Information Administration (EIA) Form-860, "Annual Electric Generator Report."

[b] MWe = Megawatts-electric.

[c] See Table D2 for key to abbreviations of utility names.

[d] Reactor Types: AGR, advanced gas-cooled, graphite-moderated reactor; BWR, boiling light-water-cooled and moderated reactor; FBR, fast breeder reactor; GCR, gas-cooled, graphite-moderated reactor; HWLWR, heavy-water-moderated, boiling light-water-cooled reactor; LGR, light-water-cooled, graphite-moderated reactor; PHWR, pressurized heavy-water-moderated and cooled reactor; PWR, pressurized light-water-moderated and cooled reactor.

[e] See Table D3 for key to abbreviations of reactor supplier names.

[f] "Date of Operation" is the date units were connected to the electrical grid; however, for U.S. units, grid connection is when a reactor receives either a provisional or a full-power license.

Note: Totals may not equal sum of components due to independent rounding.

Sources: International Atomic Energy Agency, *Nuclear Power Reactors in the World* (Vienna, Austria, April 1997). Energy Information Administration Form EIA-860, "Annual Electric Generator Report." Nuclear Regulatory Commission, *Information Digest, 1997 Edition* (NUREG-1350, May 1997) for units which started operating after 1978; Summary Information Report (NUREG-0871, June 1984) for units which started operating between 1960 through 1982.

Table D2. Key to Utility Codes for Nuclear Units

Code	Name of Utility	Country
CN	Comision Nacional de Energia Atomica (CNEA)	Argentina
EL	Electrabel M.V. Nucleaire Produktie	Belgium
FN	Furnas Centrais Electricas SA	Brazil
EA	National Electricity Company, Branch NPP-Kozloduy	Bulgaria
KZ	National Corporation For Atomic Energy Industry	Kazakhstan
MY	Industrial Association Mayak	Russia
LN	Leningrad NPP	Russia
MA	Minatomenergoprom, Ministry of Nuclear Power and Industry	Russia
RC	Rosenergoatom, Consortium	Russia
GT	Goskomatom - State Committee of Ukraine on Nuclear Power Utilization	Ukraine
HQ	Hydro Quebec	Canada
NB	New Brunswick Electric Power Commission	Canada
OH	Ontario Hydro	Canada
GV	Guangdong Nuclear Power Joint Venture Company, Ltd. (GNPJVC)	China
LP	Lingao Nuclear Power Company	China
MI	Ministry of Nuclear Industry	China
QN	Qinshan Nuclear Power Company	China
CU	Ministerio de la Industria Basica	Cuba
ED	Electrostation Dukovany	Czech Republic
ET	Electrostation Temelin	Czech Republic
IV	Imatran Voima Oy	Finland
TV	Teollisuuden Voima Oy	Finland
CE	Commissariat A L'Energie Atomique	France
CR	Centrale Nucleaire Europeene A Neutrons Rapides, SA (NERSA)	France
EF	Electricite de France	France
BK	Kernkraftwerk Brokdorf GmbH	Germany
BY	Bayernwerk AG	Germany
GG	Gemeinschaftskernkraftwerk Grohnde GmbH	Germany
GK	Gemeinschafts-Kernkraftwerk Neckar GmbH	Germany
KE	Kernkraftwerke Gundremmingen Betriebsgesellschaft MBH	Germany
KG	Kernkraftwerk Brunsbuettel GmbH	Germany
KI	Kernkraftwerk Isar GmbH	Germany
KJ	Gemeinschaftskernkraftwerk Isar 2 GmbH	Germany
KK	Kernkraftwerk Kruemmel GmbH	Germany
KN	Kernkraftwerk Lippe-Emsland GmbH	Germany
KO	Kernkraftwerk Obrigheim GmbH	Germany
KP	Kernkraftwerk Philippsburg GmbH	Germany
KS	Kernkraftwerk Stade GmbH	Germany
KU	Kernkraftwerk Unterweser GmbH	Germany
RW	Rheinisch-Westfaelisches Elektrizitaetswerk AG	Germany
PK	Paks Nuclear Power Plant Ltd	Hungary
NP	Nuclear Power Corporation of India, LTD	India
GI	Government of Iran	Iran
CB	Chubu Electric Power Company	Japan
CK	Chugoku Electric Power Company	Japan
HD	Hokkaido Electric Power Company	Japan
HU	Hokuriku Electric Power Company	Japan
JP	Japan Atomic Power Company	Japan
KA	Kansai Electric Power Company, Inc.	Japan
KY	Kyushu Electric Power Company	Japan
PF	Power Reactor and Nuclear Fuel Development Corporation	Japan

Table D2. Key to Utility Codes for Nuclear Units (Continued)

Code	Name of Utility	Country
SH	Shikoku Electric Power Company	Japan
TC	Tohoku Electric Power Company	Japan
TP	Tokyo Electric Power Company	Japan
KR	Korea Electric Power Corporation	Korea, South
IN	Ignalina Nuclear Power Plant	Lithuania
FC	Comision Federal de Electricidad	Mexico
GN	Gemeenschappelijke Kernenergiecentrale Nederland (GKN)	Netherlands
PZ	NV Electriciteits-Producktiemaatschappij Zuid-Nederland	Netherlands
PA	Pakistan Atomic Energy Commission	Pakistan
RE	Romanian Electricity Authority (RENEL)	Romania
EB	Electrostation Bohunice	Slovak Republic
EM	Electrostation Mochovce	Slovak Republic
NR	Nuklearna Elektrana Krsko	Slovenia
EK	Eskom	South Africa
AN	Asociacion Nuclear de Asco	Spain
AV	Asociacion Nuclear de Vandellos	Spain
CS	Central Nuclear de Almaraz	Spain
HC	Hidroelectrica del Cantabrico, SA	Spain
IB	Iberdrola, SA	Spain
NU	Nuclenor, SA	Spain
UE	Union Fenosa, SA	Spain
FK	Forsmark Kraftgrupp AB	Sweden
OK	OKG-Aktiebolag	Sweden
SY	Barsebeck Kraft AB	Sweden
VA	Vattenfall AB	Sweden
BR	Bernische Kraftwerke AG	Switzerland
GP	Kernkaftwerk Goesgen-Daeniken AG	Switzerland
LK	Kernkraftwerk Leibstadt	Switzerland
NK	Nordostschweizerische Kraftwerk AG	Switzerland
TW	Taiwan Power Company	Taiwan
BF	British Nuclear Fuels plc	United Kingdom
NE	Nuclear Electric plc	United Kingdom
SC	Scottish Nuclear Ltd.	United Kingdom
AK	Arkansas Power & Light Company	United States
AP	Alabama Power Company	United States
AZ	Arizona Public Service Company	United States
BE	Boston Edison Company	United States
BG	Baltimore Gas & Electric Company	United States
CA	Carolina Power & Light Company	United States
CC	Consumers Power Company	United States
CI	Cleveland Electric Illuminating Company	United States
CM	Commonwealth Edison Company	United States
CO	Consolidated Edison Company	United States
CY	Connecticut Yankee Atomic Power Company	United States
DE	Detroit Edison Company	United States
DL	Duquesne Light Company	United States
DP	Duke Power Company	United States
FF	Florida Power Corporation	United States
FP	Florida Power & Light Company	United States
GA	Georgia Power Company	United States

See notes at end of table.

Table D2. Key to Utility Codes for Nuclear Units (Continued)

Code	Name of Utility	Country
GS	Gulf States Utilities Company	United States
GU	GPU Nuclear Corporation	United States
HL	Houston Lighting & Power Company	United States
IE	Iowa Electric Light & Power Company	United States
IM	Indiana/Michigan Power Company	United States
IP	Illinois Power Company	United States
LP	Louisiana Power & Light Company	United States
MY	Maine Yankee Atomic Power Company	United States
ND	Nebraska Public Power District	United States
NH	Public Service Company of New Hampshire	United States
NM	Niagara Mohawk Power Corporation	United States
NN	Northeast Nuclear Energy Company	United States
NS	Northern States Power Company	United States
OP	Omaha Public Power District	United States
PE	Philadelphia Electric Company	United States
PG	Pacific Gas & Electric Company	United States
PL	Philadelphia Electric Company/ Public Service Electric & Gas Company	United States
PS	Public Service Electric & Gas Company	United States
PV	Pennsylvania Power & Light Company	United States
PW	Power Authority of the State of New York	United States
RG	Rochester Gas & Electric Corporation	United States
SE	South Carolina Electric & Gas Company	United States
SL	Southern California Edison Company	United States
SR	System Energy Resources, Inc.	United States
TN	Tennessee Valley Authority	United States
TO	Toledo Edison Company	United States
TX	Texas Utilities Electric Company	United States
UU	Union Electric Company	United States
VE	Virginia Electric & Power Company	United States
VY	Vermont Yankee Nuclear Power Corporation	United States
WC	Wolf Creek Nuclear Operating Corporation	United States
WE	Wisconsin Electric Power Company	United States
WP	Washington Public Power Supply System	United States
WS	Wisconsin Public Service Corporation	United States

Table D3. Key to Reactor Supplier Codes for Nuclear Units

Code	Name of Supplier	Country
ACC	ACEC/Cockerill	Belgium
ACEC	Ateliers de Constructions Electriques de Charleroi SA	Belgium
ACW	ACECOWEN/(ACEC Cockerill/Westinghouse)	Belgium
AECL	Atomic Energy of Canada, Ltd.	Canada
CGE	Canadian General Electric	Canada
DAEC	Department of Atomic Energy, Canada Ltd	Canada
OH	Ontario Hydro	Canada
CNNC	China National Nuclear Corporation	China
SKODA	SKODA Concern Nuclear Power Plant Works	Czech Republic
ACLF	ACECOWEN/Creusot-Loire/FRAMATOME	France
CNIM	Constructions Navales et Industrielles de Mediterranee	France
FRAM	Framatome	France
NOVA	Novatome NIRA/Nuclear Italina Reattori Avanzati	France
AEG	Allegemeine Elektricitaets-Gesellschaft	Germany
BBR	Brown Boveri Reaktor GmbH	Germany
KWU	Siemens Kraftwerk Union AG	Germany
SIEM	Siemens AG	Germany
DAE	Department of Atomic Energy, India	India
NPCIL	Nuclear Power Corporation of India, Ltd.	India
HIT	Hitachi, Ltd.	Japan
MHI	Mitsubishi Heavy Industries, Ltd.	Japan
TOS	Toshiba Corporation	Japan
KAE	Korea Atomic Energy Research Institite	Korea, South
KHIC	Korea Heavy Industries and Construction Company	Korea, South
RDM	Rotterdamse Drookdok Madtdschappij	Netherlands
FECNE	Fabrica Echipamente Centrale Nuclearoelectrice Bucuresti	Romania
AEE	Atomenergoexport	Russia
MNE	Ministry of Nuclear Energy of Russian Corporation	Russia
MTM	MINTYAZHMASH	Russia
A-A	ASEA-Atom	Sweden
APC	Atomic Power Construction, Ltd.	United Kingdom
EBT	English Electric Co. Ltd./Babcock and Wilcox Co./Taylor Woodrow Construction Co.	United Kingdom
GEC	General Electric Company	United Kingdom
NNC	National Nuclear Corporation	United Kingdom
NPC	Nuclear Power Company, Ltd.	United Kingdom
PPP	PWR Power Projects	United Kingdom
TNPG	The Nuclear Power Group, Ltd.	United Kingdom
UKAE	United Kingdom Atomic Energy Authority	United Kingdom
B&W	Babcock and Wilcox	United States
C-E	Combustion Engineering, Inc.	United States
GE	General Electric Company	United States
GETSCO	General Electric Technical Services Company	United States
WEST	Westinghouse Corp.	United States

Table D4. Operable Nuclear Power Plant Statistics, 1995 and 1996

Country	Number of Operable Units[a]		Net Capacity (MWe)		Amount of Electricity from Nuclear Units			1996
					Net TWh		Percent Change	Share[b] (percent)
	1995	1996	1995	1996	1995	1996		
North America								
United States	109	110	R99,515	100,685[c]	673.4	674.7	0.2	[d]19.4
Canada	21	21	14,907	14,902	92.3	87.5	-5.2	16.0
Subtotal	**130**	**131**	**114,422**	**115,587**	**765.7**	**762.2**	**-0.5**	**--**
Western Europe								
Belgium	7	7	5,631	5,712	39.2	41.4	5.6	57.2
Finland	4	4	2,310	2,355	18.1	18.7	3.0	28.1
France	56	57	58,493	59,948	358.6	378.2	5.5	77.4
Germany	20	20	22,017	22,282	145.7	152.8	4.9	30.3
Netherlands	2	2	504	504	3.8	3.9	2.6	4.8
Slovenia	1	1	632	632	4.6	4.4	-4.4	37.9
Spain	9	9	7,124	7,207	53.1	53.8	1.3	32.0
Sweden	12	12	10,002	10,040	66.7	71.4	7.0	52.4
Switzerland	5	5	3,050	3,077	23.5	23.7	1.0	44.5
United Kingdom	35	35	12,908	12,928	81.6	85.9	5.3	26.0
Subtotal	**151**	**152**	**122,671**	**124,685**	**794.9**	**834.2**	**4.9**	**--**
Eastern Europe								
Armenia	1	1	376	376	0.0	2.1	N/A	36.7
Bulgaria	6	6	3,538	3,538	17.3	18.1	4.8	42.2
Czech Republic	4	4	1,648	1,648	12.2	12.9	5.1	20.0
Hungary	4	4	1,729	1,729	13.2	14.2	7.4	40.8
Kazakhstan	1	1	70	70	0.1	0.1	12.5	0.2
Lithuania	2	2	2,370	2,370	10.6	12.7	19.1	83.4
Romania	0	1	0	650	0.0	0.9	N/A	1.8
Russia	29	29	19,843	19,843	99.4	108.8	9.5	13.1
Slovak Republic	4	4	1,632	1,632	11.4	11.3	-1.6	44.5
Ukraine	16	16	13,629	13,765	65.6	79.6	21.2	43.8
Subtotal	**67**	**68**	**44,835**	**45,621**	**229.9**	**260.5**	**13.3**	**--**
Far East								
China	3	3	2,167	2,167	12.4	13.6	10.0	1.3
Japan	51	53	39,893	42,396	286.9	287.0	0.0	33.4
Korea, South	11	11	9,120	9,120	63.7	70.3	10.4	35.8
Taiwan	6	6	4,884	4,884	33.9	36.3	7.2	29.1
Subtotal	**71**	**73**	**56,064**	**58,540**	**396.9**	**407.3**	**2.6**	**--**
Other								
Argentina	2	2	935	935	7.1	6.9	-2.1	11.4
Brazil	1	1	626	626	2.5	2.3	-8.4	0.7
India	10	10	1,695	1,695	6.5	7.4	14.9	2.2
Mexico	2	2	1,308	1,308	8.4	7.1	-15.8	5.1
Pakistan	1	1	125	125	0.5	0.3	-32.6	0.6
South Africa	2	2	1,842	1,842	11.3	11.8	4.3	6.3
Subtotal	**18**	**18**	**6,531**	**6,531**	**36.2**	**35.8**	**-1.1**	**--**
Total World	**437**	**442**	**R344,523**	**350,964**	**2,223.5**	**2,300.0**	**3.4**	**--**

[a] For all non-U.S. units, operable units are those that have generated electricity to the grid. An operable unit in the United States is one that has been issued a full-power license by the U.S. Nuclear Regulatory Commission. For all non-U.S. units, capacity is the net design electrical rating. For U.S. units, capacity is net summer capability. Capacities of individual units are subject to re-ratings from year to year. See definitions of capacities in glossary.

[b] Net nuclear electricity generation as a percentage of total net electricity generation from utilities and nonutilities. The source for nuclear generation data is the International Atomic Energy Agency (IAEA). The nuclear share of utility-generated electricity for the United States was 21.9 percent.

[c] 1996 utility generation was obtained from the Energy Information Administration, *Monthly Energy Review, May 1997*, DOE/EIA-0035(97/05) (Washington, DC, May 1997). Forecasted 1996 gross nonutility generation data was obtained from the Energy Information Administration, Projection for the Short-Term Energy Outlook Memorandum, July 1997.

[d] 1996 U.S. capacity is preliminary.

-- = Not applicable.

MWe = Megawatt-electric.

R = Revised.

TWh = Terawatthours.

Sources: **1995**–International Atomic Energy Agency, *Nuclear Power Reactors in the World* (Vienna, Austria, April 1996). **1996**–International Atomic Energy Agency, *Nuclear Power Reactors in the World* (Vienna, Austria, April 1997).

Table D5. Top 20 Nuclear Units by Generation, 1996

Nation	Unit	Type	Gross Capacity (MWe)	1996 Generation (gross MWh)
Germany	Philippsburg 2	PWR	1,424	11,472,475
Germany	Neckarwestheim 2	PWR	1,365	11,353,400
United States.	Palo Verde 3	PWR	1,307	11,320,800
Germany	Emsland	PWR	1,363	11,136,652
Germany	Grohnde	PWR	1,430	11,134,588
Germany	Brokdorf	PWR	1,395	11,124,556
United States	South Texas 2	PWR	1,315	10,920,900
Germany	Isar 2	PWR	1,420	10,879,849
United States	South Texas 1	PWR	1,315	10,680,540
Germany	Unterweser	PWR	1,350	10,432,002
Japan	Ohi 3	PWR	1,180	10,363,680
United States.	Seabrook 1	PWR	1,194	10,244,636
France	Penley 2	PWR	1,382	10,175,597
Japan	Ohi 2	PWR	1,175	10,121,935
Germany	Grafenrheinfeld	PWR	1,345	10,058,372
France	Cattenom 1	PWR	1,345	10,013,668
Germany	Gundremmingen C	BWR	1,344	9,988,213
France	Penley 1	PWR	1,382	9,917,797
Germany	Gundremmingen B	PWR	1,344	9,864,867
United States.	Palo Verde 2	PWR	1,307	9,853,400

MWe = Megawatt electric.
MWh = Megawatthour.
Source: *Nuclear News*, “Top 50 Units By Generation, 1996” (February 13, 1997), pp. 9-10.

Appendix E

World Nuclear Units Planned, Deferred, or Under Construction as of December 31, 1996

Appendix E

World Nuclear Units Planned, Deferred, or Under Construction as of December 31, 1996

Table E1. Non-Operable World Nuclear Units as of December 31, 1996

Country	Unit Name[a]	Location	Capacity (net MWe)[b]	Utility[c]	Type[d]	Reactor Supplier[e]	Percent Complete[f]	Expected Date of Operation	
								Published[g]	EIA[h] Reference
Argentina	Atucha 2	Lima, Buenos Aires	692	CN	PHWR	KWU	88	2001	2005
	Total: 1 Unit		**692**						
Brazil	Angra 2	Itaorna, Rio de Janeiro	1,245	FN	PWR	KWU	75	06/1999	2001
	Angra 3	Itaorna, Rio de Janeiro	1,229	FN	PWR	WEST	43	09/2004	--
	Total: 2 Units		**2,474**						
China	Qinshan 2	Haiyan, Zhejiang	600	MI	PWR	CNNC	10	12/2000	2002
	Qinshan 3	Haiyan, Zhejiang	600	MI	PWR	CNNC	5	12/2001	2003
	Total: 2 Units		**1,200**						
Cuba	Juragua 1	Cienfuegos	408	CU	PWR	AEE	75	2003	--
	Juragua 2	Cienfuegos	408	CU	PWR	AEE	75	2008	--
	Total: 2 Units		**816**						
Czech Republic	Temelin 1	Temelin, Jihocesky	912	ET	PWR	SKODA	95	1999	1998
	Temelin 2	Temelin, Jihocesky	912	ET	PWR	SKODA	70	2001	2000
	Total: 2 Units		**1,824**						
France	Chooz B2	Chooz, Ardennes	1,455	EF	PWR	FRAM	100	1997	1997
	Civaux 1	Civaux, Vienne	1,450	EF	PWR	FRAM	100	07/1997	1997
	Civaux 2	Civaux, Vienne	1,450	EF	PWR	FRAM	60	11/1998	1998
	Total: 3 Units		**4,355**						
India	Kaiga 1	Kaiga, Karnataka	202	NP	PHWR	NPCIL	75	11/1998	1999
	Kaiga 2	Kaiga, Karnataka	202	NP	PHWR	NPCIL	75	11/1998	2000
	Rajasthan 3	Kato, Rajasthan	202	NP	PHWR	NPCIL	70	11/1998	2000
	Rajasthan 4	Kato, Rajasthan	202	NP	PHWR	NPCIL	70	05/1999	2000
	Tarapur 3	Tarapur, Maharashtra	450	NP	PHWR	NPCIL	10	08/2003	2004
	Tarapur 4	Tarapur, Maharashtra	450	NP	PHWR	NPCIL	2	05/2004	2006
	Total: 6 Units		**1,708**						

See notes at end of table.

Table E1. Non-Operable World Nuclear Units as of December 31, 1996 (continued)

Country	Unit Name[a]	Location	Capacity (net MWe)[b]	Utility[c]	Type[d]	Reactor Supplier[e]	Percent Complete[f]	Expected Date of Operation	
								Published[g]	EIA[h] Reference
Iran	Bushehr 1	Bushehr	1,073	GI	PWR	MTM	80	2002	2005
	Bushehr 2	Bushehr	1,073	GI	PWR	MTM	80	2002	2007
	Total: 2 Units		**2,146**						
Japan	Kashiwazaki Kariwa 7	Kashiwazaki, Niigata	1,315	TP	BWR	HIT/GE	100	07/1997	1997
	Total: 1 Unit		**1,315**						
Korea, South	Ulchin 3	Ulchin, Kyongbuk	960	KR	PWR	KHIC/KAE	64	06/1998	1998
	Ulchin 4	Ulchin, Kyongbuk	960	KR	PWR	KHIC/KAE	64	06/1999	1999
	Wolsong 2	Kyongju, Kyongbuk	650	KR	PHWR	AECL/KHIC	100	06/1997	1997
	Wolsong 3	Kyongju, Kyongbuk	650	KR	PHWR	AECL/KHIC	54	06/1998	1998
	Wolsong 4	Kyongju, Kyongbuk	650	KR	PHWR	AECL/KHIC	54	06/1999	2000
	Yonggwang 5	Yonggwang, Chonnam	950	KR	PWR	KHIC/KAE	7	06/2001	2002
	Yonggwang 6	Yonggwang, Chonnam	950	KR	PWR	KHIC/KAE	7	06/2002	2003
	Total: 7 Units		**5,770**						
Pakistan	Chasnupp 1 (Chasma)	Mianwali, Punjub	300	PA	PWR	CNNC	55	03/1999	2000
	Total: 1 Unit		**300**						
Romania	Cernavoda 2	Cernavoda, Constanta	650	RE	PHWR	AECL	32	12/2001	2003
	Total: 1 Unit		**650**						
Russia	Kalinin 3	Udomyla, Tver	950	RC	PWR	MTM	95	1998	2001
	Kalinin 4	Udomyla, Tver	950	RC	PWR	MTM	90	2010	--
	Kursk 5	Kurchatov, Kursk	925	RC	LGR	MTM	98	1997	2001
	Rostov 1	Volgodonsk, Rostov	950	RC	PWR	MTM	95	2001	2002
	Rostov 2	Volgodonsk, Rostov	950	RC	PWR	MTM	40	2004	2005
	Smolensk 4	Desnogorsk, Smolensk	925	RC	PWR	MTM	86	2003	--
	Sosnovyy Bor 1	Sosnovyy Bor, St. Petersburg	600	RC	APWR	MTM	1	2003	2008
	Total: 7 Units		**6,250**						
Slovak Republic	Mochovce 1	Mochovce, Zapadoslovensky	388	EM	PWR	SKODA	88	06/1998	2000
	Mochovce 2	Mochovce, Zapadoslovensky	388	EM	PWR	SKODA	65	07/1999	2001
	Total: 2 Units		**776**						

See notes at end of table.

Table E1. Non-Operable World Nuclear Units as of December 31, 1996 (continued)

Country	Unit Name[a]	Location	Capacity (net MWe)[b]	Utility[c]	Type[d]	Reactor Supplier[e]	Percent Complete[f]	Expected Date of Operation: Published[g]	Expected Date of Operation: EIA[h] Reference
Taiwan	Lungmen 1	Yenliao, Taiwan	1,250	TW	PWR	GE	6	2003	2003
	Lungmen 2	Yenliao, Taiwan	1,250	TW	PWR	GE	6	2004	2004
	Total: 2 Units		**2,500**						
Ukraine	Khmelnitski-2	Neteshin, Khmelnitski	950	GT	PWR	MTM	95	1997	1998
	Khmelnitski-3	Neteshin, Khmelnitski	950	GT	PWR	MTM	30	12/98	2007
	Khmelnitski-4	Neteshin, Khmelnitski	950	GT	PWR	MTM	15	12/99	2010
	Rovno 4	Kuznetsovsk, Rovno	950	GT	PWR	MTM	80	1998	2000
	Total: 4 Units		**3,800**						
Total:	**45 Units**		**36,576**						

[a] The Energy Information Administration's review of the latest data sources may have resulted in revisions of names, capacities, and operation dates. For the United States, revisions are based on the Form-860 "Annual Electric Generator Report."

[b] MWe = Megawatts-electric.

[c] See Table D2 for key to abbreviations of utility names.

[d] Reactor Types: APWR, advanced pressurized light-water-moderated and cooled reactor; BWR, boiling light-water-cooled and moderated reactor; LGR, light-water-cooled, graphite-moderated reactor; PHWR, pressurized heavy-water-moderated and cooled reactor; PWR, pressurized light-water-moderated and cooled reactor.

[e] See Table D3 for key to abbreviations of reactor supplier names.

[f] Percent complete is an estimate of how close the nuclear unit is to completion.

[g] Published date is the estimated date of commercial operation.

[h] EIA projection refers to when a nuclear unit is estimated to become operable. A dash (--) indicates that the estimated year of operability is beyond the year 2015.

Note: Totals may not equal sum of components due to independent rounding.

Sources: International Atomic Energy Agency, *Nuclear Power Reactors in the World* (Vienna, Austria, April 1997); *Nuclear News,* "World List of Nuclear Power Plants" (March 1997), pp. 37-52. NAC International, "Nuclear Generation," (February 1997), Section F, pp. 1-43; Form EIA-860 "Annual Electric Generator Report."

Table E2. Planned or Indefinitely Deferred Nuclear Units as of December 31, 1996

Country	Unit Name[a]	Location	Capacity (net MWe)[b]	Utility[c]	Type[d]	Reactor Supplier[e]	Percent Complete	Expected Date of Operation: Published[f]	Expected Date of Operation: EIA Reference
Armenia	Armenia 1	Metsamor, Armenia	376	MA	PWR	AEE	N/A	1999	2001
	Total: 1 Unit		**376**						
China	Liaoning 1	Lianyungang, Jiangsu	935	MI	PWR	AEE	0	2005	2007
	Liaoning 2	Lianyungang, Jiangsu	935	MI	PWR	AEE		2008	2008
	Lingao 1	Lingao, Guangdong	985	LP	PWR	FRAM	0	2002	2004
	Lingao 2	Lingao, Guangdong	985	LP	PWR	FRAM	0	2003	2005
	Qinshan 4	Haiyan, Zhejiang	700	MI	PHWR	AECL	0	2003	2003
	Qinshan 5	Haiyan, Zhejiang	700	MI	PHWR	AECL	0	2005	2005
	Shandong 1	Shandong	935	MI	PWR	--	0	2004	2006
	Shandong 2	Shandong	935	MI	PWR	--	0	2008	2008
	Shandong 3	Shandong	935	MI	PWR	--	0	2010	2010
	Total: 9 Units		**8,045**						
India	Kudankulam 1	Tamil Nadu	1,000	NP	PWR	--	0	2006	2008
	Kadunkulam 2	Tamil Nadu	1,000	NP	PWR	--	0	2008	2010
	Rajasthan 5	Kato, Rajasthan	450	NP	PWHR	--	0	2007	2008
	Rajasthan 6	Kato, Rajasthan	450	NP	PWHR	--	0	2008	2009
	Total: 4 Units		**2,900**						
Japan	Fukushima 1-7	Fukushima	1,350	TP	ABWR	--	0	2006	2006
	Fukushima 1-8	Fukushima	1,350	TP	ABWR	--	0	2008	2008
	Hamaoka 5	Hamaoka-cho, Shizuoka	1,350	CB	ABWR	--	0	05/2005	2005
	Higashidori 1	Higashidori, Aomri	1,067	TC	BWR	--	0	2005	2005
	Higashidori 2	Higashidori, Aomri	1,067	TC	BWR	--	0	2008	2008
	Maki 1	Maki, Niigata	780	TC	BWR	--	0	2005	2005
	Namie Odaka	Fukushima	825	TC	BWR	TOS	0	2007	2009
	Onagawa 3	Tsuruga, Fukui	796	TC	BWR	TOS	0	2002	2002
	Shika 2	Shika-machi, Ishikawa	1,358	HU	ABWR	--	0	--	2005
	Tsuruga 3	Tsuruga, Fukui	1,300	JP	ABWR	--	0	2004	2005
	Total: 10 Units		**11,243**						
Korea, South	Ulchin 5	Ulchin, Kyongbuk	950	KR	PWR	KHIC/KAE	0	06/2003	2003
	Ulchin 6	Ulchin, Kyongbuk	950	KR	PWR	KHIC/KAE	0	06/2004	2004
	Total: 2 Units		**1,900**						
Pakistan	Chasnupp 2	Mianwali, Punjub	300	PA	PWR	CNNC	0	2007	2010
	Total: 1 Unit		**300**						

See notes at end of table.

Table E2. Planned or Indefinitely Deferred Nuclear Units as of December 31, 1996 (continued)

Country	Unit Name[a]	Location	Capacity (net MWe)[b]	Utility[c]	Type[d]	Reactor Supplier[e]	Percent Complete	Expected Date of Operation	
								Published[f]	EIA Reference
Romania	Cernavoda 3	Cernavoda, Constanta	650	RE	PHWR	FECNE	23	ID	--
	Total: 1 Unit		**650**						
Russia	Balakovo 5	Balakovo, Saratov	950	RC	PWR	MTM	N/A	ID	2008
	Total: 1 Unit		**950**						
Ukraine	South Ukraine 4	Konstantinovka, Nikolae	950	GT	PWR	MTM	N/A	ID	2010
	Total: 1 Unit		**950**						
United States	Bellefonte 1	Scottsboro, Alabama	1,212	TN	PWR	B&W	80	ID	--
	Bellefonte 2	Scottsboro, Alabama	1,212	TN	PWR	B&W	45	ID	--
	Watts Bar 2	Spring City, Tennessee	1,170	TN	PWR	WEST	70	ID	--
	Total: 3 Units		**3,594**						
Total:	**33 Units**		**30,908**						

[a] The Energy Information Administration's review of the latest data sources may have resulted in revisions of names, capacities, and operation dates. For the United States, revisions are based on the Form-860 "Annual Electric Generator Report."

[b] MWe = Megawatts-electric.

[c] See Table D2 for key to abbreviations of utility names.

[d] Reactor Types: ABWR advanced boiling light-water-cooled and moderated reactor; BWR, boiling light-water-cooled and moderated reactor; PHWR, pressurized heavy-water-moderated and cooled reactor; PWR, pressurized light-water-moderated and cooled reactor.

[e] See Table D3 for key to abbreviations of reactor supplier names.

[f] Published date is the estimated date of commercial operation.

ID = Indefinitely deferred.

Notes: A dash (--) indicates that the estimated year of operability is beyond the year 2015. Totals may not equal sum of components due to independent rounding.

Sources: International Atomic Energy Agency, *Nuclear Power Reactors in the World* (Vienna, Austria, April 1997); *Nuclear News,* "World List of Nuclear Power Plants" (March 1997), pp. 37-52. NAC International, "Nuclear Generation," (February 1997), Section F, pp. 1-43; Form EIA-860 "Annual Electric Generator Report."

Table E3. Status of Commercial Nuclear Units Under Construction as of December 31, 1996

Country	Percentage of Construction Completed									
	0 to 25		26 to 50		51 to 75		76 to 100		Total	
	No. of Units	Net MWe	No. of Units	Net MWe	No. of Units	Net MWe	No. of Units	Net MWe	No. of Units	Net Mwe
Western Europe										
France	0	0	0	0	1	1,450	2	2,905	3	4,355
Eastern Europe										
Czech Republic	0	0	0	0	1	912	1	912	2	1,824
Romania	0	0	1	650	0	0	0	0	1	650
Russia	1	600	1	950	1	950	4	3,750	7	6,250
Slovak Republic	0	0	0	0	1	388	1	388	2	776
Ukraine	1	950	1	950	0	0	2	1,900	4	3,800
Subtotal	2	1,550	3	2,550	3	2,250	8	6,950	16	13,300
Far East										
China	2	1,200	0	0	0	0	0	0	2	1,200
Japan	0	0	0	0	0	1	1	1,315	1	1,315
Korea, South	2	1,900	0	0	4	3,220	1	650	7	5,770
Taiwan	2	2,500	0	0	0	0	0	0	2	2,500
Subtotal	6	5,600	0	0	4	3,220	2	1,965	12	10,785
Other										
Argentina	0	0	0	0	0	0	1	692	1	692
Brazil	0	0	1	1,229	1	1,245	0	0	2	2,474
Cuba	0	0	0	0	2	816	0	0	2	816
India	2	900	0	0	4	808	0	0	6	1,708
Iran	0	0	0	0	0	0	2	2,146	2	2,146
Pakistan	0	0	0	0	1	300	0	0	1	300
Subtotal	2	900	1	1,229	8	3,169	3	2,838	14	8,136
Total World	**10**	**8,050**	**4**	**3,779**	**16**	**10,089**	**15**	**14,658**	**45**	**36,576**

MWe = Megawatt-electric.
Source: "World List of Nuclear Power Plants," *Nuclear News* (March 1996), pp. 29-44. *Nucleonics Week* (various issues).

Table E4. Status of Planned or Indefinitely Deferred Commercial Nuclear Units as of December 31, 1996

Country	Percentage of Construction Completed									
	0 to 25		26 to 50		51 to 75		76 to 100		Total	
	No. of Units	Net MWe	No. of Units	Net MWe	No. of Units	Net MWe	No. of Units	Net MWe	No. of Units	Net Mwe
North America										
United States	0	0	1	1,212	1	1,170	1	1,212	3	3,594
Eastern Europe										
Armenia[a]	1	376	0	0	0	0	0	0	1	376
Russia	1	950	0	0	0	0	0	0	1	950
Ukraine	1	950	0	0	0	0	0	0	1	950
Romania	1	650	0	0	0	0	0	0	1	650
Subtotal	4	2,926	0	0	0	0	0	0	4	2,926
Far East										
China	9	8,045	0	0	0	0	0	0	9	8,045
Japan	10	11,243	0	0	0	0	0	0	10	11,243
Korea, South	2	1,900	0	0	0	0	0	0	2	1,900
Subtotal	21	21,188	0	0	0	0	0	0	21	21,188
Other										
India	4	2,900	0	0	0	0	0	0	4	2,900
Pakistan	1	300	0	0	0	0	0	0	1	300
Subtotal	5	3,200	0	0	0	0	0	0	5	3,200
Total World	**30**	**27,314**	**1**	**1,212**	**1**	**1,170**	**1**	**1,212**	**33**	**30,908**

[a] The exact stage of construction for the Armenia 1 reactor is unknown.

MWe = Megawatt-electric.

Source: “World List of Nuclear Power Plants,” *Nuclear News* (March 1996), pp. 29-44. *Nucleonics Week* (various issues).

Appendix F

U.S. and World Nuclear Fuel Cycle Projections

Table F1. Projected World Annual Uranium Requirements, Reference Case, 1997–2015

(Million Pounds U_3O_8)

Year	United States	Canada	Eastern Europe	Western Europe	Far East	Other[a]	Total
1997	53.1	4.6	21.7	54.0	27.8	2.7	163.8
1998	49.4	4.3	23.6	51.7	28.5	3.3	160.7
1999	46.5	3.9	23.9	50.9	29.5	3.5	158.2
2000	46.1	3.9	23.5	49.8	31.7	3.7	158.7
2001	48.6	3.8	22.9	50.2	33.3	3.2	162.0
2002	45.4	4.2	23.6	48.8	37.3	3.8	163.2
2003	47.6	4.1	23.6	50.3	37.4	4.0	167.1
2004	42.9	4.3	23.7	48.8	38.8	4.6	163.1
2005	46.0	4.1	24.1	49.0	37.4	5.1	165.7
2006	43.0	4.2	24.1	47.6	39.7	5.7	164.2
2007	40.8	4.0	24.7	48.2	42.3	5.9	165.9
2008	41.7	4.0	23.6	48.4	41.2	5.2	164.1
2009	39.3	4.0	22.2	48.3	42.7	5.6	162.0
2010	41.5	3.8	21.7	48.4	43.6	5.8	164.9
2011	34.4	3.8	20.8	46.6	46.2	5.9	157.7
2012	34.2	3.6	21.3	45.6	47.5	5.9	158.2
2013	28.4	3.6	20.0	43.8	45.9	6.1	147.8
2014	29.1	3.3	19.3	42.6	46.3	6.5	147.1
2015	26.4	3.2	18.4	41.5	44.1	6.3	139.9

[a] Other includes Argentina, Brazil, India, Iran, Mexico, Pakistan, South Africa and Turkey.

Notes: See Table 2 for a list of the countries making up each region. Totals may not equal sum of components due to independent rounding. Data adjusted by three-point smoothing.

Source: Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, International Nuclear Model, File INM.WK4, 1997.

Table F2. Projected World Cumulative Uranium Requirements, Reference Case, 1997-2015

(Million Pounds U_3O_8)

Year	United States	Canada	Eastern Europe	Western Europe	Far East	Other[a]	Total
1997	53.1	4.6	21.7	54.0	27.8	2.7	163.8
1998	102.5	8.8	45.2	105.7	56.3	6.0	324.5
1999	148.9	12.7	69.1	156.6	85.8	9.5	482.7
2000	195.1	16.7	92.6	206.4	117.5	13.2	641.4
2001	243.7	20.5	115.5	256.6	150.8	16.4	803.4
2002	289.1	24.7	139.1	305.4	188.1	20.2	966.6
2003	336.7	28.8	162.8	355.7	225.5	24.2	1,133.7
2004	379.6	33.1	186.5	404.5	264.3	28.7	1,296.7
2005	425.6	37.2	210.6	453.5	301.7	33.9	1,462.5
2006	468.6	41.4	234.7	501.1	341.4	39.6	1,626.7
2007	509.4	45.4	259.4	549.2	383.7	45.4	1,792.5
2008	551.1	49.4	283.0	597.6	424.9	50.6	1,956.6
2009	590.3	53.4	305.2	645.9	467.6	56.3	2,118.7
2010	631.9	57.2	326.8	694.4	511.2	62.1	2,283.6
2011	666.2	61.0	347.6	741.0	557.4	68.0	2,441.3
2012	700.5	64.6	369.0	786.6	604.9	74.0	2,599.5
2013	728.9	68.2	389.0	830.4	650.8	80.1	2,747.3
2014	758.0	71.4	408.3	872.9	697.1	86.5	2,894.4
2015	784.5	74.6	426.7	914.4	741.2	92.9	3,034.3

[a] Other includes Argentina, Brazil, India, Iran, Mexico, Pakistan, South Africa and Turkey.

Notes: See Table 2 for a list of the countries making up each region. Totals may not equal sum of components due to independent rounding. Data adjusted by three-point smoothing.

Source: Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, International Nuclear Model, File INM.WK4, 1997.

Table F3. Projected World Annual Uranium Enrichment Service Requirements, Reference Case, 1997-2015

(Million Separative Work Units)

Year	United States	Eastern Europe	Western Europe	Far East	Other[a]	Total
1997	11.1	4.8	12.0	5.6	0.3	33.8
1998	11.0	4.7	11.7	6.1	0.3	33.9
1999	10.7	4.7	11.7	6.2	0.4	33.6
2000	10.5	5.1	11.7	6.4	0.4	34.1
2001	10.3	5.0	11.6	6.6	0.4	33.9
2002	9.9	5.1	11.4	7.2	0.4	34.0
2003	10.8	4.8	11.4	8.1	0.5	35.5
2004	9.8	5.0	11.6	8.6	0.5	35.4
2005	10.5	5.2	11.4	9.0	0.6	36.7
2006	9.3	5.3	11.6	9.1	0.7	36.0
2007	10.0	5.2	11.4	9.8	0.7	37.1
2008	9.7	5.1	11.6	9.7	0.6	36.7
2009	9.0	5.1	11.5	9.9	0.6	36.1
2010	9.0	5.0	11.1	9.7	0.7	35.6
2011	8.1	4.9	10.9	10.6	0.6	35.0
2012	8.5	4.7	10.7	10.7	0.6	35.1
2013	6.9	4.5	10.8	10.9	0.5	33.6
2014	6.9	4.4	10.2	10.9	0.6	33.0
2015	6.1	4.3	9.9	10.9	0.5	31.6

[a] Other includes Argentina, Brazil, India, Iran, Mexico, Pakistan, South Africa and Turkey.

Notes: See Table 2 for a list of the countries making up each region. Totals may not equal sum of components due to independent rounding. Data adjusted by three-point smoothing.

Source: Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, International Nuclear Model, File INM.WK4, 1997.

Table F4. Projected World Cumulative Uranium Enrichment Service Requirements, Reference Case, 1997-2015

(Million Separative Work Units)

Year	United States	Eastern Europe	Western Europe	Far East	Other[a]	Total
1997	11.1	4.8	12.0	5.6	0.3	33.8
1998	22.2	9.5	23.8	11.6	0.6	67.7
1999	32.8	14.2	35.5	17.8	1.1	101.3
2000	43.3	19.3	47.2	24.2	1.5	135.4
2001	53.6	24.2	58.7	30.8	1.9	169.3
2002	63.5	29.3	70.2	38.0	2.3	203.3
2003	74.3	34.1	81.6	46.1	2.8	238.8
2004	84.0	39.2	93.1	54.6	3.2	274.2
2005	94.5	44.4	104.5	63.6	3.8	310.9
2006	103.8	49.7	116.1	72.7	4.5	346.9
2007	113.8	55.0	127.5	82.5	5.2	383.9
2008	123.5	60.0	139.0	92.2	5.8	420.6
2009	132.5	65.1	150.5	102.1	6.5	456.7
2010	141.6	70.1	161.6	111.8	7.2	492.3
2011	149.7	75.0	172.5	122.4	7.8	527.3
2012	158.1	79.7	183.2	133.1	8.3	562.4
2013	165.0	84.2	194.0	144.0	8.9	596.1
2014	171.9	88.6	204.2	154.9	9.5	629.1
2015	178.0	92.8	214.1	165.8	10.0	660.7

[a] Other includes Argentina, Brazil, India, Iran, Mexico, Pakistan, South Africa and Turkey.

Notes: See Table 2 for a list of the countries making up each region. Totals may not equal sum of components due to independent rounding. Data adjusted by three-point smoothing.

Source: Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, International Nuclear Model, File INM.WK4, 1997.

Table F5. Projected World Annual Discharges of Spent Fuel, Reference Case, 1997-2015
(Thousand Metric Tons of Uranium)

Year	United States	Canada	Eastern Europe	Western Europe	Far East	Other[a]	Total
1997	2.1	1.6	1.2	3.6	1.5	0.4	10.4
1998	2.3	1.7	1.3	3.6	1.6	0.4	10.9
1999	2.3	1.7	1.4	3.6	1.7	0.5	11.3
2000	2.3	1.6	1.4	3.8	1.7	0.5	11.2
2001	2.2	1.5	1.4	3.6	1.7	0.6	11.0
2002	2.1	1.5	1.4	3.3	1.7	0.6	10.6
2003	2.1	1.5	1.5	3.2	1.7	0.7	10.7
2004	2.2	1.5	1.5	3.0	1.8	0.7	10.7
2005	2.0	1.6	1.5	3.1	1.9	0.8	10.8
2006	2.0	1.6	1.5	2.9	2.0	0.8	10.8
2007	1.8	1.6	1.5	2.9	2.0	0.9	10.8
2008	1.9	1.5	1.5	2.6	2.2	1.0	10.6
2009	1.8	1.6	1.6	2.4	2.1	1.1	10.6
2010	1.7	1.6	1.6	2.5	2.2	1.2	10.8
2011	1.8	1.5	1.6	2.4	2.1	1.4	10.9
2012	1.9	1.5	1.5	2.4	2.3	1.4	10.9
2013	2.2	1.5	1.6	2.4	2.3	1.4	11.3
2014	1.8	1.4	1.5	2.3	2.3	1.4	10.8
2015	1.7	1.4	1.7	2.3	2.3	1.4	10.8

[a] Other includes Argentina, Brazil, India, Iran, Mexico, Pakistan, South Africa and Turkey.

Notes: See Table 2 for a list of the countries making up each region. Totals may not equal sum of components due to independent rounding. Data adjusted by three-point smoothing.

Source: Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, International Nuclear Model, File INM.WK4, 1997.

Table F6. Projected World Cumulative Discharges of Spent Fuel, Reference Case, 1997-2015

(Thousand Metric Tons of Uranium)

Year	United States	Canada	Eastern Europe	Western Europe	Far East	Other[a]	Total
1997	2.1	1.6	1.2	3.6	1.5	0.4	10.4
1998	4.3	3.3	2.5	7.2	3.1	0.8	21.3
1999	6.7	4.9	3.9	10.9	4.8	1.3	32.5
2000	9.0	6.5	5.3	14.6	6.5	1.9	43.8
2001	11.1	8.0	6.7	18.2	8.2	2.5	54.8
2002	13.3	9.5	8.1	21.5	9.9	3.1	65.5
2003	15.4	11.0	9.6	24.7	11.6	3.8	76.2
2004	17.6	12.6	11.1	27.7	13.4	4.5	86.8
2005	19.6	14.2	12.6	30.8	15.3	5.2	97.6
2006	21.6	15.8	14.1	33.7	17.2	6.1	108.5
2007	23.4	17.4	15.6	36.5	19.3	7.0	119.2
2008	25.3	18.9	17.1	39.1	21.4	8.0	129.8
2009	27.1	20.5	18.7	41.5	23.6	9.1	140.4
2010	28.8	22.1	20.3	43.9	25.8	10.3	151.2
2011	30.7	23.6	21.9	46.4	27.9	11.7	162.1
2012	32.5	25.1	23.5	48.8	30.2	13.1	173.0
2013	34.7	26.5	25.0	51.1	32.4	14.4	184.3
2014	36.6	27.9	26.6	53.5	34.7	15.8	195.0
2015	38.3	29.3	28.2	55.8	37.0	17.2	205.8

[a] Other includes Argentina, Brazil, India, Iran, Mexico, Pakistan, South Africa and Turkey.

Notes: See Table 2 for a list of the countries making up each region. Totals may not equal sum of components due to independent rounding. Data adjusted by three-point smoothing.

Source: Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, International Nuclear Model, File INM.WK4, 1997.

Table F7. Low and High Case Nuclear Capacity Projections for 2000, 2005, 2010, and 2015
(Net Gigawatts Electric)

Country Name	Low Case				High Case			
	2000	2005	2010	2015	2000	2005	2010	2015
North America								
United States	89.1	63.0	49.1	22.1	101.0	101.0	99.4	95.0
Canada	14.1	13.7	13.6	11.5	15.0	14.7	14.8	13.1
Subtotal	103.2	76.7	62.7	33.6	116.0	115.7	114.2	108.1
W. Europe								
Belgium	5.6	5.5	5.5	5.4	5.8	5.9	6.0	6.0
Finland	2.6	2.5	2.5	2.5	2.7	2.7	2.7	2.8
France	63.2	61.0	60.2	59.5	65.5	65.0	65.8	66.6
Germany	20.7	20.4	19.9	17.9	21.5	21.8	21.7	20.0
Netherlands	0.4	0.0	0.0	0.0	0.5	0.0	0.0	0.0
Slovenia	0.6	0.6	0.6	0.6	0.7	0.8	0.8	0.8
Spain	7.1	6.8	6.8	6.7	7.3	7.3	7.4	7.5
Sweden	9.9	9.7	9.6	6.3	10.2	10.4	10.5	7.1
Switzerland	3.0	3.0	2.6	1.9	3.1	3.2	2.8	2.1
United Kingdom	11.6	10.2	9.2	6.8	12.0	10.9	10.0	7.6
Subtotal	124.7	120.0	116.8	107.5	129.4	127.9	127.7	120.5
E. Europe								
Armenia	0.4	0.8	0.7	0.7	0.4	0.9	1.0	1.0
Bulgaria	3.4	2.7	2.5	1.7	3.9	3.3	3.4	2.5
Czech Republic	3.4	3.5	3.2	3.1	3.9	4.1	4.3	4.6
Hungary	1.7	1.7	1.6	1.5	1.9	2.1	2.2	2.3
Kazakhstan	0.1	0.5	0.5	0.5	0.1	0.6	0.6	0.7
Lithuania	2.4	2.4	2.2	1.1	2.7	2.8	3.0	1.6
Romania	0.6	1.3	1.2	1.2	0.7	1.6	1.6	1.7
Russia	19.9	23.6	21.4	16.8	22.3	28.3	29.0	25.0
Slovak Republic	2.0	1.6	1.5	1.4	2.3	1.9	2.0	2.1
Ukraine	14.1	13.1	14.6	10.4	15.7	15.7	19.9	15.5
Subtotal	47.9	51.1	49.3	38.3	53.9	61.3	67.0	57.2
Far East								
China	1.9	5.6	8.4	11.7	2.2	7.3	12.4	19.8
Japan	41.9	47.5	51.2	54.7	44.0	51.4	56.9	62.4
Korea, North	0.0	1.0	1.6	1.5	0.0	1.1	2.3	2.4
Korea, South	12.3	16.8	17.0	19.1	14.3	19.4	24.6	30.4
Taiwan	4.6	7.4	6.1	5.7	5.4	8.6	8.8	9.1
Subtotal	60.7	78.2	84.3	92.7	65.8	87.8	105.0	124.1
Other								
Argentina	0.8	1.6	1.0	0.9	1.0	1.9	1.5	1.6
Brazil	0.6	1.9	1.4	1.3	0.7	2.2	2.2	2.3
India	2.3	2.3	4.7	6.1	2.7	3.0	7.1	9.7
Iran	0.0	0.9	1.7	1.7	0.0	1.1	2.4	2.6
Mexico	1.3	1.3	1.3	1.3	1.3	1.3	1.5	1.5
Pakistan	0.4	0.4	0.6	0.5	0.5	0.5	0.9	0.7
South Africa	1.7	1.7	1.5	1.5	1.8	2.0	2.0	2.2
Turkey	0.0	0.0	1.2	1.2	0.0	0.0	1.4	1.4
Subtotal	7.0	10.0	13.5	14.5	8.1	12.0	18.9	22.0
Total World	**343.6**	**336.0**	**326.5**	**286.7**	**373.2**	**404.7**	**432.9**	**431.9**

Notes: Totals may not equal sum of components due to independent rounding.
Source: Energy Information Administration, Office of Coal, Nuclear, Electric, and Alternate Fuels, Supply Analysis Division.

Appendix G

U.S. Customary Units of Measurement, International System of Units (SI), and Selected Data Tables in SI Metric Units

Appendix G

U.S. Customary Units of Measurement, International System of Units (SI), and Selected Data Tables, in SI Metric Units

Standard factors for interconversion between U.S. customary units and the International System of Units (SI) are shown in the table below. These factors are provided as a coherent and consistent set of units for the convenience of the reader in making conversions between U.S. and metric units of measure for data published in this report. Conversion factors are provided only for the U.S. units of measurement quoted in this report.

Conversion Factors for U.S. Customary Units and SI Metric Units of Measurement

To convert from:	To:	Multiply by:
feet	meters	0.304 801
short tons	metric tons	0.907 185
pounds U_3O_8	kilogram U	0.384 647
million pounds U_3O_8	thousand metric tons U	0.384 647
$per pound U_3O_8	$ per kilogram U	2.599 786

Table G1. Projected World Annual Uranium Requirements, Reference Case, 1997-2015

(Thousand Metric Tons Uranium)

Year	United States	Canada	Eastern Europe	Western Europe	Far East	Other[a]	Total
1997	20.4	1.8	8.3	20.8	10.7	1.0	63.0
1998	19.0	1.6	9.1	19.9	11.0	1.3	61.8
1999	17.9	1.5	9.2	19.6	11.4	1.3	60.8
2000	17.7	1.5	9.0	19.2	12.2	1.4	61.0
2001	18.7	1.5	8.8	19.3	12.8	1.2	62.3
2002	17.5	1.6	9.1	18.8	14.3	1.5	62.8
2003	18.3	1.6	9.1	19.4	14.4	1.5	64.3
2004	16.5	1.6	9.1	18.8	14.9	1.8	62.7
2005	17.7	1.6	9.3	18.8	14.4	2.0	63.7
2006	16.6	1.6	9.3	18.3	15.3	2.2	63.2
2007	15.7	1.5	9.5	18.5	16.3	2.3	63.8
2008	16.0	1.5	9.1	18.6	15.8	2.0	63.1
2009	15.1	1.5	8.5	18.6	16.4	2.2	62.3
2010	16.0	1.5	8.3	18.6	16.8	2.2	63.4
2011	13.2	1.5	8.0	17.9	17.8	2.3	60.7
2012	13.2	1.4	8.2	17.5	18.3	2.3	60.8
2013	10.9	1.4	7.7	16.8	17.7	2.3	56.8
2014	11.2	1.3	7.4	16.4	17.8	2.5	56.6
2015	10.2	1.2	7.1	16.0	16.9	2.4	53.8

[a] Other includes Argentina, Brazil, India, Iran, Mexico, Pakistan, South Africa and Turkey.

Notes: See Table 2 for a list of the countries making up each region. Totals may not equal sum of components due to independent rounding.

Source: Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, International Nuclear Model, File INM.WK4, 1997.

Table G2. Projected World Cumulative Uranium Requirements, Reference Case, 1997-2015
(Thousand Metric Tons Uranium)

Year	United States	Canada	Eastern Europe	Western Europe	Far East	Other[a]	Total
1997	20.4	1.8	8.3	20.8	10.7	1.0	63.0
1998	39.4	3.4	17.4	40.7	21.6	2.3	124.8
1999	57.3	4.9	26.6	60.2	33.0	3.7	185.7
2000	75.0	6.4	35.6	79.4	45.2	5.1	246.7
2001	93.7	7.9	44.4	98.7	58.0	6.3	309.0
2002	111.2	9.5	53.5	117.5	72.3	7.8	371.8
2003	129.5	11.1	62.6	136.8	86.7	9.3	436.1
2004	146.0	12.7	71.7	155.6	101.7	11.1	498.8
2005	163.7	14.3	81.0	174.4	116.0	13.0	562.5
2006	180.3	15.9	90.3	192.7	131.3	15.2	625.7
2007	195.9	17.5	99.8	211.3	147.6	17.5	689.5
2008	212.0	19.0	108.8	229.9	163.4	19.5	752.6
2009	227.1	20.5	117.4	248.5	179.9	21.6	814.9
2010	243.1	22.0	125.7	267.1	196.6	23.9	878.4
2011	256.3	23.5	133.7	285.0	214.4	26.2	939.0
2012	269.4	24.9	141.9	302.6	232.7	28.5	999.9
2013	280.4	26.2	149.6	319.4	250.3	30.8	1,056.7
2014	291.6	27.5	157.1	335.8	268.2	33.3	1,113.3
2015	301.8	28.7	164.1	351.7	285.1	35.7	1,167.1

[a] Other includes Argentina, Brazil, India, Iran, Mexico, Pakistan, South Africa and Turkey.

Notes: See Table 2 for a list of the countries making up each region. Totals may not equal sum of components due to independent rounding.

Source: Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, International Nuclear Model, File INM.WK4, 1997.

Table G3. Projected U.S. Spot-Market Price, Net Imports, Commercial Inventories, and Production

(Prices in Constant 1996 Dollars per Kilogram Uranium; All Other Projections in Thousand Metric Tons Uranium Equivalent)

	Spot-Market Price	Net Imports	Commercial Inventories	Production
1997	29.12	15.7	28.2	2.3
1998	32.24	11.7	25.3	2.5
1999	34.06	10.5	23.0	2.9
2000	34.84	10.2	21.1	3.0
2001	34.84	11.0	19.7	3.1
2002	37.44	10.5	18.7	3.1
2003	39.26	11.6	17.9	3.1
2004	40.30	10.7	17.3	3.1
2005	40.04	12.5	16.8	3.2
2006	40.30	11.5	16.4	3.2
2007	40.82	10.6	16.0	3.2
2008	40.30	12.1	15.7	3.3
2009	41.34	11.1	15.4	3.3
2010	41.08	12.0	15.2	3.3

Note: Adjusted by three-point smoothing.

Source: Energy Information Administration, Uranium Market Model run no. 1997_73.dat, July 18, 1997.

Glossary

Baseload Plant: A plant, usually housing high-efficiency steam-electric units, which is normally operated to take all or part of the minimum load of a system, and which consequently produces electricity at an essentially constant rate and runs continuously. These units are operated to maximize system mechanical and thermal efficiency and minimize system operating costs.

Boiling-Water Reactor (BWR): A light-water reactor in which water, used as both coolant and moderator, is allowed to boil in the core. The resulting steam can be used directly to drive a turbine.

Breeder Reactor: A reactor that both produces and consumes fissionable fuel, especially one that creates more fuel than it consumes. The new fissionable material is created by a process known as breeding, in which neutrons from fission are captured in fertile materials.

Burnup: A measure of the amount of energy obtained from fuel in a reactor. Typically, burnup is expressed as the amount of energy produced per unit weight of fuel irradiated or "burned." Burnup levels are generally measured in units of megawattdays thermal per metric ton of initial heavy metal (MWDT/MTIHM).

Byproduct Recovery (uranium): Uranium is recovered as a byproduct in plants where ore is treated primarily to recover other commodities such as copper or phosphoric acid. The uranium content in these ores is too low to be economically mined solely for the uranium.

Canadian Deuterium-Uranium Reactor (CANDU): A reactor that uses heavy water or deuterium oxide (D_2O), rather than light water (H_2O) as the coolant and moderator. Deuterium is an isotope of hydrogen that has a different neutron absorption spectrum from that of ordinary hydrogen. In a deuterium-oxide-moderated reactor, fuel made from natural uranium (0.71 U-235) can sustain a chain reaction.

Capacity: The load for which a generating unit is rated, either by the user or by the manufacturer. In this report, "capacity" refers to the utility's design electrical rating (see below).

Capacity Factor: The ratio of the electricity produced by a generating unit, for the period of time considered, to the energy that could have been produced at continuous full-power operation during the same period.

Centrifuge Process: The enrichment process whereby the concentration of the uranium-235 (U-235) isotope contained in natural uranium is increased to a level suitable for use in nuclear power plants (generally 3 to 5 percent) by rapidly spinning cylinders containing the uranium in the form of gaseous uranium hexafluoride (UF_6). Due to differences in the masses of isotopes, the rapid spinning separates the U-235 isotope from U-238, the principal isotope contained in natural uranium.

Commercial Operation: The phase of reactor operation that begins when power ascension ends and the operating utility formally declares to the NRC that the nuclear power plant is available for the regular production of electricity. This declaration is usually related to the satisfactory completion of qualification tests on critical components of the unit.

Construction Pipeline: The various stages involved in the acquisition of a nuclear reactor by a utility. The events that define these stages are the ordering of a reactor, the licensing process, and the physical construction of the nuclear generating unit. A reactor is said to be "in the pipeline" when the reactor is ordered and "out of the pipeline" when it completes low-power testing and begins operation toward full power. (See Operable).

Conventional mill (uranium): A facility engineered and built principally for processing of uraniferous ore materials mined from the earth and the recovery, by chemical treatment in the mill's circuits, of uranium and/or other valued coproduct components from the processed ore.

Criticality: The condition in which a nuclear reactor is just self-sustaining (i.e., the rate at which fissioning remains constant.)

Design Electrical Rating (Capacity), Net: The nominal net electrical output of a nuclear unit, as specified by the utility for the purpose of plant design.

Discharged Fuel: Irradiated fuel removed from a reactor during refueling. (See Spent Nuclear Fuel.)

Enrichment Tails Assay: A measure of the amount of fissile uranium (U-235) remaining in the waste stream from the uranium enrichment process. The natural uranium "feed" that enters the enrichment process generally contains 0.711 percent (by weight) U-235. The "product stream" contains enriched uranium (greater than 0.711 percent U-235) and the "waste" or "tails" stream contains depleted uranium (less than 0.711 percent U-235). At the historical enrichment tails assay of 0.2 percent, the waste stream would contain 0.2 percent U-235. A higher enrichment tails assay requires more uranium feed (thus permitting natural uranium stockpiles to be decreased), while increasing the output of enriched material for the same energy expenditure.

Equilibrium Cycle: An analytical term which refers to fuel cycles that occur after the initial one or two cycles of a reactor's operation. For a given reactor, equilibrium cycles have similar fuel characteristics.

Fast Breeder Reactor (FBR): A reactor in which the fission chain reaction is sustained primarily by fast neutrons rather than by thermal or intermediate neutrons. Fast reactors require little or no use of a moderator to slow down the neutrons from the speeds at which they are ejected from fissioning nuclei. This type of reactor produces more fissile material than it consumes.

Fertile Material: Material that is not itself fissionable by thermal neutrons but can be converted to fissile material by irradiation. The two principal fertile materials are uranium-238 and thorium-232.

Fissile Material: Material that can be caused to undergo atomic fission when bombarded by neutrons. The most important fissionable materials are uranium-235, plutonium-239, and uranium-233.

Fission: The process whereby an atomic nucleus of appropriate type, after capturing a neutron, splits into (generally) two nuclei of lighter elements, with the release of substantial amounts of energy and two or more neutrons.

Forward Costs: The operating and capital costs (in current dollars) still to be incurred in the production of uranium from estimated reserves; such costs are used in assigning the uranium reserves to cost categories. Forward costs include labor, materials, power and fuel, royalties, payroll and production taxes, insurance, and general and administrative costs. Expenditures prior to reserve estimates—e.g., for property acquisition, exploration, mine development, and mill construction—are excluded from forward cost determinations. Income taxes, profit, and the cost of money are also excluded. Thus, forward costs are neither the full costs of production nor the market price at which the uranium will be sold.

Forward Coverage: Amount of uranium required to assure uninterrupted operation of nuclear power plants.

Full-Power Day: The equivalent of 24 hours of full power operation by a reactor. The number of full power days in a specific cycle is the product of the reactor's capacity factor and the length of the cycle.

Gas-Cooled Fast Breeder Reactor (GCBR): A fast breeder reactor that is cooled by a gas (usually helium) under pressure.

Gaseous Diffusion Process: The enrichment process whereby the concentration of the uranium-235 (U-235) isotope contained in natural uranium is increased to a level suitable for use in nuclear power plants (generally 3 to 5 percent) by passing the uranium in the form of gaseous uranium hexafluoride (UF_6) through a series of porous membranes. In the process, the lighter U-235 isotope passes more easily through the membranes than does the heavier U-238, the principal isotope contained in natural uranium, resulting in progressively higher concentrations of U-235.

Generation (Electricity): The process of producing electric energy from other forms of energy; also, the amount of electric energy produced, expressed in watthours (Wh).

> *Gross Generation*: The total amount of electric energy produced by the generating units at a generating station or stations, measured at the generator terminals.
>
> *Net Generation*: Gross generation less the electric energy consumed at the generating station for station use.

Gigawatt-Electric (GWe): One billion watts of electric capacity.

Heavy Water: Water containing a significantly greater proportion of heavy hydrogen (deuterium) atoms to ordinary hydrogen atoms than is found in ordinary (light) water. Heavy water is used as a moderator in some reactors because it slows neutrons effectively and also has a low cross-section for absorption of neutrons.

Heavy-Water-Moderated Reactor: A reactor that uses heavy water as its moderator. Heavy water is an excellent moderator and thus permits the use of inexpensive natural (unenriched) uranium as fuel.

In situ leach mining (ISL): The recovery, by chemical leaching, of the valuable components of an orebody without physical extraction of the ore from the ground. Also referred to as "solution mining."

Kilowatt-Electric (kWe): One thousand watts of electric capacity.

Kilowatthour (kWh): One thousand watthours.

Light Water: Ordinary water (H_2O), as distinguished from heavy water or deuterium oxide (D_2O).

Light-Water Reactor (LWR): A nuclear reactor that uses water as the primary coolant and moderator, with slightly enriched uranium as fuel. There are two types of commercial light-water reactors—the boiling-water reactor (BWR) and the pressurized-water reactor (PWR).

Liquid Metal Fast Breeder Reactor (LMFBR): A nuclear breeder reactor, cooled by molten sodium, in which fission is caused by fast neutrons.

Load Following: Regulation of the power output of electric generators within a prescribed area in response to changes in system frequency, tieline loading, or the relation of these to each other, so as to maintain the scheduled system frequency and/or the established interchange with other areas within predetermined limits.

Long-Term Contract Price: Delivery price determined when contract is signed; it can be either a fixed price or a base price escalated according to a given formula.

Low-Power Testing: The period of time between a plant's initial fuel loading date and the issuance of its operating (full-power) license. The maximum level of operation during this period is 5 percent of the unit's design electrical rating.

MAGNOX: A gas-cooled power reactor that uses graphite as the moderator and carbon dioxide gas as the coolant.

Megawatt-Electric (MWe): One million watts of electric capacity.

Megawatthour (MWh): One million watthours of electric energy.

Megawattday (MWd): Twenty-four MWh's or 24 million watthours of electric energy.

Metric Tons of Initial Heavy Metal (MTIHM): The weight of the initial fuel loading (in metric tons) used in an assembly.

Metric Tons Uranium (MTU): A measure of weight equivalent to 2,204.6 pounds of uranium and other fissile and fertile materials that are loaded into an assembly during fabrication of the assembly.

Moderator: A material such as ordinary water, heavy water, or graphite, used in a reactor to slow down high-velocity neutrons, thus increasing the likelihood of further fission.

Net Summer Capability: The steady hourly output which generating equipment is expected to supply to a system load exclusive of auxiliary power as demonstrated by testing at the time of summer peak demand.

Nuclear Power Plant: A single- or multi-unit facility in which heat produced in a reactor by the fissioning of nuclear fuel is used to drive a steam turbine(s).

Nuclear Reactor: An apparatus in which the nuclear fission chain can be initiated, maintained, and controlled so that energy is released at a specific rate. The reactor apparatus includes fissionable material (fuel) such as uranium or plutonium; fertile material; moderating material (unless it is a fast reactor); a heavy-walled pressure vessel; shielding to protect personnel; provision for heat removal; and control elements and instrumentation.

Plutonium (Pu): A heavy, fissionable, radioactive, metallic element (atomic number 94). Plutonium occurs in nature in trace amounts. It can also be produced as a byproduct of the fission reaction in a uranium-fueled nuclear reactor and can be recovered for future use.

Power Ascension: The period of time between a plant's initial fuel loading date and its date of first commercial operation (including the low-power testing period). Plants in the first operating cycle (the time from initial fuel loading to the first refueling), which lasts approximately 2 years, operate at an average capacity factor of about 40 percent.

Pressurized-Water Reactor (PWR): A nuclear reactor in which heat is transferred from the core to a heat exchanger via water kept under high pressure, so that high temperatures can be maintained in the primary system without boiling the water. Steam is generated in a secondary circuit.

Reinserted Fuel: Irradiated fuel that is discharged in one cycle and inserted in the same reactor after sitting in the storage pool for at least one subsequent refueling. In a few cases, fuel discharged from one reactor has been used to fuel a different reactor.

Separative Work Unit (SWU): The standard measure of enrichment services. The effort expended in separating a mass F of feed of assay x_F into a mass P of product of assay x_P and waste of mass W and assay x_W is expressed in terms of the number of separative work units needed, given by the expression $SWU = WV(x_W) + PV(x_P) - FV(x_F)$, where $V(x)$ is the "value function," defined as $V(x) = (1 - 2x) \ln[(1-x)/x]$.

Spent Nuclear Fuel: Irradiated fuel that is permanently discharged from a reactor at the end of a fuel cycle. Spent or irradiated fuel is usually discharged from reactors because of chemical, physical, and nuclear changes that make the fuel no longer efficient for the production of heat, rather than because of the complete depletion of fissionable material. Except for possible reprocessing, this fuel must eventually be removed from its temporary storage location at the reactor site and placed in a permanent repository. Spent nuclear fuel is typically measured either in metric tons of heavy metal (i.e., only the heavy metal content of the spent fuel is considered) or in metric tons of initial heavy metal (essentially, the initial mass of the uranium before irradiation). The difference between these two quantities is the weight of the fission products.

Split Tails: Use of one tails assay for transaction of enrichment services and a different tails assay for operation of the enrichment plant. This mode of operations typically increases the use of uranium, which is relatively inexpensive, while decreasing the use of separative work, which is expensive.

Spot Market: The buying and selling of uranium for immediate or very near-term delivery, typically involving transactions for delivery of up to 500,000 pounds U_3O_8 within a year of contract execution.

Spot-Market Price: Price for material being bought and sold on the spot market.

Terawatthour (TWh): One trillion (10^{12}) watthours of electric energy.

Unfilled Requirements: Requirements not covered by usage of inventory or supply contracts in existence as of January 1 of the survey year.

Uranium (U): A heavy, naturally radioactive, metallic element of atomic number 92. Its two principally occurring isotopes are uranium-235 and uranium-238. Uranium-235 is indispensable to the nuclear industry because it is the only isotope existing in nature to any appreciable extent that is fissionable by thermal neutrons. Uranium-238 is also important, because it absorbs neutrons to produce a radioactive isotope that subsequently decays to plutonium-239, an isotope that also is fissionable by thermal neutrons.

Concentrate: A yellow or brown powder produced from naturally occurring uranium minerals as a result of milling uranium ores or processing of uranium-bearing solutions. Synonymous with "yellowcake," U_3O_8, or uranium oxide.

Natural Uranium: Uranium with the U-235 isotope present at a concentration of 0.711 percent (by weight), that is, uranium with its isotopic content exactly as it is found in nature.

Uranium Hexafluoride (UF_6): A white solid obtained by chemical treatment of U_3O_8, which forms a vapor at temperatures above 56 degrees centigrade. UF_6 is the form of uranium required for the enrichment process.

Uranium Oxide: A compound (U_3O_8) of uranium. Also referred to as "yellowcake" or concentrate when in pure form.

Enriched Uranium: Uranium enriched in the isotope U-235, from 0.711 percent (by weight) in natural uranium to an average of 3 to 5 percent U-235. Low-enriched uranium (LEU) contains up to 19 percent U-235, whereas highly enriched uranium (HEU) contains at least 20 percent U-235 and over 90 percent if used for nuclear weapons.

Fabricated Fuel: Fuel assemblies composed of an array of fuel rods loaded with uranium dioxide pellets, manufactured after conversion of enriched uranium hexafluoride to uranium dioxide.

Uranium Resource Categories: Three classes of uranium resources reflecting different levels of confidence in the categories reported. These classes are reasonable assured resources (RAR), estimated additional resources (EAR), and speculative resources (SR). They are described below:

Uranium Reserves: Estimated quantities of uranium in known mineral deposits of such size, grade, and configuration that the uranium could be recovered at or below a specified production cost with currently proven mining and processing technology and under current laws and regulations. Reserves are based on direct radiometric and chemical measurements of drill hole and other types of sampling of the deposits. Mineral grades and thickness, spatial relationships, depths below the surface, mining and reclamation methods, distances to milling facilities, and amenability of ores to processing are considered in the evaluation. The amount of uranium in ore that could be exploited within the forward cost levels are estimated according to conventional engineering practices, utilizing available engineering, geologic, and economic data.

Reasonably Assured Resources (RAR): The uranium that occurs in known mineral deposits of such size, grade, and configuration that it could be recovered within the given production cost ranges, with currently proven mining and processing technology. Estimates of tonnage and grade are based on specific sample data and measurements of the deposits and on knowledge of deposit characteristics. RAR correspond to DOE's Reserves category.

Estimated Additional Resources (EAR): The uranium in addition to RAR that is expected to occur, mostly on the basis of direct geological evidence, in extensions of well-explored deposits, little explored deposits, and undiscovered deposits believed to exist along a well-defined geologic trend with known deposits, such that the uranium can subsequently be recovered within the given cost ranges. Estimates of tonnage and grade are based on available sampling data and on knowledge of the deposit characteristics as determined in the best known parts of the deposit or in similar deposits. EAR correspond to DOE's Probable Potential Resource Category.

Speculative Resources (SR): Uranium in addition to EAR that is thought to exist, mostly on the basis of indirect evidence and geological extrapolations, in deposits discoverable with existing exploration techniques. The locations of deposits in this category can generally be specified only as being somewhere within given regions or geological trends. As the term implies, the existence and size of such deposits are speculative. The estimates in this category are less reliable than estimates of EAR. SR corresponds to DOE's Possible Potential Resources plus Speculative Potential Resources categories.