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Commercial Nuclear Power 1990

Prospects for the United States and the World

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Preface

This analysis report presents the current status and outlook for commercial nuclear generating units for all countries in the world with free market economies (FME). Information regarding operable reactors in countries with transitional and centrally planned economies is also presented. The No New Orders case of this report documents the U.S. nuclear capacity and generation projections through 2010 for all cases presented in the Energy Information Administration report *Annual Energy Outlook 1990*. Long-term projections of U.S. nuclear capacity and generation for three different scenarios through the year 2030 are provided in support of the Department of Energy's activities pertaining to the Nuclear Waste Policy Act of 1982 (as amended in 1987), and are used to produce the projections of fuel cycle requirements and spent fuel discharges contained in *World Nuclear Fuel Cycle Requirements 1990*. These projections also support the Energy Information Administration's annual report, *Domestic Uranium Mining and Milling Industry: Viability Assessment*, and are provided to the Organization for Economic Cooperation and Development (OECD) for preparation of the NEA/OECD report, *Summary of Nuclear Power and Fuel Cycle Data in OECD Member Countries*.

The World Integrated Nuclear Evaluation System (WINES) model, used for calculating the long-term nuclear capacity projections in this report, is documented in *Model Documentation of the World Integrated Nuclear Evaluation System*, Volumes I, II, and III (E.H Pechan and Associates, December 1984). The International Nuclear Model (INM), used for calculating the generation values in this report, is documented in *International Nuclear Model*, Volumes I, II, and III, prepared by System Sciences, Inc. (Bethesda Maryland). Information on obtaining the documentation and a computer tape containing all the programs, data input files for this report, and instructions for use of the models, allowing users to reproduce the results of the study, are available from the National Energy Information Center, Room 1F-048, Forrestal Building, Washington, DC 20585 (202/586-8800).

This year the report (Appendix J) contains, for the first time, information on nuclear plant construction costs as reported on the Form EIA-254. Previously, this information was contained in Energy Information Administration annual reports, the most recent of which was, *Nuclear Power Plant Construction Activity 1988*, DOE/EIA-0473 (Washington, DC, June 1989).

Since a model cannot fully address the complexities of the real world, this report does not provide unqualified predictions of the future. The projections presented in this report represent expectations of what could occur under a given set of assumptions. If conditions change, the projections will be affected accordingly. The uncertainty inherent in the projections should be recognized, so that they can be used in the proper context.

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Executive Summary

This report presents historical data on commercial nuclear power in the United States, with projections of domestic nuclear capacity and generation through the year 2030. Country-specific projections of nuclear capacity and generation through the year 2010 for other countries in the world with free market economies (FME) are also provided.[1] Additionally, information is presented regarding operable reactors and those under construction in countries with regulated market economies (RME) and centrally planned economies (CPE).

The Department of Energy is currently developing a National Energy Strategy (NES). The NES process includes a comprehensive review of the current energy situation and an analysis of potential energy futures. National Energy Strategy results are not included in this report since they are yet to be officially released by the Department. The reader is advised that NES forecasts may vary from those found in this report.

U.S. Commercial Nuclear Power

In this report, U.S. nuclear capacity projections are discussed for the intermediate term through 2010 and the long term through 2030. No New Orders, Lower Reference, and Upper Reference cases are presented for each of the projection periods. Sensitivity cases showing the effect of nuclear plant life extension are also included.

Current Status: December 31, 1989

Three U.S. nuclear units became operable and one was retired in 1989. This brought the total at the end of the year to 110 operable nuclear generating units in the United States, totaling 97.9 gigawatts of net electrical generating capacity (GWe). These units generated 529 net terawatthours (TWh) of electricity during 1989, or 17.8 percent of total U.S. electricity generation[2] (including non-utility generation) and 19.0 percent of total utility-generated electricity. The overall average capacity factor[3] (utilization rate) for nuclear units during 1989 was 62.3 percent, a decline from the exceptionally high 1988 rate of 63.5 percent, but still higher than any other year since 1978.

Projections of Installed Capacity for the Intermediate Term, Through 2010

Projections for all cases show an increase in operable nuclear capacity to 104 net GWe through the year 2000. Most of the capacity in the construction pipeline is projected to be completed by 1992, and only two units are projected to retire. In 2010, the Upper-Reference-case projection of operable capacity is 122 net GWe, the Lower-Reference-case projection is 103 net GWe, and the No-New-Orders-case projection is 100 net GWe. Ten more units are projected to retire by 2010.

Projections for the Long Term, Through 2030

The Energy Information Administration's long-term projections for the Lower Reference and Upper Reference cases assume that U.S. utilities will maintain a diversified baseload electricity supply by continuing to rely on coal and nuclear energy.

The projections of operable nuclear capacity for the year 2010 are used as a point of departure for long-term projections through 2030 in the Lower Reference and Upper Reference cases. (It is assumed that newly ordered nuclear capacity will not become operable before 2006.) The projections of net nuclear capacity in the Lower Reference and Upper Reference cases increase to 134 and 184 GWe, respectively, in 2030. The No-New-Orders-case projection of 6 GWe in 2030 results from the assumptions that there will be no new orders of nuclear reactors in the United States, and that units in operation and under construction will retire 40 years after the issuance of their operating licenses, with minor exceptions. In a sensitivity case which assumes that 70 percent of all U.S. capacity is life-extended for 20 years, the projected capacity in the No New Orders case in 2030 is 71 GWe. Depending on whether it is assumed that life-extended capacity displaces new orders, the range of projections for the

[1]Table 20 includes a complete listing of the FME countries considered in this report.
[2]Energy Information Administration, *Annual Outlook for U.S. Electric Power 1990*, DOE/EIA-0474(90), pp. 2, 11 (Washington, DC, June 1990).
[3]See the Glossary for the definition of capacity factor.

Upper Reference case for total nuclear capacity is from 184 GWe to 202 GWe in 2030.

Institutional and Technological Developments

Institutional and technological development issues are grouped into three categories. The first category--environmental issues--discusses recent progress on Clean Air Act legislation in the United States and the status of the "greenhouse" or global climate change phenomenon. The second category--U.S. nuclear industry--includes a review of U.S. nuclear technology and a discussion of nuclear power plant decommissioning. The third category--the internationalization of the nuclear power industry--discusses global nuclear research and development activities.

International Commercial Nuclear Power

Current Status: December 31, 1989

Twenty FME nations (including the United States) produced electricity from nuclear power in 1989. (Neither Italy nor Mexico generated electricity from their nuclear plants in 1989.) Nuclear generation in these countries was approximately 1,557.7 net TWh in 1989, an increase of about 2.3 percent from 1988. The number of operable nuclear units in FME countries increased from 349 in 1988 to 355 in 1989. Total operable nuclear capacity increased by about 2.3 percent to 273.6 net GWe by the end of 1989. In FME countries, excluding the United States, the 1989 construction pipeline included 70 nuclear units, totaling about 65 net GWe.

Projections for FME Through 2010

In the Lower Reference case, total operable nuclear capacity for countries belonging to the OECD[d] is projected to increase from about 255 net GWe at the end of 1989 to about 291 net GWe in the year 2010 (188 GWe when projected U.S. capacity is excluded). For non-OECD FME countries, operable nuclear capacity is projected to reach about 28 GWe in 2010. Table ES1 summarizes the 1989 nuclear capacity for the FME countries as well as the nuclear capacity projections in the Lower Reference case.

Table ES1. Lower-Reference-Case Projections of FME Operable Nuclear Capacity

Countries	1989[a]	Capacity (Net GWe)				
		1995	2000	2010	2020	2030
United States[b]	98	103	104	103	116	134
Canada	12	15	15	19	--	-
Europe	117	122	123	119	--	-
Far East	41	47	52	66	-	-
Other	6	6	8	11	-	-
Total FME	274	294	302	319	-	-
OECD	255	275	281	291	--	-
Non-OECD	18	19	21	28	--	-

[a] Status as of December 31, 1989.
[b] U.S. capacity totals are based on net summer capability ratings. For all non-U.S. units, capacity is the net design electrical rating. See Glossary for definitions.
OECD Organization for Economic Cooperation and Development
FME Free Market Economies.
Note: Totals may not equal sum of components due to independent rounding
Source: Table 8 and Table 24

[d] Footnote 41 on page 39 lists the OECD member countries.

Operable Nuclear Units in Countries With Regulated Market and Centrally Planned Economies

In nations with regulated market economies (RME) and centrally planned economies (CPE), 66 nuclear units with a total capacity of 43.8 net GWe were operable as of December 31, 1989, compared with 43.6 net GWe[5] at the end of 1988. In 1989, nuclear generation for these countries was 274.2 net TWh, or about 14 percent of their total electricity generation. The U.S.S.R. had 43 units totaling 34.2 GWe of nuclear capacity, or about 78 percent of the total nuclear capacity in the RME and CPE countries.

All the RME and CPE countries with operating nuclear plants or with nuclear plants under construction have experienced chronic shortages of electrical power. Nuclear power, however, is likely to represent a smaller fraction of total generating capacity than previously planned, and in some countries nuclear construction may be postponed. This reevaluation of nuclear power programs is due to a lack of available capital and operational safety concerns.

Status of U.S. Plant Construction

As reported on Form EIA-254, two units entered commercial operation during 1989. The units have a net summer capability of 2.3 GWe and a total construction cost of $4.2 billion. Five units remaining under construction at the end of the year have a net summer capability of 5.7 GWe and a total construction cost estimated at $21.7 billion.

[5]Some nuclear units were rerated to reflect more current data.

1. Introduction

This report presents the status at the end of 1989 and the outlook for commercial nuclear capacity and generation for all countries in the world with free market economies (FME). The report provides documentation of the U.S. nuclear capacity and generation projections through 2030. The long-term projections of U.S. nuclear capacity and generation are provided to the U.S. Department of Energy's (DOE) Office of Civilian Radioactive Waste Management (OCRWM) for use in estimating nuclear waste fund revenues and to aid in planning the disposal of nuclear waste. These projections also support the Energy Information Administration's annual report, *Domestic Uranium Mining and Milling Industry: Viability Assessment*, and are provided to the Organization for Economic Cooperation and Development. The foreign nuclear capacity projections are used by the DOE uranium enrichment program in assessing potential markets for future enrichment contracts.

The Department of Energy is currently developing a National Energy Strategy (NES). The NES process includes a comprehensive review of the current energy situation and an analysis of potential energy futures. National Energy Strategy results are not included in this report since they are yet to be officially released by the Department. The reader is advised that NES forecasts may vary from those found in this report.

The two major sections of this report discuss U.S. and foreign commercial nuclear power. The U.S. section (Chapters 2 and 3) deals with (1) the status of nuclear power as of the end of 1989; (2) projections of nuclear capacity and generation at 5-year intervals from 1990 through 2030; and (3) a discussion of institutional and technical issues that affect nuclear power. The nuclear capacity projections are discussed in terms of two projection periods: the intermediate term through 2010 and the long term through 2030. A No New Orders case is presented for each of the projection periods, as well as Lower Reference and Upper Reference cases.

The intermediate-term projections are derived from a detailed review of nuclear units both operating and under construction. The construction and regulatory status at the end of 1989 of each individual nuclear project and the progress toward its completion is assessed. The Upper and Lower Reference cases include differing amounts of capacity that is assumed to restart from a current indefinite deferred status. These cases also assume the startup of some newly ordered units between 2006 and 2010.

The intermediate-term projections of installed nuclear capacity serve as a point of departure for the U.S. long-term projections through 2030. The long-term projections were prepared, in part, using the World Integrated Nuclear Evaluation System (WINES). WINES is an aggregated energy demand model that derives nuclear generation requirements (and installed capacity) as a share of electrical generation, which is, in turn, derived as a share of delivered energy. Delivered energy requirements are derived using a demand function that incorporates demographic, economic, and energy price factors.

Chapter 4 consists of (1) a general discussion of the status of nuclear power in the foreign FME countries; and (2) Lower Reference and Upper Reference case nuclear capacity projections for individual FME countries for 1995, 2000 and 2010. Chapter 5 reviews commercial nuclear power programs in free market, regulated market and centrally planned economies. Because of political developments in Eastern Europe during the Fall of 1989, EIA has eliminated a separate appendix for discussions of commercial nuclear power programs in centrally planned economies, and incorporated the information in the body of the report.

The report also contains a number of appendices. Appendix A is a map identifying the Federal regions of the United States. Appendix B describes the reactor construction pipeline analysis and the WINES model, both of which are used in developing projections of installed nuclear capacity. Appendices C, D, E, F, and G contain detailed generating unit information for U.S. and foreign nuclear units that are operable or in the construction pipeline. Appendix H contains rosters of nuclear units that are operable or in the construction pipeline in countries with regulated market and centrally planned economies. Appendix I contains annual projections of U.S. nuclear capacity and associated electricity generation through 2030. Appendix J contains U.S. construction cost data and milestones for nuclear units in the construction pipeline. A Glossary is also included.

2. U.S. Commercial Nuclear Power

The commercial nuclear power industry in the United States remains substantially unchanged from a year ago. A variety of uncertainties remain concerning the industry, many of which could individually affect its future. Some of the uncertainties, such as waste disposal issues, operating and maintenance costs, and the possibility of extending operating lives, pertain to existing units. Others, such as capital costs, technology developments, regulatory environments, and the structure of the industry apply to anticipated new orders. Most of these issues were addressed in some manner during 1989, but, in general, their resolution will evolve over a longer time period.

This chapter describes the status of the domestic commercial nuclear power industry at the end of 1989, as well as projections for the intermediate term (through 2010) and the longer term (through 2030). The assumptions underlying the projections and the methodologies for producing them are described. Finally, the results are compared with projections from other sources.

Status as of December 31, 1989

The status of U.S. nuclear power plants that were either operable or in the construction pipeline at the end of 1989 is shown in Table 1. There were 110 operable units at that time,[a] with a total net capacity of 97.9 gigawatts-electric (GWe).

As of December 31, 1989, there were 11 nuclear units with a total net capacity of 13.1 GWe in the construction pipeline. Of these, 1 unit had loaded fuel and was undergoing low-power testing. The remaining 10 had received construction permits, although construction of 6 units has been indefinitely deferred. One unit was retired during 1989. There were 121 nuclear units in operation and in the pipeline at year-end with a combined net summer capability of 111.0 GWe (see Appendices C and D for a complete listing of operable nuclear units and those in the construction pipeline).

Table 1. Status of U.S. Nuclear Generating Units as of December 31, 1989

Status	Number of Units	Net Summer Capability (GWe)
Operable[a]		
In Commercial Operation[b]	109	96.8
In Power Ascension	1	1.1
Total	110	97.9
In Construction Pipeline		
In Low-Power Testing	1	1.2
Under Construction	4	4.6
Indefinitely Deferred[c]	6	7.4
Total[d]	11	13.1
Reactors on Order	0	0.0
Total[d]	121	111.0

[a] Operable units are those that have been issued a full power license by the Nuclear Regulatory Commission. Retired units are not included. Shoreham received a full power license in April 1989. Since the unit is not currently scheduled to operate, it is not not included in the total.
[b] Three Mile Island 2 and Hanford-N are not included.
[c] Includes Bellefonte 1 and 2, Grand Gulf 2, Perry 2, WNP1 and WNP3.
[d] Total capacity may not equal sum of components due to independent rounding.
Sources: **Capacity Data**--Energy Information Administration, Form EIA-860, "Annual Electric Generator Report" (1989). **Status Data**--Energy Information Administration, *Monthly Energy Review*, December 1989, DOE/EIA-0035(89/12) (March 1990), p. 96.

[a] For the United States, an "operable" reactor is defined as a unit that has been issued a full power license by the Nuclear Regulatory Commission (NRC).

During 1989, South Texas 2 (1,250 MWe), Vogtle 2 (1,086 MWe), and Limerick 2 (1,055 MWe) achieved operable status. One unit, Fort St. Vrain (217 MWe) was retired during the year. Rancho Seco (873 MWe) was shut down by the Sacramento Municipal Utility District following a referendum on its continued operation. There are currently no plans to operate it as a nuclear unit; however, it retains an operating license and it is included in the "operable" category in Table 1. Shoreham, owned by Long Island Lighting Co. in New York State, is not included in the totals. The unit received a full-power license in April 1989; however, it is not currently scheduled to operate, following an agreement to transfer ownership to the State and decommission it. Appendix E contains a complete listing of nuclear units ordered in the United States since 1953, including all units that were canceled before completion.

Nuclear plants produced a record 529 net terawatthours (TWh) of electricity in 1989--a 0.5 percent increase over 1988.[7] This generation was 19.0 percent of the total U.S. electricity generation by utilities during the year--down from 19.5 percent in 1988. This generation was 17.8 percent of total U.S. electricity generation (including nonutility generation).[8]

The overall average capacity factor (utilization rate) achieved by U.S. nuclear units in 1989 reached 62.3 percent, which is 1.9 percent less than the 1988 value and higher than any other year since 1978.[9]

Table 2. U.S. Nuclear Generating Units Achieving the Best Lifetime Performance Records

Ranking of Unit	Operating Utility	Reactor Type	Year of Initial Operation	Lifetime Average Value (percent)
	Highest Capacity Factors			
1. Prairie Island 2	Northern States Power	PWR	1974	84.3
2. St. Lucie 2	Florida Power and Light	PWR	1983	82.9
3. Kewaunee	Wisconsin Public Service	PWR	1974	81.6
4. Joseph M. Farley 2	Alabama Power	PWR	1981	81.5
5. Point Beach 2	Wisconsin Electric Power	PWR	1972	80.7
6. Prairie Island 1	Northern States Power	PWR	1973	80.6
7. Callaway 1	Union Electric	PWR	1984	79.4
8. Haddam Neck	Connecticut Light and Power	PWR	1967	77.3
9. Waterford 3	Louisiana P&L	PWR	1985	76.2
10. Wolf Creek	Kansas City P&L and Kansas Gas & Elec.	PWR	1985	76.1
	Lowest Forced Outage Rates[a]			
1. Point Beach 2	Wisconsin Electric Power	PWR	1972	1.2
2. Point Beach 1	Wisconsin Electric Power	PWR	1970	1.9
3. Kewaunee	Wisconsin Public Service	PWR	1974	2.6
4. Diablo Canyon 1	Pacific Gas and Electric	PWR	1984	2.8
5. Prairie Island 2	Northern States Power	PWR	1974	3.0
6. Fort Calhoun 1	Omaha Public Power District	PWR	1973	3.0
7. Callaway 1	Union Electric	PWR	1984	3.3
8. St. Lucie 1	Florida Power and Light	PWR	1976	3.4
9. Monticello 1	Northern States Power	BWR	1971	4.0
10. Joseph M. Farley 2	Alabama Power	PWR	1981	4.6

[a] Represents only unscheduled downtime (excludes refueling and scheduled maintenance).
BWR Boiling-Water Reactor
PWR Pressurized-Water Reactor
Note: Only reactors that had operated for at least three complete fuel cycles by December 31, 1989, are listed.
Source: Nuclear Regulatory Commission, *Operating Status Report*, NUREG-0020 (Washington, DC, January 1990).

[7] Based on revised data from the Energy Information Administration, *Monthly Energy Review*, January 1990, DOE/EIA-0035(90/01) (Washington, DC, January 1990).
[8] Energy Information Administration, *Annual Outlook for U.S. Electric Power 1990*, DOE/EIA-0474(90), pp. 2,11 (Washington, DC, June 1990).
[9] The capacity factors shown are consistent with those published in EIA's *Monthly Energy Review*. They are based on the net summer capability ratings and generation data from Form EIA-759, "Monthly Power Plant Report."

Units achieving top operating performance (capacity factors) during 1989 were Three Mile Island 1 (102 percent), Prairie Island 1 (99.7 percent), Hatch 1 (97.7 percent), Wolf Creek (97.7 percent), Maine Yankee (97.0 percent), Davis-Besse (96.0 percent), and Sequoyah 1 (95.0 percent). Twenty-two other units, the same number as in 1988, had annual capacity factors above 80 percent.[10] (It should be noted that a unit's annual capacity factor is highly dependent on whether or not it is refueled during a particular year.) Table 2 shows top performing U.S. units based on two measures--cumulative capacity factors and cumulative forced outage rates. The difference between 100 percent and the cumulative capacity factor for each reactor represents the time spent in refueling, scheduled maintenance, and unscheduled downtime. The forced outage rate represents only unscheduled downtime. In general, the units with low forced outage rates also had high capacity factors. In 1989, two newer units, Waterford 3 and Wolf Creek displaced older units on these lists. Note that only one boiling-water reactor (BWR) is on either of the lists.

Outlook for the Intermediate Term, Through 2010

This section presents projections of domestic installed nuclear capacity and net electrical generation from 1989 through 2010 for the No New Orders, Lower Reference, and Upper Reference cases. These cases describe a range of values, which vary as a result of differing assumptions about the schedules for individual nuclear units that currently remain uncompleted as well as assumptions about newly ordered units. These cases should not be interpreted as exhausting the range of possible nuclear supply futures. Nuclear plant life extension is not assumed to occur in these cases but is covered in a sensitivity case later in this chapter. No effects of expected changes in the Clean Air Act are included; however, a discussion is included in Chapter 3.

Basic Methodology

The methodology used in deriving the intermediate-term capacity projections was the same as that used to prepare EIA analyses presented in the *Annual Energy Outlook 1990* (AEO) and the *Annual Outlook for U.S. Electric Power*. In fact, the No New Orders case documents the U.S. nuclear capacity and generation projections through 2010 in all cases in the 1990 AEO. In general, this methodology entails a detailed review of units under construction and an estimate of the year for first operation of each unit, a method often described as "pipeline analysis" (Appendix B). The Lower Reference case is a limited growth case in which lead plants are assumed to operate beginning in 2006. The Upper Reference case includes a supply constrained growth transition in which the new unit annual ordering rate follows a trend from one GWe in 2006 to 6 GWe in 2010. Projections of electricity generation for the No New Orders, Lower Reference and Upper Reference cases are obtained from the International Nuclear Model (INM).

Intermediate-Term Case Assumptions

In addition to the reactor construction pipeline approach, the following assumptions were used to develop the intermediate-term projections.

Assumptions Applicable to All Cases

- It is assumed that nuclear units will operate for 40 years from the issuance of their operating license even though prior to 1982 nuclear operating licenses were issued for 40 years, beginning with the issuance of a construction permit.[11] An electric utility may petition the Nuclear Regulatory Commission (NRC) for a redefinition of the operating license for those nuclear units to recover the construction time. It is assumed that those licenses will be redefined. A current exception to this rule is the projected official retirement of Rancho Seco in 1990.

- Nuclear units are assumed to supply baseload power.

- The average equilibrium cycle capacity factor for existing units is assumed to increase to 68 percent in 2010. The average capacity factor for units in their first fuel cycle is assumed to be 55 percent.

- Estimates of first operation dates for the remaining nuclear units under construction reflect historical construction performance, any regulatory or financial constraints, and regional electricity demand considerations.

[10]Nuclear Regulatory Commission, *Operating Status Report*, NUREG-0020 (Washington, DC, January 1990).

[11]The average operating life for existing units with operating licenses for 40 years from the issuance of their construction permits is about 34 years.

The following assumptions apply to the Lower and Upper Reference cases.

- Utilities undertaking long-term investment are essentially assured a return on those investments.
- Some manner of turnkey pricing or risk sharing is available to utilities.
- A high-level waste repository is constructed and available to receive spent fuel by 2010. In the interim, either legislation is passed which decouples the construction of a Monitored Retrievable Storage (MRS) facility from the siting of the repository as is currently required by the Nuclear Waste Policy Act of 1982, or, tangible progress is made on the permanent site.
- Nuclear power will be economically advantageous over alternative baseload generating technologies in some regions of the country and construction and licensing leadtimes are held to 6 to 7 years.
- Financial protection of the industry is available through extension of the Price-Anderson Amendments Act of 1988 or by some similar type of liability coverage.
- New units are assumed to be improved or advanced light-water reactors.

Assumptions Applicable to the Upper Reference Case

- The reactor licensing process becomes effectively certain This includes legislated one-step licensing, the availability of a preapproved standardized design, and advanced site certification.
- All units that are indefinitely deferred, with the exception of Grand Gulf 2, are completed and become operable. (The licensee has announced the cancellation of Grand Gulf; however, it has not been officially removed from the NRC list of reactors).
- New reactor orders resume in 1999 and initially have a 7-year leadtime. The ordering rate follows a linear trend from 1 gigawatt (GWe) in the first year to 6 GWe per year 4 years later. Operable capacity from 2006 through 2010 reflects this ordering rate.

(It should be noted that, in anticipation of new orders, the DOE planning basis for the advanced reactor program is premised on the assumption that these orders will commence in 1995 and begin commercial operation by 2000).

Assumptions Applicable to the Lower Reference Case

- The reactor licensing process becomes less contentious, and includes administrative one-step licensing, the availability of a preapproved standardized design, and advanced site certification.
- Three of the indefinitely deferred units are completed and become operable. Two new lead plants are completed for operation during the 2006 through 2010 time period.
- The following units are assumed to be canceled: Grand Gulf 2, Perry 2 and WNP 3.

Intermediate-Term Projections

The EIA projection for nuclear capacity in the period from 1990 through 2010 is for continued completion of units under construction and varying degrees of activity toward the resumption of orders for new units. Operable nuclear capacity, in all cases, is expected to increase from 97.9 net GWe at the end of 1989 to 103.8 net GWe in 2000. The average annual growth rate in operable nuclear capacity is 0.5 percent per year from 1989 to 2000.

The Upper-Reference-case capacity, as shown in Table 3, increases from 103.8 GWe in 2000 to 122.1 GWe in 2010, a growth rate of 1.6 percent per year over the 10-year period. The capacity totals assume replacement of about 6.4 GWe of retiring nuclear capacity with new nuclear capacity by 2010.[12] This case assumes that five units for which construction is currently halted are eventually completed. The Lower-Reference-case capacity projections increase to 105.0 GWe in 2005 and decline to 102.9 GWe in 2010. This case assumes that three units for which construction is currently halted are eventually completed. There is a net decline in this projection because of the retirement of 6.4 GWe of capacity. Capacity projections for the No New Orders case match the growth cases through 2000, then decline to 99.7 GWe by 2010. The regional breakdown for the No New Orders case is shown in Table 4. From this it can be seen that most of the early retirements (under the 40-year life assumption) occur in the Northeast.

Nuclear generation by region is shown for 1989 and the No New Orders case in Table 5. The 1989 percent share for nuclear ranges from 34 percent in New England, to nearly zero in the North Central region. The nuclear share of generation in three regions--New York/New Jersey, the South Atlantic and the Midwest

[12] The 6.4 GWe of retirements is based upon the operable dates in Appendix C and the assumed 40 year operating lives.

Table 3. U.S. Operable Nuclear Capacity at the End of the Year, 1989, and Projections for 1990 Through 2010

Year	Capacity (Net GWe)[a]		
	No New Orders Case	Lower Reference Case	Upper Reference Case
1989[b]	97.9	97.9	97.9
1990	99.3	99.3	99.3
1995	102.8	102.8	102.8
2000	103.8	103.8	103.8
2005	103.8	105.0	105.0
2010	99.7	102.9	122.1

[a] Capacity values are based on net summer capability ratings.
[b] Actual.
Sources: **Capacities**--No New Orders Case and Lower and Upper Reference Cases through 2005--Energy Information Administration, Form EIA-860, "Annual Electric Generator Report" (1989). Capacity Values for 2010 in Lower and Upper Reference Cases include newly ordered capacity with unit capacities from reactor manufacturers.

Table 4. U.S. Operable Nuclear Capacity by Federal Region, 1989, and Projections for 2000 and 2010

Federal Region	Capacity (Net GWe)[a]		
	1989	No New Orders Case[b] 2000	2010
I New England	5.4	6.4	5.2
II New York/New Jersey	8.6	8.6	6.9
III Middle Atlantic	13.8	13.8	13.8
IV South Atlantic	26.7	30.2	30.8
V Midwest	21.7	21.7	20.4
VI Southwest	6.2	8.5	8.5
VII Central	4.0	4.0	4.0
VIII North Central	0	0	0
IX West	9.3	8.4	8.0
X Northwest	2.2	2.2	2.2
Total	97.9	103.8	99.7

[a] Capacity values are based on net summer capability ratings.
[b] Totals may not equal sum of components due to independent rounding.
Sources-- **Capacities:** Energy Information Administration, Form EIA-860, "Annual Electric Generator Report" (1989). **Projections--** Energy Information Administration, *Annual Outlook for Electric Power 1990*, DOE/EIA-0474(90) (July 1990).

Table 5. U.S. Nuclear Generation in 1989 and Projections for 2000 and 2010

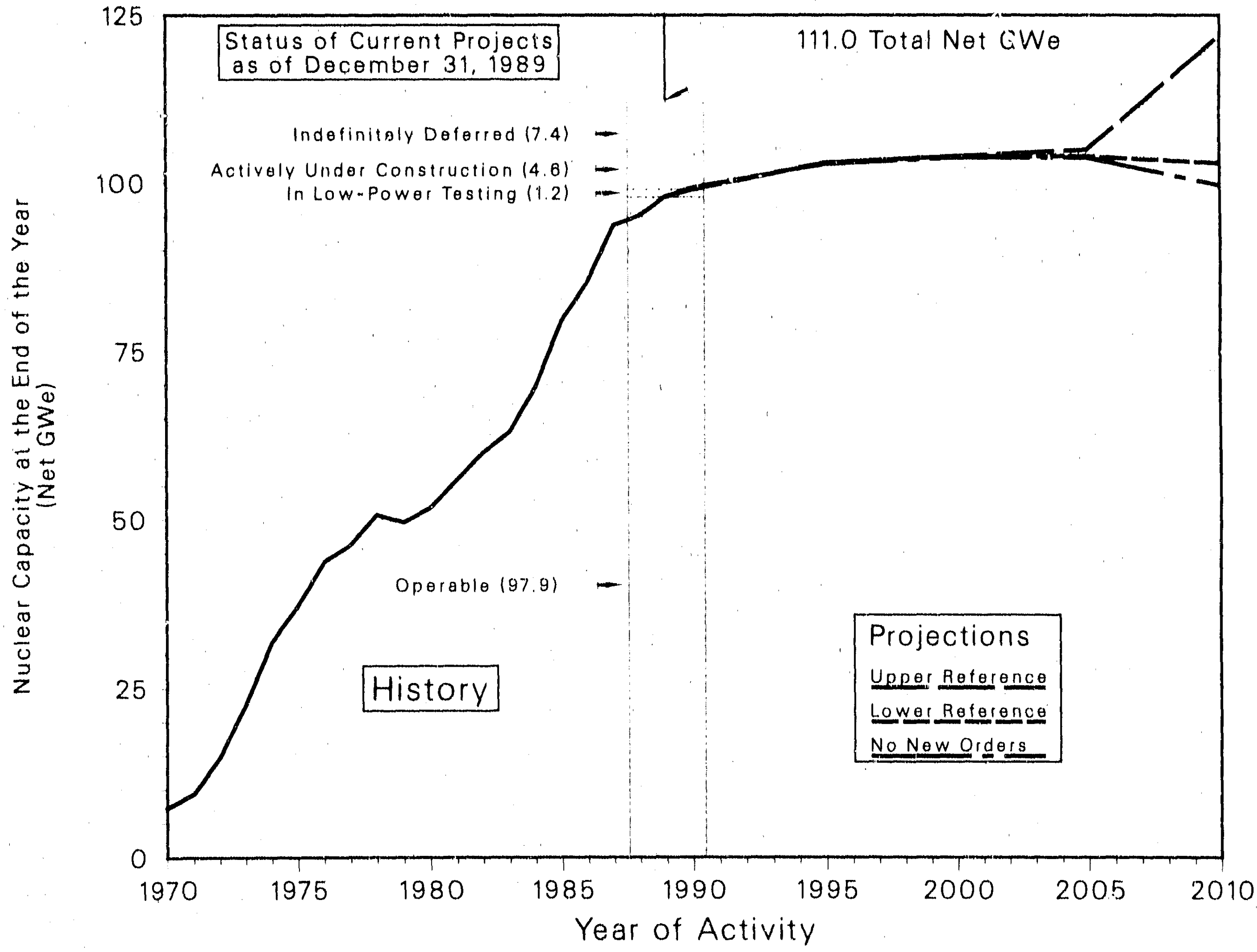
Federal Region	Actual 1989		No New Orders Case (Net TWh)[a]	
	Net TWh[a]	Percent Share[b]	2000	2010
I New England	33.1	34.0	37.6	34.3
II New York/New Jersey	45.9	26.7	44.0	36.9
III Middle Atlantic	56.1	17.2	77.1	81.6
IV South Atlantic	150.8	24.6	162.0	184.8
V Midwest	130.6	25.0	119.4	120.2
VI Southwest	31.2	8.0	50.5	53.5
VII Central	29.3	20.5	21.6	22.9
VIII North Central	.5	.3	0	0
IX West	40.4	19.0	48.4	49.2
X Northwest	11.4	7.9	11.1	11.8
Total	529.4	19.1	571.7	595.1

[a] TWh, Terawatthours. One TWh is equivalent to one billion kilowatthours.
[b] Nuclear generated electricity as a percentage of electricity generated from all sources.
Note: Totals may not equal sum of components due to independent rounding.
Sources: **1989 Data--** Energy Information Administration, Form EIA-759, "Monthly Power Plant Report" (preliminary data). **Projections--**Energy Information Administration, *Annual Outlook for U.S. Electric Power 1990*, DOE/EIA-0474(90), (Washington, DC, June 1990).

is around 25 percent. A modest projected capacity factor improvement permits an increase in generation by 2010 at an annual rate of 0.6 percent, in spite of the slight capacity decrease.

Figure 1 summarizes domestic nuclear capacity from 1970 through 1989, projections through 2010, and the status of nuclear projects at the end of 1989. The Upper- and Lower-Reference-case projections are coincident through 2005. This similarity among cases reflects the inflexibility of construction schedules for nuclear units that are nearing completion. The leveling off in projected capacity in these cases reflects the fact that only four units remain actively under construction and only two units that are currently indefinitely deferred are assumed to become operable by 2005.

Figure 1. Domestic Nuclear Capacity, 1970-2010, and Status of Nuclear Generating Units at the End of 1989



Note: The scale of this figure differs from Figure 2 in order to show detail.

Sources: Historical Capacities — Energy Information Administration, Form EIA-860, "Annual Electric Generator Report" (1989). Projections: Table 3. Status of Current Projects — Table 1.

Prospects for the Long Term, Through 2030

Long-term projections of installed nuclear capacity and electricity generation are used to estimate nuclear waste management needs and fuel cycle requirements and for planning requirements of the nuclear industry (utilities and equipment suppliers). The Nuclear Waste Policy Act of 1982, as amended in 1987, mandates the establishment of a repository for the disposal of high-level radioactive waste and the collection of fees from utilities to finance this repository.[13] The Office of Civilian Radioactive Waste Management uses the forecasts of capacity and generation over the long term to plan for waste volume and to estimate the adequacy of the fees. This section presents a range of nuclear capacity projections for 5-year intervals from 2011 through 2030. These projections result from alternative sets of assumptions associated with a No New Orders case and with Lower-Reference- and Upper-Reference-case nuclear supply scenarios.

- **Upper Reference.** A traditional demand-driven capacity growth case, produced by the World Integrated Nuclear Evaluation System (WINES), post 2010. The parameter values which define these projections assume a robust economic and electrical demand growth and, following a temporary plateau, restoration of a substantial nuclear role in providing baseload electrical power. WINES is a long-term aggregated model that derives nuclear generation requirements (and installed capacity) as a share of delivered energy. Delivered energy is projected using a demand function composed of economic growth and the growth rate for the price of aggregate energy. The WINES methodology is described in detail in Appendix B.
- **Lower Reference.** A case in which a limited number of introductory lead units provide assurance of technical and economic feasibility of nuclear power thus leading to additional orders. The capacity resulting from additional new orders is projected by WINES for the period after 2010. The assumptions for the Lower-Reference-case WINES projections assume a more modest economic growth, a somewhat longer delay before a resumption of sustained plant ordering, and a reduced share (from the present) of generation provided by nuclear power.
- **No New Orders.** A case in which capacity projections depend solely on the assumption of no new orders and, in general, reactor retirements after 40 years of operating life.

Each of these cases is discussed in detail in the following section.

Long-Term Case Assumptions

Major assumptions that govern the EIA Lower-Reference-case and Upper-Reference-case projections for the long term (2011 through 2030) are the same as the assumptions stated for the intermediate term.

The Lower Reference case is, for the most part, a supply-driven case based on a detailed examination of the U.S. nuclear power equipment manufacturing industry. In this case, new capacity projections are developed from information and assumptions related to the limitations on the ability of the industry to respond to new nuclear orders. The fact that no unit ordered since 1974 has been built has caused a general retrenchment in the industry.[14] The larger companies, such as reactor manufacturers and architect-engineers (AE's), have shifted into the service business, while smaller companies, such as subtier suppliers, have left the industry. Furthermore, the uncertainties of future costs, regulatory treatment, and leadtimes translate into a large risk factor, and the manner in which this risk will be borne is also uncertain. Resolution of the risk-bearing issue may be the principal driver of the industry's restructuring.[15] Such restructuring could include an increased foreign component. Many utilities are expected to delay nuclear orders until one or more industry leaders successfully complete a project "on time and within budget."

The Lower Reference case assumes that only a limited amount of newly ordered nuclear capacity will become operable between 2005 and 2010. Assuming these new orders are completed successfully, some other utilities are projected to begin ordering new units; however, only those with successful nuclear programs would be expected to replace retiring units with nuclear units. The projected capacities for 2015 through 2030 are produced by WINES based on the assumptions provided in Table 6.

In the Upper Reference case--the demand-driven case--long-term demand for electric power (and consequently nuclear power) is influenced by a number of factors. These include the perceived level of long-term

[13] "Nuclear Waste Policy Amendments Act of 1987," signed into law on December 22, 1987, as part of the Budget Reconciliation Act for Fiscal Year 1988 (Public Law 100-203).

[14] For a detailed discussion of this issue, see *Commercial Nuclear Power 1988*, pp. 17-19, or *Assessment of the U.S. Commercial Nuclear Power Equipment Manufacturing Industry* (report submitted to the Energy Information Administration by Science Applications International Corporation, McLean, VA, December 1987).

[15] In July 1990, a partnership consisting of Westinghouse Electric Corp. and Bechtel Power Corp. bought the Palisades nuclear power plant from Consumers Power and will operate it as an independent power producer.

Table 6. Assumed Parameter Values of the WINES Model for the United States, 2010-2030

Parameter	Assumed Values: Lower Reference Case	Assumed Values: Upper Reference Case
Labor-Age Population Growth Rate (percent per year)	-0.25	-0.25
Labor Force Participation Fraction Growth Rate (percent per year)	.10	.20
Labor Productivity Growth Rate (percent per year)	1.90	2.08
Aggregate Energy Real Price Growth Rate (percent per year)	2.04	1.84
Price Elasticity	-.55	-.50
Income Elasticity	.85	.90
Asymptotic Electrical Share of Total Delivered Energy (percent)	30	35
Asymptotic Nuclear Share of Total Electrical Generation (percent)	15.0	22.0
Electrical Halving Factor (years)	10.0	10.0
Nuclear Halving Factor (years)	25.0	20.0
Nuclear Generation Capacity Factor[a] (percent)	75.0	75.0

[a] Value is assumed to increase linearly from 68 percent in 2010 to the value shown in 2030.
WINES World Integrated Nuclear Evaluation System.
Source: Developed by the staff of the Nuclear and Alternate Fuels Division, Office of Coal, Nuclear, Electric and Alternate Fuels, Energy Information Administration, as described in the text.

economic growth and its relationship to electricity demand, and the cost and availability of electricity from all sources. An examination of historical trends suggests that the relationship between Gross National Product (GNP) and electricity consumption is much more stable than that between GNP and total energy. For example, from 1979 through 1989, total energy consumption per constant 1982 GNP dollar dropped by about 21 percent. The consumption of electricity in kilowatthours (kWh) per constant 1982 GNP dollar during the same period dropped by only 2.7 percent.[16] Several features of electricity make it an attractive energy option, and this suggests that its fraction of total energy demand will continue to grow as it replaces other forms of energy. Among the advantages of electrical energy are the following:

- It can be generated from many primary resources, allowing for diversification of supply.
- It can replace most other forms of energy supply.
- It is clean, versatile, and efficient at the point of consumption.

The Upper-Reference-case projections assume that there will be increasing electrification, and that utilities will rely increasingly on coal and nuclear fuels in constructing new capacity to meet anticipated growth in the demand for electricity. For this to occur, there must be changes in existing economic and regulatory conditions, new developments in the technology, and greater public acceptance of nuclear power. The Lower-Reference-case projections assume a similar environment, however, with a longer delay before reactor orders resume and more caution by utilities in selection of the nuclear option.

The assumption that reactor orders will resume rests on the proposition that changes in the factors described above will make nuclear power an attractive option. Political, environmental, and economic issues related to the large-scale expansion of the use of coal, which is the primary alternative to nuclear power for baseload generation, could induce utilities to give stronger consideration to nuclear power. Among these issues are the movement toward stronger air quality control regulations (principally to address the acid rain issue), and

[16] Energy Information Administration, *Annual Energy Review 1990*, DOE/EIA-0384(89), Table 8, p. 25 and Table 87, p. 201 (Washington, DC, May 1990).

uncertainties about the effects of the buildup of carbon dioxide (CO_2) in the atmosphere (the "greenhouse effect") due to the combustion of fossil fuels.

Exactly when significant amounts of new baseload generating capacity will be needed depends on retirement schedules, changes in utility load factors, levels of conservation, penetration of renewable energy and cogeneration technologies, and rates of electricity demand growth. Considering these factors and current utility construction programs, it is estimated that additional generating capacity may be needed in some regions of the country by the early 1990's. Both reference cases assume that new units will be improved or advanced light-water reactors. High-temperature gas reactors and liquid metal reactors are assumed to be available for commercial ordering later in the projection period.

The parameters used in WINES and their values for the Lower Reference and Upper Reference cases are presented in Table 6. Within the WINES model framework, economic (GNP) growth is defined as the sum of growth rates for the labor-age population, the labor force participation fraction, and labor productivity. The labor-age population growth rate is derived from World Bank population forecasts.[17] It is projected to grow by about 0.6 percent annually from 1990 through 2010 and then to decline by about 0.3 percent per year through 2030. The labor force participation fraction is assumed to increase at annual rates of 0.10 to 0.20 percent. Labor productivity is assumed to grow at a rate of 1.9 to 2.1 percent per year. These growth rates imply real (i.e., adjusted for inflation) GNP growth rates of 1.8 and 2.0 percent per year for the Lower Reference and Upper Reference cases, respectively, for the period from 2010 through 2030. The GNP growth rate for the Lower Reference case is consistent with one being discussed to support a draft National Energy Strategy Reference scenario, and the growth rate for the Upper Reference case is consistent with the Low World Oil Price case of the *Annual Energy Outlook 1990*.[18]

The function describing growth in demand for delivered energy uses these growth rates, plus assumptions regarding growth in the real price of aggregate energy and the corresponding price and income elasticities of demand for energy, to derive delivered energy requirements. The real price of aggregate energy is assumed to increase at annual rates of 2.0 and 1.8 percent for the Lower and Upper Reference cases, respectively. These price growth rates are derived from the DRI Energy Model. The price elasticities are assumed to be -0.55 and -0.50, and the income elasticities are assumed to be 0.85 and 0.90.

The electrical share of delivered energy and the nuclear share of electricity are derived using market penetration functions. These functions require assumptions regarding the long-run asymptotic shares and the halving factors.[19] The halving factor determines how fast the share from the base-year value approaches the asymptotic value. The continuing uncertainty regarding waste disposal, licensing, and safety verification procedures makes it likely that more time will be required to achieve the nuclear asymptotic share. This is reflected in the nuclear halving factor values of 20 and 25 years for the Upper Reference and Lower Reference cases, respectively. The electrical halving factor is 10 years in both cases. The asymptotic electrical share of delivered energy is assumed to be 30 percent in the Lower Reference case and 35 percent in the Upper Reference case. The 1989 actual electrical share is about 14.7 percent of delivered energy. The asymptotic nuclear share of electrical generation is assumed to be 15 percent in the Lower Reference case and 22 percent in the Upper Reference case; the 1989 nuclear share is 19.0 percent of utility electrical generation and 17.8 percent of total generation. The average capacity factor in both reference cases is assumed to increase from current levels to 68 percent in 2010 and to 75 percent in 2030.

Table 7 presents the WINES model results for the Lower and Upper Reference cases in terms of growth rates for GNP, projected nuclear capacity additions, and energy variables over the projection period of 2010 through 2030. GNP is projected to increase at an annual rate of 1.8 percent in the Lower Reference case and 2.0 percent in the Upper Reference case. Delivered energy is projected to increase at an annual rate of 0.6 percent in the Lower Reference case and 0.9 percent in the Upper Reference case. Similarly, projected growth in total electrical generation is 1.8 and 2.0 percent per year, respectively. The ratio of growth in electrical generation to GNP growth is projected to be 1.0 in both the Lower and Upper Reference cases. The time period for Table 7 has been changed from the 1989 report, and thus the growth rates are not comparable.

The electrical share of delivered energy in 2030 is projected to reach 27.0 and 32.0 percent in the Lower and Upper Reference cases, respectively. The nuclear share of electrical generation in 2030 is projected to be 14.5 and 18.8 percent in the Lower and Upper Reference cases, respectively.

[17]World Bank, *World Population Projections, 1988 Short and Long-Term Estimates by Age and Sex with Related Demographic Statistics*, M.T. Vu (Washington, DC, 1988).
[18]Energy Information Administration, *Annual Energy Outlook 1990*, DOE/EIA-0383(90) (Washington, DC, January 1990).
[19]For further explanation of these factors, see Appendix B.

Table 7. EIA/WINES Model Results for U.S. Economic and Energy Growth Rates, 2010-2030

Variable	Growth Rate (Mean Percent per Year)	
	Lower Reference Case	Upper Reference Case
Real Gross National Product (GNP)	1.8	2.0
Delivered Energy	6	.9
Electrical Generation	1.8	2.0
Installed Nuclear Capacity	1.3	2.1

EIA/WINES - Energy Information Administration/World Integrated Nuclear Evaluation System.
Source: WINES Model.

A No New Orders case was also developed. This case depicts a scenario for which the following assumptions apply.

- Three of the indefinitely deferred units are completed and become operable.
- All units in the projection are assumed to have operating lives of 40 years from the date of issuance of an operating license (current and projected). An exception is Rancho Seco, which is assumed to officially retire in 1990.
- No new orders are placed for nuclear plants through 2030, or those orders that are placed do not result in operable capacity during the projection period.

Long-Term Projections of Installed Nuclear Capacity and Generation

Projections of installed nuclear capacity and generation for 5-year intervals, beginning in 1990, are presented in Table 8. (Annual projections of capacity and generation are provided in Tables 11 and 12, respectively, in Appendix I.). Nuclear capacity is projected to grow at annual average rates of 1.3 to 2.1 percent per year over the long-term projection period (2010 through 2030), resulting in capacity projections of 134 and 184 GWe in the year 2030 for the Lower and Upper Reference cases, respectively. These projections are shown graphically in Figure 2. The wide variations in the long-term projections shown in this figure reflect the inherent uncertainty of making such projections. The No New Orders case projects 6 GWe of nuclear capacity in 2030. The projections resulting from this case are very sensitive to the reactor operating life assumption. For example, if a 30-year (instead of 40-year) operating life is assumed, operable nuclear capacity is reduced to about 6 GWe instead of 54 GWe in 2020. Several utilities are hoping to extend the operating lives of their reactors by as much as an additional 20 years. If a 60-year operating life is assumed for all reactors, the amount of nuclear capacity in the No New Orders case remains constant at about 100 GWe through 2030.

The average rate of total nuclear capacity additions implied by the Upper Reference case, when nuclear replacement capacity requirements are included, averages 7.1 GWe per year from 2006 through 2030 (Table 9). The rate of capacity additions implied by the Lower Reference case over the same time period is about 5.1 GWe per year--due mainly to a slower anticipated startup of the nuclear supply industry and a slower rate of new plant orders.

Nuclear generation is projected to grow at annual average rates of 1.6 and 2.5 percent per year over the period from 2010 through 2030 for the Lower and Upper Reference cases, respectively. The No New Orders case projects generation declining at an annual average rate of 12.6 percent per year.

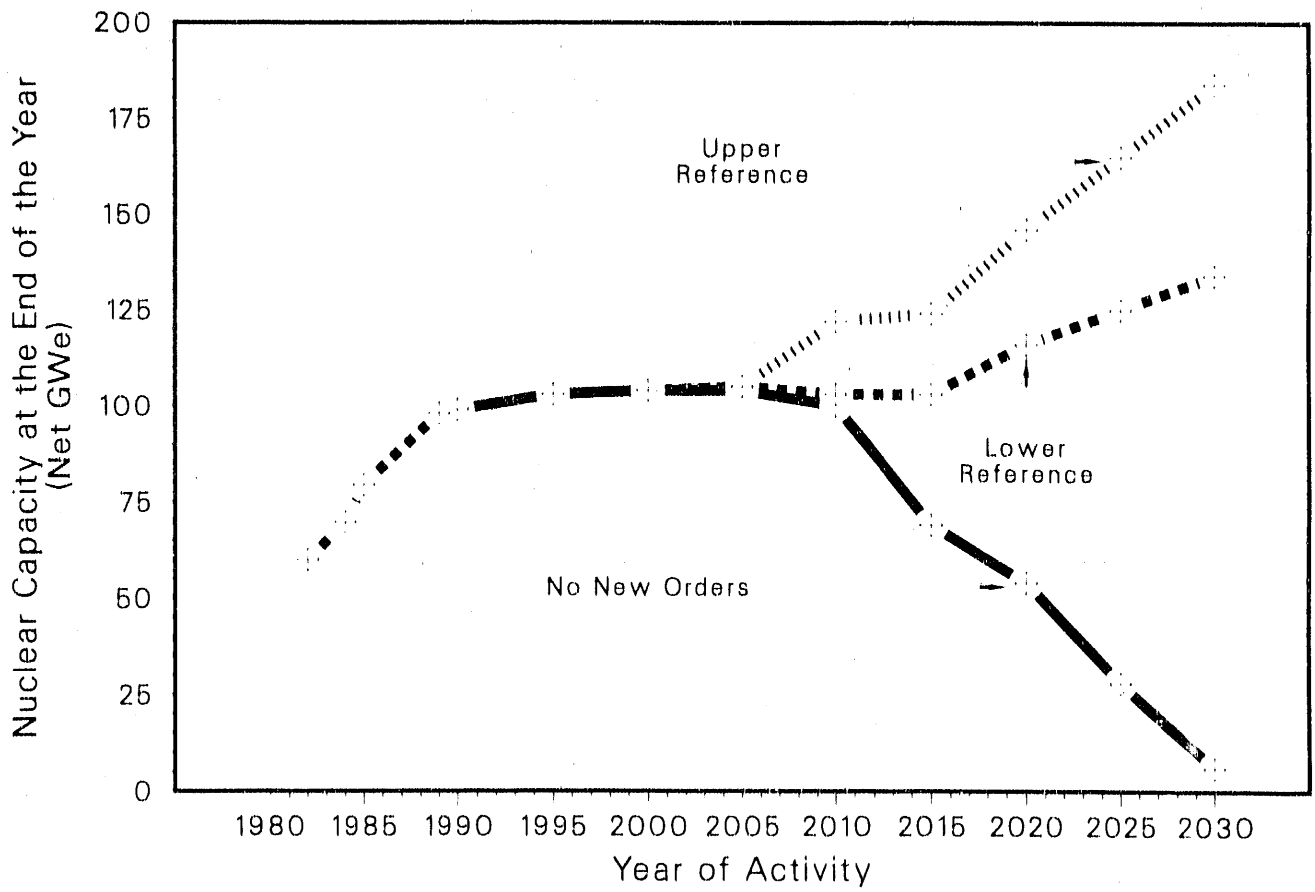
Table 8. U.S. Operable Nuclear Capacity and Generation at the End of the Year, 1989, and Projections for 1990-2030

Year	Capacity (Net GWe)[a]			Generation (Net TWh)[b]		
	No New Orders Case	Lower Reference Case	Upper Reference Case	No New Orders Case	Lower Reference Case	Upper Reference Case
1989[c]	98	98	98	529	529	529
1990	99	99	99	541	541	541
1995	103	103	103	558	558	558
2000	104	104	104	572	572	572
2005	104	105	105	592	608	608
2010	100	103	122	595	620	714
2015	89	103	124	409	596	717
2020	54	116	146	320	694	875
2025	28	125	165	165	776	1,024
2030	6	134	184	40	851	1,171

[a] Capacity values are based on net summer capability ratings.
[b] Capacity values are rounded to the nearest gigawatt. Generation values are rounded to the nearest terawatthour.
[c] Actual.

Sources: **Capacity Data**--Energy Information Administration, Form EIA-860, "Annual Electric Generator Report" (1989). **Post-2010 Capacity Projections**--WINES Model. **Historical Generation Data**--Energy Information Administration, *Monthly Energy Review*, December 1989, DOE/EIA-0035 (89/12) (March 1990). **Generation Projections**-- 1990-2000 from Energy Information Administration, *Annual Energy Outlook*, DOE/EIA-0383(90), January 1990 and International Nuclear Model (1990).

Figure 2. Domestic Nuclear Capacity, 1982-2030



Source: Table 8 and Energy Information Administration, *Monthly Energy Review* December 1989 DOE/EIA-0035(89/12) (Washington, DC, March 1990)

Table 9. Nuclear Capacity Build Rates Implied by Projections
(Net Gigawatts-Electric per Year)

Case	Period	Average Annual Retirements[a]	Average Annual Additions	Total Implied Build Rate
Lower Reference	2006-2030	3.9	1.2	5.1
Upper Reference	2006-2030	3.9	3.2	7.1

[a] Assumes a 40-year life from date of initial operation.

Source: Table 8, "U.S. Operable Nuclear Capacity and Generation at the End of the Year, 1989, and Projections for 1990-2030," and calculations by the staff of the Nuclear and Alternate Fuels Division, Office of Coal, Nuclear, Electric and Alternate Fuels, Energy Information Administration.

Sensitivity Cases

Nuclear Plant Life Extension

Nuclear power plant life extension (NUPLEX) refers to the extension of the operating life of commercial power plants by the renewal of their operating licenses upon expiration of their original or revised 40-year license term.[20]

The Atomic Energy Act of 1954[21] provided the original set of regulations regarding commercial nuclear power plant licensing, which included setting a statutory limit of 40 years for the duration of licenses issued to electric utilities that operate commercial nuclear plants. The selection of a 40-year limit was not based on the anticipated useful life of the nuclear plants but rather on financial and economic considerations.[22]

Originally, the 40-year license for a plant began with the date of issuance of the plant construction permit. In 1982, however, the Nuclear Regulatory Commission (NRC) determined that plants could be licensed for 40 years as of the date of issuance of the plant operating license, and this became standard practice for the licensing of subsequent commercial nuclear plants. Many older units licensed before this revision have since been granted licensing adjustments or extensions to allow operation for 40 years from the date of issuance of their operating license. Most of the remaining units are expected to follow suit, and as stated previously, this is assumed for these projections.

As of December 31, 1989, a total of 110 U.S. commercial nuclear units have operating licenses. A total of 32 units licensed before 1982 have not applied for license adjustments to recover the construction time and allow a full-term operating license of 40 years.[23] If these units are granted their corresponding license adjustments, expiration dates will shift to later years, as shown in Figure 3.

Four units (Dresden 2, Oyster Creek, Palisades, and San Onofre 1) have provisional operating licenses and have applied for full-term licenses. Fourteen additional commercial nuclear units formerly licensed to operate have already been shut down. Two other units, Shippingport and the Hanford-N reactor, were never licensed.[24]

The Atomic Energy Act explicitly permits the license renewal of commercial nuclear plants; however, the regulatory requirements for the scope and content of license renewal applications, the criteria for evaluating such applications, and the procedures for submitting and reviewing them have not been defined.

The NRC started a program to develop a regulatory process for license renewal in 1986 with the issuing of a Federal Register notice requesting public comments on the license renewal policy development effort and indicating its intent to develop a commission policy statement.[25]

In an August 1988 publication the NRC expressed its intention to move directly to rulemaking on a "slightly accelerated schedule" rather than issuing a policy statement prior to a rule as previously planned.[26]

[20] This discussion is taken, in part, from *Nuclear Plant Life Extension* (report submitted to the Energy Information Administration by Decision Analysis Corporation of Virginia, Vienna, VA, June 29, 1990).

[21] Atomic Energy Act of 1954, Chapter 10, Section 103, Part C.

[22] Electric Power Research Institute, *LWR Plant Life Extension*, EPRI NP-05002 (Palo Alto, California, January 1987).

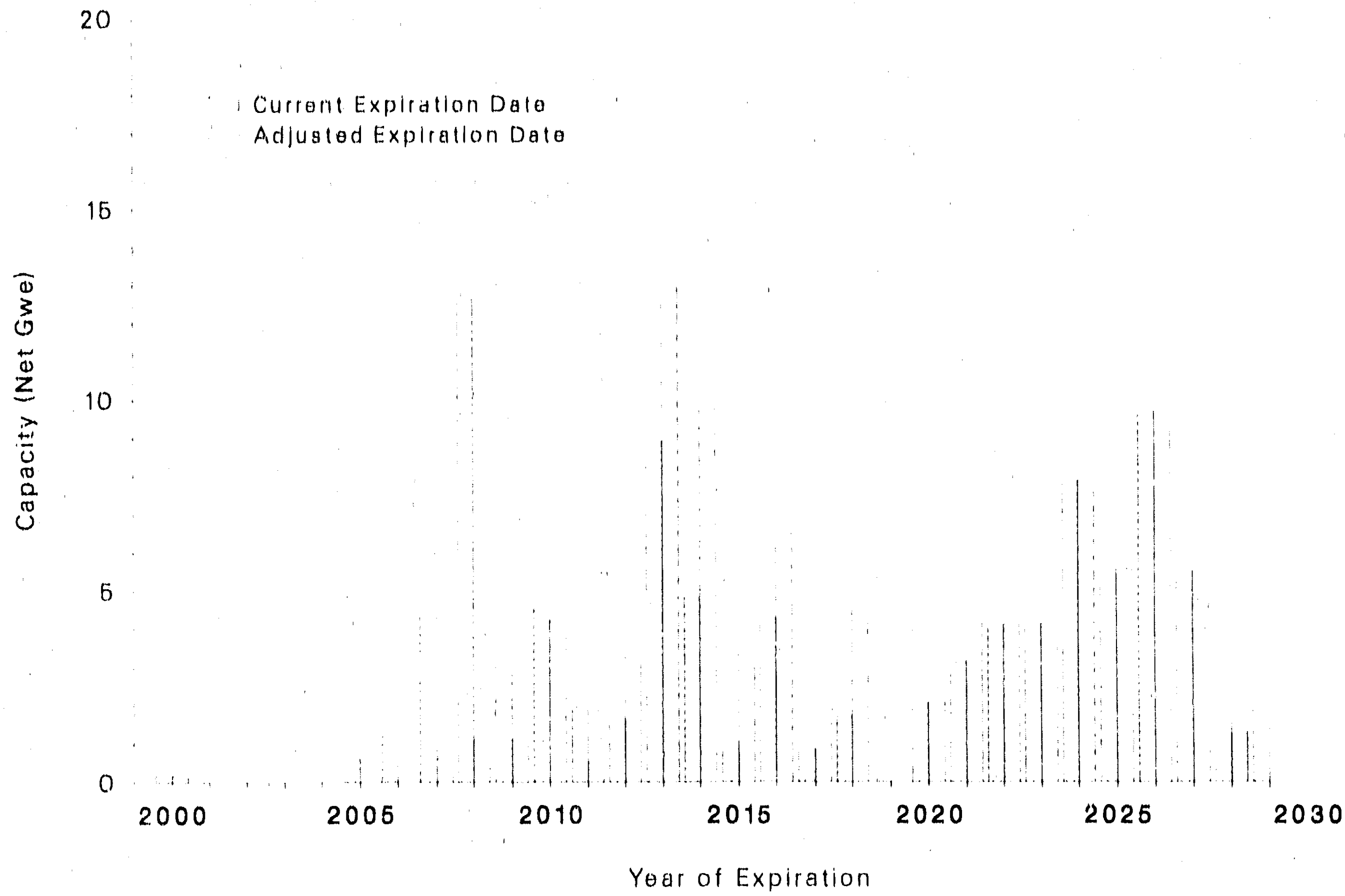
[23] Decision Analysis Corporation of Virginia, *Nuclear Plant Life Extension, Draft* DOE Contract No. DE-AC01-87EI-19801 (Vienna, VA, April 1990).

[24] *Ibid.*

[25] U.S. Nuclear Regulatory Commission, "Request for comments on the development of policy for nuclear power plant license renewal," Federal Register, Vol. 51, No. 2125, 40334, Nov. 6, 1986.

[26] U.S. Nuclear Regulatory Commission, "Regulatory option for nuclear plant license renewal," NUREG-1317, Draft for comment, August 1988.

Figure 3. Nuclear Capacity Retiring by Year of License Expiration



Source: Nuclear Regulatory Commission, *Information Digest*, NUREG-1350, Vol. 2 (Washington, DC, 1990.)

In July 1990, the NRC published the proposed rule for comment.[27] Publication of draft regulatory guidance is expected to begin in mid-1991 with review of the lead plants license renewal applications. Completion of final regulatory guidance is anticipated in early 1994, shortly after the completion of the lead plant license renewal applications review.

Electric utility industry efforts to analyze life extension, began in 1978, when the Electric Power Research Institute (EPRI) undertook a series of studies which suggested that extending the operation of current units beyond their nominal 40-year license term was both technically feasible and economically attractive.

Since 1985, under the sponsorship of utilities, EPRI and the Department of Energy (DOE), plant-specific studies have been in progress to identify and evaluate potential critical components, systems, and structures that would influence life extension decisions.

In 1988, the nuclear industry created the Nuclear Management and Resources Council (NUMARC) NUPLEX Working Group to coordinate utility support for plant life extension and to serve as the utility interface with the NRC management. The group emphasis is on developing recommended positions concerning license renewal policy, regulation, procedural framework, guidelines, criteria, and timing. In addition, the industry has been undertaking studies to evaluate the aging of hardware and its effect on plant reliability and safety.

Following the plant-specific studies, the industry and DOE have initiated the Lead Plants Project. This demonstration project is intended to support the NRC's development of a license renewal process and confirm the viability of the approach through lead plant applications reviews. The lead plants are Yankee Atomic Electric Company's Yankee Rowe and Northern States Power's Monticello.

[27] USNRC, "Nuclear Power Plant License Renewal Proposed Rule," Federal Register, Vol. 55, No. 137, July 17, 1990, pp. 29043-29062.

The Department of Energy's effort to assist the nuclear industry to achieve a viable license renewal option is now coordinated under a major program entitled Plant Lifetime Improvement Program (PLIM). The DOE PLIM program's objective has been summarized as follows: "Establish and demonstrate the license renewal process by working cooperatively with the industry to develop the technology and information needed to support the preparation of lead plant license renewal applications by 1991, and the review and approval of the applications by the NRC by 1993."[28]

Two different interpretations of NUPLEX are that: (1) decisions on extending the lives of nuclear units are independent of new-order decisions; and (2) that a life-extension decision would be made in place of a new order decision. Combining the two situations with the assumption that 70 percent of nuclear capacity will be life-extended for 20 years yields two distinct approaches. These two approaches define a range or envelope of possibilities for projected capacity with NUPLEX. Table 10 presents the No New Orders case with 70 percent of the capacity life-extended and the Upper Reference case with and without displacement of new orders by life extension. Note that in the case with displacement of new orders by life-extended capacity, the projection is the basic Upper Reference case since the amount of capacity that can be life-extended is less than that projected to be ordered. Where the life extension is added to new orders, the projected capacity in 2030 is 202 GWe or about 10 percent more than in the basic Upper Reference case.

Table 10. U.S. Operable Nuclear Capacity Assuming 70 Percent Plant Life Extension 1990-2030
(Net Gigawatts-Electric)

Year	Capacity (Net GWe)[a]		
	No New Orders Case	Upper Reference With Displacement	Upper Reference Without Displacement
1990	99	99	99
1995	103	103	103
2000	104	104	104
2005	104	105	105
2010	103	122	125
2015	90	124	141
2020	86	146	157
2025	75	165	182
2030	71	184	202

[a] Capacity values are based on net summer capability ratings.
Source: Energy Information Administration, Office of Coal, Nuclear, Electric and Alternate Fuels, Nuclear and Alternate Fuels Division Staff.

[28] SANDIA National Laboratory, "Management Plan for the Light Water Reactor Plant Lifetime Improvement Program," January 1990, p. 4.

Comparison With Other Projections

The long-term projections of installed nuclear capacity for the Upper Reference case in this year's report are lower than those presented in the 1989 issue of *Commercial Nuclear Power* (CNP89). There are a variety of changes in the WINES baseline data. One important factor is that the population parameter, which previously was defined as total population and was projected using labor-age population growth rates, has been changed to project labor-age population using the labor-age population growth rate. (Labor age is defined as 15 to 64 years.) The bulge in the U.S. population due to the "baby boom" results in a drop in growth rates in the later years of the projection. This change has a small negative effect on the nuclear capacity projection. Another change was to initialize the model in 1985 rather than 1980, causing changes in several parameters. Typically, one of the more sensitive parameters is the growth rate of Gross National Product (GNP). (While this is a model result, WINES is calibrated to yield assumed GNP growth rates.) A comparison of GNP projections for similar periods in CNP89 shows almost no change for the Upper Reference case and a modest decrease in the growth rate for the Lower Reference case. This GNP change, along with a slight increase in energy price growth, is the primary cause of the decrease in the Lower-Reference-case capacity projection. The decrease in the Upper-Reference-case projection, however, is primarily due to the change in the number of constrained periods, so that the model was not allowed to operate freely until after 2010, compared with 2005 in the 1989 report.

Table 11 compares the projections made in this report and in the 1989 report with similar forecasts and projections prepared by other organizations. Generally, the forecasts and projections from non-EIA sources fall within the range of the EIA projections. It is apparent that few organizations forecast nuclear generation and capacity beyond the year 2000. The DRI forecast assumes that no new nuclear plants will be built beyond those currently on order or under construction.

Table 11. Comparison of Projections for U.S. Nuclear Capacity at the End of the Year, 1990-2020

Source	Capacity (Net GWe)[a]				
	1990	1995	2000	2010	2020
Energy Information Administration					
1990 *Commercial Nuclear Power*					
No New Orders Case	99	103	104	100	54
Lower Reference Case	99	103	104	103	116
Upper Reference Case	99	103	104	122	146
1989 *Commercial Nuclear Power*					
No New Orders Case	99	101	102	97	52
Lower Reference Case	100	103	104	101	123
Upper Reference Case	101	105	105	136	182
DRI[b]	101	105	105	100	
NERC[c]	101	104	-	-	-
NAC[d]	101	104	106	104	-
NEI[e]	108	109	109	-	-
NUKEM[f]	102	104	104	-	-
WEFA[g]	98	103	103	-	-

[a] Capacity values are based on net summer capability ratings.
[b] DRI - Data Resources, Inc., *Energy Review* (Winter 1989-90).
[c] NERC - North American Electric Reliability Council, *1989 Electric Supply and Demand*.
[d] NAC - Nuclear Assurance Corp., *Nuclear Megawatt Generation Status Report* (February 1990).
[e] NEI - Nuclear Engineering International, *Handbook 1990*. NEI projections are based on gross capacity data.
[f] NUKEM - *Market Report on Nuclear Fuel Cycle* (April 1989).
[g] WEFA - The WEFA Group, *Energy Analysis Quarterly* (Winter 1990).

3. Institutional and Technological Developments

Introduction

This chapter discusses five topics that provide a context within which the projections of domestic and foreign nuclear capacity are made. Although they are not explicitly factored into the projections, their eventual resolution has the potential to affect the projections.[20] The first two topics are environmental in nature, specifically, Clean Air Act legislation in the United States and global climate change. The second two topics discuss the status of U.S. nuclear technology and U.S. nuclear power plant decommissioning cost estimates. The fifth topic is a discussion of the internationalization of the nuclear power industry.

Environmental Issues

Clean Air Legislation

For the first time since passage of the Clean Air Act Amendments (P.L. 95-95) in 1977, both Chambers of the U.S. Congress have passed wide-ranging legislation on air pollution. The bills, while not identical, are similar in aim and structure. Both bills contain sections that seek to reduce annual SO_2 emissions by 10 million tons from 1980 levels and annual NO_x emissions by 2 million tons from the level currently projected for 2000 from stationary sources, principally electric power plants. Another key feature is the permanent limit of 8.9 million tons per year of SO_2 emissions from electric generating plants after the year 2000. These requirements could indirectly encourage a new assessment of nuclear power production in the United States.

The Senate bill (S. 1630) was passed in April 1990. The provisions in Title IV, "Acid Deposition Control," are aimed at reducing SO_2 and NO_x emissions from fossil-steam plants. The bill requires emissions reductions in two stages, beginning January 1, 1995 and January 1, 2000, respectively. Essentially utilities are to be issued permits allowing them to emit a given quantity of SO_2 each year. These permits are tradeable, especially during the second phase. The number of permits issued to each utility is based primarily on the 1985 SO_2 emission rate and 1985 through 1987 fuel consumption of their fossil-steam plants. During each phase, a utility's plants cannot emit SO_2 in excess of the permits it was issued unless it has purchased additional permits from others.

The House bill (H.R. 3030) passed in May 1990 is very similar in its treatment of electric power plants. As in the Senate bill Title V, "Acid Deposition Control," the House bill requires emissions reductions in two stages. However, in the House bill the stages begin one year later than those in the Senate bill, December 31, 1995 and December 31, 2000, for phases I and II, respectively. The Senate bill uses the reduction expected to occur between January 1, 1995 and December 31, 1995 as bonus permits that are distributed to certain units. A second difference is that the House bill creates two trading regions (East and West) for existing plants, but the Senate bill has one region. A Conference Committee between the House and the Senate has been formed to work out the differences between the two bills. However, because the acid rain sections of the bills are so similar in their objectives, it is expected that there will not be major changes in the proposed treatment of power plant emissions in the compromise bill.

Through 2000, electric utilities have several options available for reducing their SO_2 emissions to comply with the allowance constraints. The three major options are decreasing their use of units that use medium to high sulfur coal without pollution control equipment, switching units using high sulfur coal to low sulfur coal, and retrofitting plants that use high sulfur coal with flue gas desulfurization equipment. Utilities will make use of all three options to minimize the cost of complying with the allowance constraints. The regions that will be affected the most as utilities either add pollution controls or purchase allowances, are the Midwest and the Southeast. These are also the same regions that currently have the greatest amounts of nuclear capacity (see Table 4, p. 7).

[20] The discussions of global climate change and the internationalization of the nuclear power industry are taken, in part, from *Nuclear Power Topics* while the discussion of decommissioning is taken, in part, from *Assessment of Nuclear Power Plant Decommissioning Policies and Costs*. These reports were submitted to the Energy Information Administration on May 7, 1990 and October 30, 1989, respectively, by Decision Analysis Corporation of Virginia, Vienna, VA and Science Applications International Corporation of McLean, VA.

Between 2000 and 2030, electric utilities must be able to add a significant amount of new capacity to replace retired units and satisfy increasing demand for electricity and still maintain the 8.9-million-ton cap on SO_2 emissions. SO_2 emissions from new coal-fired power plants must be offset by reductions in emissions from existing capacity through retirements, increased use of low sulfur coal, or retrofitting plants with flue gas desulfurization (FGD) equipment. A new pulverized coal-fired plant with FGD equipment can remove 90 to 95 percent of the SO_2. New clean coal technologies remove 97 to 99 percent of the SO_2. Therefore, many of the coal-fired capacity additions will most likely be new clean-coal generating technologies. Among the new technologies are atmospheric fluidized bed combustion units (AFB), pressurized fluidized bed combustion units (PFB), integrated gasification combined cycle units (IGCC), integrated steam-injected gasification units (ISTIG), and fuel cells. However, there is uncertainty about the costs, environmental impacts, and performance of the new technologies now under development. Utilities may reevaluate the nuclear option as an alternative to coal for baseload generation.

Global Climate Change and the Future of Nuclear Power

In the 1989 issue of *Commercial Nuclear Power* an overview of the environmental and energy policy in 21 countries was provided. At that time, no approved legislation addressed both global climate change and energy policy responses. It was suggested that, with the exception of a few environmentally progressive countries (the Netherlands, Sweden, and West Germany), global climate change concerns would not significantly affect fuel choices, especially in the short term.

The findings in that report continue to be supported. The international policy climate is becoming further defined. Although several environmentally progressive countries have made recent statements regarding energy responses to climate change, these countries have relatively small growth in electricity demand, thereby reducing the significance of their fuel choice decisions on worldwide nuclear capacity.

The effect of climate change concerns on nuclear capacity cannot be fully determined until response strategies are clearly defined and then implemented through policy decisions. Three factors are required for new nuclear capacity: (1) acceptance of nuclear power, (2) growth in electricity demand, and (3) financing for plant construction. Global climate change concerns may affect each of these factors.

Background

Global climate change (also referred to as global warming, or the "greenhouse effect") results primarily from the combustion of organic matter and other anthropogenic practices. These activities produce certain gases termed "greenhouse gases" because of their ability to trap solar heat reflected from the earth, just as heat is trapped in a greenhouse. Continued accumulation of these gases in the atmosphere could alter the planet's climate. This temperature increase may be sufficient to create dislocations in agriculture, precipitation patterns, population distributions, forestry, fishing, and health.

A major difficulty for policymakers addressing climate change is scientific uncertainty regarding the timing and magnitude of climate change. Opinions differ within the scientific community about the capacity of greenhouse gas sinks such as the ocean, possible atmospheric cooling effects from cloud cover, and biofeedback as a result of increased atmospheric carbon dioxide and higher temperatures. These uncertainties prevent clear definition of the impact of climate change on society; thus, it is also unclear to what extent policy responses are required. The benefits of government action on climate change are as ill defined as the costs of inaction. Scientific resolutions of climate change uncertainties will take years if not decades. However, there is growing public opinion that increased climate change risks as a result of inaction are unacceptable.

The discussion of policy responses to climate change centers on the emission of the five principal greenhouse gases: carbon dioxide (CO_2), nitrous oxide (N_2O) chlorinated fluorocarbons (CFCs), ozone (O_3), and methane (CH_4). The single largest contributor to the proliferation of greenhouse gases is the combustion of fossil fuels, chiefly coal.

Nations Most Likely to Unilaterally Alter Nuclear Policy

Three countries, The Netherlands, Sweden, and the Federal Republic of Germany (FRG), have the greatest potential to alter unilaterally nuclear energy policy in response to climate change concerns. Characteristics of this group are: (1) they are among the most progressive countries in implementation of stringent stationary source air emissions standards; (2) they have begun development of energy policies in response to climate change concerns; (3) they have both the technology and financing for nuclear power; and (4) they have marginal public acceptance of nuclear power. None of these countries is expected to alter its nuclear policy in the early 1990's.

The Netherlands, Sweden, and the FRG are among the most progressive countries in their treatment of stationary emission sources as a result of environmental considerations. Continuing in their historical patterns, these same three countries have been very active both nationally and internationally in addressing climate change. In addition to United Nations-related policy discussions of global climate change, these countries have been very active in the promotion of parallel policy negotiations such as the Declaration of the Hague (1989), the Ministerial conference at Noordwijk (1989), and the Bergen Conference (1990). In view of the more environmentally progressive nations, if the U.N. Intergovernmental Panel on Climate Change (IPCC) process (see following section for discussion of this process) fails to promote sufficient policy responses to climate change, then the parallel policy process may become more significant. The role of the Netherlands, Sweden, and the FRG in parallel policy negotiations further supports the resolution of these countries to address climate change with policy responses.

Multilateral Policy

The IPCC is the single most important international forum for multilateral discussions of climate change. It was established in 1988 by U.N. General Assembly Resolution 43/53 "to provide internationally coordinated scientific assessments of the magnitude, timing and potential environmental and socio-economic impact of climate change and realistic response strategies." The IPCC operates under the auspices of two U.N. bodies, the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP).

The IPCC is divided into three working groups: (1) science, (2) impacts, and (3) response strategies. The third group is of most interest for this discussion and is chaired by the United States. This group tries to assess the magnitude of future greenhouse gas emissions, the impacts of changing technologies, greenhouse gas sources and sinks, adaptations to climate change, strategies to reduce emissions, and social and economic implications. Additionally, this group is to consider legal matters, including the appropriateness of a climate convention or other forms of international cooperation to address potential climate change.

The IPCC's Response Strategies Working Group is expected to recommend an international policy process for dealing with climate change. Its final draft report is to be presented at the Fourth Plenary Session of the IPCC scheduled to meet in Sundsvall, Sweden, in August 1990. The IPCC draft action plan will be presented at the U.N. General Assembly in September and at the WMO-sponsored Second World Climate Conference scheduled for November.

After reviewing the IPCC recommendations, the U.N. General Assembly is expected to determine who should be charged with the task of drafting a global climate change convention for presentation at the 1992 U.N. Conference on Environment and Development. It is expected the General Assembly will, to a large extent, follow IPCC recommendation on the policy process for multilateral address of climate change. Draft reports of the IPCC Response Strategies Working Group have leaned toward a two-step policy process similar to that used to address ozone depletion, the first global environmental issue to receive multilateral policy attention. The policy process for response to this issue is thought to represent a precedent for future address of global environmental problems, including climate change. The first step in this process was the establishment of the Vienna Convention for the Protection of the Ozone Layer in 1985. This convention set down a formal statement of commitment by governments to future action with regard to ozone depleting chemicals. In 1987, these commitments were translated into requirements for reductions of specific chemical classes in the Montreal Protocol on Substances that Deplete the Ozone Layer.

The 1992 U.N. Conference on Environment and Development is likely to use a framework on climate change similar to the one used at the Vienna Convention. The issue of whether to set numerical goals for emissions reduction will be a key negotiating point at this conference. For acceptance of this convention among developing nations such as India and Brazil, it will probably include statements regarding the promotion of technological and financial assistance to developing nations for sustainable development. ("Sustainable development" is an overriding political concept at international forums addressing global environmental concerns. The World Commission on Environment and Development defines "sustainable development" as development which meets the needs of the present without compromising the ability of future generations to meet their own needs.)

The second phase of the multilateral policy process will either develop separate agreements for each of the major greenhouse gases or a comprehensive multilateral agreement on many different specific goals.

At international meetings and conferences, such as IPCC meetings and the Toronto conference on the Changing Atmosphere (1988), brief statements have been made on the nuclear option. The Toronto Conference Statement suggests a "rethinking" of the nuclear option. At these conferences, nations such as Sweden, Norway, and the Netherlands question the acceptability of the nuclear option on safety grounds.

Potential Impact of Global Climate Change on Nuclear Power Financing in Developing Nations

A multilateral policy statement acknowledging the nuclear option will not, by itself, increase the ability of developing nations to obtain financing for nuclear development. However, such a statement could provide an indication of the acceptability of the tradeoff between greenhouse gas emissions and nuclear power with its associated problems.

Nuclear Power Lending Policy at the World Bank

The primary multilateral lending institution is the World Bank. This institution was set up under the U.N. to aid developing countries. The World Bank has granted loans for power plants but never for a nuclear power plant. The Bank's policy is founded on least-cost principles. However, concerns over the adequacy of the infrastructure to support nuclear power construction and operation in developing countries may also effect the Bank's lending policy.

If the environmental impacts of fossil plant construction are fully internalized, it is possible that nuclear power will become more competitive with other power sources in cost comparisons. An indication that the World Bank may be giving more weight to environmental values is seen in the recent development of an organization within the World Bank specifically for the purpose of promoting natural gas rather than coal and oil in developing nations. The impetus for development of this organization stems from criticisms that the Bank is not doing enough to counter the threat of climate change.

The Bank has established a liaison to the IPCC process, and is currently preparing an internal policy guidance paper addressing climate change concerns. In the future, the Bank will likely address CO_2 stabilization further with the primary emphasis likely to be placed on efficiency improvements and biomass development. Traditionally, funding has been predominantly for proven power systems with relatively little lending for new technologies.

At the present time, the World Bank is not expected to alter its least-cost policy. Bank representatives assert that in many countries the large cost differential between nuclear power and other energy alternatives places a heavy burden on the nuclear option. If a multilateral policy were developed that acknowledged a nuclear component to climate stabilization programs, the Bank would likely adapt its policy to reflect international consensus. The Bank would be unlikely, however, to alter current policies on its own.

Regardless of lending policies, it is expected that eligibility for nuclear development loans and technology would remain contingent upon the borrowing nation signing an International Atomic Energy Agency (IAEA) Safeguards Agreement. These agreements allow for IAEA inspection of nuclear facilities and fuel cycles to confirm that no products of the plant are available for military purposes.

Summary

No nation is likely to respond to climate change with nuclear policy alterations in the next few years. Several nations (the Netherlands, Sweden, and FRG) appear to be more likely to alter nuclear policy unilaterally as a response to climate change. This assessment is based largely on the historical environmental progressiveness of these countries with regard to stationary source emissions and their current address of climate change. However, each of these countries has, at best, marginal acceptance of nuclear power.

Given that in the next decades, a large amount of new electric capacity will be constructed in developing nations, increasing nuclear power financing to these countries could be a significant effect of climate change concerns on worldwide nuclear capacity.

U.S. Nuclear Industry

U.S. Nuclear Technology Review

This section discusses the new nuclear reactor technologies that are emerging as candidates for commercial use in the United States. The leading candidates for new orders in the earlier part of the projection period are large (1,000+ MWe) and mid-sized (600 MWe) light-water reactors (LWRs). The larger units incorporate changes to existing designs; the smaller units incorporate passively safe design features. Two non-LWR technologies are expected to be commercially available for new orders later in the projection period. These are the helium-cooled modular high-temperature gas reactor and the sodium-cooled liquid metal reactor.

Light-Water Reactors

Light-water reactors use ordinary water as a coolant. These designs are by far the most common in the world, forming the basis of operations in every major nuclear power generating country except Canada (heavy water) and the United Kingdom (carbon dioxide and helium).

Currently, most of the commercial effort is on changes to today's LWRs. These changes fall into two primary groups: (1) evolutionary design changes to large, conventional boiling-water reactors (BWRs) and pressurized-water reactors (PWRs) and (2) major systems simplifications, use of passive safety systems and extensive modularization and prefabrication (facilitated by their smaller size), for mid-sized BWRs and PWRs. Most of the design work is in the United States and Japan.

In June 1989, the U.S. Nuclear Regulatory Commission (NRC) staff concluded that the General Electric Advanced BWR (ABWR) design satisfactorily addressed concerns over severe accidents. Final Design Approval and Certification was expected by late 1991 to early 1992. The Westinghouse Advanced PWR (APWR) was expected to receive final design certification in 1993. This design is an advanced version of the most recent Westinghouse PWRs, such as Callaway and Wolf Creek. Scheduled just behind the Westinghouse design for final design certification by the NRC is the Combustion Engineering System 80+, based on the System 80 design of the operational Palo Verde units. In June 1990, the NRC voted on a review process that could result in up to a 2-year delay in these design certifications. Another uncertainty that could lead to a delay is the level of design required for standardization.

Still evolutionary but less so than the 1,000+ MWe reactors are the mid-size advanced reactors. These reactors, generally 600 MWe or less, are at the detailed design stage. The reactors feature a modular nuclear plant design that can be built within 4 years (not including licensing), using factory-produced construction modules that will be assembled on the site of the nuclear power plant. The passive safety system uses natural physical forces--such as gravity, convection, evaporation and condensation--to cool the plant in the unlikely event of an accident. The relatively small capacity of the reactors, increased design margins, and large supplies of passively invoked and gravity-fed emergency cooling water provide a higher degree of passive safety. In 1990, DOE awarded Westinghouse and GE $50 million cost-sharing contracts for design and development work on the AP600 PWR and the Simplified BWR (SBWR), respectively. It is anticipated that the NRC will issue final design certifications for the AP600 and the SBWR by 1998. Commercial prospects for these units await further expressions of utility interest.

Gas-Cooled Reactors

The commercial modular high temperature gas-cooled reactor (MHTGR) being developed in the United States is a nuclear power system capable of providing electricity and process heat. It uses a graphite core, refractory-coated particle fuel, and helium gas as the coolant. This unique system can potentially provide safety, investment, and environmental protection margins through use of natural phenomena and properties. A major objective of the MHTGR is to preclude the need to evacuate or shelter anyone beyond the site boundary because of an accident.

The proposed commercial design eliminates the conventional containment structure found in LWRs. Instead, the fuel particles function as containments for the fission products. Also, the refractory-coated fuel can retain fission products under even severe conditions.

With the MHTGR design, shutdown heat can be removed from the core by radiation to the ground without reliance on a heat removal system that could fail, removing the potential for the fuel to overheat.

The department is funding design and development of the commercial MHTGR. The Preliminary Safety Evaluation Information Document was presented to the NRC for review. Based on this design documentation and a series of comprehensive technical meetings, the NRC issued a draft safety evaluation report in February 1989, that is being factored into the Department's plans for continued development of the concept.

The commercial MHTGR is focusing on the development of improved low enriched uranium (LEU) fuel fabrication processes, advanced methods of assuring the quality and performance of the fuel, proving the inherent heat removal capability of the design, and proving the safety features of the design. Efforts are underway to evaluate LEU fuel performance and fission product behavior, and to develop, verify, and validate analytical models and codes.

The Department has cooperative international MHTGR technology development programs with the Federal Republic of Germany, France, Switzerland, and Japan in the areas of fuel performance, physics, metals, graphite fission product behavior, safety and analytic modeling, and code development, that are facilitating and supporting commercial MHTGR development. The Department is developing a plan for the commercialization of a lead MHTGR plant.

No utility orders or commercial demonstrations of gas-cooled reactors are planned, but the design is one of two recommended for construction as a new weapons production reactor. (The other is a heavy-water reactor.) If the MHTGR is constructed for weapons material, it would be a step toward demonstrating the commercial potential of the design. Although successful operation of a MHTGR for weapons production would advance the commercial prospects of the reactor, utilities and the NRC would impose additional demonstration and test requirements on the design of a commercial version. Public acceptance of the design without a containment and cost effectiveness of the design with a containment are important open issues.

Sodium-Cooled Reactors

Sodium is the coolant of choice in a class of reactors known as liquid metal reactors (LMRs). These reactors, which have substantially different characteristics and capabilities from the water and gas reactors, are operating in most of the leading nuclear countries. Advanced designs are on the drawing board in the United States and Europe.

The use of a liquid sodium coolant has certain advantages and disadvantages over water or helium. Favoring sodium is its extremely high heat-transfer capacity and its extremely high boiling point. A large pool of sodium takes a long time to heat up, a long time to cool down, and requires a great deal of heat to boil. This means that the sodium coolant provides much more thermal stability than water or gas. On the other hand, sodium is chemically reactive, corrosive, and explosively flammable in the presence of oxygen. This means that sodium is much more difficult to work with than either water or helium.

Sodium-cooled reactors, however, have certain favorable characteristics for long-run success. The primary characteristic is their capacity to breed fuel (as in the term Liquid Metal Fast Breeder Reactor). The use of sodium as a coolant permits efficient breeding of U-238 into Pu-239. Although the generation and reprocessing of commercial plutonium is contentious and currently very uneconomical, the long-run energy potential is very high. The second characteristic of some (but not all) metal-cooled reactor designs is the use of metal (versus oxide) fuels. Metal fuels, i.e., using uranium in its metallic form rather than its oxide form, offer a greater potential for passive safety than any other reactor type (including water and gas, which cannot use metal fuels). The possibility of on-site reprocessing, thus confining the plutonium, and reductions in the type and radioactivity of waste products, thus simplifying the waste disposal problem, are other advantages of the proposed metal-fueled, sodium-cooled reactors.

In the United States, the Department of Energy is continuing to fund development of the Power Reactor Innovative Safe Module (PRISM) concept led by General Electric. In 1989, DOE awarded GE a 3-year contract for $46.7 million for design work, including resolution of NRC licensing issues, and a 2-year optional follow-on for $44.4 million for preliminary design. DOE does not plan individual funding for a commercial demonstration. DOE has thus far not been successful in enlisting utility or foreign support for the non-DOE funding required for a demonstration. With the selection of the PRISM as DOE's reference LMR, work has ceased on the Sodium Advanced Fast Reactor (SAFR), an alternate LMR designed by Rockwell International.

One of the more promising approaches to resolving the issue of long-lived waste products is the fissioning of the actinide elements[10] in a liquid metal reactor. LMR fuel can be designed to accept the actinide waste products from LMRs as well as LWRs. The neutron flux in a liquid metal reactor can be designed to fission the actinides. The result is an LMR waste product that is largely free of actinides. Since the waste product has only fission product characteristics, the waste stream can be processed for storage over hundreds of years rather than hundreds of thousands of years. Such an approach to fuel cycle management simplifies high-level waste storage. It also reclaims the fuel value of the uranium and plutonium discarded in the original LWR fuel cycle, provides part of the feed for the LMR fuel cycle, creates a common LWR-LMR fuel cycle-waste stream process, and has the potential to reduce plutonium proliferation problems.

The leading advocates of actinide control in the United States (and the world) are the developers of the Integral Fast Reactor (IFR) at Argonne National Laboratory. The IFR fuel cycle is being designed with an integral electrochemical reprocessing technique that isolates actinide wastes, maintains the isolated wastes in an intensely radioactive form (to make off-site diversion of nuclear material impossible), and reforms the waste and fresh feed into a metal fuel (rather than an oxide fuel) for insertion into a liquid metal reactor. This design is gaining increasing attention around the world, both as a means of addressing waste problems and as a potential competitor in the market for reactors designed with passively safe features.

Nuclear Power Plant Decommissioning: Cost Estimates and Estimating Methodologies

Introduction

One issue of increasing importance to the future of nuclear power worldwide is plant decommissioning. Recent experience has reduced the technical uncertainties associated with this activity; however, there is still a substantial amount of uncertainty about the costs and economics of dismantling a 40-year-old, large-scale, commercial reactor. These uncertainties could affect the economics, as well as acceptance by the public and the financial markets, of future nuclear power plants. This section, therefore, discusses some issues associated with nuclear power plant decommissioning costs, concentrating on the issues that drive the economics of decommissioning.

[10]Actinide isotopes, which are alpha emitters with half-lives of tens of thousands of years

Cost Estimators

There are two main sources of detailed engineering/economic decommissioning cost estimates: Battelle Pacific Northwest Laboratory (PNL) and TLG Engineering, Inc. (TLG). The PNL estimates are the basis for the official U.S. Nuclear Regulatory Commission (NRC) estimates. The TLG approach uses the Atomic Industrial Forum — National Environmental Studies Program (AIF NESP) method.[11] The TLG and PNL estimates, either on a generic or a site specific basis, form the basis for almost all of the cost estimates used by the utilities and approved by public utility commissions. Other estimators include Nuclear Energy Services, Inc., Bechtel Power Corporation, and Stone and Webster Engineering Corp.

Background on Principal Cost Estimates

The PNL estimates are based on studies originally done for the NRC in 1978. These studies provide detailed engineering/economic estimates on every aspect of physical decommissioning.[12] [13] PNL's first major update of the 1978 cost estimates was reported in a 1985 Electric Power Research Institute (EPRI) study.[14] Table 12 summarizes the original and updated (to 1984)

Table 12. Summary of Reevaluated Decommissioning Costs for Light-Water Reactors

	Estimated Costs (Million 1984 Dollars)[a]					
					Entombment (Internals Removed)	
	Immediate Dismantlement		Deferred Dismantlement After 50 years		100 Years of Surveillance	
	PWR	BWR	PWR	BWR	PWR	BWR
Base Case Estimated Decommissioning Costs:						
(1978 dollars)	33.0	43.6	22.1	26.4	3.9	3.9
(1984 dollars)	65.0	87.1	41.4	45.8	5.9	5.9
Possible Additional Costs Additional Staff Needed to Reduce Average Annual Radiation Dose to:						
5 rem per year	7.4	4.3				
[illegible] rem per year	16.1	16.9				
1 rem per year	59.6	79.7				
Use of External Decommissioning Contractor	12.7	20.7	11.9	16.4		
Pre-Commissioning Engineering						
Internal (utility)	5.5	5.5	4.4	4.4		
External (contractor)	7.3	7.3	5.8	5.8		
Supplies for Extra Staff (5 rem/yr average dose)	1.2	2				
NRC Licensing Activities	0.1	0.1	0.1	0.1	1.0	1.0
Subtotal (5 rem/yr):						
Utility (internal) Staffing	79.2	97.2	45.9	50.3	[b] 6.9	[b] 6.9
Contractor (external) Staffing	93.7	119.7	59.2	68.1	[b] 6.9	[b] 6.9
Total Estimated Cost:						
Utility Staffing	79.2	97.2	[d] 75.4	[d] 98.1	[c] 63.7	[b] 91.3
Contractor Staffing	93.7	119.7	[d] 94.3	[d] 125.6	[c] 65.5	[b] 93.1

[a] Costs include a 25 percent contingency.
[b] Surveillance costs only.
[c] Sum of surveillance and dismantlement costs.
[d] Difference between subtotal and total represents preparation and surveillance costs.
Source: Electric Power Research Institute, *Updated Costs for Decommissioning Nuclear Power Facilities*, EPRI NP-4012 (Palo Alto, CA, May 1985), p. 1-2.

[11] The Atomic Industrial Forum is now known as the U.S. Council for Energy Awareness.
[12] NUREG/CR-0130 for PWRs and NUREG/CR-0672 for BWRs. Portland General Electric's Trojan station and Washington Public Power Supply System's WNP-2 station were the reference PWR and BWR, respectively.
[13] An additional study, NUREG/CR-1266, covering fuel cycle facilities, was part of the 1978 project, but is not discussed in this report.
[14] Electric Power Research Institute, *Updated Costs for Decommissioning Nuclear Power Facilities*, EPRI NP-4012 (Palo Alto, CA, May 1985).

costs for the two reference 1,100-MWe single-unit power plants. The total cost for immediate dismantlement (DECON) of a PWR and a BWR is estimated at $94 and $120 million (1984 dollars), respectively, assuming contractor staffing. Total costs for 50-year safe storage and deferred dismantlement (SAFSTOR) are estimated to be a few million dollars higher.

Subsequent updates to 1986 dollars are contained in NUREG/CR-0130 Addendum 4 and NUREG/CR-0672 Addendum 3; they are the basis for the NRC's 1988 rulemaking establishing the required decommissioning funding levels of $105 million for an average 1,100-MWe PWR and $135 million for an average 1,100-MWe BWR. Lower funding levels are specified for smaller reactors. Table 13 shows details of the most recent PNL updates for the immediate dismantlement (DECON) case for the reference PWR and BWR. The totals for the 30-year SAFSTOR case are similar to the ones for DECON and for purposes of brevity are not shown.

Future cost estimates (not NRC funding requirements) can be estimated over time by adjusting the base case physical decommissioning requirements for changes in various cost categories, e.g., low-level waste disposal and radiation exposure limits. These issues are discussed later.

In a roughly parallel chronological and technical track with PNL, TLG has been developing separate decommissioning cost estimates. The detailed procedures and guidelines involved in the TLG estimates were prepared for the AIF-NESP. The most recent estimates done under AIF auspices were published in 1986.[35] Independent of the AIF-NESP projects, TLG has conducted numerous site-specific cost estimates for individual utilities. Table 14 is a General Accounting Office (GAO) comparison of TLG's site-specific estimates to NRC's estimates.[36] The TLG estimates are uniformly higher than the NRC estimates, sometimes significantly so. For the 25 nuclear units shown, the NRC estimates averaged 29 percent lower, or $45 million per plant. It should be noted, however, that GAO's version of NRC's estimates (the right column of Table 14) is the result of simple scaling, according to size, of the reference BWR and PWR analyses rather than any detailed, plant-specific analysis. GAO also lowered the TLG estimates to exclude demolition and site restoration, since the NRC does not include these costs in its decommissioning estimates.

Table 13. Summary of the Estimated Cost For Immediate Dismantlement of a Reference PWR and Reference BWR

(Millions of 1986 Dollars)

Cost Category	PWR	BWR
Disposal of Radioactive Material		
Activated Material	6.4	7.2
Contaminated Internals	4.0	23.5
Other Building Internals	19.0	
Radioactive Waste	2.1	4.5
Total Disposal Cost	31.5	35.3
Staff Labor	14.4	28.1
Energy	6.7	7.1
Special Tools and Equipment	1.3	3.2
Miscellaneous Supplies	2.5	3.0
Specialty Contractors	.6	.6
Nuclear Insurance	1.5	1.5
Environmental Surveillance	.3	
License Fees	.1	.1
Cost Adders	6.0	3.5
Additional Staff to Reduce Average Annual Dose to 5 rem/year	10.3	16.7
External Decommissioning Operations Contractor	5.9	5.9
Predecommissioning Engineering by an External Contractor	1.0	.2
Post TMI-2 Impacts by an External Contractor	.7	.1
Subtotal	82.8	105.4
25 percent Contingency	20.7	26.4
Total	103.5	131.8

Source: *Technology, Safety and Costs of Decommissioning a Reference Pressurized Water Reactor Power Station*, NUREG/CR-0130 Addendum 4, p. 3.2, and *Technology, Safety and Costs of Decommissioning a Reference Boiling Water Reactor Power Station*, NUREG/CR-0672 Addendum 3, p. 3.2.

[35] Atomic Industrial Forum, *Guidelines for Producing Commercial Nuclear Power Plant Decommissioning Cost Estimates*, AIF/NESP-036, Vols. 1-2 (Bethesda, MD, 1986).

[36] U.S. General Accounting Office, *NRC's Decommissioning Cost Estimates Appear Low*, GAO/RCED-88-184 (Washington, DC, July 1988).

Table 14. Comparison of TLG Site-Specific Estimates to NRCs Cost Estimates

Plant Description[a]	Size of Plant[b]	Type of Plant	Inflation Rate Assumptions Used[c]			NRCs Estimates[d]
			3-Percent	10-Percent	15-Percent	
1985 Estimates						
Plant A	-	PWR	120	130	136	96
Plant B	-	PWR	120	130	136	96
Plant C	-	PWR	123	133	139	96
Plant D	-	PWR	137	148	155	105
Plant E	-	PWR	135	146	152	105
Plant F		PWR	147	159	166	105
Plant G	-	PWR	146	157	164	105
Duane Arnold	538	BWR	127	137	143	118
Perry	1,205	BWR	202	218	228	135
River Bend	936	BWR	154	166	174	129
Crystal River	821	PWR	135	146	152	97
Diablo Canyon	1,131	PWR	164	177	185	105
Diablo Canyon	1,156	PWR	197	213	222	105
1986 Estimates[e]						
Plant H	1,150	PWR	174	NA	NA	105
Plant I	610	BWR	170	NA	NA	120
Plant J	1,085	BWR	206	NA	NA	133
Palo Verde	1,270	PWR	156	NA	NA	105
Palo Verde	1,270	PWR	146	NA	NA	105
Palo Verde	1,270	PWR	159	NA	NA	105
Vogtle	1,157	PWR	162	NA	NA	105
Vogtle	1,157	PWR	133	NA	NA	105
1987 Estimates						
Brunswick	821	BWR	150	141	135	126
Brunswick	821	BWR	174	164	157	126
H.B. Robinson	770	PWR	104	96	94	96
Shearon Harris	900	PWR	150	141	135	99

[a] Some plant names could not be used because information is considered proprietary.
[b] Expressed in megawatts of electricity.
[c] Different inflation rate assumptions were used to convert 1985 and 1987 TLG estimates to 1986 dollars. The consumer price index rate used averaged 3 percent. The 10-percent rate and the 15-percent rate used were presented during testimony before the California and Arizona public utility commissions, respectively. No adjustments were made if TLG estimates were in 1986 dollars.
[d] Estimates have been adjusted to reflect less than 1,000-megawatt plants. The estimates reflect 1986 dollars.
[e] Figures shown in the "3-Percent" column represent TLG estimates in 1986 dollars.
Source: Government Accounting Office, *NRC Decommissioning Cost Estimates Appear Low*, GAO/RCED-88-184.
NA not applicable

Basis for Cost Estimating

The PNL and TLG cost-estimating techniques are similar. In each case, the physical aspects of decommissioning, including planning, staffing, operations, and waste disposal, are divided into work units. Measurements of time, worker radiation exposure, equipment requirements, and component removal are made for each task. Difficulty factors are applied to each task. The task estimates are then summed to yield a "bottom-up" engineering estimate.

PNL and TLG agree on what technical activities are necessary to complete each type of decommissioning. Both cost estimates include engineering, planning, contractors, labor, waste transportation, waste disposal, power consumption, and other processes necessary to return the site to a releasable, nonradioactive state.

Important assumptions implicit in the cost estimates are:

- No expectation or adjustment for bottlenecks in labor or materials
- Sufficient lead time to manufacture all required equipment and obtain all required labor and materials
- All special equipment easily produced
- Labor supplied by existing building trade unions
- No problems meeting the ALARA (As Low As Reasonably Achievable) radiation exposure limits.

Some important costs associated with the physical activity of releasing a nuclear site for unrestricted use are not part of the decommissioning cost estimates. The removal, packaging, shipping, and disposal of spent fuel, including pool-stored fuel, fuel in casks, and the final core, are not decommissioning costs but plant operating costs. The ultimate disposal of the spent fuel poses a potential problem for some units, however, because the long-term high-level waste disposal repository is currently projected to be available to accept waste in 2010, and 12 of the 110 operable units (year end 1989) are scheduled to be retired before then. Unless a temporary site, such as the monitored retrievable storage, becomes available, utilities have the following options if the plant is retired before 2010:

- Leave the fuel on site. Thus, utilities that leave everything on site could drop far down the list for repository shipping.
- Use on-site casks. This option is realistic for cooled fuel but not realistic for hot fuel (less than about 5 years out of core). Shipment of casks to other sites owned by the utility is possible for a few but not many. Shipment to other sites is unlikely.
- Ship the spent fuel to France for reprocessing. It is not clear if this is legal, but some U.S. utilities have proposed it.
- Life-extend the unit.
- Ship the fuel to a monitored retrievable storage (MRS) facility, if one is available.

The most likely outcome is that fuel will be left on-site in the storage pool or in dry storage. This scenario is called "cold shutdown." Every utility is aware of this possibility, but none is accounting for it or preparing official estimates of its cost. TLG has developed an unpublished estimate that a 4-year delay in beginning decommissioning at one small BWR would cost $28 million (1988 dollars) for minimum utility staff labor alone during cold shutdown. The cost of the energy needed to decommission the unit was estimated at $1 million to $1.5 million per year. No contingencies, O&M, repairs, decommissioning contractor (DOC), or extra security was included.

Neither the demolition and removal of nonradioactive structures nor the restoration of the site to a greenfield condition is part of the decommissioning cost estimates, since there is no NRC requirement for these tasks.

An important additional area of agreement in cost estimating is on the use of current actual costs rather than projected costs, even though the decommissioning activity itself is not scheduled for many years, and the future costs are certain to be higher than current costs. Thus, the cost of low-level waste disposal, a key cost component, is based on current waste disposal charges, not the much higher projected charges under the forthcoming regional compacts.[17]

Sources of Disagreement over Cost Estimates

TLG and PNL disagree on the treatment of a number of cost-estimating issues.[18] Important differences in assumptions include the following:

- Size and composition of utility and contractor staffs
- Single versus double shifting
- Application of difficulty factors
- Pipe-cutting assumptions
- Steam generator removal
- Demolition.

Size and Composition of Utility and Contractor Staffs

Table 15 shows PNL's estimate of PNL's and TLG's cumulative staff labor requirement at the reference BWR. PNL maintains that TLG has large numbers of extra staff in several areas, including engineers and technicians and additional staff time for security personnel and others. TLG fundamentally disagrees on labor requirements, arguing that the utility cannot turn over complete responsibility to the Decommissioning Operations Contractor and that a sizeable utility staff will be required. TLG believes that PNL's estimate of the man-hours required to complete the job is too low.

Single Versus Double Shifting

PNL estimates are based on two shifts per day. TLG estimates are based on a single shift. Disagreement on this issue is declining as PNL includes certain cost factors that TLG has already included. TLG single-shifts everything except cutting and packaging the reactor vessel. It argues that the second shift provides no savings since additional costs are created by extra management staff, the second-shift wage differential, a 50-percent premium on equipment rental, and reduced efficiency. PNL, however, argues that TLG's large utility/DOC overhead staff costs are inflated due to the length of the decommissioning period under a single-shift approach.

[17]Stephen S. Bernow and Bruce E. Biewald, "Nuclear Power Plant Decommissioning Cost Estimation for Planning and Rate Making," *Public Utilities Fortnightly*, October 29, 1987, pp. 14-20.

[18]Personal communication with Richard I. Smith (PNL), Thomas S. LaGuardia (TLG), Francis W. Seymore (TLG), and William A. Cloutier (TLG) and *Comparison of Two Decommissioning Estimates for The Same Reactor Station*, R.I. Smith seminar paper, April 10, 1988.

Table 15. PNL Comparison of Staff Labor Estimates Without Demolition at Reference BWR
(Staff-Years)

Category	TLG	PNL
Utility	493	172
DOC Overhead	362	182
DOC Workers	556	390
Total	1,411	744
Time Span (years)	4	4

Source: R.I. Smith (PNL), Preliminary results. Final results to be published in forthcoming *Technology, Safety and Costs of Decommissioning a Reference Boiling Water Reactor Power Station*, NUREG/CR-0672, Addendum 4.

Difficulty Factors

Difficulty factors are used to adjust basic time estimates.[19] The difficulty factors are height, respiratory protection, radiation, protective clothing, and work breaks. TLG applies its difficulty factors to the upper bounds in unit factor cost development, resulting in higher estimates of the cost of a job than PNL.

An example used by PNL is TLG's application of difficulty factors during the entire time a decontamination rig is in operation and the workers are largely waiting for the decontamination solution to complete its circulation. PNL argues that the difficulty factors apply only to the set-up/tear-down/move-time and not to the solution circulation time. TLG agreed with PNL that its work difficulty factor estimation for the decontamination rig example may be high. However, TLG emphasizes that there are very few other decommissioning operations where the staff sets up some equipment (subject to work difficulty factors) and then waits while the equipment works by itself.

Pipe-Cutting Assumptions

The pipe-cutting disagreement is over the average length of a cut pipe and the average difficulty factor. PNL estimates that a cut is necessary, on average, every 7 feet. TLG estimates 5 feet. TLG also applies higher difficulty factors to the task. According to PNL, the combined effect of fewer cuts and less difficulty is a significant cost reduction. TLG argues that 5 feet is appropriate but disputes the notion that it is possible to specify the average pipe cut precisely without inspecting every pipe. In the pipe-cutting area and in certain other areas, TLG notes that PNL did not restate its 1978 requirements in the light of post-TMI backfits, other backfits, increased complexity, and other operational changes. According to TLG, these changes, by adding lots of bending pipe, adding new structures that interfere with pipe and other structures, and reducing the clearance around pipes makes the average pipe-cutting assignment more difficult and less productive. TLG also emphasizes that difficulty factors are an average of the available working space in good and bad plants.

PNL states that its review of backfitted plants shows minimal impact on decommissioning costs. PNL estimates the cost impact on BWRs and PWRs from post-TMI backfits to be about $100,000 and $260,000, respectively. PNL also disagrees with what it describes as TLG's method of taking the total pipe length for the plant and dividing by five to arrive at the average number of pipe cuts.

Steam Generator Removal

TLG believes that PNL's estimate of 16,000 man-hours to remove four steam generators is low. TLG notes that removal at Surry took 24,000 man-hours per steam generator. (The Surry removal took place after PNL made its 1978 estimates.) PNL provides an extensive summary of steam generator removal issues (mostly from the perspective of occupational dose) in its NUREG update. Although PNL acknowledges uncertainty over steam generator dose effects, it notes, that recent experience at Sweden's Ringhals PWR supports its belief that the operation can be done much more quickly and simply than TLG believes.

Summary of Cost Differences

PNL calculates that the cost-estimating difference between PNL and TLG on the reference BWR amounts to $56.4 million, excluding demolition/restoration. This figure is calculated as follows:

[19] The higher the difficulty factor, the larger will be the factor used to scale the basic time estimate.

Category	Cost (Millions)
Size of Utility/DOC Staff	$29.5
Decommissioning Labor	$11.1
Other	$15.8
Total	$56.4

The NRC stands by the PNL estimates and techniques. Experts are split on whether the NRC estimates are too low. According to the Government Accounting Office (GAO), most experts (whom GAO did not identify by name) believe that the NRC estimates (and hence the PNL estimates) are too low.[40]

Independent of the accuracy of the PNL estimates, it is NRC's position that the funding levels in its rulemaking do not represent actual costs and that they should not be used for bids or ratemaking. Rather, the estimates reflect the level at which NRC would feel the company has made a good faith estimating effort and provided reasonable assurance that the funds will be available. The NRC does not want to do site-specific reviews or check the utilities' costs. It wants the utilities to revise costs periodically rather than rely on some NRC number as the single valid estimate.

Sources of Cost Escalation

PNL's 1984 and 1986 updates of decommissioning costs are based on cost increases for new requirements and escalation of existing costs. Among the new requirements, the most significant increases are in the staff needed to reduce average radiation dosage, use of an external decommissioning contractor, and pre-decommissioning engineering. It is worth noting that the cost impact of stringent dose reductions is much more important in the DECON case than in the SAFSTOR case. Should doses at actual decommissioning operations turn out high, thus forcing more stringent dose reductions or enforcement of regulations, the differential cost impact can be expected to widen.

For cost escalation factors, Tables 16 and 17 show the PNL adjustment from 1978 to 1984 by major cost category in the DECON case. (These costs and cost categories can be compared directly to those in Table 12 to see the cost escalation to 1986. Tables 18 and 19 show the SAFSTOR case. The following discussions primarily concern the DECON case (Tables 12, 13, 16, and 17). The figures show that the largest escalation to 1984 took place in the categories of radioactive waste disposal and on-site energy, but that since 1984, energy costs have dropped while waste disposal costs have soared.

Table 16. PWR: Adjustment of Estimated Costs for Immediate Dismantlement to 1984 Cost Base

Cost Category	Estimated 1978 Costs (million dollars)	Cost Adjustment Factor	Estimated 1984 Costs (million dollars)	Percent of Total Estimated Costs Before Contingency Allowance
Disposal of Radioactive Material				
Neutron-Activated	2.734	2.2	5.995	
Contaminated	5.183	3.0	15.356	
Radioactive Wastes	693	2.3	1.613	
Total Disposal Costs	8.610	2.7	22.964	44.2
Staff Labor	8.986	1.6	14.378	27.6
Energy	3.500	2.6	9.100	17.5
Tools and Equipment	822	1.5	1.233	2.4
Miscellaneous Supplies	1.559	1.5	2.339	4.5
Specialty Contractors	544	1.6	870	1.7
Nuclear Insurance	800	1.4	1.120	2.1
License Fees	0		0	0
Subtotal	24.821		52.004	100.0
Contingency	6.205		13.001	
Total Costs	31.026	2.1	65.005	

Note: Cost adjustment factors are rounded to nearest tenths.
Source: Electric Power Research Institute, *Updated Costs for Decommissioning Nuclear Power Facilities* EPRI NP-4012 (Palo Alto, CA, May 1985), p. 1-2.

[40]U.S. General Accounting Office, *NRC's Decommissioning Costs Appear Low*, U.S. GAO/RCED-88-184 (Washington, DC, July 1988).

Table 17. BWR: Adjustment of Estimated Costs for Immediate Dismantlement to 1984 Cost Base

Cost Category	Estimated 1978 Costs (million dollars)	Cost Adjustment Factor	Estimated 1984 Costs (million dollars)	Percent of Total Estimated Costs Before Contingency Allowance
Disposal of Radioactive Material				
Neutron Activated	2.300	2.0	4.498	
Contaminated	4.909	3.2	15.900	
Radioactive Wastes	1.409	2.0	2.979	
Total Disposal Costs	8.678	2.4	23.377	44.2
Staff Labor	17.561	1.6	28.098	27.0
Energy	3.519	a	10.088	17.5
Tools and Equipment	2.016	1.5	3.024	2.4
Miscellaneous Supplies	1.859	1.5	2.789	4.5
Specialty Contractors	.356	1.6	.570	1.7
Nuclear Insurance	.800	1.4	1.120	2.1
License Fees	.051	a	b 0	0
Subtotal	34.840		69.666	100.0
Contingency	8.710		17.417	--
Total Costs	43.550	2.0	87.083	

[a] Cost adjustments for energy are based on cost adjustment factors of 2.6 for electricity and 3.4 for fuel oil.
[b] Not included in costs.
Note: Cost adjustment factors are rounded to nearest tenths.
Source: Electric Power Research Institute, *Updated Costs for Decommissioning Nuclear Power Facilities*, EPRI NP-4012 (Palo Alto, CA, May 1985), p. 1-2.

Table 18. PWR: Adjustment of Estimated Costs for Preparations for Safe Storage to 1984 Cost Base

Cost Category	Estimated 1978 Costs (million dollars)	Cost Adjustment Factor	Estimated 1984 Costs (million dollars)	Percent of Total Estimated Costs Before Contingency Allowance
Disposal of Radioactive Material (Radioactive Wastes)	0.644	2.3	1.262	8.7
Staff Labor	3.651	1.6	5.842	40.9
Energy	1.865	2.6	4.849	33.9
Tools and Equipment	.075	1.5	.113	.8
Miscellaneous Supplies	.892	1.5	1.338	9.4
Specialty Contractors	.305	1.6	.488	3.4
Nuclear Insurance	.294	1.4	.412	2.9
License Fees	0			
Subtotal	7.626		14.304	100.0
Contingency	1.907		3.576	
Total Costs	9.533	1.9	17.880	

Notes: These estimates do not include dismantling costs. Cost adjustment factors rounded to nearest tenths.
Source: Electric Power Research Institute, *Updated Costs for Decommissioning Nuclear Power Facilities*, EPRI NP-4012 (Palo Alto, CA, May 1985), p. 1-2.

Table 19. BWR: Adjustment of Estimated Costs for Preparations for Safe Storage to 1984 Cost Base

Cost Category	Estimated 1978 Costs (million dollars)	Cost Adjustment Factor	Estimated 1984 Costs (million dollars)	Percent of Total Estimated Costs Before Contingency Allowance
Disposal of Radioactive Material (Radioactive Wastes)	1.210	2.0	2.401	7.9
Staff Labor	11.254	1.6	18.006	59.4
Energy	2.122	a	6.297	20.8
Tools and Equipment	.351	1.5	.527	1.7
Miscellaneous Supplies	1.361	1.5	2.042	6.8
Specialty Contractors	.196	1.6	.314	1.0
Nuclear Insurance	.500	1.4	.700	2.3
License Fees	.038	1.0	.038	.1
Subtotal	17.038		30.325	100.0
Contingency	4.260		7.581	
Total Costs	21.298	1.8	37.906	

[a] Cost adjustments for energy are based on cost adjustment factors of 2.8 for electricity and 3.4 for fuel oil.

Notes: These estimates do not include dismantling costs. Cost adjustment factors rounded to nearest tenths.

Source: Electric Power Research Institute, *Updated Costs for Decommissioning Nuclear Power Facilities*, EPRI NP 4012 (Palo Alto, CA, May 1985), p. 1-2.

For the PWR case, the weighted-average escalation multiplier of 2.7 for waste disposal for the 6-year period to 1984 implies a nominal annual rate of increase of just under 18 percent.[41] For the BWR case, the weighted average escalation multiplier of 2.4 implies an annual increase of just under 16 percent. From 1984 to 1986, waste disposal costs increased at a nominal annual rate of 17 percent in the PWR case and 23 percent in the BWR case. Apart from the increases in disposal costs and the itemized cost adders (Table 13), the differences between PNL's 1984 update and its 1986 update for DECON and SAFSTOR for BWRs and PWRs are minor.

The cost increases in the waste disposal category cover the costs of containers, transportation, and burial. The largest component in the cost category--burial--has been increasing at more than twice the average for the category.

Projected increases in low-level waste (LLW) disposal costs are equal to or greater than the increases that accumulated over the past decade. For example, the current charge for LLW disposal at the Barnwell, South Carolina, site is approximately \$36 per cubic foot, excluding surcharges and taxes. One estimate projects the following disposal costs (1988 dollars) for mid-1990's disposal at a newly developed LLW disposal site.[42]

Disposal Volume (ft^3)	\$/ft^3
50,000	240
100,000	140
150,000	100
200,000	90
500,000	60

Because the typical size of a disposal site at the new compacts is in the middle range of those shown above, constant-dollar disposal costs of \$100 per cubic foot or more can be considered realistic.[43] Since the volume of LLW from a typical reactor is on the order of 350,000 to 500,000 cubic feet, with the larger volumes associated with BWRs, burial costs alone could exceed \$50 million in constant dollars. The cost of containers and transportation, taking into account their lower rate of escalation, would add 30 to 40 percent to the total. Disposal costs in the range of \$50 to 70 million (1988 dollars) are thus not unrealistic for mid-1990s decommissioning. These figures compare with current PNL estimates of \$31 to 35 million (1986 dollars).

Another issue is the impact of these charges on volume compaction and incineration. As costs go up, incentives to compact or incinerate go up. But if volume goes

[41] Almost all of the waste is low level, Class C and below, however, some of the waste is currently classified as "above Class C."

[42] Philip Bradbury, Manager, Low-Level Radioactive Waste Disposal Programs, Bechtel National, Inc. Oak Ridge, TN. Paper presented at the *ASME Decommissioning Course*, Pittsburgh, PA, September 1988.

[43] Similar costs are projected by others. See Stephen S. Bernow and Bruce E. Biewald, "Nuclear Power Plant Decommissioning: Cost Estimation for Planning and Rate Making," *Public Utilities Fortnightly*, October 29, 1987, pp. 14-20.

down, site costs have to be amortized over smaller volumes and the cost per cubic foot increases.

Actual Versus Projected Costs

The difference between the PNL (and TLG) estimates and estimates based on expectations of much higher burial and other costs raises an important question. The question is whether decommissioning estimates should be based on actual or projected costs. Decommissioning studies uniformly base their estimates on actual costs. Each estimator, as well as the NRC, makes it clear that the estimates reflect current conditions and that as conditions change the estimates should be updated. For a variety of reasons, the use of actual costs and current conditions has resulted in decommissioning estimates that appear very low over time.

According to one study, current decommissioning cost estimates typically assume:

- A precisely defined scope of work
- No future evolution of regulation or unforseen technological problems
- No real price escalation
- Hypothetical facilities for the disposal of radioactive waste
- No additions of equipment to the power plant during its operating life.[44]

This study continues by saying that, "In effect, the current overnight engineering estimates fail to recognize both foreseeable future developments and the inevitable surprises that will emerge as full-scale nuclear plant decommissioning is actually attempted." The authors go on to recommend a contingency factor approach to cost estimation.[45] A precise scope of work is reasonably certain today. However, a contingency factor applied to the scope of work is indeed reasonable. For the assumptions that relate to future changes, even known changes, such as increased LLW disposal charges, the use of future costs in current estimates is inappropriate because ratemaking requires historical or current costs (plus inflation, in some cases), not future costs or escalated costs. Even though there is little doubt that the charge for LLW disposal will escalate at a rapid rate, the higher future costs cannot be charged to current ratepayers until they are certain costs. While it may be possible to charge future disposal costs today through a long-term levelized payment scheme, it is inconceivable that future changes in work scope, regulation, and capital additions could be similarly levelized. Moreover, it is impossible to charge current ratepayers today for the possibility that cold-shutdown will be required in 2010 or that secondary-side contamination will add millions to the cost of decommissioning. The result is that future costs must be incorporated through future adjustments.

To the extent that future cost increases are not currently captured through commission-accepted escalation factors, contingency factors, and other variables, the decommissioning cost estimates provided by PNL, TLG, or others (which include contingencies but exclude escalators) will understate the future costs of decommissioning. The estimators, the utilities, the NRC, and the State commissions know this. As a consequence, most or all State commissions are requiring periodic updates of decommissioning costs for ratemaking purposes and including an inflation (but not escalation) factor for estimating future value. The overall concept appears to be one of frequent updates to minimize the size of the catch-up required at any given time. Should escalation be modest, this approach will succeed. If escalation picks up, especially if it picks up just before decommissioning is to take place, the update approach will require large revenue increases at that time. In the overall context of a utility system, however, the ratepayer impact will be modest.

Future Developments

For the next few years, cost estimates for decommissioning will be based on increasingly detailed studies of existing plants, some information from demonstration decommissioning projects, notably Shippingport, and some foreign information. Preliminary indications of the trend in decommissioning costs are mixed.

On the optimistic side, there is little doubt in the industry about the technical feasibility of decommissioning and the exact methods for physical removal of the decommissioning material. Some recent evidence in steam generator replacement suggests that the industry is learning to control exposures through careful operations. Although the regional LLW compacts have not opened, there is reduced concern about their eventual existence.[46] On the pessimistic side, there is concern about the costs of waste disposal, including transport, burial, and site release. One important concern is that a large amount of material will be extremely low in radioactivity but will not be low enough to meet NRC standards for release. The resulting requirement for disposal of material that had not been considered radioactive will be costly.

[44]Bernow and Biewald, *ibid.*

[45]Under the contingency factor approach, the "baseline" costs will first be estimated. Then, the estimator will use a contingency factor, measured in percent, to increase the "baseline" estimates. Both PNL and TLG use a 25 percent contingency factor. These contingency factors are used to capture the effects of unforeseen factors, such as bad weather.

[46]It should be noted that the constitutionality of the Low Level Waste Act, the legislation establishing the regional compacts, has recently been challenged. A ruling by the court, that this legislation is unconstitutional could affect decommissioning costs.

Another issue is the widely recognized but unpublicized difference between meeting State standards for decommissioning, i.e., site restoration, and meeting NRC standards, i.e., site release. The post-release costs for decommissioning, which are not part of the NRC estimates, could be significant.

A third potential problem is residual contamination on presumably nonradioactive structures and components. According to TLG, the cost of disposing of such material is not reflected in any PWR cost estimate but could run into the millions.

A fourth issue is worker productivity, especially toward the end of the decommissioning project. Shippingport productivity declined sharply and workmen's compensation claims increased sharply with 6 months to go on the project. It may be necessary to increase sharply the pay of workers who would otherwise want to avoid working themselves out of a job.

Global Nuclear R&D Activities

The nuclear industry is becoming increasingly international. This trend is evident in both the commercial and the governmental sectors. International and intercorporate agreements, mergers, and cooperation have led to sharing in research and development (R&D) activities as well as in other areas. Many of the arrangements are clearly commercial. However, cooperation for marketing often leads to shared research or joint development projects.

Commercial Cooperation in the Private Sector

The move toward cross-country cooperation is evident in the private sector. During 1989 and the early months of 1990, a number of agreements and mergers were announced. This process has permitted firms to achieve economies by centralizing some of their major nuclear R&D projects and by eliminating competitive efforts.

One of the most active participants in this process has been ASEA Brown Boveri, Ltd. (ABB), based in Zurich, Switzerland. ABB itself is the result of the 1988 merger of ASEA, a major Swedish electrical equipment manufacturer, with the Swiss concern of Brown Boveri to form the largest electrical equipment supplier in the world. ASEA-Atom, now a division of ABB called ABB-Atom, has been prominent in nuclear research and development since the 1950's. During the past year, ABB has pursued links to promote its nuclear business. With Westinghouse, ABB formed ABB Westinghouse Nuclear Services to supply nuclear services to utilities in Europe. ABB and Westinghouse also have a joint venture company to supply transmission and distribution markets in the Americas and another joint venture, Innovative Technologies Incorporated, to provide fuel and other services in the United States. In November, ABB merged with Combustion Engineering in anticipation of growth in the U.S. commercial nuclear plant market during the next decade. The new U.S. nuclear division of the combined companies is now called ABB Combustion Engineering Nuclear Power. ABB also has a joint venture with United Engineers, the U.S. architecture-engineering firm, to market the ASEA-Atom PIUS reactor in the United States. ABB and Siemens (West Germany) recently formed a joint marketing company, HTR-GmbH, to sell high-temperature gas-cooled reactors in Europe. In 1990, ABB signed agreements or held discussions with power generation companies and equipment manufacturers in Italy, Spain, and Poland.

ABB is not the only foreign company linking with U.S. manufacturers. Babcock and Wilcox has a joint venture with Framatome (France) for services in North America and another with Nuclear Power International, the PWR design and marketing joint venture formed by Framatome and Siemens, for marketing nuclear technology globally. General Electric and its Japanese partners (Hitachi, Toshiba, and the Tokyo Electric Power Company (TEPCO)) have developed an advanced boiling-water reactor (ABWR) design. TEPCO has already placed an order for two of these 1,350-MWe ABWRs. General Electric is also engaged with its international partners Ansaldo of Italy, Hitachi and Toshiba of Japan, and KEMA/NUCON of the Netherlands, in the design of a simplified 600 MWe boiling-water reactor (SBWR). Westinghouse and its Japanese partners, Mitsubishi and Kansai Electric, are jointly developing a 1,300-MWe advanced pressurized-water reactor (APWR). Although no orders have yet been placed, a sale to Kansai is anticipated. Westinghouse and Mitsubishi are engaged in another joint project to develop an advanced simplified reactor for the Japan Atomic Power Company.

In Eastern Europe, Bechtel has a contract with Transelektro Foreign Trading Company to supply information and materials for managing complex nuclear activities to the Hungarian Electricity Board and the Paks Nuclear Power Station Company in Hungary. Siemens/Kraftwerk Union (West Germany) contracted to supply reactor loose-parts monitoring technology systems to Atomenergoexport (AEE) for PWRs operating in the Soviet Union. Two West German companies (Preussenelektra AG and Bayernwerk AG) announced their intention to form joint ventures with several organizations in the German Democratic Republic (GDR), including VE Kombinat Kernkraftwerke Bruno Leuschner, operator of the Nord nuclear plant in the Greifswald area. Electricite de France (EdF) signed a service and engineering contract with the Ministry of Nuclear Energy and Industry of the Soviet Union. Skoda (Czechoslovakia) is seeking a partner in Western Europe for two new units at the Temelin nuclear site.

International Cooperation

Japan Nuclear Fuel Industries (JNFI) signed an agreement to exchange information on low-level waste disposal with the United Kingdom's Nirex radioactive waste agency. JNFI also has agreements with the European national agencies UKAEA (United Kingdom Atomic Energy Agency), CEA (Commissariat a l'Energie Atomique of France), and SKB (SvenskKrnbrnlehantering AB of Sweden). Japan has collaborated with Belgium for a number of years in research and development on nuclear fuels. Several new projects are in the planning stage. The Soviet Union signed a technology transfer agreement with EdF in December 1989. In November, the Soviet Union signed an agreement on nuclear cooperation with Brazil including technology transfer for small reactors and fast breeder reactors (FBRs). The cooperation will be at the government level as well as between engineering associations in both countries. The Soviet Union and the European Community also signed a bilateral agreement that includes exchange of scientific and technical information on nuclear energy. West Germany and Brazil will continue their agreement for nuclear cooperation for 5 years. However, there was opposition to this extension in both countries and Brazil's financial problems will limit the scope of cooperation.

European utilities are funding a common effort to develop a European Fast Reactor (EFR). The collaboration is coordinated through an informal operation called EFR Associates. The participating utilities are EdF, Nuclear Electric (UK); Preussenelektra and Rheinisch-Westfaelisches Elektrizitaetswerk (FRG), and Ente Nazionale per L'Energia Elettrica (Italy). The French, British, and West German partners are providing almost all the financial support since Italian participation is limited by the current nuclear moratorium in Italy. An agreement signed early in 1989 calls for collaboration on research and development, development of a joint reactor design, and sharing of other scientific information. The shared R&D permits the three active countries to realize savings because research is split among the participants. The French are working on core physics; the British are concentrating on core mechanics; and the Germans are responsible for work on core cooling.

Global Nuclear R&D Projects

The momentum continues toward internationalizing all nuclear research and development activities since such work is expensive. Shared projects and information reduce costs and eliminate duplication of effort. Public concern for safety in commercial nuclear operations demands extensive testing during each phase of technical development. International cooperation can allow accumulation and documentation of test experience more rapidly, which also can reduce costs.

The contraction of the market for commercial nuclear reactors has reduced the number of active firms committed to nuclear development. Even a large firm hesitates on making a full commitment to risky investment in nuclear R&D because of the uncertainties about a revival in commercial nuclear plant orders and because of the difficulty of proving a new plant or component safe enough to be publicly accepted. By combining, through mergers or joint ventures, companies can reduce their individual investments and insure that there will be fewer competing new developments. At the national level, the same economic considerations promote collaborative research. Western Europe, moving toward economic union in 1992, is also moving toward unified scientific and technical efforts. Japan wants to link its nuclear research to international efforts in order to make its nuclear industry internationally competitive. U.S. companies want to maintain commercial viability in Europe and Asia where the commercial nuclear sector is likely to expand. Economics is driving nations and firms to look at commercial nuclear power in a global way and is promoting international R&D.

4. International Commercial Nuclear Power

Introduction and Current Status

The 1990 edition of this report has been organized somewhat differently than previous CNP reports due to political developments in Eastern Europe during the Fall of 1989. The countries in this region are now attempting to create, within a revised political structure, an economy that embodies at least some features of western market economies. Therefore, EIA has eliminated a separate appendix for discussion of commercial nuclear power programs in countries that have or had centrally planned economies and combined them with other foreign countries in Chapter 5 of this report. However, the countries added to Chapter 5 are not included in the projections of Chapter 4 because of insufficient data.

For the countries with free market economies (FME), nuclear-generated electricity continued to grow in 1989. The number of operable nuclear generating units in FME countries increased from 340 in 1987 to 349 in 1988 and 355 in 1989. Total FME nuclear generation in 1989 reached a level of 1,557.7 net terawatthours (TWh), compared with 1,523.2 net TWh in 1988 (Table 20). This represents an increase in generation of 2.3 percent. (Neither Italy nor Mexico generated electricity from their nuclear plants in 1989.)

Twenty FME countries produced nuclear-generated electricity in 1989. The United States, France, Japan, West Germany, Canada, and United Kingdom accounted for over 80 percent of the total FME production. Three countries produced 50 percent or more of their electricity from nuclear power: France (74.6 percent), Belgium (60.7 percent), and South Korea (50.2 percent).

The United States led all FME countries in bringing new units on line in 1989 with three units entering service. Six countries followed with one unit each. Total FME operable nuclear capacity increased by 2.3 percent over the level in 1988, to 273.6 GWe at the end of 1989.[47] Table 21 shows that in 1989 U.S. nuclear capacity accounted for about 38 percent of the total operable nuclear capacity in countries belonging to the Organization for Economic Cooperation and Development (OECD)[48] and about 36 percent of total operable nuclear capacity in all FME countries. (Outside the United States, operable units are defined as those that have generated electricity to the grid.) In 1989, the overall nuclear share of net electricity generation in the OECD countries was 22.8 percent, compared with 23.5 percent in 1988.[49] Appendix F lists all the operable foreign FME nuclear units as of December 31, 1989.

Table 22 shows the status of the foreign FME nuclear construction pipeline as of December 31, 1989. One unit was added to Japan's construction pipeline since last year's report. Even as total nuclear operable capacity was increasing, the amount of capacity in the construction pipeline continued to decrease, from 84.9 GWe in 1987 to 74.8 GWe in 1988 and 64.5 GWe in 1989. The decline can be attributed mostly to the completion of six units and very few new orders.

Figure 4 shows the extent of completion of nuclear units in the foreign FME construction pipeline for the end of years 1985 through 1989. In 1989, 54 percent of the units in the construction pipeline were 25 percent or less complete. The proportion of units that were between 26 and 75 percent complete increased from 15 to 21 percent. The proportion of units in the pipeline that were 76 percent or more complete decreased to 17 percent.

The continuing decline during the past several years in the number of units in the construction pipeline is due to several factors. First, countries continue to review the role of nuclear power in their energy plans, in the wake of the 1986 Chernobyl 4 accident in the

[47]All capacity ratings in this chapter represent net capacity. The 1988 operable capacity was revised to 267.5 net GWe from the 268.1 net GWe published in last year's report.

[48]The OECD countries considered in this study are Belgium, Canada, Finland, France, West Germany, Italy, Japan, the Netherlands, Spain, Sweden, Switzerland, Turkey, the United Kingdom, and the United States. Austria, another OECD country, is not included since Gemeinschaftskraftwerk Tullnerfeld GmbH owner of the canceled Tullnerfeld-1 unit at Zwentendorf, moved to liquidate all remaining nuclear assets in 1989 and neared a formal decision to convert the plant to a gas-fired station.

[49]Nuclear Energy Agency, Organization for Economic Cooperation and Development, *Summary of Nuclear Power and Fuel Cycle Data in OECD Member Countries, Provisional* (Paris, April 1990).

Soviet Union. Second, some countries have overbuilt generating capacity, due to highly optimistic forecasts of demand. As a result of slower than expected economic growth in the 1980's, those forecasts have not been realized. Third, some countries with sufficient capacity to meet near-term demand are reassessing their future expansion plans, particularly with respect to conservation programs. Thus, most countries have delayed the construction of current projects and the placement of new nuclear orders. Appendix G lists the units in the nuclear construction pipeline in foreign FME countries, including information on the stage of completion for each unit as of December 31, 1989.

Table 20. FME Operable Nuclear Power Plant Statistics, 1988 and 1989

Country	Number of Operable Units[a]		Net Capacity[a] (MWe)		Amount of Electricity from Nuclear Units			1989 Nuclear Share[b] (percent)
					Net TWh		Percent Change	
	1988	1989	1988[c]	1989	1988	1989		
* **United States**	108	110	95,091	97,869	527.0	529.4	0.4	17.8
* **Canada**	18	18	R11,872	11,872	78.2	76.2	-2.6	15.9
Europe								
* Belgium	7	7	R5,500	5,500	40.9	38.8	-5.1	60.7
* Finland	4	4	2,310	2,310	18.4	18.0	-2.2	35.4
* France	55	55	R52,588	52,588	260.2	289.0	11.1	74.6
* Germany, West	21	22	21,461	22,686	137.8	139.7	1.4	33.9
* Italy	2	2	R1,120	1,120	.0	.0	.0	.0
* Netherlands	2	2	R497	497	3.4	3.8	11.8	5.3
* Spain	10	10	R606	7,606	48.3	53.3	10.4	37.6
* Sweden	12	12	R9,817	9,802	66.4	63.0	-5.1	45.3
* Switzerland	5	5	2,930	2,956	21.5	21.5	.0	41.6
* United Kingdom	40	39	R11,921	11,242	53.3	59.2	11.1	20.8
Yugoslavia	1	1	632	620	3.9	4.5	15.4	5.2
Subtotal	159	159	R116,382	116,927	654.1	690.8	5.6	41.4
Far East								
* Japan	38	39	R28,253	29,265	174.8	168.3	-3.7	25.5
Korea, South	8	9	R6,270	7,220	38.0	45.0	18.4	50.2
Taiwan	6	6	R4,924	4,924	29.3	27.1	-7.5	35.2
Subtotal	52	54	R39,447	41,409	242.1	240.4	-.7	29.1
Other								
Argentina	2	2	935	935	5.1	4.6	-9.8	11.4
Brazil	1	1	626	626	.6	1.7	183.3	.7
India	6	7	R1,154	1,374	5.4	3.4	-37.0	1.6
Mexico	0	1	0	654	0	0	0	0
Pakistan	1	1	125	125	.2	.1	-50.0	.2
South Africa	2	2	1,840	1,840	10.5	11.1	5.7	7.4
Subtotal	12	14	R4,680	5,554	21.8	20.9	-4.1	3.0
Total OECD	322	325	R250,966	255,313	1,430.2	1,460.2	2.1	22.8
Total Non-OECD	27	30	R16,506	18,318	93.0	97.5	4.8	10.4
Total FME	349	355	R267,472	273,631	1523.2	1557.7	2.3	22.7

[a] For all non-United States 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 from the U.S. Nuclear Regulatory Commission. For all non-United States units, capacity is the net design electrical rating. For United States units, capacity is net summer capability. Capacities of individual units are subject to reratings from year to year. See definitions of capacities in glossary.

[b] Net electricity generated from nuclear power generating units as a percentage of net electricity generated from all sources. The sources for nuclear generation are the OECD and the IAEA for the OECD and non-OECD countries, respectively. The nuclear share of utility-generated electricity for the United States was 19.0 percent.

[c] Some nuclear units were rerated to reflect more current data.

FME Free Market Economies.

* Member of the Organization for Economic Cooperation and Development.

NA, Not Available.

R, This figure is a revision of the figure published in *Commercial Nuclear Power 1989: Prospects for the United States and the World*, DOE/EIA-0438(89) (Washington, DC, September 1989).

Sources: **1988**--Energy Information Administration, *Commercial Nuclear Power 1989: Prospects for the United States and the World*, DOE/EIA-0438(89) (Washington, DC, September 1989). **1988 United States Capacity**--Energy Information Administration, *Monthly Energy Review*, December 1988, DOE/EIA-0035(88/12) (Washington, DC, March 1989), and December 1988, DOE/EIA-0035(88/12) (Washington, DC, March 1989); **1988 Operable Units and Capacity**-- Appendices C and F of this report; **1989 Generation**--The source of nuclear generation is the Organization for Economic Cooperation and Development (OECD), Nuclear Energy Agency (NEA), *Summary of Nuclear Power and Fuel Cycle Data in OECD Member Countries, Provisional* (Paris, France, April 1990). The source of nuclear generation for non-OECD countries is the International Atomic Energy Agency (IAEA), *Nuclear Power Reactors in the World* (Vienna, Austria, April 1990). **1989 Nuclear Share**--The source of nuclear shares is the OECD, NEA, *Summary of Nuclear Power and Fuel Cycle Data in OECD Member Countries, Provisional* (Paris, France, April 1990). The source of nuclear shares for non-OECD countries is the IAEA, *Nuclear Power Reactors in the World* (Vienna, Austria, April 1990).

Table 21. FME Operable Nuclear Capacity as of December 31, 1989

Countries	Net Nuclear Capacity (GWe)	Percent of Total OECD Capacity	Percent of Total FME Capacity
OECD			
United States	97.9	38.3	35.8
Foreign	157.4	61.7	57.5
Total OECD	255.3	–	93.3
Non-OECD	18.3	–	6.7
Total FME	273.6	–	-

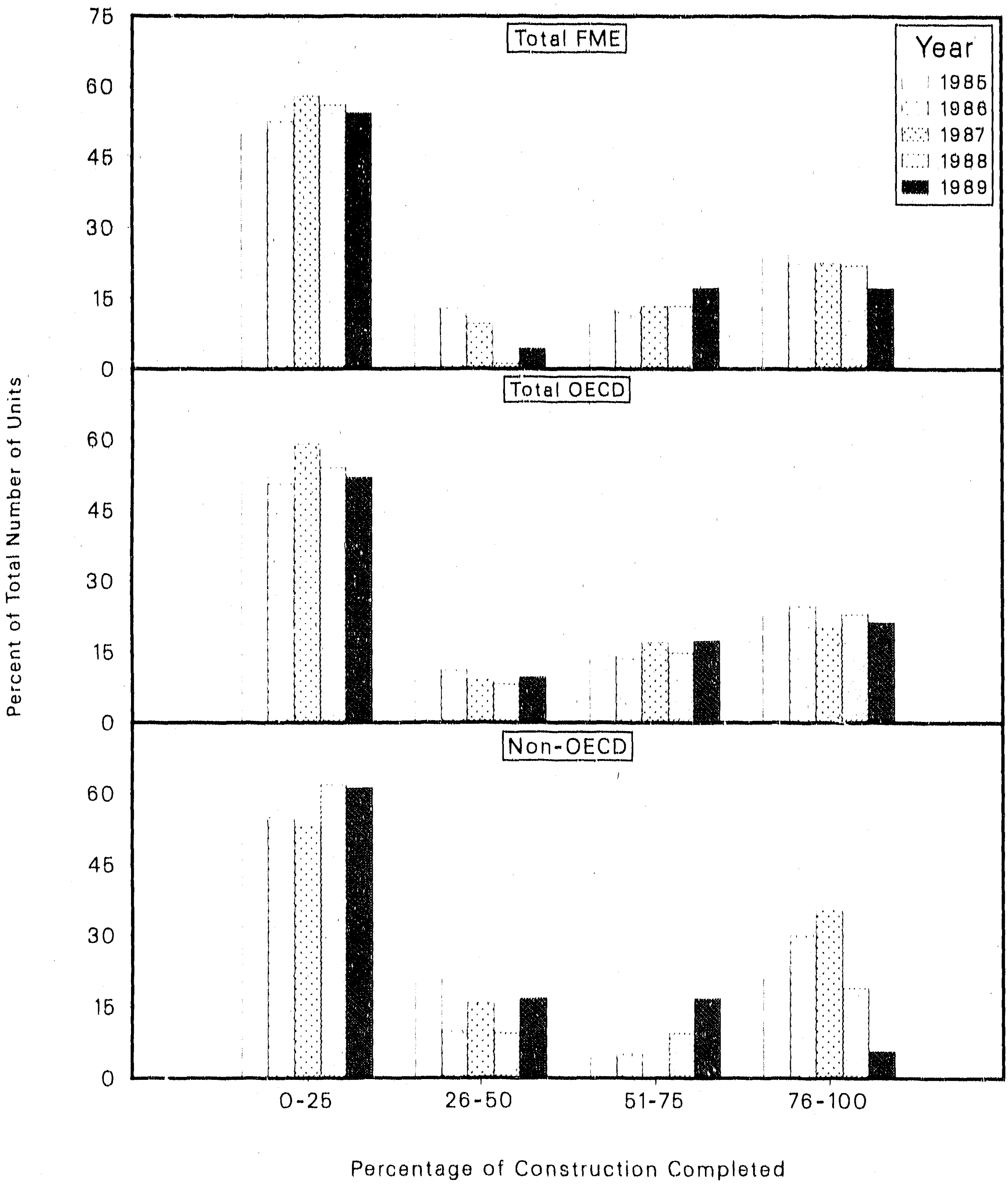
OECD Organization for Economic Cooperation and Development.
FME Free Market Economies.
Source: Table 20.

Table 22. Status of Foreign (FME) Commercial Nuclear Generating Units in the Construction Pipeline as of December 31, 1989

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
* **Canada**	0	0	1	881	1	881	2	1,762	4	3,524
Europe										
* France	1	1,455	0	0	4	5,550	4	5,240	9	12,245
* Germany, West	0	0	0	0	0	0	1	295	1	295
* Italy	0	0	0	0	2	1,964	1	40	3	2,004
* Spain	4	4,002	0	0	1	975	1	975	6	5,952
* Switzerland	1	1,140	0	0	0	0	0	0	1	1,140
* United Kingdom	1	1,200	1	1,175	0	0	0	0	2	2,375
Subtotal	7	7,797	1	1,175	7	8,489	7	6,550	22	24,011
Far East										
* Japan	20	20,748	3	3,100	1	280	2	1,646	26	25,774
Korea, South	2	1,850	0	0	0	0	0	0	2	1,850
Taiwan	2	1,900	0	0	0	0	0	0	2	1,900
Subtotal	24	24,498	3	3,100	1	280	2	1,646	30	29,524
Other										
Argentina	0	0	0	0	1	692	0	0	1	692
Brazil	0	0	1	1,229	1	1,229	0	0	2	2,458
Egypt	2	1,800	0	0	0	0	0	0	2	1,800
India	4	880	1	220	1	220	1	220	7	1,540
Mexico	0	0	1	654	0	0	0	0	1	654
Pakistan	1	300	0	0	0	0	0	0	1	300
Subtotal	7	2,980	3	2,103	3	2,141	1	220	14	7,444
Total OECD	27	28,545	5	5,156	9	9,650	11	9,958	52	53,309
Total Non-OECD	11	6,730	3	2,103	3	2,141	1	220	18	11,194
Total Foreign FME	38	35,275	3	7,259	12	11,791	12	10,178	70	64,503

* OECD country member.
OECD Organization for Economic Cooperation and Development.
FME Free Market Economies
Source: Appendix G.

Figure 4. Status of Foreign (FME) Commercial Nuclear Generating Units in the Construction Pipeline as of December 31, 1989



FME Free Market Economies
OECD Organization for Economic Cooperation and Development

Source: Table 22 and *Nuclear News*, "World List of Nuclear Power Plants," February 1986–1990.

In 1989, the Organization for Economic Cooperation and Development (OECD) published the results of a study jointly undertaken by the OECD Nuclear Energy Agency and International Energy Agency on the projected costs of generating electricity.[50] Eighteen OECD countries and five non-OECD countries (under the auspices of the International Atomic Energy Agency) participated in the study. Using common reference assumptions of a 30-year life and a 72 percent levelized lifetime capacity factor, and an annual discount rate of 5 percent, the following results were reported. For lifetime baseload operation, nuclear power plants were projected to have an economic advantage over alternative baseload generating options in Japan, a majority of countries in OECD Europe, in regions of North America distant from coalfields, and in the non-OECD countries, except in the low-cost coal regions of Brazil, China, and India.

The number of operable units in countries with regulated market and centrally planned economies, RME and CPE, respectively, decreased from 72 in 1988 to 66 in 1989 (Table 23). Total RME and CPE nuclear generation, in 1989 reached a level of 274.2 gross TWh compared with 276.3 in 1988. This represents a decrease in generation of 0.8 percent.

Four RME and one CPE countries produced nuclear-generated electricity in 1989. The Soviet Union accounted for over 75 percent of the total RME and CPE production. Three countries produced 25 percent or more of their electricity from nuclear power: Hungary (50 percent), Bulgaria (33 percent), and Czechoslovakia (28 percent).

Outlook for Countries with Free Market Economies

Methodology

Operable nuclear capacity for foreign FME countries through 2010 is projected in two steps. Initially, a "construction pipeline" analysis, as discussed in Appendix B, is used to project capacity on the basis of units in operation and those under construction or planned that can reasonably be expected to be completed during the projection period. Because the construction pipeline is exhausted in different years for different countries, the first step in the projection process involves identifying the year through which current and planned nuclear construction projects could be completed for each FME country. Appendix G lists these years and contains unit-specific information and estimates of operable dates within the 5-year projection intervals for each of the projection scenarios.

Table 23. Nuclear Capacity and Generation in Countries with Regulated Market and Centrally Planned Economies as of December 31, 1989

Country	Number of Operable Units[a]		Net Capacity[a] (MWe)		Amount of Electricity from Nuclear Units			1989 Nuclear Share[b] (percent)
					Gross TWh		Percent Change	
	1988	1989	1988	1989	1988	1989		
Bulgaria	5	5	2,585	2,585	16.0	14.6	-8.8	32.9
Czechoslovakia	8	8	3,264	3,264	21.7	22.9	5.5	27.6
Germany, East	5	6	1,702	2,102	10.9	11.1	1.8	10.9
Hungary	4	4	1,645	1,645	12.0	13.0	8.3	49.8
U.S.S.R.	50	43	34,384	34,186	215.7	212.6	-1.4	12.3
Total RME	22	23	9,196	9,596	60.6	61.6	1.7	24.1
Total CPE	50	43	34,384	34,186	215.7	212.6	-1.4	12.3
Total	72	66	43,580	43,782	276.3	274.2	-.8	13.8

[a] Operable units are those that have generated electricity to the grid. Capacity of individual units are subject to rerating from year to year. See definitions of capacities in glossary.

[b] Net electricity generated from nuclear power generating units as a percentage of net electricity generated from all sources.

Sources: **1988**--Energy Information Administration, *Commercial Nuclear Power 1989: Prospects for the United States and the World*, DOE/EIA-0438(89) (Washington, DC, September 1989). **1988 Operable Units and Capacity**-- Appendix H1 of this report; **1989 Generation**--International Atomic Energy Agency (IAEA), *Nuclear Power Reactors in the World* (Vienna, Austria, April 1990). **1989 Nuclear Share**--IAEA, *Nuclear Power in the World* (1990).

[50] Organization for Economic Cooperation and Development, Nuclear Energy Agency/International Energy Agency, *Projected Costs of Generating Electricity From Power Stations for Commissioning in the Period 1995-2000* (OECD, Paris, France, 1989).

In the second step, projections for time periods beyond those derived from the construction pipeline analysis are based on the World Integrated Nuclear Evaluation System (WINES). (Appendix B describes the reactor construction pipeline methodology, the structure of the WINES model and supporting data sources.) Table 24 shows projections of operable nuclear capacity in the Lower and Upper Reference cases through 2010 for FME countries.

The projections of foreign FME operable capacity based on the construction pipeline approach result from a thorough analysis of each country's nuclear program, similar to the method used to derive U.S. capacity projections through 2010. Chapter 5 briefly reviews active nuclear programs in individual FME countries and presents available information on countries with regulated market economies (formerly countries with centrally planned economies); centrally planned economies, and potential or inactive nuclear programs in other countries. For the latter nations, EIA has projected possible nuclear capacity in 2010 only for Egypt because we believe that the political and/or economic climate in the countries not included in Table 24 makes it unlikely that they will have operable nuclear units during any portion of the projection period.

The near term projection in the Lower and Upper Reference cases are based on alternative estimates of completion dates for units under construction or in advanced planning stages. The expected completion dates for each unit under the two scenarios are based on assumptions about the ability of each country to adhere to its nuclear progaram.

Table 24. 1985, 1989 FME Operable Nuclear Capacities and Projected Capacities for 1995, 2000, and 2010
(Net Gigawatts-Electric)

Country	1985[a]	1989[b]	1995		2000		2010	
			Lower Reference Case	Upper Reference Case	Lower Reference Case	Upper Reference Case	Lower Reference Case	Upper Reference Case
* **United States**	79.5	97.9	102.8	102.8	103.8	103.8	102.9	122.1
* **Canada**	10.0	11.9	15.4	15.4	15.4	17.5	19.3	27.1
Europe								
* Belgium	5.5	5.5	5.5	5.5	5.5	5.5	5.5	6.0
* Finland	2.3	2.3	2.3	2.3	2.3	2.6	3.1	3.4
* France	37.8	52.6	59.6	61.1	60.9	62.3	62.3	68.4
* Germany, West	16.4	22.7	23.0	23.0	23.0	23.0	23.0	25.2
* Italy	1.3	1.1	1.1	1.2	1.2	2.1	3.1	3.4
* Netherlands	.5	.5	.5	.5	.5	.5	.5	1.0
* Spain	5.7	7.6	7.6	8.6	8.6	9.6	10.3	11.9
* Sweden	9.4	9.8	9.3	9.8	8.6	9.8	.0	9.8
* Switzerland	2.9	3.0	3.0	3.0	3.0	3.0	3.0	3.3
* United Kingdom	10.7	11.2	9.9	9.9	8.4	8.4	7.6	8.3
Yugoslavia	.6	.6	.6	.6	.6	.6	.6	.7
Subtotal	93.1	116.9	122.4	125.5	122.6	127.4	119.0	141.4
Far East								
* Japan	23.7	29.3	35.1	39.1	39.9	43.7	49.9	51.8
Korea, South	2.7	7.2	7.2	7.2	7.2	9.1	10.2	10.5
Taiwan	4.9	4.9	4.9	4.9	4.9	5.9	6.3	9.2
Subtotal	31.3	41.4	47.2	51.2	52.0	58.7	66.4	71.5
Other								
Argentina	.9	.9	.9	1.6	1.6	1.6	1.8	2.4
Brazil	.6	.6	.6	1.9	1.9	3.1	3.1	3.1
Egypt	0	.0	0	0	0	0	.2	.2
India	1.2	1.4	1.6	1.6	1.6	2.5	2.6	3.1
Mexico	0	.7	.7	1.3	1.3	1.3	1.3	1.6
Pakistan	.1	.1	.1	.1	.1	.1	.2	.3
South Africa	1.8	1.8	1.8	1.8	1.8	1.8	1.8	2.1
Subtotal	4.6	5.6	5.8	8.3	8.4	10.3	11.0	12.8
Total OECD	205.6	255.3	275.1	282.2	281.1	291.8	290.5	341.7
Total Non-OECD	13.0	18.3	18.5	21.0	21.1	26.0	28.1	33.2
Total FME	218.6	273.6	293.6	303.2	302.2	317.8	318.[illegible]	374.9

[a] Status as of December 31,1985.
[b] Status as of December 31,1989.
* OECD country member
OECD Organization for Economic Cooperation and Development
FME Free Market Economies
Note: Totals may not equal sum of components due to independent rounding.
Sources: **1985**--*Commercial Nuclear Power Prospects for the United States and the World*, DOE/EIA-0438(86), Table 15, p. 36. **1989**--Appendices C and E, Table 20. **1990-2010**-- WINES model for various years. See Table G2, p. 122.

WINES Model Parameter Assumptions

The assumptions for all economic parameters (Table 25) in the WINES model, except capacity factors, are based on three groupings: (1) OECD countries; (2) Asian countries (OECD member Japan, South Korea, and Taiwan); and (3) non-OECD FME countries. Table 26 shows energy parameter values used for the projections while Table 27 lists the capacity factor values used in the WINES model. The assumptions regarding parameter values are judgmental and generally fall within the ranges found in the literature.[51]

The economic growth rate, as measured by the increase in gross domestic product (GDP), is defined as the sum of growth rates for the labor-age population, the labor force participation fraction, and labor productivity. The growth rates for the labor-age population are derived from World Bank projections.[52] The fractional growth rate of labor force participation for all countries is assumed to be 0 in the Lower Reference case and 0.1 in the Upper Reference case. Labor productivity is assumed to grow in the range of 1.8 to 2.0 percent annually for all OECD countries except Japan and from 2.0 to 2.25 percent annually for the Asian and non-OECD FME countries.

Economic growth is combined with the aggregate energy price growth rate in the form of a "demand for delivered energy" function. The elasticity values used in this function are based on estimates of long-run price and income elasticities. Energy price elasticities are generally considered to be greater (in absolute value) for the developed countries than for developing countries, reflecting the premise that high-income countries have better opportunities for adjustment (substitution) than do countries with relatively low incomes. Similarly, income elasticities are generally considered to be lower for high-income countries, due to their greater technological opportunities and greater availability of capital for investment in energy-saving alternatives.

Table 25. Economic Parameter Values Assumed in the WINES Model for Different Country Groups

Parameter	OECD Europe	Asia[a]	Non-OECD FME Countries
Labor Force Participation Fraction Growth Rate			
Lower Reference Case	0.0	0.0	0.0
Upper Reference Case	.1	.1	.1
Labor Productivity Growth Rate			
Lower Reference Case	1.8	2.0	2.0
Upper Reference Case	2.0	2.25	2.25
Aggregate Energy Real Price Growth Rate			
Lower Reference Case	2.0	2.0	2.0
Upper Reference Case	1.5	1.5	1.5
Price Elasticity (-)[b]			
Lower Reference Case		0.4, 0.40, 0.6	
Upper Reference Case		0.3, 0.35, 0.5	
Income Elasticity[b]			
Lower Reference Case		1.0, 0.85, 0.7	
Upper Reference Case		1.1, 1.00, 0.8	

[a] Includes Japan, South Korea, and Taiwan.
[b] Choice of value depends on per capita Gross Domestic Product (see text).
OECD Organization for Economic Cooperation and Development.
FME Free Market Economies.
Source: Prepared by staff of the Nuclear and Alternate Fuels Division, Office of Coal, Nuclear, Electric, and Alternate Fuels, Energy Information Administration.

[51] B.I. Choe, A. Lambertini, and P. Pollak, *Global Energy Prospects* (World Bank Staff Working Paper No. 489, August 1981); W. Haefele, *Energy in a Finite World: A Global Energy Systems Analysis* (International Institute for Applied Systems Analysis, Ballinger, 1981); Energy Information Administration, *World Energy Forecasting: Methodologies and Recommended Strategies*, ORNL/Sub/82-43131/1 (Washington, DC, March 1983); OECD, Nuclear Energy Agency, *Nuclear Energy and its Fuel Cycle: Prospects to 2025* (Paris, France, 1982); World Bank, *Price Prospects for Major Primary Commodities*, Volume 5: Energy, Report No. 814/84 (Washington, DC, September 1984).

[52] M.T. Vu, *Short-Term Population Projection, 1980-2000 and Long-Term Projection, 2000 to Stationary Stage by Age and Sex for All Countries of the World* (World Bank, Washington, DC, December 1985).

Table 26. Energy Parameter Values Assumed in the WINES Model for Different Country Groups

Parameter	OECD Europe						Asia[b]	Non-OECD FME
	Robust Nuclear[a]	Canada	Italy	United Kingdom	West Germany	Other		Other
Asymptotic Electrical Share of Total Delivered Energy								
Lower Reference Case	28	28	20	28	28	25	28	15
Upper Reference Case	30	30	25	30	30	28	30	20
Asymptotic Nuclear Share of Total Electrical Generation[c]								
Lower Reference Case	54	25	15	25	40	25	54	15
Upper Reference Case	57	30	20	30	45	30	57	20

[a] Includes Belgium, Finland, France, and in the Upper Reference case Sweden.
[b] Includes Japan, South Korea, and Taiwan.
[c] The asymptotic values do not apply to those countries that are projected to exceed the indicated nuclear shares as a result of the completion of units currently in the construction pipeline. The nuclear shares for these countries remain constant, at their projected base-year levels (see Appendix G, Table G2), through 2010.
OECD Organization for Economic Cooperation and Development
WINES World Integrated Nuclear Evaluation System.
FME Free Market Economies.
Source: Prepared by staff of the Nuclear and Alternate Fuels Division, Office of Coal, Nuclear, Electric and Alternate Fuels, Energy Information Administration.

Table 27. Capacity Factors for Commercial Nuclear Power Plants in FME Countries
(Percent)

Country	Annual Capacity Factors[a]										Projections for the Year 2010
	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	
Argentina	75	90	60	51	20	65	65	68	57	44	65
Belgium	81	84	72	76	87	82	77	83	85	81	75
Brazil		b	..	b	36	50	2	17	6	28	65
Canada	82	88	82	79	72	72	73	72	77	74	75
Egypt	..	b	..	b	..	b	..	b	..	b	65
Finland	57	72	82	87	92	90	89	92	91	90	75
France	60	58	53	62	70	71	67	60	58	62	70
Germany, West	55	67	70	70	76	87	78	75	74	69	70
India	49	41	29	33	43	45	44	47	52	34	65
Italy	17	21	58	62	63	60	74	2	0	0	65
Japan	61	60	69	68	70	71	76	77	71	71	70
Korea, South	67	56	73	60	70	66	77	82	67	74	65
Mexico		b		b	..	b	..	b	..	b	65
Netherlands	90	78	84	76	81	82	88	75	82	80	75
Pakistan	7	19	7	19	24	23	44	26	16	6	65
South Africa	..	b	..	b	69	37	55	39	67	69	65
Spain	53	65	49	47	64	63	74	80	78	81	65
Sweden	65	64	61	60	76	71	81	77	77	74	70
Switzerland	80	85	84	87	88	85	83	85	83	84	85
Taiwan	73	66	53	66	72	65	60	73	68	62	65
Turkey	..	b		b	..	b	..	b	..	b	65
United Kingdom	47	49	56	57	56	56	51	54	56	55	65
United States	56	58	57	54	56	58	57	57	64	62	68
Yugoslavia	NA	NA	NA	NA	55	60	69	77	71	71	65
Average FME	60	62	51	62	64	65	66	63	62	61	70

[a] Annual capacity factors of individual countries are calculated as averages of monthly capacity factors. Annual FME capacity factors are calculated as the average of the individual countries.
[b] No operable commercial nuclear capacity.
FME Free Market Economies
NA, not available
Note: Frequently electricity generation accumulated during precommercial operation (i.e., during startup) is reported as a lump-sum value at the time the unit is first included in tabulations of monthly generation. In most cases, exact disaggregation of such lump-sum values into monthly components is not possible. Therefore, such sums have been disaggregated in this table on the basis of historical startup patterns for comparable units.
Sources: **1980-1989**--Foreign: based on data in *Nucleonics Week* (New York: McGraw-Hill), various issues; United States: Energy Information Administration, *Monthly Energy Review*, December 1989, DOE/EIA-0035(89/12) (Washington, DC, March 1990). **2010**--Nuclear and Alternate Fuels Division, Office of Coal, Nuclear, Electric and Alternate Fuels, Energy Information Administration.

For developing countries, the income elasticities greater than 1.0 in the Upper Reference case are due to the potential for energy-intensive industrialization as income increases. The price and income elasticities vary over time for countries that change from low- to middle- or from middle- to high-income economies (based on World Bank definitions).[53] The elasticity ranges presented for each scenario in Table 25 correspond to per capita GDP below $1,410 (1985 U.S. dollars), between $1,410 and $4,500, and above $4,500 for low-, middle-, and high-income countries, respectively.[54] The energy price growth rate, which is assumed to be the same for all countries, ranges from 2.0 to 1.5 percent per year. The order is reversed, because the Lower Reference case refers to low energy growth and is associated with higher price increases.

The electrical and nuclear penetration models require an assumption regarding the market shares that each technology will attain in the long run. The assumptions vary for each scenario (Lower Reference and Upper Reference). For the OECD countries with robust nuclear programs (selected countries with a current nuclear share above 35 percent) the asymptotic electrical share of delivered energy is assumed to range from 28 to 30 percent, while the asymptotic nuclear share of electrical generation ranges from 54 to 57 percent.

For most of the other OECD countries (except Japan), the asymptotic electrical share ranges from 20 to 30 percent. The asymptotic nuclear share for Canada, the United Kingdom and "Other" OECD Europe countries is assumed to be 25 to 30 percent. For the Asian countries, the assumed asymptotic electrical and nuclear share ranges are 28 to 30 and 54 to 57 percent, respectively. For the non-OECD FME countries the asymptotic electrical and nuclear shares are each assumed to range from 15 to 20 percent.

The capacity factors shown in Table 27 were developed in a two-step process. First, nuclear capacity and generation information from a Nuclear Energy Agency (NEA) survey[55] was used to develop capacity factors by country for the WINES base year (i.e., the final year of the construction pipeline). Second, capacity factors for 2010 were based on historical values achieved and expectations regarding each country's construction program and the operating performance of generating units. Table 27 shows the historical capacity factors achieved by FME countries during the 1980 through 1989 period, as well as the projected capacity factors for 2010 that were used in the WINES model to develop the present forecast. For the developed countries, nuclear power programs are generally expected to be more mature, with a smaller fraction of units in the first and second refueling cycles. As a result, average capacity factors are projected to be higher for countries well into their construction programs.

The Upper- and Lower-Reference-case projections of total primary energy requirements and electrical generation for the constrained period (i.e., the period prior to the WINES forecast) were obtained from the OECD Nuclear Energy Agency (NEA). For non-OECD countries, Upper-Reference-case estimates for total primary energy and electrical generation for the constrained period were obtained from the International Energy Agency (IEA). Lower-Reference-case estimates of total primary energy requirements and electrical generation for non-OECD countries were generated from the IEA data using a widening range of uncertainty amounting to -2.5 percent age points per 5-year interval culminating with a differential of -10.0 percent from the IEA estimate for the year 2005.

WINES Model Projections

The following discussion focuses on the Lower-Reference-case projections. Table 24 and Figure 5 show operable nuclear capacity in 1989 and the EIA projections of capacity through 2010. This year's projection of total FME nuclear capacity for 1995 is 0.5 percent lower than in the 1989 report. The lower projection is due primarily to delays in the projected construction start dates or completion dates of units rather than a reduction in the number of units in the pipeline.[56]

Table 28 shows the projected growth rates of real gross domestic product, electrical generation, nuclear capacity, and the ratio of electrical generation to gross domestic product associated with the capacity projections for actual or planned nuclear power programs.

Total operable nuclear capacity for the OECD countries is projected in the Lower Reference case to increase from its 1985 level of 205.6 at a compound average annual growth rate of about 1.4 percent, reaching 290.5 net GWe in 2010. This compares with a growth rate of 2.1 percent in the Upper Reference case. Nuclear share associated with the projection for the Lower Reference case represents 23.8 percent of total electrical generation for OECD countries in 2010. Electricity generation for the OECD countries is projected to increase at a rate of 1.8 percent per year over this period.

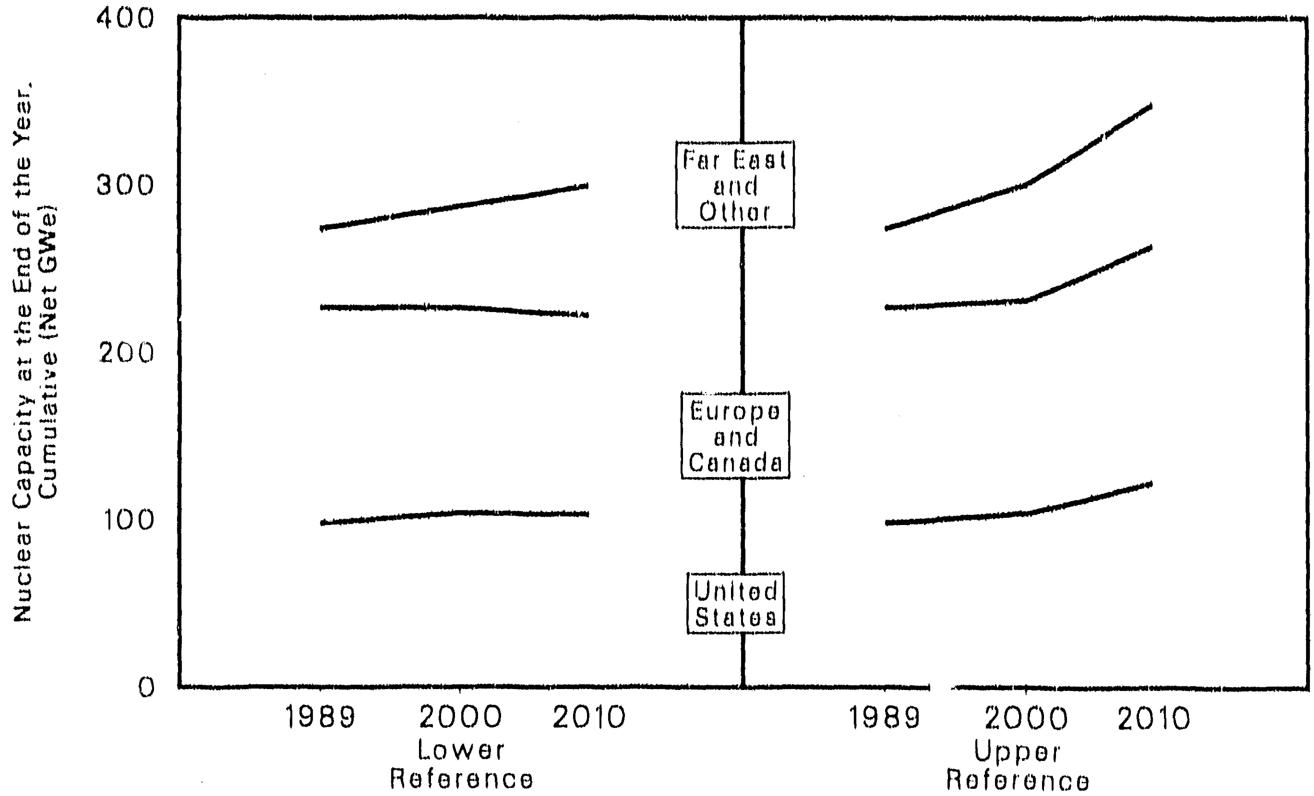
[53]World Bank, *World Development Report, 1987* (Washington, DC, 1987).

[54]For the OECD Robust Nuclear category, Canada, and most of the other OECD countries, the elasticities do not change over time, since these countries are projected to remain in the high-income range over the entire projection period.

[55]Organization for Economic Cooperation and Development (OECD), Nuclear Energy Agency (NEA), *Summary of Nuclear Power and Fuel Cycle Data in OECD Member Countries, Provisional* (Paris, France, April 1990).

[56] *Ibid.*

Figure 5. FME Operable Nuclear Capacity at the End of the Year, 1989, and Projections for 1990 Through 2010



FME = Free Market Economies.
Source: Table 29.

Projected requirements for delivered energy in the non-OECD FME countries (which include the "Other" country group, along with South Korea, Taiwan, and Yugoslavia) increase in the Lower Reference case at a rate of about 0.3 percent per year from 1985 through 2010. The electrical share of this requirement increases from 18.2 percent to 23.8 percent during the 1985 through 2010 period. In the Lower Reference case, operable nuclear capacity for the non-OECD FME countries is projected to increase from the 1985 level of 13.0 GWe at an average rate of 2.2 percent per year, reaching 28.1 GWe in 2010.

Total operable nuclear capacity for FME countries is projected in the Lower Reference case to increase from 273.6 net GWe in 1989 to 319 net GWe in 2010. Europe and Canada accounted for 47.1 percent of total FME nuclear capacity in 1989; this share decreases to 43.4 percent by 2010 (Figure 5 and Table 29). A similar trend holds for the Upper Reference case (not shown in Table 29). The U.S. portion of FME nuclear capacity in the Lower Reference case is projected to decrease from the 1989 level of 35.8 percent to 32.3 percent in 2010.

Comparison With Projections From Previous Years

The 1990 EIA Lower-Reference-case projection of OECD nuclear capacity in the year 1995 is 0.7 percent lower than the 1989 projection. For the years 2000 and 2010, the 1990 EIA projections of OECD nuclear capacity are 2.1 and 7.6 percent lower, respectively, than the 1989 projections.

In the 1990 Lower Reference case, 1.8 percent less FME capacity (including U.S. capacity) is projected to come on line in 2000 than was projected in the Lower Reference case in 1989. The slight decline can be attributed mostly to longer construction times and Sweden's decision to begin phasing out nuclear power starting in 1995. The 1.8 percent loss in FME capacity translates to about 6 GWe less capacity.

Table 28. EIA/WINES Model, Lower-Reference-Case, Economic and Energy Growth Rates, for FME Countries, 1985-2010

Country	Growth Rates (mean percent per year)			Ratio of Electrical Generation to GDP Growth Rate
	Real Gross Domestic Product (GDP)	Electrical Generation	Nuclear Capacity	
* **United States**	a2.0	2.0	1.2	0.9
* **Canada**	2.4	1.8	2.7	.7
Europe				
* Belgium	1.7	2.2	0	1.4
* Finland	1.9	2.1	1.4	1.1
* France	2.1	2.0	2.0	.9
* Germany, West	1.3	.9	1.4	.7
* Italy	1.7	3.3	3.5	2.4
* Netherlands	2.0	2.0	.4	1.0
* Spain	2.3	2.8	2.4	1.3
* Sweden	1.7	.2	NA	.1
* Switzerland	1.0	1.1	.1	.8
* United Kingdom	1.9	1.5	1.7	.8
Yugoslavia	2.2	3.6	1.9	2.1
Far East				
* Japan	2.1	1.6	2.9	.8
Korea, South	3.2	0.9	6.2	3.6
Taiwan	3.3	4.4	1.2	1.6
Other				
Argentina	3.3	3.5	2.6	1.1
Brazil	4.0	4.4	6.6	1.2
Egypt	4.0	3.2	NA	.7
India	4.1	7.9	2.8	3.4
Mexico	4.6	4.6	NA	1.0
Pakistan	4.9	9.4	.9	3.7
South Africa	4.4	3.5	.0	.7
OECD Average	1.9	1.8	1.4	1.0
Non-OECD Average	3.8	5.1	2.2	1.9

a Value shown is Gross National Product (GNP)
* OECD country member.
EIA/WINES Energy Information Administration/World Integrated Nuclear Evaluation System.
FME Free Market Economies
NA Not Applicable.
Sources: **1985 Values**--Mathtech, Inc., *Energy Data Base: World Integrated Nuclear Evaluation System (WINES)*, prepared under DOE Contract No. DE-AC05-84OR21400, January 1985. **Values for 2010**--Based on WINES projections.

Table 29. Operable Nuclear Capacities, 1988-1989, and Lower-Reference-Case Projections for FME Country Groups, 1995-2010

Year	Country	Capacity (Net GWe)	Percent of FME Total[a]
1988	United States	95.1	35.6
	Canada	R11.9	4.4
	Europe	R116.4	43.5
	Far East	R39.4	14.7
	Other	4.7	1.8
	Total FME	R267.5	100.0
1989	United States	97.9	35.8
	Canada	11.9	4.3
	Europe	116.9	42.7
	Far East	41.4	15.1
	Other	5.6	2.0
	Total FME	273.6	100.0
1995	United States	102.8	35.0
	Canada	15.4	5.2
	Europe	122.4	41.7
	Far East	47.2	16.1
	Other	5.8	2.0
	Total FME	293.6	100.0
2000	United States	103.8	34.3
	Canada	15.4	5.1
	Europe	122.6	40.6
	Far East	52.0	17.2
	Other	8.4	2.8
	Total FME	302.2	100.0
2010	United States	102.9	32.3
	Canada	19.3	6.1
	Europe	119.0	37.4
	Far East	66.4	20.8
	Other	11.0	3.5
	Total FME	318.6	100.0

[a] Some totals may not equal the sum of components due to independent rounding.

FME Free Market Economies.

R, This figure is a revision of the figure published in *Commercial Nuclear Power 1989: Prospects for the United States and the World*, DOE/EIA-0438(89) (Washington, DC, September 1989).

Source: Table 20 and Table 24

Comparison With Other Projections

Table 30 compares EIA nuclear capacity projections with projections from other organizations for the OECD FME countries. The 1990 EIA projections are lower than the most recent projections of Nuclear Assurance Corporation (NAC), Nuclear Engineering International (NEI) and NUKEM.

For OECD countries in the year 1995, the 1990 EIA Lower-Reference-case and Upper-Reference-case projections of 275 and 282 net GWe, respectively, are lower than the NAC, NEI and NUKEM projections of 306, 301 and 282 GWe, respectively. For non-OECD countries in the year 1995, the EIA Lower-Reference-case and Upper-Reference-case projections of 19 and 21 GWe, respectively, are lower than the NAC, NEI and NUKEM projections of 24, 25 and 22 GWe, respectively.

Table 30. Comparison of Projections of FME Nuclear Capacity at the End of the Year, 1995, 2000, and 2010

Countries	Projection		Capacity (Net GWe)		
	Year	Source	1995	2000	2010
OECD	1989[a]	NAC	289	310	-
	1989[b]	[c]NEI	300	320	-
	1989[d]	NUKEM	288	309	-
	1989[e]	EIA	277-289	287-300	315-388
	1990[f]	NAC	306	332	-
	1990[g]	[c]NEI	301	308	-
	1990[h]	NUKEM	282	299	-
	1990[i]	EIA	275-282	281-292	291-342
Non-OECD	1989[a]	NAC	21	28	-
	1989[b]	[c]NEI	27	26	-
	1989[d]	NUKEM	24	34	-
	1989[e]	EIA	19-21	21-23	34-47
	1990[f]	NAC	24	31	-
	1990[g]	[c]NEI	25	27	-
	1990[h]	NUKEM	22	31	-
	1990[i]	EIA	19-21	21-26	28-33
Total FME	1989[a]	NAC	310	342	
	1989[b]	[c]NEI	327	346	-
	1989[d]	NUKEM	312	343	-
	1989[e]	EIA	295-310	308-323	348-435
	1990[f]	NAC	282	301	-
	1990[g]	[c]NEI	327	335	-
	1990[h]	NUKEM	304	330	-
	1990[i]	EIA	294-303	302-318	319-375

[a] Nuclear Assurance Corporation (NAC), *Nuclear Megawatt Generation Status Report*, February 1989.
[b] *1989 Nuclear Engineering International*, "World Nuclear Industry Handbook 1989."
[c] Nuclear Engineering International projections are based on gross capacity data.
[d] NUKEM, *Market Report on the Nuclear Fuel Cycle* (April 1989).
[e] Energy Information Administration, *Commercial Nuclear Power 1989 (CNP): Prospects for the United States and the World*, DOE/EIA-0438(89) (Washington, DC, September 1989). 1989 projections shown are, respectively, the Lower Reference and Upper Reference cases for 2000 and 2010. The 1995 Lower Reference and Upper Reference case projections shown are part of the same projection series but were not published in CNP 1989.
[f] Nuclear Assurance Corporation (NAC), *Nuclear Megawatt Generation Status Report*, February 1990.
[g] *1990 Nuclear Engineering International*, "World Nuclear Industry Handbook 1990."
[h] NUKEM, *Market Report on the Nuclear Fuel Cycle* (April 1990).
[i] 1990 EIA: Consistent with this report, Table 24. 1990 EIA Projections shown are, respectively, the Lower Reference and Upper Reference cases.

OECD Organization for Economic Cooperation and Development.
FME Free Market Economies.

5. Review of Foreign Nuclear Power Programs

Introduction

This chapter concentrates chiefly on a review of nuclear power programs in foreign countries with nuclear power plants that are either operational, under construction, or planned. This chapter is organized into three major sections: (1) countries with free market economies; (2) countries with regulated market economies (formerly countries with centrally planned economies); and (3) countries with centrally planned economies.

Chapter 4 includes an explanation of the methodology used in projecting operable nuclear capacity for countries with active, potential, or, inactive nuclear programs. Table 28 on page 48 lists the projected economic and energy growth rates for each country for which nuclear capacity is projected. Nuclear capacity is not projected for countries with regulated market or centrally planned economies. Table 20 on page 38 lists the current nuclear share for countries with free market economies.

Projected nuclear share is documented in the archived WINES model, which is available from the National Energy Information Center. Excerpts from these projections are highlighted at the end of each country writeup.

Information in this chapter was derived from diverse sources,[57] some of which cited project completion estimates obtained through unofficial channels. In contrast, the material in Appendix G was developed from two principal sources using a consistent set of definitions and project information based on official utility estimates. The country-specific discussions in this chapter focus on the Lower Reference case projections.

Countries With Free Market Economies

OECD Countries

Belgium

Belgian nuclear generating capacity reached 5.5 GWe with the 1985 completion of Doel 4 and Tihange 3, the last two units in its nuclear construction pipeline. The seven nuclear units, all pressurized-water reactors (PWR), achieved an average capacity factor during 1989 of about 81 percent. The nuclear share of total electricity generation in 1989 fell to 60.7 percent from 66 percent in 1988.

Belgium officially canceled plans for the 1,390-MWe Doel 5 PWR in December 1988, and government officials proposed a cogenerating gas-steam plant for the equivalent capacity. Belgian authorities have issued a report stating that the country will need at least 3,500 MWe of new capacity before 2000, with about 725 MWe expected from the 1,455-MWe Chooz reactors in France. The Chooz PWRs are to supply 25 percent of their power to Belgium starting in 1992. French vendors were to receive construction contracts for Doel 5 in reciprocation for the contracts that France gave the Belgian industry in constructing the Chooz B1 and B2 units.

The Belgian government studied the country's nuclear industry in 1989 and was expected to issue recommendations calling for a single government regulatory agency. Parliament would ultimately discuss the recommendations and decide, possibly in 1990, on the structure and control of such an agency. Currently both public and private bodies are involved in Belgian nuclear regulation: (1) two government ministries control nuclear safety and ambient radiation; (2) three private companies award commercial licenses for nuclear

[57]Primary sources of information in this chapter include various issues of *Nuclear Engineering International* (Surry, United Kingdom: Business Press, Ltd.); *Nuclear Europe*(Switzerland: European Nuclear Society); *Nuclear News* (LaGrange, Illinois: American Nuclear Society); *Nuclear Fuel and Nucleonics Week* (New York: McGraw-Hill); *1989 Annual Review* (Denver, Colorado, Nuexco); *Nuclear Status in Countries With Centrally Planned Economies* (report submitted to the Energy Information Administration by Decision Analysis Corporation of Virginia, Vienna, VA and Science Applications International Corporation, McLean, VA, June 29, 1990). Most of the sources reflect information reported through April 30, 1990, but a few sources include information reported through May 1990.

power plants and derive income from those plants; and (3) other national and regional authorities approve the construction of nuclear plants. Depending on the outcome of the parliamentary debate on the matter, there might be one public agency ultimately controlling all aspects of nuclear security and safety, including commercial licensing and coordination of waste disposal. If such an agency were created, the three licensing companies would be dissolved. Other government officials propose letting the licensing companies survive but with tighter control by the government regulatory body.

Three private utilities control 95 percent of the Belgian electricity market and generate most of their power from nuclear plants. The three utilities plan a merger in 1990 to prepare for a deregulated European Community (EC) energy market in the mid-1990's.

Projections for 2000 assume no additional nuclear capacity. In the Lower Reference case installed capacity will remain constant at 5.5 GWe by 2010. The nuclear share of Belgian electricity generation in the Lower Reference case is projected to decrease from nearly 60.7 percent in 1989 to 38.5 percent in the year 2010. EIA projects electricity generation to grow at a yearly rate of 2.2 percent from 1985 through 2010. These projections are based on an economic growth rate of 1.7 percent per year.

Canada

Canadian nuclear policies and regulations are under the jurisdiction of two different authorities. Atomic Energy of Canada, Ltd. (AECL) is responsible for promoting and developing nuclear energy, and the Atomic Energy Control Board (AECB) is responsible for its regulation. The role of the AECB is similar to that of the U.S. Nuclear Regulatory Commission (NRC). The major difference is that Provincial governments may directly participate in the regulatory process, and may require safety assessments as a condition for the construction and continued operation of nuclear plants. Such an assessment program was undertaken in Ontario Province, where nuclear-generated electricity already accounts for a significant portion of total electricity generation. The safety assessment program was instituted by the Ontario legislature in reaction to concerns raised by the accident at Chernobyl in April 1986.

Canada has been developing heavy-water reactor technology since the end of World War II. In contrast to other reactor types, the heavy-water reactor is fueled with natural (nonenriched) uranium. The development of the Canadian pressurized heavy-water-moderated and cooled reactor (PHWR), the Canadian Deuterium-Uranium (CANDU) reactor, began in 1962 with the construction of the 22-MWe NPD demonstration unit, which was decommissioned in 1988. This was followed in 1968 with the Douglas Point 220-MWe prototype CANDU reactor, now shut down. One advantage of the CANDU reactor is improved operating performance due to on-line refueling capability, and lower temperature and pressure parameters. All operating and planned Canadian reactors are CANDUs.

Canada has 18 units presently in operation with an installed nuclear capacity of 11.9 GWe. Work on the four Darlington units with 3.5 GWe of capacity continued during 1989. The Darlington 2 unit was shut down halfway through its precommercial testing process in February 1990 due to a cracked rotor that could take 2 years to replace if the crack resulted from a fault generic to rotors in the three other Darlington units. If the rotor can be replaced from Unit 4, which is the last unit scheduled for service, testing could resume around May 1990.

In December 1989, Ontario Hydro (OH) submitted its 25-year plan to the Ontario Minister of the Environment. The plan includes proposals for new hydroelectric facilities, natural gas-fired plants, nuclear power plants, conservation, efficiency improvements and power purchases from independent power producers and neighboring provinces to meet the electricity needs of Canada's most populous province. The largest portion of new electricity is expected to be nuclear generated.

The proposed schedule calls for the utility to begin work on the first of four CANDU-A reactors in 1995; the units would come on-line between 2003 and 2006. An environmental assessment for the first of four CANDU-B reactors would be submitted to the provincial government in 1996; they would come on-line between 2009 and 2012. The first two of four CANDU-C units would go on-line by 2013, with the other two units to be completed after the 25-year period of the OH plan. (The CANDU-A,B, and C series represent evolutionary design improvements in CANDU PHWR technology.) The OH proposal states that the additional nuclear capacity must arrive in large quantities so that OH can meet its projected demand. The OH low-growth scenario expects demand growth averaging 1.5 percent per year, with 2.2 percent per year assumed for the middle-growth scenario, and 2.7 percent per year for the high-growth scenario. The utility notes that by 2014 approximately 8,500 MWe of capacity will have been shut down because of aging.

The Canadian and Soviet governments have signed a comprehensive nuclear cooperation agreement that could end 25 years of on-again, off-again technical discussions on full-scale nuclear trade. The new nuclear cooperation agreement will enable Canadian companies, notably OH and AECL, to respond to Soviet interest in acquiring Canadian nuclear safety equipment and technology.

> In the Lower Reference case, Canadian nuclear capacity is projected to grow to 15.4 GWe by 2000, and to reach 19.3 GWe in the year 2010. The nuclear share of electricity generation is projected to increase from 15.9 percent in 1989 to 18.6 percent in 2010. EIA projects electrical generation to grow at a rate of 1.8 percent per year from 1985 through 2010. These projections are based on an economic growth rate of 2.4 percent per year.

Finland

Under Finland's Nuclear Energy Act, which became effective in March 1988, a new Advisory Committee on Nuclear Energy was attached to the regulatory body, the Finnish Centre for Radiation and Nuclear Safety (STUK), that was established in 1984. The government sets down general safety regulation, while STUK prepares detailed regulatory guides. Finland has three stages to its procedure for licensing nuclear power plants: a decision in principle; a construction license; and an operating license. The Parliament is involved in the first stage which includes siting, environmental aspects, and arrangements for nuclear fuel and waste management. The Government issues the two licenses.

Finland has four operable nuclear units with a total capacity of 2.3 GWe, but it has no nuclear fuel cycle industry. The Soviet Union supplied the two reactors for the Loviisa nuclear power plant that is operated by the Finnish state utility Imatran Voima Oy (IVO); it also provides the reactors' fuel assemblies under long-term contracts and agreements. Sweden supplied the reactors for the Olkiluoto nuclear plant that is operated by the private utility Teollisuuden Voima Oy (TVO), which currently obtains uranium, enrichment services and fuel assemblies from suppliers in Australia, Canada, China, West Germany and the USSR.

A 1989 report by the Finnish power industry projected increasing electricity consumption in the 1990's to exceed supply by 1994. Demand for power was estimated to increase at an annual rate of 2 to 3 percent through 1998. To build more conventional power plants would conflict with the country's commitments to reduce air pollution. Finnish companies are contracting to import sizable amounts of natural gas and electricity from Norway and the USSR.

Although the current government promised in 1986 to suspend any decision on the fifth nuclear unit during its term of office, it now appears that planning for such a reactor may begin after the 1991 elections. Expansions of coal- and peat-fired plants would conflict with party support of a cleaner environment that advocated reducing by 1993 the sulfur and carbon dioxide emissions to half of their current levels. It is doubtful that Finland could expand its hydroelectric power capacity because of the country's law on preserving natural waterways. Also, Sweden or the USSR may not have surplus electricity available for export in the late 1990's or after 2000. Finnish industry hopes that a decision to construct the fifth nuclear unit will be made before 1992. A company, Perusvoima, has been set up to plan and build such a reactor and has informed the government that it must decide by 1992 to build the plant that could be generating electricity by 1998. A Perusvoima official has stated that, if Finland purchased a nuclear plant now, it would buy this plant from ABB Atom, now part of Asea Brown Boveri, whose safety standards and technical requirements are in line with those in Finland.

> In the Lower Reference case, Finland's nuclear capacity is projected to remain constant at 2.3 GWe through 2000 and reach 3.1 GWe in 2010. The nuclear share of electricity generation is expected to decrease from its 1989 level of 35.4 percent to 27.3 percent by 2010. Electrical generation is projected to grow at a rate of 2.1 percent per year from 1985 through 2010. These projections are based on a yearly economic growth rate of 1.9 percent.

IVO International Ltd. and Atomenergoexport plan to cooperate on optimizing the economics and verifying the safety of Soviet VVER-1000 PWRs. The USSR has offered to supply its VVER-1000 to Finland which would be able to assist in the development of the reactor. A Finnish safety expert believes that the current design does not meet the advanced requirements of the regulatory agency STUK. Specialists at IVO International think that by 1992 the VVER-1000 will be competitive with reactors offered by ABB Atom and Nuclear Power International, the Siemens/KWU and Framatome partnership, which are the other alternatives for a fifth Finnish nuclear unit.

France

The French nuclear power program began in 1956 with the operation of a 2-MWe experimental reactor, and in the late 1960's PWR technology became the foundation of the French program. Framatome, the French supplier, has developed and manufactured a standard-design PWR based on a Westinghouse Corp. license, thereby creating substantial savings in the costs of engineering and production. This standardization has helped the national utility, Electricite de France (EdF), to build its nuclear reactors in an average construction time of less than 6 years.

In December 1989, the National Assembly debated various aspects of French energy policy. The Assembly apparently will become more involved in developing the nations's energy policies, especially the back end of the fuel cycle and the breeder option. One topic debated was a proposed 1986 bill to create a nuclear safety organization that would be independent of the federal government and might have veto power over construction permits or operating licenses for nuclear facilities.

France has 55 operable nuclear units with a capacity of 52.6 GWe. No units went into service during 1989, but three PWRs were connected to the grid in February 1990 - the 1,300-MWe Cattenom 3, the 1,310-MWe Golfech 1 and the 1,330-MWe Penley 1. Another six units with 8.3 GWe of capacity remain in the construction pipeline. Although these six units create a temporary period of overcapacity for EdF, the utility expects that future increases in domestic business demand and exports will eliminate any excess reserve capacity by 1992 or 1993. EdF plans to shut down its Saint Laurent A1 GCR (gas-cooled reactor) in 1990. The remaining GCRs (Saint Laurent A2, Chinon A3 and Bugey 1) are scheduled for closing between 1990 and 1994, with the Saint Laurent A2 to be decommissioned after work is completed on the first unit. These reactors will not be dismantled until several decades after their decommissioning.

EdF's nuclear generation rose 5 percent in 1989 to 285 billion kWh, which was 75 percent of the utility's total power generation. It exported 42 billion kWh, 12 percent of its 1989 production, and signed firm contracts to export an additional 6 or 7 billion kWh annually starting in 2000. EdF might attain yearly exports of 50 billion kWh to neighboring countries in 1991 or 1992, and its Chairman indicated that his ultimate goal was to export 80 billion kWh per year if the European transmission network can be improved sufficiently.

The utility's 900-MWe PWRs averaged an 81-percent availability, while the 1,300-MWe reactors averaged only a 62-percent availability. Since EdF, unlike most other countries, uses its nuclear power plants for load-following as well as for baseload generation, the availability factor is a more appropriate measure than average capacity factor, especially when comparing the performance levels of French plants to those noted for other countries in this report.

EdF plans to repair its 1,300-MWe reactors in the next 2 years by inspecting the steam generator tubes on both operating units and those under construction, plugging problem tubes, and performing chemical cleaning. There will be lower availability from these reactors during the repair outages, and the lost nuclear generation will be replaced by power from more costly fuels.

> Nuclear capacity in France is projected in the Lower Reference case to increase from 52.6 GWe in 1989 to 62.3 GWe in 2010. Nuclear capacity is expected to grow at a rate of 2.0 percent per year. EIA projects the nuclear share of electricity to decrease slightly from 74.6 percent in 1989 to 70.5 percent in 2010. Electrical generation is projected to grow at a rate of 2.0 percent per year from 1985 through 2010. These projections are based on an economic growth rate of 2.1 percent per year.

In August 1989, government officials issued a permit allowing the Superphenix fast breeder (Creys-Malville) to operate for 405 full-power equivalent days or until the current fuel load is exhausted. The Superphenix had been reconnected to the grid in April 1989 but was again taken out of service in the fall of 1989 after a bubble of argon gas was detected in the core of the 250-MW prototype Phenix fast breeder. Subsequent tests disclosed that, should a similar bubble develop in the Superphenix reactor, it would not cause any significant problems. The large FBR returned to service in Spring 1990.

The Hungarian Electricity Board (MVMT) and EdF have agreed to prepare a joint study during 1990 on the possibility of EdF supplying two 900-MWe PWRs for the Paks nuclear power station. EdF would provide 70 percent of the construction costs and be repaid by transmission to western Europe of power generated by these units. New transmission lines would need to be constructed, possibly in Austria, with sales of power beginning in 1997 or 1998. The French would supply the uranium, take back the spent fuel, and provide operating assistance to the Hungarians for up to 5 years.

EdF and a French institute signed agreements in 1989 and 1990 with Soviet organizations for cooperation in various nuclear fields. Possible areas of cooperation might be the safety of operating nuclear power plants; accident recovery based on actions taken after the Chernobyl accident; the design, construction, and decommissioning of nuclear facilities; and enrichment of reprocessed uranium.

French organizations have also continued or started nuclear cooperation with Czechoslovakia and Morocco. Comisariat a l'Energie Atomique (CEA) officials met in April 1990 with Czechoslovakian officials and plan to improve their nuclear cooperation in four areas: (1) reactor safety, including component aging and updated operating procedures; (2) design of new types of reactors as well as studies related to fuel and accident prevention; (3) the fuel cycle, especially the storage of spent fuel and decommissioning; and (4) advanced training in nuclear engineering. Since 1984, a CEA/EdF subsidiary has been aiding Morocco in a study of potential power generation in that nation.

Germany, West

As of December 31, 1989 West Germany had 22 operable nuclear units with a total capacity of 22.7 GWe. The units generated 33.9 percent of all the electricity produced in the Federal Republic in 1989. Neckarwestheim 2, a 1,300-MWe PWR designed and built by Kraftwerk Union (KWU) of Siemens AG, was connected to the grid in 1989. The government of North Rhine-Westphalia (NRW), the federal government, and the operating company Hoechtemperatur Kernkraftwerk GmbH (HKG) have agreed to decommission the THTR-300. The three partners will contribute jointly to finance decommissioning without seeking a further 2 years of operation.

> Nuclear capacity in West Germany is projected in the Lower Reference case to increase from its 1989 total of 22.7 GWe to 23.0 GWe in 1995. Capacity in 2010 will remain constant at 23.0 GWe. EIA projects the nuclear share of electricity generation to decrease slightly from its 1989 level of 33.9 percent to 28.8 percent by 2010. Electrical generation is projected to grow at a rate of 0.9 percent per year from 1985 through 2010. These projections are based on an economic growth rate of 1.3 percent per year.

The country has only one nuclear unit, the SNR-300 FBR in Kalkar, remaining in its nuclear construction pipeline. The German Supreme Court in Karlsruhe is expected to rule in July 1990 on the constitutionality of a federal order to step up licensing of the unit. The Court is to rule specifically whether state licensing officials may continue to study the safety of the SNR-300 before issuing an operating license. The pending Court verdict will be significant, because it is expected to draw the boundary between federal and state powers in licensing of all nuclear facilities in West Germany.

In early 1990, East and West Germany planned to set up an Energy Commission to discuss ways of expanding nuclear power production in the German Democratic Republic (GDR). The Commission of experts from government ministries in both countries will meet several times during the year. East German officials have stated that they want more nuclear generating plants to replace antiquated lignite-fired plants. At present consumption rates, that country will have exhausted its lignite resources within 30 years. Presently, lignite supplies about 85 percent of the country's electricity production. Also, a plan to complete a 380-KV transmission line from West Germany through Berlin and to the GDR has already been approved. The first leg of the two-leg transmission line was completed in September 1989. One thousand kilowatthours of electricity will be delivered from Preussenelektra AG in West Germany to the GDR.

Italy

The Italian commercial nuclear power program began in the 1950's with the ordering of three nuclear units by the state electric utility, Ente Nazionale per l'Energia Electtrica (ENEL). Two operable nuclear units remained as of December 31, 1989, with a total capacity of 1.1 GWe. Three additional units, totaling 2.0 GWe, are currently under construction.

The Italian government had approved an ambitious nuclear construction program that called for an additional 10 GWe of nuclear capacity before the year 2000. The 1986 accident at Chernobyl, however, renewed anti-nuclear sentiment and a referendum on the government's nuclear power policy was called by popular petition and held in November 1987; this resulted in a 5-year suspension of the planned expansion.

The government later proposed a nonnuclear policy in its 1988 through 1992 energy plan. This policy calls for the mothballing of the Caorso plant, and the decommissioning of the Trino Latina and Garigliano plants, with the nuclear sections entombed for 30 years and the remainder of the units converted to gas-fired units. (Trino 1 and Caorso are still on standby loaded with fuel. ENEL has stated that Trino 1 is ready to restart on demand, whereas some backfits are necessary to restart the Caorso reactor.) The 70-percent complete two-unit Montalto di Castro plant will be converted to an oil-, gas-, or, coal-fired plant with four 640-MWe units going into service in the 1995 through 1997 period.

Due to the shutdown of all its nuclear plants and prolonged delays in construction of conventional power plants, the country currently imports about 14 percent of its electricity from France, Switzerland, and West Germany. ENEL had projected an annual rate of growth of 3.2 percent in electricity generation; however, demand has been running well over 4 percent for the past few years.

The Italian nuclear sector is currently planning for a renaissance of nuclear power when the country's nuclear construction moratorium expires in 1992. When the government put a 5-year ban on the construction of nuclear stations, the government left room for the nuclear sector to explore new solutions aimed at enhancing the safety of any future Italian plants. To chart the country's future course in nuclear power the government approved, under the creation of a "management committee," the current National Energy Plan. Although its report has not been released, the committee recommended that Italy participate in various international nuclear development projects, choose an appropriate reactor type, carry out a detailed design, and construct a plant at an appropriate time.

ENEL is active in the working groups of international organizations involved in nuclear safety, including the World Association of Nuclear Operators and its work on advanced reactor concepts, such as gas- and sodium-cooled reactors. The utility has contacted major vendors and is collaborating on three ongoing reactor projects, two sponsored jointly by the U.S. Department of Energy and the Electric Power Research Institute, and one with Asea Brown Boveri (ABB). In addition, ENEL has conducted in-depth studies on ABB's Process Inherent Ultimate Safety (PIUS) reactor.

> The EIA expects Italy's installed nuclear capacity in the Lower Reference case to total 1.2 GWe by the year 2000. Italian nuclear capacity is projected to reach 3.1 GWe in the year 2010. The nuclear share of electricity generation is projected to be 4.7 percent in 2010. Electricity generation is projected to grow at a rate of 3.3 percent per year during that period. These projections are based on an economic growth rate of 1.7 percent per year.

Japan

Japan's set up its nuclear infrastructure in 1956, placing responsibility for nuclear energy under two government organizations. The Science and Technology Agency (STA) is responsible for all research and development activities, and the Ministry of International Trade and Industry (MITI) is responsible for commercial and industrial activities. The Atomic Energy Commission (AEC) and the Nuclear Safety Commission (NSC) of the Prime Minister's Office provide overall coordination of nuclear activities. The NSC establishes safety regulations, and the AEC provides policy guidance for nuclear energy development. One of the main organizations under STA is the Japan Atomic Energy Research Institute (JAERI), which was established in 1956 to handle research and development for LWRs, high-temperature reactors, and fusion reactors. STA also incorporates the Power Reactor and Nuclear Fuel Development Corporation of Japan, which is responsible for developing plans to complete the nuclear fuel cycle and continuing research on breeder reactors.

Some years ago the Japanese government and domestic reactor manufacturers began collaborating in the development and construction of advanced thermal and fast breeder reactors (FBRs). The prototype 148-Mwe Fugen ATR can use various fuels, including plutonium, and was loaded with mixed oxide fuel in 1988. The three manufacturers of the prototype 250-MWe Monju FBR are developing various designs for these reactors. The Monju FBR is about 75 percent complete and is expected to be operable in 1993.

> EIA projects that Japan's nuclear capacity in the Lower Reference case will increase at an average rate of about 2.9 percent from 1985 through 2010. The nuclear share of electricity generation is projected to increase from its 1989 level of 25.5 percent to 32.3 percent in 2010. Electricity generation is projected to grow at a rate of 1.6 percent from 1985 through 2010. These projections are based on an economic growth rate of 2.1 percent per year.

Kashiwazaki Kariwa 5 was connected to the grid in September 1989 and began commercial operation in April 1990, bringing Japan's nuclear capacity to 29.3 GWe. The country has 39 operable nuclear units and ranks third among FME countries in terms of installed nuclear capacity. Japan has 26 units with 25.8 GWe of capacity in the nuclear construction pipeline.

Japan's nuclear generating units had an average capacity factor of 70 percent for the year ending March 31, 1990, the lowest in 7 years. The PWRs had the highest average capacity factor of 75 percent, with the Tomari 1 unit operating at 100-percent capacity. Largely because of Fukushima Daini 3 being off-line virtually all of 1989, the BWRs operated at an average capacity factor of 67 percent during the same period.

The AEC stated in a late 1989 paper that Japan's best energy mix calls for nuclear power generation to play a key role. It was felt that the country needs to become less dependent on petroleum than in the past, particularly in view of potential global environmental damage; its rapidly increasing demand for energy; and poor prospects for renewable energies such as solar and wind.

The JAERI and the United Kingdom's Atomic Energy Authority signed a 3-year agreement in March 1990 to exchange scientific and technical information on GCRs and PWRs. France and Japan have extended their nuclear cooperation agreement to 2017; Japan's cooperative agreement with the United States also runs to 2017. Japan has used largely French technology to design its Rokkashomura commercial reprocessing plant now under construction.

The Netherlands

The Dutch nuclear power program began in the early 1960s with the ordering of a 55-MWe BWR at Dodewaard, which became operational in 1968. A second unit, the 445-MWe Borssele PWR, began commercial operation 5 years later. After 2 years of public debate, the Dutch government in 1984 approved the construction of at least two more nuclear units, each of 900- to 1,300-MWe capacity. The coalition government reached its decision after review of a report from the Economics Ministry, which concluded that 4,000 MWe of nuclear capacity would be required by the end of the century, assuming a 1.0 percent annual growth in electricity demand during the intervening period. The Parliament approved the government plan in June 1985.

EIA projects that nuclear capacity for the Netherlands in the Lower Reference case will remain constant at 0.5 GWe through 2010. The nuclear share of electricity generation is projected to decrease to 3.7 percent in 2000 and remain constant through 2010. Electrical generation is projected to grow at an annual rate of 2.0 percent from 1985 through 2010. These projections are based on an economic growth rate of about 2.0 percent per year.

The plan to construct additional nuclear capacity was shelved, however, in May 1986 because of the Chernobyl accident. At that time the government mandated a full study of the safety of, and alternatives to, nuclear energy. The Dutch government has postponed a decision on building additional nuclear capacity until after national elections are held in early 1990. The safety study was not completed in time for the results to be considered in the country's mid-1989 long-term planning review of electricity needs. The next such review will be made in mid-1991. In planning the future energy program, the government has emphasized cost effectiveness and remaining competitive with industrial rivals in Europe.

Spain

Spain currently has 10 operable nuclear units totaling 7.6 GWe and has 6 other units with 6.0 Gwe of nuclear capacity in its construction pipeline. In 1984 the Spanish government approved its 1983 National Energy Plan forbidding completion of the two-unit Valdecaballeros nuclear plant, which was scheduled to go on-line before 1989. The moratorium was imposed because of apparent overcapacity of electricity in the country.

In 1989, the Energy Secretary reaffirmed that the National Energy Plan to be published in 1991 will include a revision of the nuclear moratorium, but said no decision will be made on the future program before then. Many nuclear industry officials are confident, however, that construction on the two units will resume in the near future. Valdecaballeros 1 is 80 percent complete, and Valdecaballeros 2 is 60 percent complete.

In the Lower Reference case, Spain's nuclear capacity is projected to increase to 8.6 GWe in 2000, and 10.3 GWe in 2010. EIA projects the nuclear share of electricity generation to decrease from the 1989 level of 37.6 percent to 23.8 percent in 2010. Electricity generation is projected to grow at a rate of 2.8 percent per year from 1985 through 2010. These projections are based on a yearly economic growth rate of 2.3 percent.

In April 1989, Endesa began purchasing stock in Sevillana de Electricidad and other Spanish utilities. The move is thought to be part of a major rearrangement of the Spanish electricity industry to prepare for the opening of the European single market in 1992.

Speculation about the future shape of the industry has centered on a three-way split said to be favored by the Ministry of Industry. Under the new arrangement, Endesa and Ideduero, another Spanish utility, would each control 35 percent of the market with the remaining 30 percent held by Hidroelectrica Espanola SA. Smaller companies would be absorbed by the new groupings, which, it is hoped, would be large enough to compete in the new climate of a European energy market in the 1990's.

Sweden

The Swedish nuclear power program began in the 1960's, and its first commercial unit, Oskarshamn 1, went into operation in 1971. Currently, Sweden's installed nuclear capacity is 9.7 GWe. Nuclear plants and hydropower each supply about 50 percent of the country's electricity.

During the 1970's Sweden experienced increasing opposition to nuclear power, primarily because of concerns over safety. In 1980, a referendum was held and the nuclear expansion program was allowed to continue. However, in the following year the Parliament used the referendum as a basis for deciding to close all of the country's nuclear plants by 2010.

In reaction to the 1986 Chernobyl accident, the Social Democratic government proposed in 1987 and 1988 that the phaseout of nuclear power should be speeded up by permanently closing two nuclear units in 1995 and 1996 (presumably one each at Barsebaeck and Ringals). The proposal was later accepted by the Parliament. In June 1988, Sweden's Parliament denied the Minister of Energy and Environment the freedom to decide which units would be closed in 1995 and 1996, ruling that no decision will be taken before the autumn of 1990. At that time details of both the timing and implementation of nonnuclear alternatives will be evaluated, and a study will be made of how a nuclear phaseout might affect the country's economy, employment and environment.

> The EIA Lower Reference case projects that Swedish nuclear capacity will decline to 8.6 GWe by 2000. In accordance with the current policy for a total nuclear phaseout by 2010, the nuclear share of electricity generation is projected to fall from its 1989 value of 45.3 percent to 0 percent in 2010. Electrical generation is projected to increase at a rate of 0.2 percent per year from 1985 through 2010. These projections are based on a yearly economic growth rate of 1.7 percent.

Public discussions held in August 1989 on Sweden's energy policy have made it clear that the ruling Social Democratic Party is divided on the nuclear phaseout issue. A Social Democratic working group, formulating the party's policy for the coming decade, has concluded that Parliament made three decisions that are incompatible unless it is possible to reduce rapidly releases of carbon dioxide, especially those from traffic. The three Parliament decisions are: (1) the phaseout of nuclear power shall start with one unit in 1995, a second unit in 1996, and the remaining units by 2010; (2) the total amount of CO_2 emissions should not increase; and (3) no additional large-scale hydroelectric plants can be constructed.

In January 1990, Rune Molin, a trade union leader, was appointed Sweden's new Minister of Industry, and responsibility for energy policy was transferred from the Ministry of Environment to the Ministry of Industry. This transfer of responsibility has led some critics to believe that Sweden's nuclear phaseout might be modified in 1990 if it becomes apparent that early shutdowns of nuclear power plants will lead to high electricity costs. It is already evident that higher prices will pose difficulties for electricity-intensive industries, located mainly in northern Sweden. Unionized industries account for one-third of Swedish exports. Opposition to an early, or any, phaseout of nuclear power is growing among the trade unions, who claim that the country's energy policies in general, and the nuclear plans in particular, will result in a loss of Sweden's traditional competitive advantage based on low-cost electricity.

Switzerland

Switzerland currently has five operable nuclear units totaling 3.0 GWe and the 1,140-MWe Graben unit under construction. In 1989, hydropower accounted for about 57 percent of the total electricity produced, with nuclear power contributing about 42 percent and oil-fired generation contributing the rest.

In 1988 the Swiss federal government and Parliament canceled the 950-MWe Kaiseraugst nuclear unit. The decision to terminate the project was based mostly on its site in the Canton of Aargau, which is very close to the major population center of Basel. Since no petition was filed within a 90-day period for a referendum against the Kaiseraugst decision, the owners of the terminated nuclear unit will be compensated $225 million as approved by Parliament. Similarily, the Nationalrat, the lower house of Parliament, moved to terminate the Graben project in the Bern canton, and is seeking a similar compensation plan that was awarded to the Kaiseraugst consortium members. To help offset potential electricity shortages due to the government's decision, the Swiss utility in Baden will import an additional 100 MWe of nuclear power from France, beginning in 1996. Nordostschweizersche Kraftwerke (NOK), which distributes electricity to nine cantons (districts) in northeastern Switzerland, expects to be some 30 percent dependent on imported electricity.

The Nationalrat rejected two antinuclear initiatives in February 1990. One initiative was a 10-year moratorium on all nuclear activity, while another initiative demanded a ban on further nuclear construction and the phased shutdown of operating nuclear units as quickly as possible. Parliament members' arguments centered primarily on the need to keep the nuclear option alive for economic and environmental reasons.

The Federal Executive Council (FEC) also recommended that both initiatives be rejected; a national vote on the issue will likely be scheduled for late 1990 or early 1991.

> EIA forecasts Swiss nuclear capacity in the Lower Reference case to remain constant through 2010. The nuclear share of electricity generation is projected to fall to 35.1 percent in 2010 from its 1989 level of 41.6 percent. Electricity generation is projected to grow at a rate of 1.1 percent per year from 1985 through 2010. These projections are based on an annual economic growth rate of 1.6 percent.

United Kingdom

The United Kingdom Atomic Energy Authority (UKAEA) was established in the 1950's to develop the nuclear program in Great Britain, Scotland, and Northern Ireland. The nuclear industry in the United Kingdom (U.K.) began in 1953 with the construction of four 50 MWe experimental units at Calder Hall, which were connected to the electrical grid between 1956 and 1959. From 1956 to 1963, the Central Electricity Generating Board (CEGB) of Great Britain ordered eight stations with two units each.

In 1989 British nuclear capacity decreased to 11.2 GWe with the shutdown of the Berkeley 2 and Hunterston A2 units. One new unit, Torness Point 2, a 625-MWe advanced-gas reactor (AGR) was connected to the grid in 1989. The completion of this unit leaves Sizewell B and Hinkley Point C as the sole projects in the British construction pipeline. In 1989 nuclear power plants, performing at an average capacity factor of 55 percent, supplied about 21 percent of the U.K.'s total electricial generation. Electrical demand in the U.K. is currently rising about 3 percent annually, higher than the CEGB's estimated average growth of 2 percent used to calculate its investment needs.

In November 1989, the U.K. government announced that the entire nuclear power sector of the electric utility industry would be withdrawn from the government's electricity supply industry privatization program. The original privatization program, announced in early 1988, has evolved into a plan to break up the CEGB into four companies. Operating as private entities, National Power, Power Gen and National Grid Company will handle non-nuclear operations. The public Nuclear Electric Company will be responsible for the nuclear market in England and Wales. Scottish Nuclear, a subdivision of SSEB, will remain a public company and wil' direct the Scottish market.

National Power was originally intended to take over all the nuclear plants in England and Wales; however, the company sought government guarantees that, among other things, would shield it from any cost overruns, construction delays, or required changes to improve safety and protect the environment. Energy Secretary John Wakeham stated that the government would not provide such unprecedented guara..tees to a private company and that all of the nuclear plants would be held in the public sector because the high costs of nuclear power would not attract private investment.

At the Hinkley Point C public inquiry in July 1989 the CEGB announced that it would continue with its building application for the unit rather than cancelling it as some had expected. It did, however, withdraw the application for the remaining PWRs, Wylfa B and Sizewell C.

> EIA projects U.K. nuclear capacity in the Lower Reference case to decrease from its 1989 level of 11.2 installed GWe to 8.4 GWe by 2000, and to 7.6 GWe in 2010. The nuclear share of electricity generation is projected to decrease from 20.8 percent in 1989 to 12.6 percent in 2010. Electricity generation is projected to grow at a rate of 1.5 percent per year from 1985 through 2010. These projections are based on a yearly economic growth rate of 1.9 percent.

Non-OECD Countries

Argentina

Argentina established a National Atomic Energy Commission (CNEA) in 1956 to direct the country's national energy plan and control all aspects of its nuclear technology. It currently has two operating nuclear units with a total net capacity of 0.9 GWe as well as the 692-MWe Atucha 2 under construction. The Atucha 2 unit is about 66 percent complete and is now expected to go on-line in 1995; its completion has been delayed by a large foreign debt and hyperinflation.

Both Argentine operating nuclear units, Atucha 1 and Cordoba 1, have experienced problems. The Atucha 1 unit was restarted in January 1990 after a 17-month outage for repairs. Apparently in the 1980's, the reactor was operated without undergoing required full maintenance checks, but the current CNEA director has pledged that his administration will give the highest priority to nuclear plant maintenance. Some design changes are being made on the Atucha 2 unit so that a similar problem with broken fuel tubes can be avoided.

Although Argentina's total installed generating capacity is 12,643 MW, the system has been plagued with problems. Because Cordoba 1 generated 10 to 15 percent of Argentine baseload power in 1989, its shutdown in July 1989 for long-delayed maintenance led to rotating electricity blackouts in Buenos Aires and other large cities. The Government had delayed its scheduled October 1988 shutdown because of widespread power shortages caused by Atucha 1 being off-line and reduced capacity at other generating plants. Cordoba 1 was returned to service in September 1989.

> EIA projects Argentine nuclear capacity in the Lower Reference case to be 1.8 GWe by 2010. The nuclear share of electrical generation is projected to fall from its 1989 level of 11.4 percent to about 9.5 percent by 2010. Electrical generation is projected to grow at an annual rate of 3.5 percent. These projections are based on an economic growth rate of 3.3 percent per year.

Argentina is continuing its efforts to develop an independent fuel cycle and become a major supplier of nuclear fuel services and materials to third world countries. It has signed bilateral nuclear agreements with at least twenty nations, including Algeria, which reportedly is interested in the Argentine-designed 380-MWe Argos PHWR. An agreement with Brazil extends a nuclear development pact that could lead to joint construction of the PHWR or other nuclear power plants in both Argentina and Brazil. However, the heavy debt burdens of Brazil and Argentina preclude any near-term progress in nuclear power plant construction.

Brazil

The Brazilian nuclear power program began in 1972 with the ordering of its only operable nuclear unit, the 626-MWe Angra dos Reis 1. Angra 1 began its second refueling outage in October 1989, and the state-owned nuclear utility, Furnas Centrais Electricas SA, planned to restart it in December 1989. However, on a petition from local Green Party politicians, a lower court Judge barred the restart on grounds that safety was inadequate, even though the unit received a favorable report by the IAEA's Operational Safety Review Team. On January 3, 1990, a higher court ruled that Angra 1 could be restarted, which the utility did immediately.

Angra 1's checkered history began with its long precommercial testing period from April 1982 to January 1985 and included a 16-month shutdown starting in 1987 for extensive repairs to the electric generator and modifications to the steam generators. Furnas has sued the plant's supplier, Westinghouse, claiming tens of millions of dollars in damages for poor workmanship. The case remains unsettled.

Brazil currently has two nuclear units (Angra 2 and 3) totaling 2.5 GWe in its construction pipeline. Furnas, which is responsible for construction of Angra 2 and 3 in the reorganized Brazilian nuclear program, has announced that the Brazilian Congress authorized the company to invest $200 million on the Angra plants during 1990. The government believes that power shortages are likely in the 1990's without rapid completion of the Angra facilities. Angra 2 reportedly is 69 percent complete, and Angra 3 is 28 percent complete.

> EIA projects Brazil's nuclear capacity in the Lower Reference case to increase from its 1989 level of 0.6 GWe to 1.9 GWe in 2000 and to reach 3.1 GWe by the year 2010. The nuclear share of electricity generation is projected to reach 3.4 percent in 2010. Electricity generation is projected to grow at a rate of 4.4 percent per year from 1985 through 2010. These projections are based on an economic growth rate of 4.0 percent annually.

The 1,245-MWe Angra 2, originally planned to be generating by 1993, is now expected to start operating in 1995, according to the latest evaluations by Electrobras, the Brazilian public electric sector holding company. Most of the equipment for Angra 2 is already purchased. The unit was supplied by Siemens AG's Kraftwerk Union division, and the 1990 budgeted funds are to be used on equipment installation.

In August 1989, Argentina signed a number of cooperative agreements with the Brazilian government, including an extension of an existing nuclear development pact that could eventually lead to joint nuclear power plant construction in both countries.

India

India currently has seven operating nuclear generating units totaling 1.4 GWe as the Narora 1 unit was connected to the grid in July 1989. It has seven nuclear units with 1.5 GWe of capacity in the construction pipeline, all of which are PHWRs similar to the CANDU design. Construction of Narora 2 began in 1976, and the unit is scheduled to begin operation in 1990. Kakrapar 1 and 2, each with a capacity of 220 MWe, are expected to be in commercial service by 1991 and 1992, respectively, and construction is progressing on Kaiga 1 and 2 and Rajasthan 3 and 4.

Many failures and deficiencies in the equipment and components at the Tarapur and Rajasthan reactors during the 1970's led to lengthy shutdowns of these units, but repairs to and replacement of defective parts and equipment during the 1980's generally seem to have resolved most of the problems. While numerous design and engineering changes were made in the later Madras reactors to improve their performance and reliability, there still have been operating problems causing unplanned outages and occasional operation of the units at half their design capacity.

Indian nuclear capacity in the Lower Reference case is forecast to increase to 1.6 GWe by 2000 and reach 2.6 GWe by 2010. EIA projects a nuclear share of electricity generation of 1.1 percent in 2010. Electricity generation is projected to grow at a rate of 7.9 percent per year from 1985 through 2010. These projections are based on an economic growth rate of 4.1 percent per year.

The Narora reactor site has required more extensive seismic engineering than was necessary at other Indian nuclear sites, and numerous design changes have caused construction delays and cost increases. Environmental groups have opposed the Narora project because of its proximity to a large population center. There also has been environmental opposition to the planned nuclear plant near the Nagarjunasagar hydroelectric project in Andhra Pradesh; over 40,000 people live near the proposed plant site. In 1989 an official committee of the Indian government stated that nuclear power plants should not be located within a radius of about 10.5 miles in areas with populations exceeding 10,000 people.

The country's electrical generating capacity totals about 58,000 MWe, and the Central Electricity Authority of India has projected that this amount will triple by 2000, with about 5.8 percent (10,000 MWe) being nuclear. The remaining plant types are expected to be coal-, gas-, and oil-fired, and hydroelectric.

Prime Minister V.P. Singh appointed a new AEC chairman in early 1990 who wants to accelerate nuclear power generation in India. The chairman, P. K. Iyengar, is apprehensive about LWRs but thinks their use might be necessary to reach India's target of an additional 10,000 MWe of nuclear capacity by 2000. He will not accept foreign offers of turnkey nuclear plant construction and, in discussions with France and the USSR, he has insisted on substantial Indian participation in the design and construction of additional nuclear reactors in India. Iyengar also believes that India can successfully enrich its own uranium since initial experiments have gone well. He recently said that nuclear power is environmentally benign and well suited for densely populated states like Kerala where the AEC has been seeking a suitable plant location.

India's uranium resources are sufficient to sustain about 10,000 MWe of nuclear capacity. Some of the new nuclear units will be 220-MWe PHWRs, with others expected to be larger PHWRs. The 500-MWe Rajasthan 5 through 8 PHWRs have estimated dates of commercial operation in 1997 and 1998. India hopes to have these units in commercial operation within 97 months after receiving approval for their construction.

India uses indigenous natural uranium to fabricate fuel for its PHWRs at the Nuclear Fuel Complex (NFC) in Hyderabad. The NFC also fabricates fuel elements for the two BWRs at Tarapur from French enriched uranium.

Korea, South

The Republic of Korea (ROK) currently has nine operable nuclear units totalling 7.2 GWe. In 1989, one unit, the 920-MWe Uljin 2, was connected to the grid. Construction of Yonggwang 11 and 12 950-MWe units that are scaled-down versions of Combustion Engineering's 1,300-MWe PWR, was scheduled to begin in 1989; however, the construction permit was delayed. Completion of Yonggwang 11 and 12 is currently scheduled for 1995 and 1996, respectively.

Nuclear power has made a significant contribution to the ROK's rapid industrialization and economic growth in the past two decades. Nuclear power now accounts for half of South Korea's electricity production.

In September 1989, Korea Electric Power Corporation (KEPCO) announced that the utility will order two more PWRs in addition to the new CANDU unit it plans to order from Atomic Energy of Canada, Ltd. The new PWRs, Korean nuclear units 13 and 14, are expected to be completed during the late 1990's and will form the basis for a standardized series-Korea Standard Nuclear (KSN 1). At least six units are expected to be ordered before 2000. The advanced PWRs of the KSN 1 series will be based on the Yonggwang 3 and 4 reactor design. As with the existing Yonggwang project, the KSN 1 project will be managed by KEPCO, with major components manufactured by Korea Heavy Industries and Construction Company; Advanced Energy Research Institute designing the nuclear steam supply system and fuel; Korea Power Engineering Company handling the architecture and engineering; and Korea Nuclear Fuel Company fabricating the fuel.

A second standardized series, KSN 2, based on passively safe designs, is scheduled to begin construction in the late 1990's. The new nuclear units will be needed to meet expected electricity demand growth of 5 to 8 percent per year.

A South Korean government committee approved a KEPCO plan to import about 40 metric tons of enriched uranium annually from the Soviet Union. The Soviets will accept consumer electronic goods as partial payment for the material. This decision may clear the way for South Korea and the USSR, which currently do not have formal diplomatic relations, to begin cooperation in commercial nuclear power ventures.

The South Korean Atomic Energy Commission (AEC) has endorsed KEPCO's plan for a second PHWR at the Wolsong site. Bids for Wolsong 2 were to have been invited in late 1989, but the invitation was postponed to early 1990 because plans to privatize the state-owned Korea Heavy Industries and Construction Company, a potential bidder for the project, were unsuccessful.

> EIA projects South Korea's Lower Reference case nuclear capacity to increase to 10.2 GWe in 2010. The nuclear share of electricity generation is projected to decrease from 50.2 percent in 1989 to 17.4 percent by 2010. Electricity generation is projected to grow at a rate of 6.9 percent per year from 1985 through 2010. These projections are based on an economic growth rate of 3.2 percent per year.

Mexico

Mexico's troubled economy and public opposition to nuclear power following the Chernobyl accident have been primarily responsible for the downward revisions of the country's original program to build twenty nuclear units by the year 2000. The Comision Federal de Electricidad's first two nuclear units at Laguna Verde were originally scheduled to come on line in 1984 and 1985, but were delayed due to financial constraints. The 654-MWe BWR Laguna Verde 1 was ordered from General Electric in 1972 and was connected to the grid in April 1989. Work on unit 2 is about 50 percent complete, with fuel loading scheduled for December 1991 and connection to the grid in April 1995.

> For Mexico the nuclear capacity projection for 2010 in the Lower Reference case is 1.3 GWe. The nuclear share of electrical generation is expected to reach 2.6 percent by 2010. Electricity generation is projected to grow at a rate of 4.6 percent per year from 1985 through 2010. These projections are based on an economic growth rate of 4.6 percent annually.

Pakistan

Pakistan's sole nuclear power plant (Kanupp) is a 125-MWe PHWR that was ordered from Canadian General Electric. It is owned by the Pakistan Atomic Energy Commission (PAEC) and began operation in 1971. However, because Pakistan has declined to sign the NPT or accept full-scope IAEA safeguards on all its nuclear facilities, the Canadian government suspended its technical assistance and supply of spare parts/fuel for Kanupp in 1976. Therefore, the PAEC has experienced some difficulties in operating Kanupp at full capacity; to the end of 1989 the plant's lifetime availability factor was 50.8 percent.

As of September 1989, Pakistan had 7,220 MWe of electrical generating capacity and of this total, 2,900 MWe was hydroelectric, 4,195 MWe was gas-/oil-fired, and 125 MWe was nuclear. By 2006, the government estimates that the country will need 33,100 MWe of capacity, of which about 4,600 MWe is expected to be nuclear.

China is selling Pakistan a 300-MWe PWR that will be under IAEA safeguards; the reactor will be an improved version of the Chinese Qinshan 1 that is scheduled to begin initial operation in December 1990. Chinese companies are expected to start construction of the Pakistan unit in 1990 and complete the work by the end of 1996. Pakistani firms are manufacturing about 75 percent of the plant's equipment, with the remainder to be imported. The unit will be built at the Chashma site in northern Punjab where the PAEC has acquired extensive acreage for a planned nuclear complex that was to include a reprocessing plant and a 900-MWe PWR bought from western suppliers.

In fact, in early 1990, plans were officially approved for acquiring six nuclear units with a capacity of 2,400 MWe, with one of the reactors likely to be a 900-MWe PWR from France. Both Pakistan and France claim that financing construction of the reactor at the Chashma site is the only important obstacle although the two countries have yet to resolve their dispute over a contract for a Pakistani reprocessing plant that a French company canceled in 1976. The Pakistani government wants Belgian as well as French participation in building the 900-MWe PWR since the Belgians had earlier assisted the Pakistani nuclear program. South Korea and the Soviet Union also have expressed interest in supplying nuclear power plants to Pakistan, but no agreements on such plants have been made to date.

EIA projects nuclear capacity in Pakistan for the Lower Reference case to remain constant at 0.1 GWe through the year 2000. This scenario assumes that the Chashma station will not come on line before the end of that projection period. Electricity generation is projected to grow at a rate of 9.4 percent annually from 1985 through 2010. These projections are based on an economic growth rate of 4.9 percent per year.

In 1989, Pakistan approved a 20-year plan for domestic manufacture of nuclear reactors, possibly starting with a duplicate of Kanupp, since no operating 300-MWe LWR is available as a reference. Subsequently, the country would strive to develop a 300-MWe version of Kanupp and eventually a 600-MWe PHWR or PWR, depending on economics. The program for expanding nuclear power generation in Pakistan by 2010 involves private Pakistani companies collaborating in reactor development with foreign firms, so that Pakistan's failure to sign the NPT should not be an issue. The PAEC projects that the country might have about 6,000 MWe of installed nuclear generating capacity by 2000.

South Africa, Republic of

The Republic of South Africa is the only country in Africa with an operable nuclear power plant. Its nuclear power program began in 1965 with the operation of an experimental research reactor, the Safari 1, a 20-MWe unit supplied by a U.S. reactor vendor. Several other research reactors have since been installed. In 1976, South Africa ordered its first commercial nuclear power plant near Capetown. The Koeberg 1 and 2 units, supplied by Framatome, became operational in 1984 and 1985, respectively; they give South Africa 1.8 GWe of nuclear capacity.

The Electricity Supply Commission of South Africa (ESCOM) has built coal-fired plants in recent years but plans to order another nuclear power plant by the mid-1990's. It has been examining various coastal sites for future nuclear plants and has acquired one site at Cape St. Francis.

Nuclear capacity in South Africa is projected to remain constant at its 1989 level of 1.8 GWe through 2010. EIA projects the nuclear share of electricity generation to reach 3.7 percent by 2010. Electrical generation is projected to grow at a rate of 3.5 percent per year from 1985 through 2010. These projections are based on an economic growth rate of 4.4 percent annually.

Taiwan

Taiwan's most recent operable nuclear unit, Maanshan 2, entered service in 1985. Six units are presently in operation with an installed nuclear capacity of 4.9 GWe; they produce about 40 percent of Taiwan's total electrical generation and have averaged a 68-percent capacity factor over the past 3 years. With no available economically accessible reserves of fossil fuels, the country's only primary source of indigenous energy is hydroelectric power.

With time nearing for a decision on Taiwan's long-stalled nuclear power construction program, government and political leaders have begun to take sides over the desirability of increasing nuclear capacity. Both the Premier and Economic Minister of Taiwan have come out publicly for a resumption of plans by the state-owned Taiwan Power Company (Taipower) to build its seventh and eighth nuclear units. The Premier believes that Taiwan's economic development requires expansion of nuclear generating capacity because new sources for hydro power are limited, and overreliance on fossil-fired plants would place too great a burden on the environment. The Democratic Progressive Party and, in particular, the newly elected Taipei county executive, however, have hardened their resistance to nuclear power.

Four of the six nuclear units in operation are located in Taipei County, at Shimin Hsiang and Kuosheng, and the prospective site for the two planned units is also within this county. Although the plant was to be sited at Yenliao, it may now be relocated near the existing plant at Kuosheng. Originally, the twin 950-MWe units were to have been in operation in the early 1990's, but an equipment contract was canceled in 1982. Government officials cited a decline in electricity consumption forecasts as the basis for their decision and said they would revive the project in a few years. Antinuclear sentiment grew in Taiwan during the 1980's, fueled by the Chernobyl accident and suspicions about Taipower's safety capabilities.

Taipower plans a campaign to win greater support for nuclear power, as it believes the two units need to be operating by 1998 and 1999 to avoid serious power shortages. The utility may take several steps to win public support, such as subsidies to local communities; provision of free electricity in the region near plant sites; and upgrading the safety, reliability, and availability of existing nuclear plants.

> EIA projects that Lower Reference case nuclear capacity in Taiwan will remain constant at 4.9 GWe through 2000 and grow to 6.3 GWe by 2010. Taiwan generated 35.2 percent of its electricity from nuclear reactors during 1989. This percentage is expected to fall to 21.3 percent between now and the end of the projection period in 2010. Electricity generation is projected to grow at a rate of 4.4 percent per year from 1985 through 2010. These projections are based on an economic growth rate of 3.3 percent annually.

Yugoslavia

Yugoslavia's only nuclear unit, the 632-MWe Krsko PWR, was ordered in 1973 and began operation in 1981. The more industrialized republics of Yugoslavia have been forced to meet energy demands by importing large quantities of oil and electricity. Experts have been concerned that existing fossil-fuel generating facilities would consume all of the country's coal reserves in a short period of time. Revised government plans for energy development apparently will emphasize domestic resources, chiefly coal, oil, and gas, and will forecast reduced energy demand. The plans do not become official policy until adopted by all Yugoslav provinces and republics. Currently, Yugoslavia plans to add 5,000 MWe of hydroelectric capacity by 2000.

In June 1989 the Federal Chamber, the upper house of the Yugoslavian Parliament, revised a bill drafted by the Federal Executive Council (FEC) that had called for a moratorium on construction of nuclear facilities until 2000. The new bill specifically prohibits for an indefinite period the construction of nuclear plants, the preparation of nuclear-related investment programs, and technical documentation for nuclear plant construction. The FEC draft allowed site studies and other preparatory work leading up to but not including a final investment decision.

The current law allows but does not define "scientific research and development research." While it permits mining-geological exploration, geological-seismic research, and nuclear waste management activities, the law terminates federal funding of research related to nuclear energy safety. The new law does not refer to the operating Krsko nuclear power plant; rather its intent is to block government-supported plans to construct four 1000-MWe nuclear units by 2002. Although 3 years ago an electric utility consortium asked for international tenders on these units, no final vendor recommendations were announced because of the construction program's suspension.

> EIA projects Lower Reference case nuclear capacity in Yugoslavia to remain constant at its present level of 0.6 GWe through 2010. The nuclear share of electricity generation is projected to decline to 1.6 percent by 2010. Electrical generation is projected to grow at a rate of 3.6 percent per year from 1985 through 2010. These projections are based on an economic growth rate of 2.2 percent per year.

Countries With Potential or Inactive Nuclear Power Programs

This section explains briefly the present status of countries with potential or inactive nuclear programs.

Bangladesh

In early 1990, the president of Bangladesh ordered the country's Atomic Energy Commission to determine the availability of loans from Islamic countries for the construction of a 300- to 500-MWe nuclear power plant at Rooppur. Demand in the region is projected to reach 1,200 MWe by 1995, so that new baseload capacity is needed in western Bangladesh.

Egypt

Egypt and Argentina signed a nuclear cooperation agreement in November 1988. This pact may give an edge to Argentina's proposed Argos design for a 380-MWe PHWR if Egypt decides to order a nuclear unit. Egypt had previously been negotiating with Kraftwerk Union of West Germany for a 1,000-MWe PWR unit.

Indonesia

In 1986, three consortia of reactor vendors submitted proposals to the Indonesian government for construction of a 600-MWe nuclear unit. The proposals called for build-operate-transfer (BOT) arrangements which have yet to be used in bringing nuclear power to less developed nations. Indonesia has never accepted any of these proposals. In early 1990 it made a third request to the Japanese government for financing a feasibility study and site determination for an Indonesian nuclear reactor; this request reportedly is for $9.3 million. The feasibility study could take 4 years to complete. The Japanese government is expected to decide on the grant request by July 1990.

Iran

In 1979, the Iranian revolutionary government canceled contracts for two 1,300-MWe PWRs at Bushehr; the contracts had been signed with Siemens/KWU in 1974. Since 1984, Iran has been trying to reactivate the project with foreign assistance. In early 1990 the USSR agreed to build two 440-MWe nuclear units in Iran and to assist that country in completing the Bushehr reactors. The Soviet-Iranian agreement, it is reported, also includes Iranian export of natural gas to the Soviet Union beginning April 1, 1990.

Israel

Israel has never signed the NPT but is willing to allow IAEA inspection of any nuclear power plants built in that country. Israel has also negotiated with Canada to purchase a CANDU reactor that would be constructed at Shivta in the Negev desert. Israel expects its next power plant to be nuclear; the capacity of that reactor apparently will depend on which vendor supplies the unit.

Philippines

The Philippine government has, for political reasons, never authorized startup of its 620-MWe PNPP-1, which was completed in 1986, despite prolonged power shortages in the Manila area. Its lawsuit against Westinghouse, the PNPP-1 vendor, has continued, and may not be settled for some time although most of the counts have been referred for settlement to an international arbitration body. The litigation charged Westinghouse with plant deficiencies and bribery in its construction.

Turkey

The Turkish government still wants to build a nuclear power plant at Akkuyu but has postponed a final decision in the matter. It is no longer negotiating with Atomic Energy of Canada, Ltd., for a 600-MWe PHWR. However, in May 1989 it was reported that Turkey expected to sign a letter of intent with an Argentine firm, Investigaciones Aplicadas, for a modular 25-MW Carem 15 LWR. The unit would be sited near Ankara and used for baseload power. If the small reactor works well, Turkey may ultimately decide to buy the Argentine Argos PHWR.

Countries With Regulated Market Economies (RME)

Over the past year the Eastern European countries of Bulgaria, Czechoslovakia, East Germany, Hungary, Poland, and Romania have experienced dramatic political changes. In each case the change is away from central economic planning and toward a market driven economy. This is a critical change from recent practices and will influence the direction and pace of nuclear power in all non "western" countries. The changes or shifts in the decision-making criteria include increased considerations for:

- Safety and risk
- Environmental impacts
- Public preferences
- Availability and cost of capital
- The changing political climate in Europe
- Economic costs/benefits
- Balanced power supplies.

In RME countries, each at a different stage on the path toward a free market economy, the role and status of nuclear power is being systematically reevaluated. The outcome of the reevaluation will influence the operation of existing power plants (nuclear and conventional), and the completion of planned power plants.

All the regulated market economy (RME) and centrally planned economy (CPE) countries with operating nuclear plants or with nuclear plants under construction have critical shortages of electric power, and coal generates most of their power. In many cases coal is burned in inefficient, highly polluting plants with little or no pollution control equipment. Other sources of electric power include hydropower, natural gas, and imported electricity.

In many of these countries, however, nuclear power is likely to represent a smaller fraction of the electrical power capacity than previously planned, and in some of them nuclear power may be completely eliminated. This is due to several factors: (1) the lack of capital; (2) the know-how to construct and operate nuclear power plants and (3) the 1986 Chernobyl accident.

This section summarizes nuclear power programs in countries with RMEs. Only those countries with nuclear capacity that is operable or scheduled to be constructed are considered. Tables H1 and H2 list the operable nuclear generating units and those under construction for RMEs and CPEs (see next section). Every effort has been made to assure that the best available information is incorporated into this section; however, the reader is cautioned that data sources for these countries are not as reliable or as prevalent as those used for the market countries covered in the beginning of this chapter.

This chapter is compiled from various sources that present their data differently and may contradict information in other publications.[58] Four RMEs and one CPEs had operable nuclear capacity in 1989 and produced a total of 274.2 net terawatthours (TWh) from 66 units. This was 13.8 percent of their total electricity generation.[59]

Bulgaria

Bulgaria currently has five nuclear generating units in operation totaling 2.6 GWe and another 4.8 GWe of nuclear capacity in its construction pipeline. The four 408-MWe and one 953-MWe Kozloduy VVER PWRs produced 35.0 percent of the country's electricity in 1989. The units operating or under construction were supplied by Atomenergoexport of the Soviet Union. Kozloduy 6, another 953-MWe PWR, is scheduled for connection to the grid in 1990.

In 1988, Czechoslovakia's Skoda Works was awarded the contract for the first 953-MWe nuclear unit to be constructed at the Belene site. Construction has been delayed, with the startup for Belene 1 scheduled for 1992, and the other three units scheduled to be operational at 30-month intervals thereafter. However, no nuclear components have yet been delivered for the Belene 1 unit, and little construction work has been done on Belene 2. After demonstrations against the nuclear plant in early 1990, the Bulgarian government suspended construction work and appointed a parliamentary committee to study the need for power and the safety of the Belene plant. The parliamentary committee will study: (1) whether increased efficiency can sufficiently reduce energy consumption; and (2) the probable seismic risk in the Belene area which suffered a strong earthquake in 1974. After that earthquake, the Soviet Union improved the seismic resistance of its later VVERs. The committee expects to discuss the seismic issue with nuclear experts in western countries. To date, these foreign experts have judged that the Bulgarian design containment at the Belene plant provides more than adequate safety. Bulgaria believes that the Soviet VVER-1000 reactors have a large margin of safety.

Czechoslovakia

Czechoslovakia[60] operates the four-unit Bohunice and Dukovany nuclear plants with an installed capacity of 3.3 GWe. These eight VVER-440 PWRs produced 30 percent of the country's electricity in 1989. Among countries that formerly had centrally planned economies but are now evolving into new political and economic structures, Czechoslovakia is second only to the Soviet Union in both operable nuclear capacity and nuclear capacity under construction. The current Czechoslovak energy plan calls for installed nuclear capacity to increase to 10,300 MWe by 2000, a total which would exceed coal-fired capacity for the first time and would generate 61.8 million kWh, or, 59.7 percent of expected electricity generation in that year.

The Czechoslovak Atomic Energy Commission planned to decide in early 1990 on the basic safety of the Bohunice 1 and 2 units that are similar to the East German VVER-440 units in the Greifswald region. Two of the latter reactors were shut down in early 1990 after a safety review. However, work on the Bohunice units began 4 years after construction started on the East German Nord 1 and 2 PWRs, so that the Czechoslovak reactors incorporated improved component design and manufacture, including higher quality Czechoslovak materials and better quality assurance than in other Soviet-design VVERs.

Siemens/KWU diagnostic systems to improve safety have been installed at the Dukovany PWRs and will be placed at the Bohunice plant by 1991. The West German company has offered to improve reactor safety in Czechoslovakia, and a West German official planned to visit the country in April 1990 to discuss further technology transfers.

[58]Primary sources of information in countries with Regulated Market Economies include various issues of *Nuclear Engineering International Society* (Surry, United Kingdom: Business Press, Ltd.); *Nuclear News* (La Grange, Illinois: American Nuclear Society); *Nucleonics Week*, and *Nuclear Fuel* (New York: McGraw-Hill).

[59]International Atomic Energy Agency, *Nuclear Power Reactors in the World*, April 1990 Edition (Vienna, Austria, April 1990).

[60]In April 1990, the country's name was officially changed to the Czech and Slovak Federal Republic.

Czechoslovakian and other Eastern European officials agree that the Soviet-design instrumentation and control (I&C) systems in all VVERs present a safety problem. Modern electronics as well as safety improvements to their pressure vessels are needed in these reactor systems to ensure proper operation.

The 380-MWe Mochovce 1 unit had been scheduled to begin operation in the Fall of 1989, but its startup was first delayed to September 1991 and then delayed again to 1992. The unit's I&C system may undergo a complete examination and potential reconstruction. Czechoslovak officials insist that the delay was unrelated to recent I&C problems at the East German Nord units. The Czechoslovakian I&C system was designed jointly with the Soviets, and is unique to the second-generation VVERs under construction at Mochovce.

The Czechoslovak energy minister suspended construction work on the Temelin 3 and 4 units in January 1990. However, work is to continue on the Temelin 1 and 2 units that are scheduled for completion in 1992 and 1994, respectively. Austrian experts will be involved in studies designed to bring the safety of Temelin 1 and 2 up to Western standards. Environmentalists in Czechoslovakia have criticized the country's nuclear program in general and the four proposed VVER-1000 reactors at the Temelin plant in particular.

A Czechoslovak official in the fuel and energy ministry believes that the Temelin 3 and 4 units will either be canceled or redesigned to incorporate western technology. The Czechoslovaks have discussed the possible participation of Western reactor vendors in completing these Temelin units. Because of other priorities and 1990 elections, the new government may not decide on the future of the Temelin plant for some time.

Czechoslovakian firms have been actively involved in the effort of the Council for Mutual Economic Assistance (CMEA) countries to share in the manufacture of hardware in Soviet-designed nuclear reactors.[61] They supplied 80 percent of the hardware for the Temelin units as well as some heavy nuclear components for reactors in the USSR and other nations in Eastern Europe.

Electricite de France contracted with Czechoslovakia in 1989 to supply software for its nuclear units. The French Commissariat a l'Energie Atomique (CEA) plans to strengthen its cooperation with Czechoslovakia in four general areas: (1) safety, including component aging and updating procedures for reactor operation; (2) design of new, improved reactors; (3) the fuel cycle, especially spent fuel storage and dismantling of nuclear facilities; and (4) training programs for Czechoslovakian students at French nuclear engineering schools and research laboratories. The CEA programs with Czechoslovakia are to be defined during 1990.

Germany, East

East Germany currently has six operable nuclear generating units totaling 2.1 GWe (Nord 1-5 and Rheinsberg) and has nine other units with 6.6 GWe of nuclear capacity in its construction pipeline. Nord 6 through 8 are Soviet VVER-440s, while the six Stendal units are VVER-1000s. All these reactors were initially scheduled to become operational in the early 1990's, but their construction has been delayed for a variety of reasons. The East Germans' highest nuclear priority will be to complete the remaining Nord units. In 1989 nuclear energy supplied about 11 percent of East Germany's electricity.

Electricity demand in the GDR is estimated to increase by 2 percent per year, and possibly more as a result of closer political and economic ties to West Germany. East Germany will need about 8,000 MWe of new and replacement generating capacity in service by 2000, at least half of which is likely to be nuclear.

The German Democratic Republic (GDR) held elections in March 1990 to establish a caretaker government that could govern the country prior to its ultimate reunification with West Germany. There is an uncertain future for VEB Kombinat Kraftwerksanlagenbau mbH (KAB) that built the Nord 1-4 units. A reunified Germany will privatize the KAB and other state-owned entities in the GDR. The KAB is awaiting a Soviet decision to supply heavy components for the Stendal 1 and 2 units by the Spring of 1992 although a West German nuclear official believes that Siemens AG/KWU will step into the picture if the USSR fails to act expeditiously. Also, the new German government may decide that the Stendal reactors should meet western safety standards.

A January 1990 agreement between West and East German officials provided for expert panels to cooperate in four areas: (1) harmonizing the nuclear fuel cycle of the two countries; (2) unifying German nuclear law on the basis of the West German Atomic Act; (3) nuclear materials transport; and (4) waste management. The first panel is responsible for unifying noncommercial fuel cycle policy and regulation although the ultimate role of industry in waste management programs is expected to be discussed in the near future. West German officials are anxious to have one set of waste conditioning practices throughout a unified German state. They also want to learn the details of Soviet uranium supply agreements with East Germany, including the transfer of spent fuel to the USSR.

[61]The following countries are members of the CMEA or COMECON: Bulgaria, Cuba, Czechoslovakia, East Germany, Hungary, Poland, Romania and USSR.

East Germany and the USSR currently have a fuel cycle agreement that commits the Soviet Union to supply fresh fuel for the lifetime of the Nord and Stendal reactors and to accept all their spent fuel for Soviet reprocessing. This agreement applies apparently to the ten Soviet-design PWRs in operation and under construction at the Nord and Stendal sites. However, since the GDR wants its future units to be of Western design, it hopes that the Soviets would agree to furnish fresh fuel for Western reactors and take back their spent fuel, so that East Germany does not have to invest in a spent fuel waste management plan for a small number of Western reactors.

In early 1990, a West German reactor safety agency reported embrittlement to the pressure vessel on the Nord 1 and 2 nuclear units in East Germany, which are early Soviet-design VVER-440s. The safety agency advised shutting down both reactors until technical questions on their safety are resolved. The GDR regulators subsequently closed the Nord 2 reactor and planned also to shut down Nord 3. Although the USSR annealed the pressure vessel on the Nord 1 unit in 1988 to correct an earlier embrittlement problem, West German safety experts may ultimately recommend also closing that reactor. IAEA nuclear safety officials also examined the Nord nuclear plant and found that its deficiencies were largely attributed to a few repetitive causes, particularly failures in the I&C equipment and poor reliability and maintenance of the safety systems. The agency plans to recruit an expert team to advise plant personnel on correcting these problems.

Intra-German nuclear safety cooperation has been impeded to date because West Germany and the USSR have an agreement to share a wide range of information on nuclear safety, while the limited GDR-USSR agreement does not include reactor safety. Some West Germans believe that the Soviets restricted their distribution of data relating to nuclear safety to COMECON nations so that the design deficiencies in VVER reactor systems or components would not be revealed. Because of the evolving political climate in East Germany, the USSR may agree to include GDR officials in West German-Soviet exchanges of nuclear safety information that could pertain to the GDR's nuclear program.

GDR officials state that the latest problems at the Nord plant will delay by up to 6 months the commercial operation of the Nord 5 unit for expensive backfitting to the I&C systems. The officials believe that design and construction of Soviet RMBK or VVER reactors reflect a lower level of nuclear technology compared to Western nuclear technology. They claim that the USSR's nuclear establishment has largely caused East German nuclear power problems because of insufficient Soviet attention to improving safety standards, instituting design changes, and assuring quality control on its reactor components and materials.

The East German State Office for Radiation Protection & Nuclear Safety (SAAS) has issued new safety requirements for the first four Nord nuclear reactors. These units probably will undergo some backfitting along with improved management to increase safety over the reactors' planned 25-year lifetimes. There also will be a thorough examination of reactor materials in these units as well as probabilistic risk assessment of the PWRs to determine what other safety improvements should be made.

The first two VVER-1000 units at Stendal are not expected to go on line until after 1995 although their official startup had been scheduled for 1992. West German safety experts are to examine these two reactors and recommend any needed safety improvements, some of which might be provided by western suppliers.

The pilot 62-MWe Rheinsberg PWR will be decommissioned in 1992. It has been used to train operators from various countries and to test fuel assemblies.

An energy commission was to be set up in early 1990 that would include experts from government ministries in both East and West Germany. The commission probably will meet several times each year, and one of its tasks reportedly will be possible expansion of nuclear power generation in the GDR. Senior East German officials hope to replace the country's old lignite-fired plants with more nuclear power plants which they consider their chief option as the GDR's lignite resources will be exhausted within 30 years. They would like to begin decommissioning some lignite-fired power plants in 1990 and reduce the country's annual consumption of lignite by up to 100 metric tons.

Three West German utilities and the reactor vendor Siemens/KWU may be involved in plans to construct future nuclear reactors at Stendal and Leipzig. The East Germans currently want their nuclear reactors to reflect modern Western technology and safety standards. If such projects are undertaken, the cash-rich West German utilities probably would largely finance reactor construction, with possible development loans from the federal government. The utilities might supervise reactor construction and assist GDR officials in obtaining nuclear steam supply systems from a reactor vendor such as Siemens.

The West German government has approved a plan to complete a 380-kilovolt transmission line between the two Germanies. The first leg of this line is ready to transmit 500 kWh from Preussenelektra AG to the GDR in 1990 and 1991. By 1992, when the two German grids are fully linked, East Germany will be able to obtain as much as 1 billion kWh per year from the West German grid.

Hungary

Hungary operates four Soviet VVER-440 reactors at the Paks nuclear plant on the Danube River. The plant has a net capacity of 1.6 GWe and in 1989 supplied about 13 percent of the country's electricity. Although four other VVER-440s were originally planned for the site, the Paks 7 and 8 units were eliminated because of cooling water limitations. In November 1989, the Hungarian government canceled the plans to build the Paks 5 and 6 units with Soviet-design reactors; those units were initially scheduled to be operational in the mid-1990's. The government ordered an end to all preparatory work on those units as it suspended its 1986 agreement with the Soviet Union for their design and construction. Hungary claimed to have canceled these plants because of lower than expected growth in energy demand rather than concern over the Soviet-design reactors; however, neither the USSR nor Hungary could currently finance construction of these units.

Hungary's peak electrical demand currently is 6,523 MWe, with the country's power plants providing 5,350 MWe and the USSR supplying 1,850 MWe. Much of the imported electricity may be unavailable in the future because of Soviet power shortages, although 1,100 MWe is under firm contracts.

The Hungarian Electricity Board (MVMT) hopes to obtain foreign capital for construction of a major new power station before 2000. Several foreign utilities have indicated to the MVMT that they would be interested in building either nuclear or lignite power plants, with about half of the electrical output exported to Italy and other Western European nations. A jointly owned utility might be established with Hungary holding 30 to 35 percent of the shares. It would pay about one-third of plant construction costs and 80 to 90 percent of operating costs, while its foreign partner would finance its contribution through western capital markets. The project would rely on the BOT principle (build, operate, transfer), and is estimated to cost $2 to $3 billion. To date, feasibility studies are underway only with the French utility EdF and the Canadian utility Ontario Hydro.

Both the French and Canadian offers include fuel supply for the nuclear plant and return to the foreign country of the spent fuel, but the latter presents a problem because of the need for transportation through third countries. It also is uncertain whether Hungarian uranium might provide a portion of the fuel supply through continued operation of the Mecsek mine, a heavily state-subsidized operation, that is now scheduled to shut down in December 1990.

Ontario Hydro and MVMT have been studying the feasibility of Canadian aid in the construction of one or more CANDU nuclear reactors in Hungary. A prefeasibility study was completed in December 1989, and the feasibility study was to be completed by July 1990. Discussions held in early 1990 included MVMT, Ontario Hydro, the Italian utility Ente Nazionale per l'Energia Elettrica and the Canadian reactor vendor Atomic Energy of Canada, Ltd. (AECL). The participants considered alternate proposals for one or two 680-MW CANDU units or four 450-MWe CANDU's that could transmit electricity from Hungary to Western Europe, possibly through Austria. Such power can only be exported after Hungary's generating plants are connected to the West European grid.

EdF signed an agreement in early 1990 to collaborate with the MVMT on building two 900-MWe PWRs at the Paks nuclear plant that would replace the canceled Soviet VVERs initially planned as the Paks 5 and 6 units. EdF would provide 70 percent of the construction financing, a possible investment of $2 billion, that would be paid off over 20 years, beginning in 1997 or 1998, with sales of electricity to the Western European grid over new transmission lines to be constructed in Austria. The French would supply the uranium for the plant, take back the spent fuel, and supply operating assistance to MVMT for up to 5 years. Bechtel, an American company, contracted with the Transelektro Foreign Trading Company to supply the Hungarian Electricity Board and the Paks Nuclear Power Station with tools and processes for such present and future activities as scheduling and project management of nuclear power operations and radioactive waste disposal.

Poland

Like most of Eastern Europe, Poland relies on coal for much of its electric power generation, and demand for power far exceeds supply. Because of this situation, the country embarked on an aggressive nuclear course in the early 1980's. The plan was to complete four 950-MWe nuclear power plants by the mid-1990's and an additional 2,000 to 4,000 MWe by the end of the century.

Construction on the first of two Soviet VVER-440 PWRs (Zarnowiec 1 and 2) is about 40 percent complete. About 70 percent of the reactor components for the first unit have been manufactured and delivered to the site. Construction on the Zarnowiec 3 and 4 units never began and has been officially deferred. On December 27, 1989 the Polish Council of Ministers ordered a year-long halt to construction at the Zarnowiec nuclear site near Gdansk. The government cited a "difficult economic situation" as the reason for the interruption; presently no funding will be allocated for the Zarnowiec project until 1991. In the meantime, a new energy policy is to be formulated and public opinion about nuclear power surveyed.

During 1990, experts from two Belgian companies, the West German reactor vendor Siemens/KWU, and the IAEA planned to review the past construction on the Zarnowiec nuclear plant and decide whether and how construction of Zarnowiec 1 and 2 should be completed. The IAEA studies were to emphasize two safety-related aspects of the project - absence of a containment and the perceived seismic risk of the site. If it is decided that the two nuclear units should be completed, the Polish nuclear establishment wants the reactors upgraded with western technology to the extent possible while still retaining the basic Soviet design.

Romania

Romania has no nuclear power plants in operation but is building the Cernavoda plant of five 625-MWe PHWRs that were ordered from Canada's AECL. Despite the presence of AECL personnel at the site, construction of this nuclear plant has proceeded slowly. However, the caretaker Romanian government signed contracts in early 1990 to obtain the AECL's aid in reorganizing construction at the plant. The Canadian work force will be quadrupled, and Romania now plans to have Cernavoda 1 and 2 producing electricity by 1994. AECL officials claim that the first unit is less than 50 percent complete, but possibly could be finished in 2 years with improved work conditions and better management at the plant site along with a renewal of Canadian credit to expedite early delivery of additional components for the unit.

The former government had planned to build thirteen units with 12,000 MWe of nuclear generating capacity, and officials of the caretaker government later made some policies on nuclear energy. After the May elections, a new, extensive nuclear energy program can be established although environmental groups could delay its implementation or cause major changes therein. If the newly elected leaders view nuclear power as a continuing priority, and with Canada's further support, the remaining Cernavoda units might be completed by 1996. Moreover, another six-unit plant could be constructed by the end of the 1990's, possibly in western Romania, and a third site in the eastern region might be exploited by around 2010.

During November 1989, the former Romanian government put into effect an energy conservation law that sharply reduced the availability of electricity for businesses and private homes. Therefore, the successor governments have had to face a large increase in the demand for power and expect to pursue the country's nuclear power program. They probably will continue nuclear cooperation with their past partners Canada and the USSR, but possibly also engage in new ventures with Western nations such as France or Spain. However, Romania does not plan to import turnkey Soviet nuclear plants, and has canceled the Moldavia VVER-1000 plant that was to be built with Soviet assistance.

The caretaker government has claimed that only nuclear power can solve the country's huge energy problems. A Romanian official has noted that the public is opposed on environmental grounds to fossil-fired plants but not to those using nuclear fuels. He stated that the country's energy sector must be completely reorganized to produce greater efficiency. The energy ministry, which is being reorganized, has signed an agreement with EdF to modernize its coal-fired power plants. Romania's energy consumption is likely to rise by up to 50 percent in future years, but no new plant could go into service for 5 years. Power imports from Bulgaria, West Germany, France or the USSR either are scarce or require improved or new transmission lines. Romania's current total generating capacity is 17,000 MWe.

The former Atomic Energy Commission has been dissolved, and a new Energy Minister is responsible for the country's nuclear energy program. A newly established National Commission for Nuclear Activities, Control aspires to promote international cooperation in safeguards, physical protection safety, quality assurance, and radiological protection. Under the new commission, the regulation, licensing and enforcement of nuclear controls will be separated from the promotion of nuclear energy development under the Ministry of Electrical Energy and other research activities of the Institute of Atomic Energy.

Countries With Centrally Planned Economies (CPE)

The People's Republic of China

The Peoples Republic of China's nuclear policy has been largely unaffected by the events in Eastern Europe; however, the events at Tiananmen Square in 1989 and a worse than expected balance of payment problem have slowed international cooperation. Although it is more difficult now to assess the future of China's nuclear program, the country's need for electricity continues to drive its aggressive program for nuclear power development.

In the early 1980's, China planned five 2,000-MWe nuclear power plants along its populous eastern coast but, because of a shortage of funds and insufficient fabrication capacity, shelved its plans for all but the three units now being built. China now appears committed to the development of four 600- to 1,000- MWe nuclear units by 2000. These projects include the Qinshan 1, the two French-designed PWRs at Daya Bay, another project proposed for Jiangsu province in the east, and a plant in northeastern Liaoning province.

The country's first nuclear unit, Qinshan 1, is more than 80 percent complete; it is mostly of domestic design and is being constructed by Chinese firms. Siemens/KWU of the Federal Republic of Germany is providing construction management services. Only a few key components are foreign, among them the reactor vessel from Japan and the main pumps from West Germany. Qinshan 1 should generate its first electricity by late 1990.

China's second nuclear power project is located at the Guangdong site near Daya Bay. The project consists of two 900-MWe units that were scheduled to operate in 1992 and 1993. Work was halted, however, in late 1987 and resumed in early 1988 after correction of design deficiencies. The units, supplied by Framatome, are a joint venture by the Guangdong Nuclear Investment Company (75 percent) and the Hong Kong Nuclear Investment Company (25 percent). China Power and Light (the utility serving Hong Kong) will take 70 percent of the power generated by the units.

The Beijing Institute of Nuclear Engineering was awarded the design contract for the second phase of the Qinshan 2 and 3 600-MWe PWR's that are expected to be completed later this year. The Siemens/Framatome joint venture, Nuclear Power International, has recently reconfirmed its offer to help build the 600-MWe units, but the issue of price remains uncertain.

In 1988 China announced plans to construct nuclear units on Hainan Island, located at the extreme southern end of the mainland, and in Fujian Province. Hainan has been declared a "special economic zone," similar to what Hong Kong will become when it reverts to Chinese control in 1997. The development program for Hainan calls for electrical generating capacity, now at about 200 MWe, to increase tenfold. Power plants of several types would be built to satisfy the expected growth; however, only one is currently slated to be nuclear.

The Fujian project is at an earlier stage of consideration. It is located on the southeastern coast between Shanghai and Hong Kong, an area deemed likely to experience considerable economic growth in the near future. Other potential sites for additional plants are near the Daya Bay nuclear plant and in the Taishan District.

In November 1989, China agreed to supply a 300-MWe PWR to Pakistan. A formal agreement to begin construction on the Chashma unit in the Mianwali District of northern Punjab is expected shortly, according to the Chairman of the Pakistan Atomic Energy Commission. The Pakistan reactor will be an improved version of the Qinshan unit, and its construction would involve bilateral cooperation with China supplying most of the technology and expertise as well as fuel and spare parts. In addition, China would supply Pakistan with its own indigenous enriched uranium supplies. The plant would be operated under IAEA safeguards and is scheduled to be completed by 1996.

Cuba

The Cuban Government is now building its first nuclear power plant, the two-unit Juragua, located at Cienfuegos. In 1986, Cuban leader Fidel Castro disclosed his nation's intention to construct a third unit in eastern Cuba once the Juragua plant is completed. However, the twin 408-MWe PWR station, supplied by the Soviet Union, has been delayed due to the addition of new safety features. Unit 1 is now scheduled for connection to the grid in 1992. Cuba also is establishing a nuclear regulatory infrastructure.

North Korea

In 1985, the Peoples' Democratic Republic of Korea signed the Nuclear Non-Proliferation Treaty (NPT) as a prerequisite to receiving a planned four-unit nuclear power plant from the Soviet Union. Although the Soviet Union announced that it would help North Korea to construct the four PWRs between 1986 and 1990, no construction has ever begun. In a report submitted to the National Assembly for review by the government's National Unification Board, North Korea had yet to select a site for the four Soviet VVERs which would have a combined capacity of 1,760 MWe. The delay in the nuclear project could be attributed to the country's deteriorating financial situation.

Soviet Union

The USSR connected two 950-MWe PWRs to the grid in 1989 - South Ukraine 3 and Zaporozhe 5. It currently has 43 operable nuclear generating units with 34.2 MWe of capacity; another 53 units with 55.5 GWe are in the construction pipeline. The development of nuclear power is considered very important in the Soviet energy picture since it is difficult and expensive to bring energy from the country's far northern and eastern regions to the many consumers in the European Soviet region. Also, the power industry reportedly accounts for about one-quarter of Soviet industrial pollution. However, some citizens and public officials have opposed nuclear power projects in certain areas of the USSR because of safety considerations.

The USSR plans to replace the steam generators on all of its VVER-1000s that have operated for more than 40,000 hours; it will backfit the nuclear units with shorter periods of operation. Investigations have determined that the steam generators suffer from both poor design and defective manufacturing. The generators have already been replaced on three reactors, while those on eleven other nuclear units will be replaced in coming years. Generators on the VVER-440s are arranged differently than on the VVER-1000s and do not need to be replaced.

The Soviets have developed a program to anneal pressure vessels on the VVERs that have been built in the USSR and supplied to Comecon countries in eastern Europe. Western safety experts have been skeptical of the program's credibility since the Soviets had provided little information about it; however, the USSR was expected to provide considerable data about the program at a 1990 international meeting on reactor pressure components. Investigations have revealed that the Soviet annealing procedure may not have solved the embrittlement problem in the pressure vessels, and possibly needs to be improved.

The USSR permanently closed down its Beloyarsk 2 unit in October 1989. It will shut down the Novovoronezh 2 unit in 1990 and decommission the reactor in 1991. These two old units were judged not worth backfitting to modern safety standards. During the next 10 to 20 years the Soviet Union plans to decommission nuclear units that cannot be modified to meet the accepted criteria of safe reactor operation; it will replace them with newer and safer reactors. Other nuclear power plants will be modified to meet the safety criteria. In February 1990 the Soviet Union announced a delay in the commissioning of the Rostov 1 950 MWe PWR near Volgodonsk so that an environmental study could be undertaken.

The Armenian republic has suffered energy shortages since the closure of its two VVERs in early 1989, and new nuclear units are being considered, presumably at sites more distant from earthquake-prone areas. Also in 1989, the USSR halted construction of the Atkash nuclear plant with four 950-MWe units. There had been concerns about possible seismic risk in the region, and the Atkash site is to be converted to other uses. Geological investigations were suspended for the nuclear power plant at the Muyezerka site in the Karelian area near the Finnish border, and no further work is to be done there until after enactment of a new Soviet law on nuclear regulation.

In early 1990 the prototype BN 350 FBR was being repaired but has recently been used only for water desalination rather than to generate electricity. There are no current plans to shut down this unit although it is uncertain how much longer it will be operated after repairs are completed.

The USSR reported to the IAEA in 1989 on the details of a 1957 accident at the Kyshtym military nuclear facility in the southern Urals that produced plutonium. Failure of a cooling system in a tank containing high-level waste resulted in a chemical explosion and a release of radioactivity that was roughly 4 percent of that released in the 1986 Chernobyl accident. The experiences acquired by the Soviet Union from its 1957 and 1986 nuclear accidents have been compiled into a guide for use by the civilian and military nuclear industries in the USSR. The guide provides planning and implementation measures designed to reduce the radiological and radio-ecological consequences of radioactivity releases to the environment resulting from unexpected accidents. The investigations carried out in the southern Urals aided the Soviets in predicting the long-term effects of the Chernobyl accident, and in developing methods to reduce land and water contamination in the Ukraine and Byelorussia.

A feasibility report in expected to be completed in 1990 on methods to improve the long-term effectiveness of the sarcophagus enclosing the Chernobyl 4 reactor that was destroyed in the 1986 accident. After detailed planning is done, the work might start by 1992. The containment structure probably will be effective for at least 30 years although internal components may need additional reinforcement. A processing plant is planned to condition and package the large amounts of contaminated material that have accumulated within the 18.5-mile zone around the Chernobyl plant.

In March 1990 the Ukrainian government announced that the Chernobyl nuclear power plant will be phased out during the next 5 years and then closed. Also, it does not want any more nuclear plants within its borders. The central Soviet government has exerted final control over such decisions in the past but, as power is shifted gradually to the republics, it may allow the Ukrainian decision to prevail. While some Ukrainians believe that the three remaining Chernobyl reactors are dangerous, authorities in Moscow and the Ukraine insist that the nuclear units are needed to avoid energy shortages in the region as well as to provide power for Eastern Europe. The Ukrainian republic currently has twelve other operating reactors plus eight nuclear units under construction. In August 1989 the President of the Ukrainian Academy of Sciences called for a halt to all current construction of nuclear power plants in the republic until new, safer reactors can be designed and built. He also suggested the development of alternative energy sources.

Although Byelorussia received most of the nuclear fallout from the Chernobyl 4 accident in 1986, few of its residents have been permanently relocated. It is estimated that 4 million people are living on contaminated land; however, no more than 200,000 people are now scheduled for ultimate resettlement by 1995 in clean areas. There also will be some resettlement of people living in certain portions of the Ukrainian and Russian republics. Opinions differ on the level of radioactive contamination in the food and water supplies of Byelorussia, the Ukraine and the Russian republic, and whether the government officials are properly monitoring such contamination. The IAEA announced in May 1990 its plan to send 100 specialists to the USSR for a study of the long-term consequences of the Chernobyl accident as well as an evaluation of planned Soviet responses to any future nuclear emergencies.

The Soviet Union is considering two possible approaches for its VVER-92 project to design an economic PWR that incorporates passively safe features. One approach would be a 1,000-MWe reactor based on the VVER-88 design, while the other approach would involve a 500-MWe reactor that would have a lower capital cost and fit better into the Soviet grid. The first VVER-92s might be commissioned in the late 1990's.

The Soviet Union has reorganized its nuclear bureaucracy. The nuclear committee has been merged with the committee supervising general industrial safety to become a regulatory body than is more concerned with nuclear plant licensing than with supervision of operating nuclear units. Under consideration is a four-stage process, ranging from licenses for nuclear plant construction sites to those for actual construction and operation up through licenses for decommissioning.

In 1989 and early 1990 the USSR signed nuclear cooperation agreements or contracts with various foreign companies and governments. An agreement with the U.S. Department of Energy involves the assistance of the U.S Institute of Nuclear Power Operations in running a new program to improve the operation and management of Soviet commercial nuclear power reactors; the program will initially focus on the first-generation Soviet PWRs at the Novovoronezh plant. An agreement between the USSR and EdF, the French utility, includes possible cooperation in such fields as operational safety; design, construction and decommissioning of nuclear facilities; and established or improved procedures to recover from nuclear power plant accidents. An agreement between the Canadian and Soviet governments relates to cooperation on facilities for fuel fabrication, uranium isotope separation, and production of heavy water as well as certain technology transfers pertaining to nuclear power generation in both countries. An agreement between the Soviet Union and Nuclear Power International, a partnership of West German and French reactor vendors, provides for cooperation in the development of future PWRs in the USSR, possibly including assistance in the design and development of the VVER-92.

The Soviet Union has signed contracts with Siemens/KWU of West Germany for certain services and products, including the following: (1) seismic analyses of VVER-1000s under construction in the USSR; (2) delivery of control systems during 1990-1991 to bring operating Soviet PWRs up to western standards; and (3) supplying reactor monitoring systems for Soviet PWRs.

The USSR also has discussed possible procurement or sale of nuclear reactors with other foreign nations, which include the following:

1. An agreement to build two 440-MWe nuclear units in Iran and assist in completing that country's two 1,196-MWe Bushehr units. Iran expected to begin exporting natural gas to the USSR in April 1990 in partial exchange for the Soviet aid.

2. Negotiations with India about supplying Soviet VVER-88s for the Kudankulam nuclear project in which these PWRs would be tailored to Indian grid requirements and anticipated operating procedures.

3. Discussions with China on the sale of a 2,000-MWe nuclear plant that would be constructed near Jiangsu in the province of Lianoning.

4. Continuing negotiations with a West German consortium for joint design and construction of an 80-MWe HTGR at Dimitrovgrad, USSR.

5. Plans to supply nuclear technology to North Korea after 1994 at a site yet to be selected.

Over a number of years the Soviet Union designed both light water reactors (VVERs) and light water cooled, graphite-moderated reactors (RMBKs) for the USSR but supplied only VVERs to its COMECON partners. However, those Eastern European countries are now even more concerned about the safety and reliability of Soviet nuclear reactors, and it is likely that many of the nuclear units in their construction pipelines will be built either with redesigned Soviet reactors or entirely with western technology.

In June 1989, a Soviet official announced that the country's latest power development program calls for under 100,000 megawatts of nuclear generating capacity by 2000, only two-thirds of the minimum goal set in earlier long-term plans. Future nuclear plants are to be built in remote areas with the latest reactor technology. The draft of the new program was to be released for public debate. Although the program emphasizes the VVERs, it also includes reactors for district heating and nuclear cogeneration. By 2010 nuclear power might supply about 25 percent of the total energy in the Soviet Union.

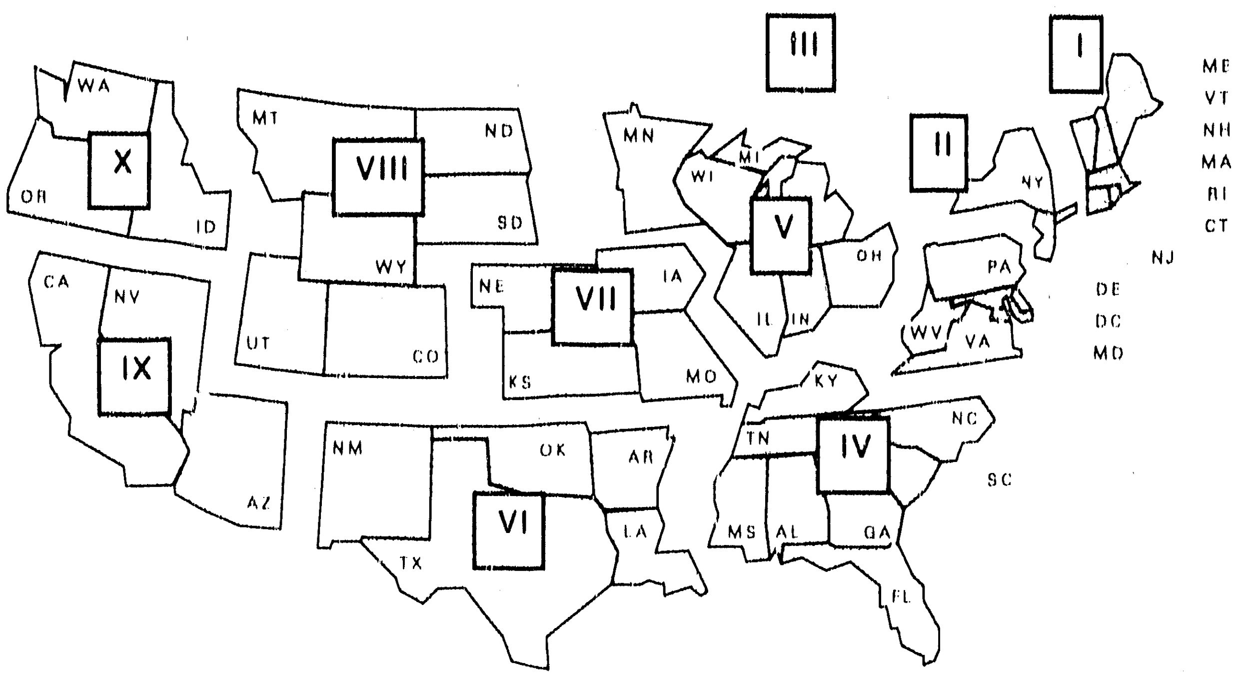
Appendix A

Federal Regions

Appendix A

Federal Regions

Figure A1. Federal Regions



Region I	Maine, Vermont, New Hampshire, Massachusetts, Rhode Island, Connecticut	Region VI	New Mexico, Oklahoma, Arkansas, Texas, Louisiana
Region II	New York, New Jersey	Region VII	Nebraska, Iowa, Kansas, Missouri
Region III	Pennsylvania, Delaware, D.C., Maryland, Virginia, West Virginia	Region VIII	Montana, North and South Dakota, Wyoming, Utah, Colorado
Region IV	Kentucky, Tennessee, North and South Carolina, Mississippi, Alabama, Georgia, Florida	Region IX	California, Nevada, Arizona, Hawaii (not shown)
Region V	Minnesota, Wisconsin, Michigan, Illinois, Indiana, Ohio	Region X	Washington, Oregon, Idaho, Alaska (not shown)

Appendix B

Notes on Projection Methodology

Appendix B

Notes on Projection Methodology

Reactor Construction Pipeline Methodology

As a general rule, the EIA analysis begins with a careful assessment of the current status of each individual reactor project and the momentum or progress toward its completion. Data collected for each project include reported construction completion dates, current and projected licensing activities, utility financial status, projected regional electricity demand, and other pertinent information. The data are derived from a variety of sources, including the following: Nuclear Regulatory Commission (NRC) construction and licensing reports; Form EIA-254, "Semiannual Report on Status of Reactor Construction"; utility announcements; trade journals; newspaper reports; and conversations with knowledgeable individuals. From these data, each project is evaluated as to its position in the overall planning, licensing, or "construction pipeline."

Timing estimates for each project are based on recent progress or forward movement in licensing or construction from the position of a previous forecast. This includes such indicators as changes in percent of construction completed, anticipated or completed licensing actions, and announced delays. Average construction and licensing times derived from an analysis of Form EIA-254 data show that nuclear units that began commercial operation in 1971 to 1973 were constructed in 4 to 6 years. By the mid-1970s, 1974 through 1977, the average construction time had increased to 7 to 8 years. By 1977, the average time from start of construction to commercial operation had exceeded 9 years, and by 1982 the average time had reached nearly 12 years. For nuclear units currently in the construction pipeline, electric utilities estimate the average time from the start of construction to commercial operation will be approximately 11.5 years. The total construction lead-time for these units, from the application for a construction permit to commercial operation, is projected to be 14 years. However, there are some recent examples of shorter construction times,[62] and legislation designed to decrease licensing lead-times, proposed by the DOE and the NRC separately, has been introduced in Congress.

Table B1 presents statistics on the expected average and median times between milestones for 38 nuclear units in the construction pipeline, estimated by the utilities in their fourth-quarter (December 31) 1984 submission of the Form EIA-254. The median times are reported because for some of the milestones the wide range of variation in the estimates is due to only a few units. For purposes of estimating operable capacity, it is assumed that a unit becomes operable approximately halfway between the date of first criticality and the commercial operation date.

Given the lead-times shown in Table B1, other factors relative to utility planning, scheduling, and construction are introduced into the projections. For example, a utility's schedule may call for a project completion date which is later than that indicated by the historical data analysis. Utilities with multiple units usually have a preferred startup sequence and specific time intervals for phasing in later units. Where the historical data analysis may indicate a longer construction time than utility plans for earlier units, subsequent units may also be delayed according to the utility sequencing schedules. All of these factors are considered in the projections for the Lower Reference and Upper Reference cases.

[62]The Florida Power and Light St. Lucie 2 unit, for example, had a construction period of under 6 years

Table B1. Average Estimated Times Between Milestones for U.S. Nuclear Units in the Construction Pipeline in 1984

Milestones	Estimated Times in Months			
	Average	Median	Minimum	Maximum
From Application for Construction Permit to Start of Construction	19.7	18	4	47
From Start of Construction to Application for Operating License	63.5	49	30	132
From Application for Operating License to First Criticality	75.9	70	21	148
From First Criticality to First Operation at Full Power	6.6	6	1	23
From First Operation at Full Power to Commercial Operation	2.7	2	1	11
Total Construction Leadtime	168.4	161	122	266

Source: Energy Information Administration, *Nuclear Power Plant Construction Activity 1984*, DOE/EIA-0473(84) Washington, DC, July 1985).

World Integrated Nuclear Evaluation System (WINES)

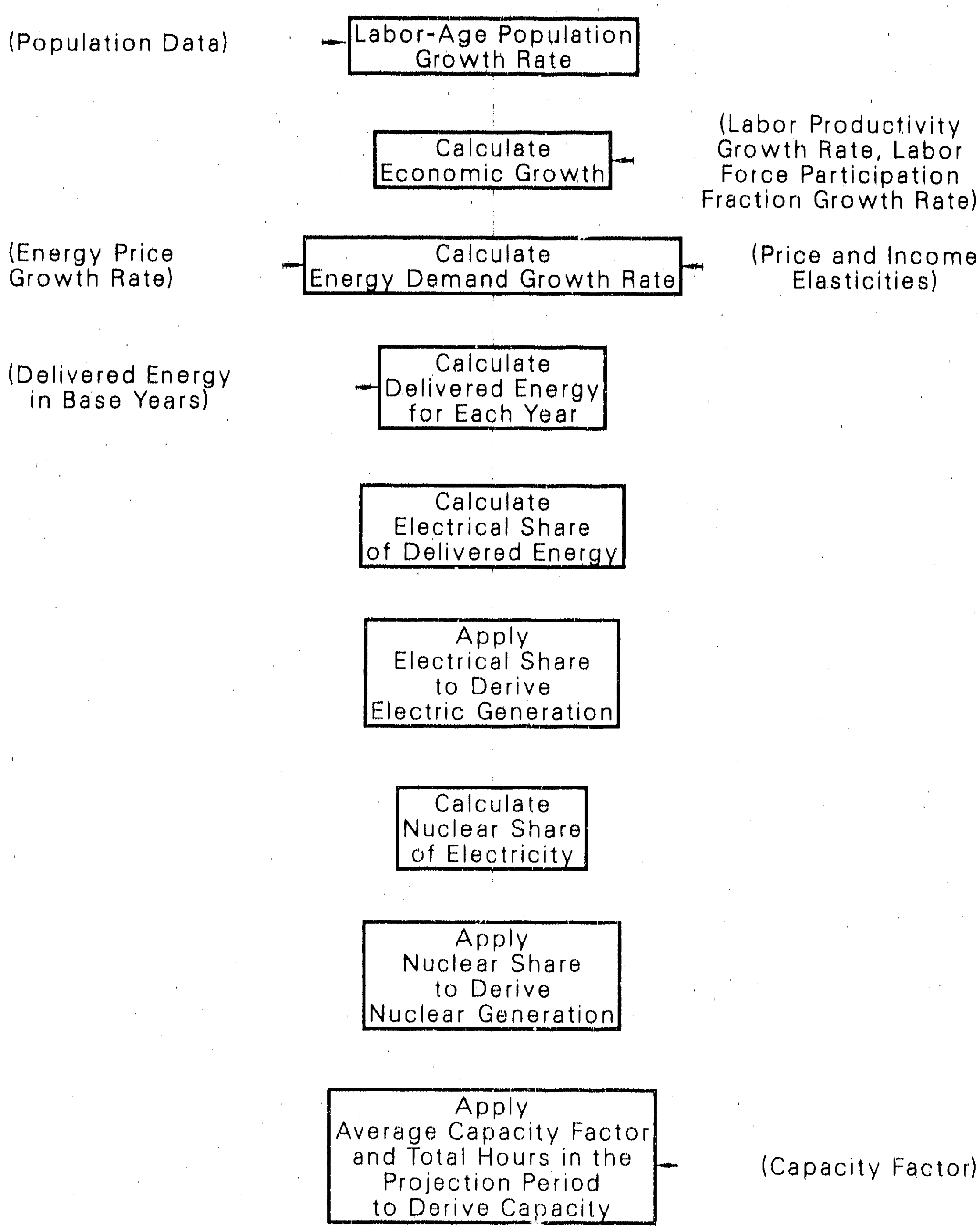
The World Integrated Nuclear Evaluation System (WINES) has been developed to project long-term nuclear generating capacity worldwide.[63] [64] [65] Energy projections can be made for each of 125 countries and can be aggregated by regions or by economic and political groupings. WINES is a relatively simplistic model, utilizing a "top-down" aggregated approach. The model is of a partial equilibrium nature, in that there is no feedback from the energy sector to the rest of the economy, such as is typically found in more detailed microeconomic models. The primary objective of the model is to produce projections of long-range world energy, electrical generation, and nuclear capacity.

The driving variables of the WINES model are economic growth and growth in the price of energy. Labor-age population and participation rates, as well as labor productivity, provide the basis for projecting economic growth, which is then combined with the price of aggregate energy to form a demand function (with constant price and income elasticities) for delivered energy. The growth rate for delivered energy is combined with a beginning-year initial value of delivered energy to develop a projection of delivered energy in the long term.

The electrical share of delivered energy and the nuclear share of electricity are derived using market penetration (logistic) models, which adjust the respective shares from current values to anticipated asymptotic values over time. Electrical generation for each year of the projection period is derived by applying the electrical share to delivered energy for that year. In the same manner, nuclear generation is derived by applying the nuclear share to the electrical generation for each year. Nuclear capacity is calculated from nuclear generation, assuming that sufficient capacity will be constructed to satisfy the generation requirement, utilizing an assumed average capacity factor. The model is specified in terms of growth rates up to the point at which absolute delivered energy demand is derived. From that point on, absolute amounts are calculated (i.e., electricity, nuclear generation, and nuclear capacity). A flow chart describing the WINES methodology is shown in Figure B1.

[63]E.H. Pechan and Associates, *Model Documentation of the World Integrated Nuclear Evaluation System, Volume 1, Model Documentation* (Washington, DC, June 1985).
[64]E.H. Pechan and Associates, *Model Documentation of the World Integrated Nuclear Evaluation System, Volume 2, Model Description* (Washington, DC, June 1985).
[65]E.H. Pechan and Associates, *Model Documentation of the World Integrated Nuclear Evaluation System, Volume 3, Executive Summary/Model Abstract* (Washington, DC, June 1985).

Figure B1. Flow Chart for the WINES Methodology



Source: Energy Information Administration, *Commercial Nuclear Power 1984: Prospects for the United States and the World*, DOE/EIA-0438(84) (Washington, DC, November 1984), p. 76.

Although WINES is conceptually simple, a number of variables and parameters are required to generate nuclear capacity projections. One key data set, labor-age population growth rates, is derived from the World Bank population projections by evaluating the change in the population between the ages of 15 and 60 years (inclusive) for each country over 5-year intervals.[66] Another major source of data for the OECD countries and several others is the OECD survey conducted in 1980 and updated in 1983, 1984, and 1985.[67] [68] For each country, an estimate is provided for 1980 and for 5-year intervals to 2000 (for most countries) for the following variables:

- Total primary energy requirements
- Electricity generation requirements
- Nuclear generation requirements
- Nuclear capacity.

The survey responses in most cases provide the base-year values for these variables and those derived from them (e.g., delivered energy, electricity share, nuclear share). If values of the energy data for individual years are not reported in the OECD survey, these are interpolated linearly, where possible, from previous and subsequent periods. The survey is supplemented in several cases by the "pipeline" analysis method described in this report.

The energy data used in the WINES model are documented in a recent report by Mathtech, Inc.[69] Primary sources of data for non-OECD countries are the United Nations *Yearbook* (1982) and the World Bank *1982 World Development Report*. For several non-OECD countries that are expected soon to initiate nuclear programs, OECD survey data are used in place of the United Nations statistics. For some countries, total primary energy values are derived from the Central Intelligence Agency *Handbook of Economic Statistics* (1983). All other parameters take on assumed values, based upon other empirical work, or are combinations of assumed and survey values.

Mathematical Description

The model is specified in terms of growth rates up to the point at which absolute delivered energy demand is derived. From that point on, absolute amounts are calculated (i.e., electricity, nuclear generation, and nuclear capacity).

GNP Growth

Economic theory suggests that economic activity, in the long run, is primarily influenced by the size and productivity of the labor force. Labor force size is determined by the labor-age population (the potential labor force) and labor participation rates. GDP growth (GNP is used for the United States; see the Glossary for a definition of these terms) is specified as the combination of the growth rates of these three factors:

$$g_t = LAP + PART + PROD \quad , \quad (1)$$

where:

g_t is the GDP growth rate in year t of the forecast period,
LAP is the labor-age population growth rate,
$PART$ is the labor force participation growth rate, and
$PROD$ is the labor productivity growth rate.

Delivered Energy

The growth in delivered energy is then calculated using an energy demand growth function:

$$d_t = \gamma \cdot g_t + \pi \cdot p_t \quad , \quad (2)$$

where:

d_t is the delivered energy growth rate,
γ is the income elasticity,
π is the price elasticity, and
p_t is the growth rate for real aggregate energy prices.

The price and income elasticities are discrete functions of per capita GDP. That is, they change over time whenever countries move from low to middle or middle to high income economies according to World Bank categories. Energy demand is generally considered to be more price elastic and less income elastic for higher income countries. The shift in elasticities reflects the commonly accepted premise that high income countries have greater opportunities for adjustments of energy consumption than do lower income countries.

The actual level of delivered energy (D_t) for each year is derived by applying this calculated growth rate to the base year and each subsequent year:

$$D_t = D_{t-1}(1 + d_t) \quad . \quad (3)$$

[66]World Bank, *Short-Term Population Projection, 1980-2000 and Long-Term Projection, 2000 to Stationary Stage by Age and Sex for All Countries of the World*, M.T. Vu (Washington, DC, July 1984).
[67]Organization for Economic Cooperation and Development, Nuclear Energy Agency, "Tabulation of WPNFCR Questionnaire Responses from OECD Member Countries," FCRDOC (80)54 (Paris, France, December 1980).
[68]Organization for Economic Cooperation and Development, Nuclear Energy Agency, *Summary of Nuclear Power and Fuel Cycle Data in OECD Member Countries* (Paris, France, March 1983, March 1984, and April 1985).
[69]Mathtech, Inc., *Energy Data Base: World Integrated Nuclear Evaluation System* (Arlington, Virginia, January 1985).

Electrical Share

The electrical share of delivered energy is derived using a logistic curve penetration model:

$$f_t^E = \frac{f_\infty^E}{1 + e^{-(\alpha + \beta t)}} \quad , \qquad (4)$$

where:

f_t^E is the electrical share in year t,

f_∞^E is the electrical share asymptotic limit,

α and β are the parameters of the logistic curve,

$\alpha = \ln\left[f_0^E \;/\; (f_\infty^E - f_0^E)\right]$,

$\beta = (1 / h) \cdot \ln\left[(f_\infty^E + f_0^E) \;/\; f_0^E\right]$,

f_0^E is the base year electrical share, and

h is the halving factor for the logistic curve.

The total electricity generation for each year (E_t) is calculated by applying this share to total delivered energy:

$$E_t = f_t^E \cdot D_t \qquad (5)$$

Nuclear Share of Electrical Energy

The nuclear share of electrical generation is also derived using a logistic penetration function:

$$f_t^N = \frac{f_\infty^N}{1 + e^{-(\tau + \mu t)}} \quad , \qquad (6)$$

where:

f_t^N is the nuclear share of electricity in year t,

f_∞^N is the asymptotic nuclear share,

τ and μ are the logistic curve parameters,

$\tau = \ln\left[f_0^N \;/\; (f_\infty^N - f_0^N)\right]$, and

$\mu = (1 / h) \cdot \ln\left[(f_\infty^N + f_0^N) \;/\; f_0^N\right]$.

Again, nuclear generation (N_t) is calculated by applying the nuclear share to total electricity for each year:

$$N_t = f_t^N \cdot E_t \quad . \qquad (7)$$

Finally, nuclear generating capacity is calculated using an average capacity factor (CF):

$$C_t = N_t / (CF \cdot 365 \cdot 24) \quad . \qquad (8)$$

Appendix C

U.S. Nuclear Generating Units Operable as of December 31, 1989

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Appendix C

U.S. Nuclear Generating Units Operable as of December 31, 1989

Table C1. Roster of U.S. Nuclear Generating Units Operable as of December 31, 1989, by Federal Region and State

Site	Unit Name	Capacity [a] (Net MWe)	Utility [b]	Reactor [c] Type	Reactor [c] Supplier	Date Operable
Region I -- New England						
Connecticut						
Haddam Neck	Haddam Neck (Connecticut Yankee)	565	Connecticut L&P	PWR	W	8/67
Waterford	Millstone 1	652	Connecticut L&P	BWR	GE	11/70
Waterford	Millstone 2	863	Connecticut L&P	PWR	CE	11/75
Waterford	Millstone 3	1,137	Connecticut L&P	PWR	W	1/86
Maine						
Wiscasset	Maine Yankee	845	Maine Yankee Atomic Power	PWR	CE	11/72
Massachusetts						
Plymouth	Pilgrim 1	667	Boston Edison	BWR	GE	7/72
Rowe	Yankee Rowe 1	167	New England Power	PWR	W	11/60
Vermont						
Vernon	Vermont Yankee	496	Vermont Yankee Nuclear Power	BWR	GE	9/72
Total Region I		5,391 [d]				
Region II -- New York/New Jersey						
New York						
Buchanan	Indian Point 2	849	Consolidated Edison	PWR	W	6/73
Buchanan	Indian Point 3	965	Power Authority of the State of New York	PWR	W	4/76
Rochester	Robert E. Ginna	470	Rochester Gas & Electric	PWR	W	12/69
Oswego	Nine Mile Point 1	610	Niagara Mohawk Power	BWR	GE	11/69
Oswego	Nine Mile Point 2	1,072	Niagara Mohawk Power	BWR	GE	7/87
Scriba	James A. Fitzpatrick	800	Power Authority of the State of New York	BWR	GE	2/75
New Jersey						
Forked River	Oyster Creek 1	620	Jersey Central P&L	BWR	GE	9/69
Salem	Salem 1	1,106	Public Service E&G and Philadelphia Electric	PWR	W	12/76
Salem	Salem 2	1,106	Public Service E&G and Philadelphia Electric	PWR	W	6/81
Salem	Hope Creek 1	1,031	Public Service E&G	BWR	GE	7/86
Total Region II		8,629				

See footnotes at end of table.

Table C1. Roster of U.S. Nuclear Generating Units Operable as of December 31, 1989, by Federal Region and State (Continued)

Site	Unit Name	Capacity [a] (Net MWe)	Utility [b]	Reactor [c] Type	Reactor [c] Supplier	Date Operable
Region III -- Middle Atlantic						
Maryland						
Lusby	Calvert Cliffs 1	825	Baltimore G&E	PWR	C-E	1/75
Lusby	Calvert Cliffs 2	825	Baltimore G&E	PWR	C-E	12/76
Pennsylvania						
Berwick	Susquehanna 1	1,050	Pennsylvania P&L	BWR	GE	11/82
Berwick	Susquehanna 2	1,050	Pennsylvania P&L	BWR	GE	6/84
Middletown	Three Mile Island 1	808	Metropolitan Edison	PWR	B&W	6/74
Lancaster	Peach Bottom 2	1,051	Philadelphia Electric and Public Service E&G	BWR	GE	2/74
Lancaster	Peach Bottom 3	1,035	Philadelphia Electric and Public Service E&G	BWR	GE	9/74
Pottstown	Limerick 1	1,055	Philadelphia Electric	BWR	GE	8/85
Pottstown	Limerick 2	1,055	Philadelphia Electric	BWR	GE	8/89
Shippingport	Beaver Valley 1	810	Duquesne Light	PWR	W	6/76
Shippingport	Beaver Valley 2	833	Ohio Edison	PWR	W	8/87
Virginia						
Surry	Surry 1	781	Virginia Electric & Power	PWR	W	7/72
Surry	Surry 2	781	Virginia Electric & Power	PWR	W	3/73
Mineral	North Anna 1	915	Virginia Electric & Power	PWR	W	4/78
Mineral	North Anna 2	915	Virginia Electric & Power	PWR	W	8/80
Total Region III		**13,789**				
Region IV -- South Atlantic						
Alabama						
Decatur	Browns Ferry 1	1,065	Tennessee Valley Authority	BWR	GE	10/73
Decatur	Browns Ferry 2	1,065	Tennessee Valley Authority	BWR	GE	8/74
Decatur	Browns Ferry 3	1,065	Tennessee Valley Authority	BWR	GE	9/76
Dothan	Joseph M. Farley 1	816	Alabama Power	PWR	W	8/77
Dothan	Joseph M. Farley 2	825	Alabama Power	PWR	W	5/81
Florida						
Florida City	Turkey Point 3	666	Florida P&L	PWR	W	11/72
Florida City	Turkey Point 4	666	Florida P&L	PWR	W	6/73
Ft. Pierce	St. Lucie 1	839	Florida P&L	PWR	C-E	5/76
Ft. Pierce	St. Lucie 2	839	Florida P&L	PWR	C-E	6/83
Red Level	Crystal River 3	666	Florida Power Corp	PWR	B&W	1/77
Georgia						
Baxley	Hatch 1	760	Georgia Power	BWR	GE	11/74
Baxley	Hatch 2	772	Georgia Power	BWR	GE	9/78
Waynesboro	Vogtle 1	1,086	Georgia Power	PWR	W	3/87
Waynesboro	Vogtle 2	1,086	Georgia Power	PWR	W	3/89
Mississippi						
Port Gibson	Grand Gulf 1	1,142	System Energy Resources, Inc.	BWR	GE	9/84

See footnotes at end of table.

Table C1. Roster of U.S. Nuclear Generating Units Operable as of December 31, 1989, by Federal Region and State (Continued)

Site	Unit Name	Capacity [a] (Net MWe)	Utility [b]	Reactor [c] Type	Reactor [c] Supplier	Date Operable
Region IV -- South Atlantic (continued)						
North Carolina						
Cowens Ford Dam	McGuire 1	1,129	Duke Power	PWR	W	9/81
Cowens Ford Dam	McGuire 2	1,129	Duke Power	PWR	W	3/83
New Hill	Shearon Harris 1	860	Carolina P&L	PWR	GE	1/87
Southport	Brunswick 1	790	Carolina P&L	BWR	GE	12/76
Southport	Brunswick 2	790	Carolina P&L	BWR	GE	4/75
South Carolina						
Clover	Catawba 1	1,129	North Carolina Electric Membership Corporation	PWR	W	1/85
Clover	Catawba 2	1,129	North Carolina Municipal Power	PWR	W	5/86
Hartsville	H.B. Robinson 2	665	Carolina P&L	PWR	W	9/70
Jenkinsville	Summer 1	885	South Carolina E&G	PWR	W	11/82
Seneca	Oconee 1	846	Duke Power	PWR	B&W	5/73
Seneca	Oconee 2	846	Duke Power	PWR	B&W	12/73
Seneca	Oconee 3	846	Duke Power	PWR	B&W	9/74
Tennessee						
Daisy	Sequoyah 1	1,148	Tennessee Valley Authority	PWR	W	7/80
Daisy	Sequoyah 2	1,148	Tennessee Valley Authority	PWR	W	12/81
Total Region IV		**26,697** [d]				
Region V -- Midwest						
Illinois						
Braidwood	Braidwood 1	1,090	Commonwealth Edison	PWR	W	7/87
Braidwood	Braidwood 2	1,090	Commonwealth Edison	PWR	W	5/88
Byron	Byron 1	1,120	Commonwealth Edison	PWR	W	2/85
Byron	Byron 2	1,120	Commonwealth Edison	PWR	W	1/87
Clinton	Clinton 1	930	Illinois Power	BWR	GE	4/87
Cordova	Quad Cities 1	769	Commonwealth Edison	BWR	GE	4/72
Cordova	Quad Cities 2	769	Commonwealth Edison	BWR	GE	5/72
Morris	Dresden 2	772	Commonwealth Edison	BWR	GE	4/70
Morris	Dresden 3	773	Commonwealth Edison	BWR	GE	7/71
Seneca	LaSalle 1	1,048	Commonwealth Edison	BWR	GE	9/82
Seneca	LaSalle 2	1,048	Commonwealth Edison	BWR	GE	3/84
Zion	Zion 1	1,040	Commonwealth Edison	PWR	W	6/73
Zion	Zion 2	1,040	Commonwealth Edison	PWR	W	12/73
Michigan						
Bridgman	Donald C. Cook 1	1,030	Indiana & Michigan Electric	PWR	W	2/75
Bridgman	Donald C. Cook 2	1,100	Indiana & Michigan Electric	PWR	W	3/78
Charlevoix	Big Rock Point	67	Consumers Power	BWR	GE	12/62
Newport	Fermi 2	1,028	Detroit Edison	BWR	GE	7/85
South Haven	Palisades	755	Consumers Power	PWR	C-E	12/71

See footnotes at end of table.

Table C1. Roster of U.S. Nuclear Generating Units Operable as of December 31, 1989, by Federal Region and State (Continued)

Site	Unit Name	Capacity [a] (Net MWe)	Utility [b]	Reactor [c] Type	Reactor [c] Supplier	Date Operable
Region V -- Midwest (continued)						
Minnesota						
Monticello	Monticello	541	Northern States Power	BWR	GE	6/71
Red Wing	Prairie Island 1	504	Northern States Power	PWR	W	12/73
Red Wing	Prairie Island 2	504	Northern States Power	PWR	W	12/74
Ohio						
Oak Harbor	Davis-Besse 1	856	Cleveland Elec. Illum.	PWR	B&W	8/77
North Perry	Perry 1	1,185	Ohio Edison	BWR	GE	11
Wisconsin						
Carlton	Kewaunee	530	Wisconsin Public Service	PWR	W	6/74
Two Creeks	Point Beach 1	485	Wisconsin Electric Power	PWR	W	11/70
Two Creeks	Point Beach 2	485	Wisconsin Electric Power	PWR	W	8/72
Total Region V		**21,679**				
Region VI -- Southwest						
Arkansas						
Russellville	Arkansas Nuclear 1	836	Arkansas P&L	PWR	B&W	7/74
Russellville	Arkansas Nuclear 2	858	Arkansas P&L	PWR	C-E	12/78
Louisiana						
St. Francisville	River Bend 1	936	Gulf States Utilities	BWR	GE	11/85
Taft	Waterford 3	1,075	Louisiana P&L	PWR	C-E	9/85
Texas						
Bay City	South Texas 1	1,251	Houston L&P	PWR	W	8/88
Bay City	South Texas 2	1,250	Houston L&P	PWR	W	6/89
Total Region VI		**6,206**				
Region VII -- Central						
Iowa						
Palo	Duane Arnold	500	Iowa Electric L&P	BWR	GE	5/74
Kansas						
Burlington	Wolf Creek	1,128	Kansas City P&L and Kansas Gas & Electric	PWR	W	6/85
Missouri						
Fulton	Callaway 1	1,118	Union Electric	PWR	W	10/84
Nebraska						
Brownville	Cooper	778	Nebraska Public Power District	BWR	GE	5/74
Fort Calhoun	Fort Calhoun 1	476	Omaha Public Power District	PWR	C-E	8/73
Total Region VII		**4,000**				

See footnotes at end of table.

Table C1. Roster of U.S. Nuclear Generating Units Operable as of December 31, 1989, by Federal Region and State (Continued)

Site	Unit Name	Capacity [a] (Net MWe)	Utility [b]	Reactor [c] Type	Reactor [c] Supplier	Date Operable
Region IX -- West						
Arizona						
Wintersburg	Palo Verde 1	1,221	Arizona Public Service	PWR	C-E	6/85
Wintersburg	Palo Verde 2	1,221	Arizona Public Service	PWR	C-E	4/86
Wintersburg	Palo Verde 3	1,221	Arizona Public Service	PWR	C-E	11/87
California						
Avila Beach	Diablo Canyon 1	1,073	Pacific Gas and Electric	PWR	W	11/84
Avila Beach	Diablo Canyon 2	1,079	Pacific Gas and Electric	PWR	W	8/85
Clay Station	Rancho Seco	873	Sacramento Municipal Utility District	PWR	B&W	10/74
San Clemente	San Onofre 1	436	Southern California Edison	PWR	W	7/67
San Clemente	San Onofre 2	1,070	Southern California Edison	PWR	C-E	9/82
San Clemente	San Onofre 3	1,080	Southern California Edison	PWR	C-E	9/83
Total Region IX		**9,274**				
Region X -- Northwest						
Oregon						
Prescott	Trojan	1,104	Portland General Electric	PWR	W	12/75
Washington						
Richland	WNP-2	1,100	Washington Public Power Supply System	BWR	GE	4/84
Total Region X		**2,204**				
Total United States (110 Units)		**97,869**				

[a] Net summer capability.
[b] Principal owner.
[c] Reactor Type: BWR, boiling-water reactor; HTGR, high-temperature gas-cooled reactor; LGR, light-water-cooled, graphite-moderated reactor; PWR, pressurized water reactor. Reactor Supplier: B&W, Babcock and Wilcox Co.; C-E, Combustion Engineering, Inc.; GE, General Electric; W, Westinghouse Corp. Electric Corporation.
[d] Totals may not equal sum of components due to independent rounding.
Source: Capacity shown is net summer capability, as reported to the Energy Information Administration (EIA) in the January 1989 Form EIA-860 survey.

Appendix D

U.S. Nuclear Generating Units in the Construction Pipeline as of December 31, 1989

Appendix D

U.S. Nuclear Generating Units in the Construction Pipeline as of December 31, 1989

Table D1. Roster of U.S. Nuclear Generating Units in the Construction Pipeline as of December 31, 1989, by Federal Region and State

Site	Unit Name	Net Summer Capability (Net MWe)	Utility [a]	Reactor [b]		Status [c]		Estimated Operable Date [d]		
									EIA [e]	
				Type	Supplier	% Complete	License	Utility [d]	LR	UR
Region I -- New England										
New Hampshire										
Seabrook	Seabrook 1	1,150	Public Service Co of New Hampshire	PWR	W	100	LP [f]	3/90	6/90	6/90
Total Region I		**1,150**								
Region II --	**New York/New Jersey**	0 [h]								
Region III --	**Middle Atlantic**	0								
Region IV -- South Atlantic										
Alabama										
Scottsboro	Bellefonte 1	1,212	Tennessee Valley Authority	PWR	B&W	85	ID	(g)	6/2000	6/2000
Scottsboro	Bellefonte 2	1,212	Tennessee Valley Authority	PWR	B&W	56	ID	(g)	6/2009	6/2009
Mississippi										
Port Gibson	Grand Gulf 2	1,250	Middle South Utilities	BWR	GE	34	ID	(g)	--	--
Tennessee										
Spring City	Watts Bar 1	1,170	Tennessee Valley Authority	PWR	W	99	CP	6/91	6/92	6/92
Spring City	Watts Bar 2	1,170	Tennessee Valley Authority	PWR	W	84	CP	(g)	3/95	3/95
Total Region IV		**6,014**								
Region V -- Midwest										
Ohio										
North Perry	Perry 2	1,179	Cleveland Electric Illuminating	BWR	GE	44	ID	(g)	--	6/2009
Total Region V		**1,179**								

See footnotes at end of table.

Table D1. Roster of U.S. Nuclear Generating Units in the Construction Pipeline as of December 31, 1989, by Federal Region and State (Continued)

Site	Unit Name	Net Summer Capability (Net MWe)	Utility [a]	Reactor [b]		Status [c]		Estimated Operable Date [d]		
				Type	Sup-plier	% Com-plete	Li-cense	Utility [d]	EIA [e] LR	EIA [e] UR
Region VI -- Southwest										
Texas										
Glen Rose	Comanche Peak 1	1,150	Texas Utilities Generating Co.	PWR	W	99	CP [i]	10/89	4/90	4/90
Glen Rose	Comanche Peak 2	1,150	Texas Utilities Generating Co.	PWR	W	87	CP	4/91	3/92	3/92
Total Region VI		**2,300**								
Region VII -- Central		0								
Region VIII -- North Central		0								
Region IX -- West		0								
Region X -- Northwest										
Washington										
Richland	WNP 1	1,250	Washington Public Power Supply System	PWR	B&W	63	ID	(g)	6/2001	6/2001
Satsop	WNP 3	1,250	Washington Public Power Supply System	PWR	C-E	75	ID	(g)	--	6/2006
Total Region X		**2,500**								
Total United States (11 Units)		**13,143** [h]								

[a] Principal owner.
[b] Reactor Type: BWR, boiling-water reactor; PWR, pressurized-water reactor. Reactor Suppliers: B&W, Babcock and Wilcox Co.; C-E, Combustion Engineering, Inc.; GE, General Electric Corporation; W, Westinghouse Corp.
[c] License Status: CP, construction permit issued; ID, indefinitely deferred; LP, low power operating license issued.
[d] Represents the approximate midpoint between the first fuel load date and the commercial operation date, as reported on Form EIA-254, second half 1989.
[e] EIA estimates for the Lower Reference (LR) and Upper Reference (UR) cases, as described in the text.
[f] Seabrook received a Full-Power License in March of 1990.
[g] No commercial operation date has been estimated by the utility.
[h] Shoreham received a full power license in April 1989. Since the unit is not currently scheduled to operate, it has not been included in the total for units in the construction pipeline or operable units.
[i] Comanche Peak received a Low-Power License in February, and a Full-Power License in April of 1990.
Sources: Nuclear Regulatory Commission, *Licensed Operating Reactors*, NUREG-0020 (December 1983); Nuclear Regulatory Commission, *Regulatory Licensing Status Summary Report*, NUREG-0580 (January 1985); and Energy Information Administration, Form EIA-254, "Semiannual Report on Status of Reactor Construction" (1988).

Appendix E

Nuclear Generating Unit Reactors Ordered in the United States, 1953-1989

99/100

Appendix E

Nuclear Generating Unit Reactors Ordered in the United States, 1953-1989

Table E1. Nuclear Generating Unit Reactors Ordered in the United States, 1953-1989, by Year of Order

Year of Order	Yearly Total: No. of Units Ordered	Yearly Total: Design Capacity (MWe)	Individual Reactors: Unit Name	Individual Reactors: Design Capacity (MWe)	Individual Reactors: Reactor Supplier [a]	Individual Reactors: Current Status (December 31, 1989)
1953	1	60	Shippingport	60	W	Shut down, 1974. Resumed operation in 1977 as a light-water breeder reactor. Retired in 1982.
1955	2	465	Indian Point 1	265	B&W	Shut down, 1974. Operating license withdrawn in 1980.
			Dresden 1	200	GE	Shut down, 1978. Decommissioning being planned.
1956	1	175	Yankee Rowe 1	175	W	Operating.
1958	1	65	Humboldt Bay	65	GE	Shut down, 1976. Decommissioning being planned.
1959	1	72	Big Rock Point	72	GE	Operating.
1962	2	632	La Crosse	50	A-C	Retired 1987.
			Haddam Neck (Connecticut Yankee)	582	W	Operating.
1963	5	3,018	Malibu	462	W	Canceled, 1972.
			San Onofre 1	436	W	Operating.
			Hanford-N	850	GE	Shut down. [b]
			Nine Mile Point 1	620	GE	Shut down. Restart planned for 8/89.
			Oyster Creek	650	GE	Operating.
1965	7	4,475	Dresden 2	794	GE	Operating.
			Fort St. Vrain	330	GA	Shutdown 1989.
			Robert E. Ginna	470	W	Operating.
			Pilgrim 1	655	GE	Operating.
			Millstone 1	660	GE	Operating.
			Indian Point 2	873	W	Operating.
			Turkey Point 3	693	W	Operating.

See footnotes at end of table.

Table E1. Nuclear Generating Unit Reactors Ordered in the United States, 1953-1989, by Year of Order (Continued)

Year of Order	Yearly Total: No. of Units Ordered	Yearly Total: Design Capacity (MWe)	Unit Name	Design Capacity (MWe)	Reactor Supplier [a]	Current Status (December 31, 1989)
1966	20	16,514	Dresden 3	794	GE	Operating.
			Palisades	805	C-E	Operating.
			H.B. Robinson 2	700	W	Operating.
			Point Beach 1	497	W	Operating.
			Monticello	545	GE	Operating.
			Quad-Cities 1	789	GE	Operating.
			Browns Ferry 1	1,065	GE	Shut down. Restart unknown.
			Browns Ferry 2	1,065	GE	Shut down. Restart planned for 9/89.
			Oconee 1	887	B&W	Operating.
			Oconee 2	887	B&W	Operating.
			Quad-Cities 2	789	GE	Operating.
			Peach Bottom 2	1,065	GE	Shut down. [c]
			Peach Bottom 3	1,065	GE	Shut down. [d]
			Salem 1	1,090	W	Operating.
			Vermont Yankee	514	GE	Operating.
			Fort Calhoun 1	478	C-E	Operating.
			Surry 1	788	W	Operating.
			Surry 2	788	W	Operating.
			Diablo Canyon 1	1,084	W	Operating.
			Three Mile Island 1	819	B&W	Operating.
1967	31	26,470	Bell	838	--	Canceled, 1972.
			Bailly	644	GE	Canceled, 1981.
			Crystal River 3	825	B&W	Operating.
			Kewaunee	535	W	Operating.
			Maine Yankee	825	C-E	Operating.
			Prairie Island 1	530	W	Operating.
			Point Beach 2	497	W	Operating.
			Shoreham	820	GE	Operating license issued. [e]
			Zion 1	1,040	W	Operating.
			Three Mile Island 2	906	B&W	Shut down due to 1979 accident
			Arkansas Nuclear 1	850	B&W	Operating.
			Cooper	778	GE	Operating.
			Indian Point 3	965	W	Operating.
			Turkey Point 4	693	W	Operating.
			Calvert Cliffs 1	845	C-E	Operating.
			Calvert Cliffs 2	845	C-E	Operating.
			Oconee 3	887	B&W	Operating.
			Salem 2	1,115	W	Operating.
			Browns Ferry 3	1,065	GE	Shut down. Restart unknown.
			Prairie Island 2	530	W	Operating.
			Donald C. Cook 1	1,030	W	Operating.
			Donald C. Cook 2	1,100	W	Operating.
			Zion 2	1,040	W	Operating.
			Rancho Seco 1	918	B&W	Operating. [f]
			Beaver Valley 1	835	W	Operating.
			Limerick 1	1,065	GE	Operating.
			Limerick 2	1,065	GE	Operating.
			North Anna 1	907	W	Operating.
			Hatch 1	777	GE	Operating.
			Millstone 2	870	C-E	Operating.
			St. Lucie 1	830	C-E	Operating.

See footnotes at end of table.

Table E1. Nuclear Generating Unit Reactors Ordered in the United States, 1953-1989, by Year of Order (Continued)

Year of Order	Yearly Total: No. of Units Ordered	Yearly Total: Design Capacity (MWe)	Individual Reactors: Unit Name	Design Capacity (MWe)	Reactor Supplier [a]	Current Status (December 31, 1989)
1968	16	15,167	Verplanck 1	1,115	GE	Canceled, 1972.
			Verplanck 2	1,115	GE	Canceled, 1972.
			Brunswick 1	821	GE	Operating.
			Brunswick 2	821	GE	Operating.
			Duane Arnold 1	538	GE	Operating.
			Sequoyah 1	1,148	W	Operating.
			Sequoyah 2	1,148	W	Operating.
			Midland 1	492	B&W	Canceled, 1986.
			Midland 2	818	B&W	Canceled, 1986.
			Susquehanna 1	1,065	GE	Operating.
			Susquehanna 2	1,052	GE	Operating.
			Diablo Canyon 2	1,084	W	Operating.
			Fermi 2	1,093	GE	Operating.
			Davis-Besse 1	906	B&W	Operating.
			Trojan	1,130	W	Operating.
			James A. Fitzpatrick	821	GE	Operating.
1969	7	7,203	Joseph M. Farley 1	829	W	Operating.
			Hope Creek 1	1,067	GE	Operating
			Hope Creek 2	1,067	GE	Canceled, 1981.
			Zimmer 1	810	GE	Canceled, 1984.
			McGuire 1	1,180	W	Operating.
			McGuire 2	1,180	W	Operating.
			Forked River 1	1,070	C-E	Canceled, 1980.
1970	14	14,272	North Anna 2	907	W	Operating.
			San Onofre 2	1,070	C-E	Operating.
			San Onofre 3	1,080	C-E	Operating.
			Hatch 2	784	GE	Operating.
			Arkansas Nuclear 2	912	C-E	Operating.
			LaSalle 1	1,078	GE	Operating.
			LaSalle 2	1,078	GE	Operating.
			North Coast 1	583	W	Canceled, 1978.
			Bellefonte 1	1,235	B&W	Indefinitely deferred.
			Bellefonte 2	1,235	B&W	Indefinitely deferred.
			Watts Bar 1	1,165	W	Under construction.
			Watts Bar 2	1,165	W	Under construction. [g]
			Waterford 3	1,151	C-E	Operating.
			Joseph M. Farley 2	829	W	Operating.
1971	21	21,193	Crystal River 4	897	W	Canceled, 1972.
			Stanislaus 1	1,200	GE	Canceled, 1979.
			Stanislaus 2	1,200	GE	Canceled, 1979.
			Summer 1	900	W	Operating.
			WNP 2	1,100	GE	Operating.
			Byron 1	1,120	W	Operating.
			Byron 2	1,120	W	Operating.
			Shearon Harris 1	915	W	Operating.
			Shearon Harris 2	915	W	Canceled, 1983.
			Shearon Harris 3	900	W	Canceled, 1981.
			Shearon Harris 4	900	W	Canceled, 1981.
			North Anna 3	907	B&W	Canceled, 1982.
			North Anna 4	907	B&W	Canceled, 1980.
			Fulton 1	1,160	GA	Canceled, 1975.
			Fulton 2	1,160	GA	Canceled, 1975.
			Beaver Valley 2	852	W	Operating.
			Vogtle 1	1,210	W	Operating.
			Vogtle 2	1,210	W	Operating.
			Nine Mile Point 2	1,080	GE	Operating.
			Summit 1	770	GA	Canceled, 1975.
			Summit 2	770	GA	Canceled, 1975.

See footnotes at end of table.

Table E1. Nuclear Generating Unit Reactors Ordered in the United States, 1953-1989, by Year of Order (Continued)

Year of Order	Yearly Total: No. of Units Ordered	Yearly Total: Design Capacity (MWe)	Individual Reactors: Unit Name	Design Capacity (MWe)	Reactor Supplier [a]	Current Status (December 31, 1989)
1972	38	41,373	Perryman 1	845	C-E	Canceled, 1972.
			Perryman 2	845	C-E	Canceled, 1972.
			Fermi 3	1,171	GE	Canceled, 1974.
			Quanicassee 1	1,150	W	Canceled, 1974.
			Quanicassee 2	1,150	W	Canceled, 1974.
			Vidal 1	770	GA	Canceled, 1974.
			Vidal 2	770	GA	Canceled, 1974.
			Grand Gulf 1	1,250	GE	Operating.
			Grand Gulf 2	1,250	GE	Indefinitely deferred.
			Pilgrim 2	1,150	C-E	Canceled. 1981.
			Greenwood 2	1,264	B&W	Canceled, 1980.
			Greenwood 3	1,264	B&W	Canceled, 1980.
			Perry 1	1,205	GE	Operating.
			Perry 2	1,205	GE	Indefinitely deferred.
			Seabrook 1	1,198	W	Operating license issued.
			Seabrook 2	1,198	W	Canceled, 1988. [h]
			Catawba 1	1,145	W	Operating.
			Catawba 2	1,145	W	Operating.
			River Bend 1	934	GE	Operating.
			Atlantic 1	1,150	W	Canceled, 1978.
			Atlantic 2	1,150	W	Canceled, 1978.
			Braidwood 1	1,120	W	Operating.
			Braidwood 2	1,120	W	Operating.
			Douglas Point 1	1,146	GE	Canceled, 1977.
			Douglas Point 2	1,146	GE	Canceled, 1977.
			Surry 3	859	B&W	Canceled, 1977.
			Surry 4	859	B&W	Canceled, 1977.
			Comanche Peak 1	1,150	W	Under construction.
			Comanche Peak 2	1,150	W	Under construction.
			Clinch River Breeder	350	W	Canceled, 1983.
			St. Lucie 2	804	C-E	Operating.
			WNP 1	1,266	B&W	Indefinitely deferred. [i]
			Barton 1	1,159	GE	Canceled, 1977.
			Barton 2	1,159	GE	Canceled, 1977.
			Hartsville A1	1,205	GE	Canceled, 1984.
			Hartsville A2	1,205	GE	Canceled, 1984.
			Hartsville B1	1,233	GE	Canceled, 1982.
			Hartsville B2	1,233	GE	Canceled, 1982.

See footnotes at end of table.

Table E1. Nuclear Generating Unit Reactors Ordered in the United States, 1953-1989, by Year of Order (Continued)

Year of Order	Yearly Total: No. of Units Ordered	Yearly Total: Design Capacity (MWe)	Individual Reactors: Unit Name	Design Capacity (MWe)	Reactor Supplier [a]	Current Status (December 31, 1989)
1973	**41**	**46,975**	Tyrone 2	1,150	W	Canceled, 1974.
			Vogtle 3	1,113	W	Canceled, 1974.
			Vogtle 4	1,113	W	Canceled, 1974.
			Clinton 1	950	GE	Operating
			Clinton 2	950	GE	Canceled, 1983.
			Blue Hills 1	918	C-E	Canceled, 1978.
			Millstone 3	1,156	W	Operating.
			Pebble Springs 1	1,260	B&W	Canceled, 1982.
			Allens Creek 1	1,150	GE	Canceled, 1982.
			Allens Creek 2	1,150	GE	Canceled, 1976.
			Cherokee 1	1,280	C-E	Canceled, 1983.
			Cherokee 2	1,280	C-E	Canceled, 1982.
			Cherokee 3	1,280	C-E	Canceled, 1982.
			Perkins 1	1,280	C-E	Canceled, 1982.
			Perkins 2	1,280	C-E	Canceled, 1982.
			Perkins 3	1,280	C-E	Canceled, 1982.
			Jamesport 1	1,150	W	Rejected by New York State, 1980.
			Callaway 1	1,188	W	Operating.
			Callaway 2	1,120	W	Canceled, 1981.
			Haven 1	900	W	Canceled, 1980.
			Haven 2	900	W	Canceled, 1978.
			South Texas 1	1,250	W	Operating.
			South Texas 2	1,250	W	Operating.
			Sterling	1,150	W	Canceled, 1980.
			Tyrone 1	1,100	W	Canceled, 1979.
			Wolf Creek	1,150	W	Operating.
			WNP 3	1,242	C-E	Indefinitely deferred. [i]
			River Bend 2	934	GE	Canceled, 1984.
			Palo Verde 1	1,304	C-E	Operating.
			Palo Verde 2	1,304	C-E	Operating.
			Palo Verde 3	1,304	C-E	Operating.
			Atlantic 3	1,150	W	Canceled, 1978.
			Atlantic 4	1,150	W	Canceled, 1978.
			Black Fox 1	1,150	GE	Canceled, 1982.
			Black Fox 2	1,150	GE	Canceled, 1982.
			Davis-Besse 2	906	B&W	Canceled, 1980.
			Davis-Besse 3	906	B&W	Canceled, 1980.
			Skagit-Hanford 1	1,277	GE	Canceled, 1983.
			South River 1	1,150	B&W	Canceled, 1978.
			South River 2	1,150	B&W	Canceled, 1978.
			South River 3	1,150	B&W	Canceled, 1978.

See footnotes at end of table.

Table E1. Nuclear Generating Unit Reactors Ordered in the United States, 1953-1989, by Year of Order (Continued)

Year of Order	Yearly Total: No. of Units Ordered	Yearly Total: Design Capacity (MWe)	Individual Reactors: Unit Name	Design Capacity (MWe)	Reactor Supplier [a]	Current Status (December 31, 1989)
1974	28	33,265	Orange 1	1,300	C-E	Canceled, 1975.
			Orange 2	1,300	C-E	Canceled, 1975.
			St. Rosalie 1	1,160	GA	Canceled, 1975.
			St. Rosalie 2	1,160	GA	Canceled, 1975.
			Somerset 1	1,200	GE	Canceled, 1975.
			Somerset 2	1,200	GE	Canceled, 1975.
			Zimmer 2	1,170	GE	Canceled, 1978.
			Jamesport 2	1,150	W	Rejected by New York State, 1980.
			Blue Hills 2	918	C-E	Canceled, 1978.
			Nees 1	1,150	W	Canceled, 1979.
			Nees 2	1,150	W	Canceled, 1979.
			Pebble Springs 2	1,260	B&W	Canceled, 1982.
			Greene County	1,212	B&W	Canceled, 1979.
			Montague 1	1,150	GE	Canceled, 1980.
			Montague 2	1,150	GE	Canceled, 1980.
			Skagit-Hanford 2	1,277	GE	Canceled, 1983.
			WNP 4	1,218	B&W	Canceled, 1982.
			WNP 5	1,240	C-E	Canceled, 1982.
			Fort Calhoun 2	1,136	W	Canceled, 1977.
			Marble Hill 1	1,130	W	Canceled, 1985.
			Marble Hill 2	1,130	W	Canceled, 1985.
			Phipps 1	1,233	GE	Canceled, 1982.
			Phipps 2	1,233	GE	Canceled, 1982.
			Yellow Creek 1	1,285	C-E	Canceled, 1984.
			Yellow Creek 2	1,285	C-E	Canceled, 1984.
			Barton 3	1,159	GE	Canceled, 1975.
			Barton 4	1,159	GE	Canceled, 1975.
			Sears Isle	1,150	W	Canceled, 1977.
1975	4	4,148	South Dade 1	1,100	W	Canceled, 1977.
			South Dade 2	1,100	W	Canceled, 1977.
			Sundesert 1	974	W	Canceled, 1978.
			Sundesert 2	974	W	Canceled, 1978.
1976	3	3,804	Vandalia (Iowa 1)	1,270	B&W	Canceled, 1982.
			Erie 1	1,267	B&W	Canceled, 1980.
			Erie 2	1,267	B&W	Canceled, 1980.
1977	4	5,040	NYSE&G 1	1,250	C-E	Rejected by New York State, 1980.
			NYSE&G 2	1,250	C-E	Rejected by New York State, 1980.
			Palo Verde 4	1,270	C-E	Canceled, 1979.
			Palo Verde 5	1,270	C-E	Canceled, 1979.
1978	2	2,240	Carroll County 1	1,120	W	Canceled, 1988.
			Carroll County 2	1,120	W	Canceled, 1988.

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

[c]Resumed operation, June 1989

[d]Restart authorized

[e]A tentative agreement has been made between the State of New York and Long Island Lighting Company to close the plant.

[f]Shutdown by referendum, June 1989.

[g]Unit is in an indefinite slowdown. No schedule exists for its completion.

[h]Construction permit expired in October, 1988

[i]Extension of Construction Permit requested

Sources: Energy Information Administration, *U.S. Commercial Nuclear Power*, DOE/EIA-0315 (Washington, DC, November 1984); Energy Information Administration, *Nuclear Plant Cancellations: Causes, Costs, and Consequences*, DOE/EIA-0392 (Washington, DC, April 1983); Energy Information Administration, Form EIA-254, "Semiannual Report on Status of Reactor Construction"; Nuclear Regulatory Commission, *Licensed Operating Reactors*, NUREG-0020 (November 1986)

Appendix F

Foreign FME Nuclear Generating Units Operable as of December 31, 1989

Appendix F

Foreign FME Nuclear Generating Units Operable as of December 31, 1989

Table F1. Roster of Nuclear Generating Units Operable as of December 31, 1989, in Foreign Countries with FME

Country	Unit Name [a]	Location	Capacity [b] (Net MWe)	Utility [c]	Reactor Type [d]	Reactor Supplier [e]	Date of Operation [f]
Argentina	Atucha 1	Lima, Buenos Aires	335	CN	PHWR	SIEM/KWU	1974
	Embalse	Cordoba, Rio Tercero	600	CN	PHWR	AECL	1983
Total	**2 Units**		**935**				
Belgium	Doel 1	Antwerp	400	ID	PWR	ACE	1974
	Doel 2	Antwerp	400	ID	PWR	ACE	1975
	Doel 3	Antwerp	900	EB	PWR	FRAM	1982
	Doel 4	Antwerp	1,010	EB	PWR	ACEC	1985
	Tihange 1	Huy, Liege	870	SE	PWR	ACLF	1975
	Tihange 2	Huy, Liege	900	IT	PWR	FRAM	1982
	Tihange 3	Huy, Liege	1,020	IT	PWR	ACEC	1985
Total	**7 Units**		**5,500**				
Brazil	Angra 1	Itaorna	626	BZ	PWR	WEST	1982
Total	**1 Unit**		**626**				
Canada	Bruce 1	Tiverton, Ontario	769	ON	PHWR	AECL	1977
	Bruce 2	Tiverton, Ontario	769	ON	PHWR	AECL	1976
	Bruce 3	Tiverton, Ontario	769	ON	PHWR	AECL	1977
	Bruce 4	Tiverton, Ontario	769	ON	PHWR	AECL	1978
	Bruce 5	Tiverton, Ontario	860	ON	PHWR	AECL	1984
	Bruce 6	Tiverton, Ontario	837	ON	PHWR	AECL	1984
	Bruce 7	Tiverton, Ontario	860	ON	PHWR	AECL	1986
	Bruce 8	Tiverton, Ontario	837	ON	PHWR	AECL	1987
	Gentilly 2	Becancour, Quebec	638	HQ	PHWR	AECL	1982
	Pickering 1	Pickering, Ontario	515	ON	PHWR	AECL	1971
	Pickering 2	Pickering, Ontario	515	ON	PHWR	AECL	1971
	Pickering 3	Pickering, Ontario	515	ON	PHWR	AECL	1972
	Pickering 4	Pickering, Ontario	515	ON	PHWR	AECL	1973
	Pickering 5	Pickering, Ontario	516	ON	PHWR	AECL	1982
	Pickering 6	Pickering, Ontario	516	ON	PHWR	AECL	1983
	Pickering 7	Pickering, Ontario	516	ON	PHWR	AECL	1984
	Pickering 8	Pickering, Ontario	516	ON	PHWR	AECL	1985
	Point Lepreau	Bay of Fundy, New Brunswick	640	NB	PHWR	AECL	1982
Total	**18 Units**		**11,872**				
Finland	Lovisa 1	Lovisa	445	IV	PWR	AEE	1977
	Lovisa 2	Lovisa	445	IV	PWR	AEE	1980
	Olkiluoto 1	Olkiluoto	710	TV	BWR	A-A	1978
	Olkiluoto 2	Olkiluoto	710	TV	BWR	A-A	1980
Total	**4 Units**		**2,310**				

See footnotes at end of table.

Table F1. Roster of Nuclear Generating Units Operable as of December 31, 1989, in Foreign Countries with FME (Continued)

Country	Unit Name [a]	Location	Capacity [b] (Net MWe)	Utility [c]	Reactor Type [d]	Reactor Supplier [e]	Date of Operation [f]
France	Belleville 1	Cher	1,310	EF	PWR	FRAM	1987
	Belleville 2	Cher	1,310	EF	PWR	FRAM	1988
	Bugey 1	Ain (near Lyon)	540	EF	GCR	VAR	1972
	Bugey 2	Ain	920	EF	PWR	FRAM	1978
	Bugey 3	Ain	920	EF	PWR	FRAM	1978
	Bugey 4	Ain	900	EF	PWR	FRAM	1979
	Bugey 5	Ain	900	EF	PWR	FRAM	1979
	Cattenom 1	Moselle	1,300	EF	PWR	FRAM	1986
	Cattenom 2	Moselle	1,300	EF	PWR	FRAM	1987
	Chinon A3	Indre-et-Loire	360	EF	GCR	VAR	1966
	Chinon B1	Indre-et-Loire	870	EF	PWR	FRAM	1982
	Chinon B2	Indre-et-Loire	870	EF	PWR	FRAM	1983
	Chinon B3	Indre-et-Loire	905	EF	PWR	FRAM	1986
	Chinon B4	Indre-et-Loire	905	EF	PWR	FRAM	1987
	Chooz A	Ardennes	305	SN	PWR	ACE	1967
	Creys-Malville	Isere	1,200	EF	LMFBR	NOVA	1986
	Cruas 1	Ardeche	880	EF	PWR	FRAM	1983
	Cruas 2	Ardeche	915	EF	PWR	FRAM	1984
	Cruas 3	Ardeche	880	EF	PWR	FRAM	1984
	Cruas 4	Ardeche	880	EF	PWR	FRAM	1984
	Dampierre 1	Loiret	890	EF	PWR	FRAM	1980
	Dampierre 2	Loiret	890	EF	PWR	FRAM	1981
	Dampierre 3	Loiret	890	EF	PWR	FRAM	1981
	Dampierre 4	Loiret	890	EF	PWR	FRAM	1981
	Fessenheim 1	Haut-Rhin	880	EF	PWR	FRAM	1977
	Fessenheim 2	Haut-Rhin	880	EF	PWR	FRAM	1977
	Flamanville 1	Manche	1,330	EF	PWR	FRAM	1985
	Flamanville 2	Manche	1,330	EF	PWR	FRAM	1986
	Gravelines B1	Nord	910	EF	PWR	FRAM	1980
	Gravelines B2	Nord	910	EF	PWR	FRAM	1980
	Gravelines B3	Nord	910	EF	PWR	FRAM	1981
	Gravelines B4	Nord	910	EF	PWR	FRAM	1981
	Gravelines C5	Nord	910	EF	PWR	FRAM	1984
	Gravelines C6	Nord	910	EF	PWR	FRAM	1985
	Le Blayais 1	Gironde	910	EF	PWR	FRAM	1981
	Le Blayais 2	Gironde	910	EF	PWR	FRAM	1983
	Le Blayais 3	Gironde	910	EF	PWR	FRAM	1983
	Le Blayais 4	Gironde	910	EF	PWR	FRAM	1983
	Nogent sur Seine 1	Aube	1,310	EF	PWR	FRAM	1987
	Nogent sur Seine 2	Aube	1,310	EF	PWR	FRAM	1988
	Paluel 1	Seine-Maritime	1,330	EF	PWR	FRAM	1984
	Paluel 2	Seine-Maritime	1,330	EF	PWR	FRAM	1984
	Paluel 3	Seine-Maritime	1,330	EF	PWR	FRAM	1985
	Paluel 4	Seine-Maritime	1,330	EF	PWR	FRAM	1986
	Phenix	Gard	233	EF	LMFBR	CEM	1973
	St. Laurent A1	Loir-et-Cher	390	EF	GCR	VAR	1969
	St. Laurent A2	Loir-et-Cher	450	EF	GCR	VAR	1971
	St. Laurent B1	Loir-et-Cher	915	EF	PWR	FRAM	1981
	St. Laurent B2	Loir-et-Cher	880	EF	PWR	FRAM	1981
	Saint-Alban 1	Isere	1,335	EF	PWR	FRAM	1985
	Saint-Alban 2	Isere	1,335	EF	PWR	FRAM	1986
	Tricastin 1	Drome	915	EF	PWR	FRAM	1980
	Tricastin 2	Drome	915	EF	PWR	FRAM	1980
	Tricastin 3	Drome	915	EF	PWR	FRAM	1981
	Tricastin 4	Drome	915	EF	PWR	FRAM	1981
Total	**55 Units**		**52,588**				
Germany, West (Federal Republic of Germany)	Biblis A	Worms/Rhein	1,146	RW	PWR	SIEM/KWU	1974
	Biblis B	Worms/Rhein	1,240	RW	PWR	SIEM/KWU	1976
	Brokdorf	Brokdorf	1,307	RW	PWR	SIEM/KWU	1986
	Brunsbuettel	Brunsbuettel	771	KG	BWR	AEG	1977
	Emsland KKE	Lingen	1,242	KN	PWR	KWU	1988
	Grafenrheinfeld KKG	Grafenrheinfeld	1,235	BY	PWR	SIEMS/KWU	1982
	Grohnde (KWG)	Grohnde	1,300	GG	PWR	SIEMS/KWU	1984
	Gundremmingen B	Gundremmingen	1,240	KB	BWR	SIEM/KWU	1984
	Gundremmingen C	Gundremmingen	1,246	KB	BWR	SIEM/KWU	1984
	Isar KKI 1	Ohu (Isar)	870	KI	BWR	SIEMS/KWU	1977
	Isar KKI 2	Ohu (Isar)	1,285	KI	BWR	SIEMS/KWU	1988
	Kruemmel KKK	Geestacht-Kruemmel	1,260	KK	BWR	AEG	1983

See footnotes at end of table.

Table F1. Roster of Nuclear Generating Units Operable as of December 31, 1989, in Foreign Countries with FME (Continued)

Country	Unit Name [a]	Location	Capacity [b] (Net MWe)	Utility [c]	Reactor Type [d]	Reactor Supplier [e]	Date of Operation [f]
Germany, West (continued)	Mulheim-Kaerlich	Mulheim-Kaerlich	1,165	SK	LMFBR	IBN	1986
	Neckarwestheim 1	Neckarwestheim	795	GK	PWR	SIEMS/KWU	1976
	Neckarwestheim 2	Neckarwestheim	1,225	GK	PWR	SIEMS/KWU	1989
	Obrigheim KWO	Obrigheim	340	KO	PWR	SIEM/KWU	1968
	Philippsburg KKP 1	Philippsburg	864	KP	BWR	SIEM/KWU	1979
	Philippsburg KKP 2	Philippsburg	1,268	KP	PWR	SIEM/KWU	1984
	Stade KKS	Stade	640	KS	PWR	SIEM/KWU	1972
	THTR 300	Hamm-Ventrop	294	HK	HTGR	HRB	1985
	Unterweser	Essenhamm	1,230	KU	PWR	SIEMS/KWU	1978
	Wuergassen (KWW)	Wuergassen	640	PR	BWR	AEG	1971
Total	**22 Units**		**22,686**				
India	Madras 1	Kalpakkam, Tamil Nadu	220	IA	PHWR	L-T	1983
	Madras 2	Kalpakkam, Tamil Nadu	220	IA	PHWR	L-T	1985
	Narora 1	Narora, Uttar Pradesh	220	IA	PHWR	WIL	1989
	Rajasthan 1	Kota, Rajasthan	207	IA	PHWR	CGE	1972
	Rajasthan 2	Kota, Rajasthan	207	IA	PHWR	L-T	1980
	Tarapur 1	Bombay	150	IA	BWR	GE	1969
	Tarapur 2	Bombay	150	IA	BWR	GE	1969
Total	**7 Units**		**1,374**				
Italy	Caorso [g]	Caorso, Piacenza	860	IL	BWR	AM/OETSO	1978
	Trino Vercellese	Vercelli	260	IL	PWR	WEST	1964
Total	**2 Units**		**1,120**				
Japan	Fugen ATR	Tsuruga	148	PF	LWCHWR	HIT	1978
	Fukushima Daiichi 1	Fukushima	439	TP	BWR	GE	1970
	Fukushima Daiichi 2	Fukushima	760	TP	BWR	GE	1973
	Fukushima Daiichi 3	Fukushima	760	TP	BWR	TOS	1974
	Fukushima Daiichi 4	Fukushima	760	TP	BWR	HIT	1978
	Fukushima Daiichi 5	Fukushima	760	TP	BWR	TOS	1977
	Fukushima Daiichi 6	Fukushima	1,067	TP	BWR	GE	1979
	Fukushima Daini 1	Fukushima	1,067	TP	BWR	TOS	1981
	Fukushima Daini 2	Fukushima	1,067	TP	BWR	HIT	1983
	Fukushima Daini 3	Fukushima	1,067	TP	BWR	TOS	1984
	Fukushima Daini 4	Fukushima	1,067	TP	BWR	HIT	1987
	Genkai 1	Genkai, Saga	529	KY	PWR	MHI	1975
	Genkai 2	Genkai, Saga	529	KY	PWR	MHI	1980
	Hamaoka 1	Hamaoka-cho, Shizuoka	515	CB	BWR	TOS	1975
	Hamaoka 2	Hamaoka-cho, Shizuoka	815	CB	BWR	TOS	1978
	Hamaoka 3	Hamaoka-cho, Shizuoka	1,066	CB	BWR	TOS	1987
	Ikata 1	Ikata-cho, Ehime	538	SP	PWR	MHI	1977
	Ikata 2	Ikata-cho, Ehime	538	SP	PWR	MHI	1981
	Kashiwazaki Kariwa 1	Niigata	1,067	TP	BWR	TOS	1985
	Kashiwazaki Kariwa 5	Niigata	1,067	TP	BWR	HIT	1989
	Mihama 1	Mihama-cho	320	KA	PWR	WEST	1970
	Mihama 2	Mihama-cho	470	KA	PWR	MHI	1972
	Mihama 3	Mihama-cho	780	KA	PWR	MHI	1976
	Ohi 1	Ohi-cho	1,120	KA	PWR	WEST	1977
	Ohi 2	Ohi-cho	1,120	KA	PWR	WEST	1978
	Onagawa 1	Oshikagun	497	TC	BWR	TOS	1983
	Sendai 1	Sendai, Kagoshima	846	KY	PWR	MHI	1983
	Sendai 2	Sendai, Kagoshima	846	KY	PWR	HIT	1985
	Shimane 1	Kashima-cho, Shimane	439	CK	BWR	HIT	1973
	Shimane 2	Kashima-cho, Shimane	791	CK	BWR	MHI	1988
	Takahama 1	Takahama-cho	780	KA	PWR	WEST	1974
	Takahama 2	Takahama-cho	780	KA	PWR	MHI	1975
	Takahama 3	Takahama-cho	830	KA	PWR	MHI	1984
	Takahama 4	Takahama-cho	830	KA	PWR	MHI	1984
	Tokai 1	Tokai Mura	129	JP	GCR	GEC	1965
	Tokai 2	Tokai Mura	1,056	JP	BWR	GE	1978
	Tomari 1	Tomari Hokkaido	550	HD	PWR	MHI	1988
	Tsuruga 1	Tsuruga	340	JP	BWR	GE	1969
	Tsuruga 2	Tsuruga	1,115	JP	PWR	MHI	1986
Total	**39 Units**		**29,265**				

See footnotes at end of table.

Table F1. Roster of Nuclear Generating Units Operable as of December 31, 1989, in Foreign Countries with FME (Continued)

Country	Unit Name [a]	Location	Capacity [b] (Net MWe)	Utility [c]	Reactor Type [d]	Reactor Supplier [e]	Date of Operation [f]
Korea, South	Ko-Ri 1	Ko-Ri, Kyongnam	556	KR	PWR	WEST	1977
	Ko-Ri 2	Ko-Ri, Kyongnam	605	KR	PWR	WEST	1983
	Ko-Ri 3	Ko-Ri, Kyongnam	895	KR	PWR	WEST	1986
	Ko-Ri 4	Ko-Ri, Kyongnam	895	KR	PWR	WEST	1985
	Ulchin 1	Ulchin, Kyongbuk	920	KR	PWR	FRAM	1988
	Ulchin 2	Ulchin, Kyongbuk	920	KR	PWR	FRAM	1989
	Wolsong	Kampo, Kyongbuk	629	KR	PHWR	AECL	1982
	Yonggwang 1	Yonggwang, Chonnam	900	KR	PWR	WEST	1986
	Yonggwang 2	Yonggwang, Chonnam	900	KR	PWR	WEST	1987
Total	**9 Units**		**7,220**				
Mexico	Laguna Verde 1	Laguna Verde, Veracruz	654	FC	BWR	GE	1989
Total	**1 Unit**		**654**				
Netherlands	Borssele	Borssele	442	PZ	PWR	SIEM/KWU	1973
	Dodewaard	Dodewaard, Betuwe	55	GN	BWR	RDM	1968
Total	**2 Units**		**497**				
Pakistan	Kanupp	Karachi	125	PA	PHWR	CGE	1971
Total	**1 Unit**		**125**				
South Africa	Koeberg 1	Capetown	920	SA	PWR	FRAM	1983
	Koeberg 2	Capetown	920	SA	PWR	FRAM	1985
Total	**2 Units**		**1,840**				
Spain	Almaraz 1	Almaraz, Caceres	900	CS	PWR	WEST	1981
	Almaraz 2	Almaraz, Caceres	900	CS	PWR	WEST	1983
	Asco 1	Asco, Tarragona	898	CF	PWR	WEST	1983
	Asco 2	Asco, Tarragona	898	CF	PWR	WEST	1985
	Cofrentes	Cofrentes	958	HE	BWR	GE	1984
	Jose Cabrera	Madrid	153	UE	PWR	WEST	1968
	Santa Maria de Garona	Santa Maria de Garona, Burgas	440	CT	BWR	GE	1971
	Trillo 1	Trillo, Guadalupe	997	UE	PWR	SIEM/KWU	1988
	Vandellos 1	Tarragona	480	HI	GCR	SEAC	1972
	Vandellos 2	Tarragona	982	EM	PWR	WEST	1987
Total	**10 Units**		**7,606**				
Sweden	Barseback 1	Malmohus	600	SY	BWR	A-A	1975
	Barseback 2	Malmohus	585	SY	BWR	A-A	1977
	Forsmark 1	Uppsala	970	SB	BWR	A-A	1980
	Forsmark 2	Uppsala	970	SB	BWR	A-A	1981
	Forsmark 3	Uppsala	1,090	SB	BWR	A-A	1984
	Oskarshamn 1	Oskarshamn	442	OK	BWR	A-A	1971
	Oskarshamn 2	Oskarshamn	605	OK	BWR	A-A	1974
	Oskarshamn 3	Oskarshamn	1,160	OK	BWR	A-A	1985
	Ringhals 1	Varberg	750	SB	BWR	A-A	1974
	Ringhals 2	Varberg	800	SB	PWR	WEST	1974
	Ringhals 3	Varberg	915	SB	PWR	WEST	1980
	Ringhals 4	Varberg	915	SB	PWR	WEST	1982
Total	**12 Units**		**9,802**				
Switzerland	Beznau 1	Doettingen	350	NK	PWR	WEST	1969
	Beznau 2	Doettingen	350	NK	PWR	WEST	1971
	Goesgen	Daniken, SO	940	GP	PWR	KWU	1979
	Leibstadt	Leibstadt	990	LK	BWR	GETSCO	1984
	Muhleberg	Berne	326	BR	BWR	GETSCO	1971
Total	**5 Units**		**2,956**				

See footnotes at end of table.

Table F1. Roster of Nuclear Generating Units Operable as of December 31, 1989, in Foreign Countries with FME (Continued)

Country	Unit Name[a]	Location	Capacity[b] (Net MWe)	Utility[c]	Reactor Type[d]	Reactor Supplier[e]	Date of Operation[f]
Taiwan	Chinshan 1	Shimin Hsiang	604	TW	BWR	GE	1977
	Chinshan 2	Shimin Hsiang	604	TW	BWR	GE	1978
	Kuosheng 1	Kuosheng	951	TW	BWR	GE	1981
	Kuosheng 2	Kuosheng	951	TW	BWR	GE	1982
	Maanshan 1	Maanshan	907	TW	PWR	WEST	1984
	Maanshan 2	Maanshan	907	TW	PWR	WEST	1985
Total	6 Units		4,924				
United Kingdom	Bradwell 1	Essex	123	NE	GCR	TNPG	1962
	Bradwell 2	Essex	123	NE	GCR	TNPG	1962
	Calder Hall 1	Cumbria	50	BF	GCR	UKAE	1956
	Calder Hall 2	Cumbria	50	BF	GCR	UKAE	1957
	Calder Hall 3	Cumbria	50	BF	GCR	UKAE	1958
	Calder Hall 4	Cumbria	50	BF	GCR	UKAE	1959
	Chapel Cross 1	Dumfriesshire	48	BF	GCR	UKAE	1958
	Chapel Cross 2	Dumfriesshire	48	BF	GCR	UKAE	1959
	Chapel Cross 3	Dumfriesshire	48	BF	GCR	UKAE	1959
	Chapel Cross 4	Dumfriesshire	48	BF	GCR	UKAE	1960
	Dounreay PFR	Highland	234	UK	LMFBR	UKAE	1975
	Dungeness A1	Kent	212	NE	GCR	TNPG	1965
	Dungeness A2	Kent	212	NE	GCR	TNPG	1965
	Dungeness B1	Kent	360	NE	AGR	APC	1983
	Dungeness B2	Kent	360	NE	AGR	APC	1985
	Hartlepool R1	Cleveland	420	NE	AGR	NNC	1983
	Hartlepool R2	Cleveland	420	NE	AGR	NNC	1984
	Heysham 1 R1	Lancashire	420	NE	AGR	NNC	1983
	Heysham 1 R2	Lancashire	420	NE	AGR	NNC	1984
	Heysham 2 R1	Lancashire	615	NE	AGR	NNC	1988
	Heysham 2 R2	Lancashire	615	NE	AGR	NNC	1988
	Hinkley Point A1	Somerset	235	NE	GCR	EBT	1965
	Hinkley Point A2	Somerset	235	NE	GCR	EBT	1965
	Hinkley Point B1	Somerset	560	NE	GCR	NPC	1976
	Hinkley Point B2	Somerset	560	NE	GCR	NPC	1978
	Hunterston A1	Ayrshire, Scotland	150	SC	GCR	GEC	1964
	Hunterston B1	Ayrshire, Scotland	575	SC	AGR	TNPG	1976
	Hunterston B2	Ayrshire, Scotland	575	SC	AGR	TNPG	1977
	Oldbury 1	Gloucestershire	217	NE	GCR	TNPG	1967
	Oldbury 2	Gloucestershire	217	NE	GCR	TNPG	1968
	Sizewell A1	Suffolk	210	NE	GCR	EBT	1966
	Sizewell A2	Suffolk	210	NE	GCR	EBT	1966
	Torness 1	Dunbar East Lothan, Scotland	625	SC	AGR	NNC	1988
	Torness 2	Dunbar East Lothan, Scotland	625	NE	AGR	NNC	1989
	Trawsfyndd 1	Wales	195	NE	GCR	APC	1965
	Trawsfyndd 2	Wales	195	NE	GCR	APC	1965
	Winfrith SGHWR	Dorset	92	UK	HWLWR	UKAE	1967
	Wylfa 1	Anglesey	420	NE	GCR	EBT	1971
	Wylfa 2	Anglesey	420	NE	GCR	EBT	1971
Total	39 Units		11,242				
Yugoslavia	Krsko	Krsko, Slovenia	620	YG	PWR	WEST	1981
Total	1 Unit		620				
Total Operable Capacity in Foreign FME Countries (245 Units)			175,762				

[a]EIA's review of the latest data sources has resulted in revisions of names, capacities, and grid operation dates for some of the units listed in this table.
[b]Some nuclear units were rerated to reflect more current data.
[c]See Table F2 for key to abbreviations of utility names.
[d]Reactor Types: AGR, advanced gas-cooled reactor; ALWR, boiling light-water reactor; BWR, boiling-water reactor; FBR, fast breeder reactor; GCR, gas-cooled reactor, HTGR, high-temperature, gas-cooled reactor; HWLWR, heavy water-moderated, boiling light-water-cooled reactor; LMFBR, liquid metal fast breeder reactor; LWCHWR, light-water cooled, heavy-water-moderated reactor; PHWR, pressurized heavy-water-moderated and cooled reactor; PWR, pressurized water reactor.
[e]See Table F3 for key to abbreviations of reactor supplier names.
[f]For all foreign countries, operable units are those that have generated electricity to the grid.
[g]The Caorso unit shut down since 1987 is currently mothballed, that is maintained in a state of "active preservation."
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Sources: *Nuclear News*, "World List of Nuclear Power Plants" (February 1990), pp. 63-81, *Nuclear Engineering International*, "World Nuclear Industry Handbook 1990," pp. 25-41, International Atomic Energy Agency, *Nuclear Power Reactors in the World* (Vienna, Austria, April 1990).

Table F2. Key to Utility Codes for Rosters of Foreign FME Commercial Nuclear Generating Units

Code	Name of Utility	Country
BF	British Nuclear Fuels plc	United Kingdom
BK	Kernkraftwerk Brokdorf GmbH	West Germany
BY	Bayernwerk AG	West Germany
BZ	Furnas Centrais Eletricas SA	Brazil
CB	Chubo Electric Power Company, Inc.	Japan
CF	Fuerzas Electricas de Cataluna SA	Spain
CK	Chugoku Electric Power Company	Japan
CN	Comision Nacional de Energia Atomica	Argentina
CS	Compania Sevillana de Electricidad SA	Spain
CT	Centrales Nucleares del Norte SA	Spain
EB	Societes Reunies d'Energie du Bassin de l'Escaut	Belgium
EF	Electricite de France	France
EG	Ministry of Electricity	Egypt
EM	Empresa Nacional Hidroelectrica del Ribagorzana SA	Spain
FC	Comision Federal de Electricidad	Mexico
FE	Fuerzas Electricas del Noroeste SA	Spain
GG	Gemeinschaftskernkraftwerk Grohnde	West Germany
GK	Gemeinschaftskernkraftwerk Neckar	West Germany
GN	Gemeeschappelijke Kernenergiecentrale Nederland NV	Netherlands
GP	Kernkraftwerk Goesgen-Daeniken AG	Switzerland
HD	Hokkaido Electric Power Company	Japan
HE	Hidroelectrica Espanola SA	Spain
HI	Hispano-Francesca de Energia Nuclear SA	Spain
HK	Hochtemperatur Kernkraftwerk GmbH	West Germany
HQ	Hydro Quebec	Canada
HU	Hokuriku Electric Power Company, Inc.	Japan
IA	Indian Atomic Energy Commission	India
IB	Iberduero SA	Spain
ID	Indivision Doel	Belgium
IL	Ente Nazionale per l'Energia Elettrica	Italy
IT	Societe Intercommunicale Belge de Gaz et d'Electricite	Belgium
IV	Imatran Voima Oy (IVO)	Finland
JP	Japan Atomic Power Company	Japan
KA	Kansai Electric Power Company	Japan
KB	Kernkraftwerk RW-Bayernwerk GmbH	West Germany
KG	Kernkraftwerk Brunsbuettel	West Germany
KI	Kernkraftwerk Isar	West Germany
KK	Kernkraftwerk Kruemmel GmbH	West Germany
KN	Kernkraftwerk Lippe-Emsland GmbH	West Germany
KO	Kernkraftwerk Obrigheim GmbH	West Germany
KP	Kernkraftwerk Philippsburg	West Germany
KR	Korean Electric Power Company	Korea
KS	Kernkraftwerk Stade GmbH	West Germany
KU	Kernkraftwerk Unterweser GmbH	West Germany
KY	Kyushu Electric Power Company, Inc.	Japan
LK	Kernkraftwerk Leibstadt	Switzerland
NB	New Brunswick Electric Power Commission	Canada
NE	Nuclear Electric	United Kingdom
NK	Nordostschweizerische Kraftwerke AG	Switzerland
NU	Nuclear Electricity plc	United Kingdom
OK	OKG Aktiebolag	Sweden
ON	Ontario Hydro Corporation	Canada
PA	Pakistan Atomic Energy Commission	Pakistan
PF	Power Reactor and Nuclear Fuel Development Corporation	Japan
PR	Preussenelektra AG	West Germany
PZ	NV Provinciale Zeeuwse Energie-Maatschappij	Netherlands
RW	Rheinisch-Westfaelisches Electrizitaetswerk AG	West Germany
SA	Electricity Supply Company of South Africa	South Africa
SB	Statens Vattenfallsverk	Sweden
SC	Scottish Nuclear	United Kingdom
SE	Societe Belgo-Francaise d'Energie Nucleaire Monsane	Belgium
SK	Schnell-Bruter-Kernkraftwerksgesellschaft	West Germany
SN	Societe d'Energie Nucleaire Franco-Belge des Ardennes	France
SP	Shikoku Electric Power Company	Japan
SY	Sydsvenka Kraft AB	Sweden
TC	Tohoku Electric Power Company, Inc.	Japan
TP	Tokyo Electric Power Company	Japan
TV	Teollisuuden Voima Oy (TVO)	Finland
TW	Taiwan Power Company	Taiwan
UE	Union Electrica-Fenosa SA	Spain
UK	United Kingdom Atomic Energy Authority	United Kingdom
YG	Savske Electrane and Electroprivreda	Yugoslavia

Table F3. Key to Reactor Supplier Codes for Rosters of Foreign FME Commercial Nuclear Generating Units

Code	Name of Supplier	Country
A-A	ASEA-Atom AB	Sweden
ACE	ACEC with COP/TOSI and Westinghouse Corp.	Belgium
ACEC	Ateliers de Constructions Electriques de Charleroi SA	Belgium
ACLF	ACEC/COP/Creusot-Loire/FRAM/WEST	France
AECL	Atomic Energy of Canada, Ltd.	Canada
AEE	Atomenergoexport	U.S.S.R.
AEG	Allgemeine Elektrizitaet-Gesellschaft, AEG-Telefunken AG	West Germany
AM/GETSCO	Ansaldo Meccanico Nucleare SpA/General Electric Technical Services Company	Italy
APC	Atomic Power Construction, Ltd.	United Kingdom
BBR	Babcock/Brown Boveri Reaktor GmbH	West Germany
CEM	Compagnie Electro Mechanique	France
CGE	Canadian General Electric	Canada
COP/TOSI	Cockerill Ougree-Providence/Franco Tosi SpA	Belgium
EBT	English Electric Co. Ltd/Rabcock and Wilcox Co./Taylor Woodrow Construction Co.	United Kingdom
FRAM	Framatome: Societe Franco-Americaine de Constructions Atomiques SA	France
GE	General Electric Company (United States)	United States
GEC	General Electric Company (United Kingdom)	United Kingdom
GETSCO	General Electric Technical Services Company	United States
HIT	Hitachi	Japan
HRB	Hochtemperatur-Reaktorbau GmbH	West Germany
IBN	Internationale Natrium Brutreaktorbau GmbH/Hochtief AG	West Germany
L-T	Larsen and Toubro, Ltd.	India
MHI	Mitsubishi Heavy Industries, Ltd.	Japan
NIRA	Nucleare Italiana Reattori Avanzati	Italy
NNC	National Nuclear Corporation	United Kingdom
NOVA	Novatome	France
NPC	Nuclear Power Company, Ltd.	United Kingdom
R&C	Richardson & Cruddas	India
RDM	Rotterdamse Drookdok Madtdschappij	Netherlands
SACM	Societe Alsacienne de Constructions Mecaniques	France
SFAC	Societe des Forges et Ateliers du Creusot	France
SIEM/KWU	Siemens AG/KWU	West Germany
TNPG	The Nuclear Power Group, Ltd.	United Kingdom
TOS	Toshiba	Japan
UKAE	United Kingdom Atomic Energy Authority	United Kingdom
VAR	Various suppliers	Various countries
WEST	Westinghouse Corp	United States
WIL	Walchandhagar Industries, Ltd.	India

Appendix G

Foreign FME Nuclear Generating Units in the Construction Pipeline as of December 31, 1989

Appendix G

Foreign FME Nuclear Generating Units in the Construction Pipeline as of December 31, 1989

Table G1. Roster of Nuclear Generating Units in the Construction Pipeline as of December 31, 1989, in Foreign Countries with FME

Country	Unit Name [a]	Location	Capacity [b] (Net MWe)	Utility [c]	Type [d]	Reactor Supplier [e]	% Com-plete	Expected Date of Operation: Published [f]	EIA [g]: LR	EIA [g]: UR
Argentina	Atucha 2	Lima, Buenos Aires	692	CN	PHWR	SIEM/ KWU	66	[h]6/94	2000	1995
Total	**1 Unit**		**692**							
Brazil	Angra 2	Itaorna	1,229	BZ	PWR	SIEM/ KWU	69	[h]12/94	2000	1995
	Angra 3	Itaorna	1,229	BZ	PWR	SIEM/ KWU	28	[h]3/97	2005	2000
Total	**2 Units**		**2,458**							
Canada	Darlington 1	Newcastle Township, Ontario	881	ON	PHWR	AECL	96	[h]12/90	1995	1990
	Darlington 2	Newcastle Township	881	ON	PHWR	AECL	99	[h]2/90	1990	1990
	Darlington 3	Newcastle Township	881	ON	PHWR	AECL	75	[h]12/91	1995	1995
	Darlington 4	Newcastle Township	881	ON	PHWR	AECL	45	[h]12/92	1995	1995
Total	**4 Units**		**3,524**							
Egypt	El-Dabaa 1	El-Dabaa	900	EG	PWR	NA	0	NA	2020	2010
	El-Dabaa 2	El-Dabaa	900	EG	PWR	NA	0	NA	--	2020
Total	**2 Units**		**1,800**							
France	Cattenom 3	Moselle	1,300	EF	PWR	FRAM	94	[i]2/90	1990	1990
	Cattenom 4	Moselle	1,300	EF	PWR	FRAM	81	[h]6/91	1990	1990
	Chooz B1	Ardennes	1,455	EF	PWR	FRAM	70	[h]6/92	1995	1995
	Chooz B2	Ardennes	1,455	EF	PWR	FRAM	51	[h]10/93	2000	1995
	Civaux 1	Vienne	1,455	EF	PWR	FRAM	0	[i]4/96	2005	2000
	Golfech 1	Tarn et Garonne	1,310	EF	PWR	FRAM	93	[i]2/90	1995	1995
	Golfech 2	Tarn et Garonne	1,310	EF	PWR	FRAM	60	[h]5/93	1995	1995
	Penley 1	Seine Maritime	1,330	EF	PWR	FRAM	94	[i]2/90	1990	1990
	Penley 2	Seine-Maritime	1,330	EF	PWR	FRAM	70	[h]3/92	1995	1995
Total	**9 Units**		**12,245**							

See footnotes at end of table.

Table G1. Roster of Nuclear Generating Units in the Construction Pipeline as of December 31, 1989, in Foreign Countries with FME (Continued)

Country	Unit Name [a]	Location	Capacity [b] (Net MWe)	Utility [c]	Type [d]	Reactor Supplier [e]	% Complete	Expected Date of Operation		
								Published [f]	EIA [g]	
									LR	UR
Germany, West	Kalkar SNR-300	Kalkar	295	SK	FBR	IBN	100	[h]1992	1995	1995
Total	**1 Unit**		**295**							
India	Kaiga 1	Kaiga, Karnataka	220	IA	PHWR	NA	18	[h]1994	2005	2000
	Kaiga 2	Kaiga, Karnataka	220	IA	PHWR	NA	18	[h]1995	2010	2005
	Kakrapar 1	Kakrapar	220	IA	PHWR	L-T	57	[h]2/91	2005	2000
	Kakrapar 2	Kakrapar	220	IA	PHWR	L-T	44	[h]2/92	2005	2000
	Narora 2	Narora, Uttar Pradesh	220	IA	PHWR	R&C	85	[h]1990	1995	1995
	Rajasthan 3	Kato, Rajasthan	220	NA	PHWR	NA	10	[h]1994	2005	2000
	Rajasthan 4	Kato, Rajasthan	220	NA	PHWR	NA	10	[h]1995	2010	2005
Total	**7 Units**		**1,540**							
Italy	Cirene	Latina	40	IL	LHWR	NIRA	96	ID	2000	1995
	Montalto di Castro 1	Montalto di Castro	982	IL	BWR	AMGE	75	ID	2005	2010
	Montalto di Castro 2	Montalto di Castro	982	IL	BWR	AMGE	70	ID	2010	2005
Total	**3 Units**		**2,004**							
Japan	Ashihama 1	Ashihama	1,067	CB	BWR	NA	0	[j]12/96	2020	2010
	Ashihama 2	Ashihama	1,067	CB	BWR	NA	0	[j]1998	2010	2005
	Ashihama 3	Ashihama	1,067	CB	BWR	NA	0	[j]2001	2020	2010
	Genkai 3	Genkai, Saga	1,127	KY	PWR	NA	42	[j]3/94	1995	1995
	Genkai 4	Genkai, Saga	1,127	KY	PWR	NA	3	[j]1999	2005	2000
	Hamaoka 4	Hamaoka-cho	1,092	CB	BWR	NA	19	[j]9/93	2000	1995
	Higashidori 1	Higashidori	1,067	TC	BWR	NA	0	[j]7/2003	--	2015
	Houhoko 1	Houhoko	1,067	CK	BWR	NA	0	[j]2000	2010	2005
	Houhoko 2	Houhoko	1,067	CK	BWR	NA	0	[j]2000	2010	2005
	Ikata 3	Shikoku	846	SP	PWR	NA	32	[j]3/95	2000	1995
	Kashiwazaki Kariwa 2	Niigata	1,067	TP	BWR	TOS	93	[h]10/90	1990	1990
	Kashiwazaki Kariwa 3	Niigata	1,067	TP	BWR	TOS	22	[j]7/93	2000	1995
	Kashiwazaki Kariwa 4	Niigata	1,067	TP	BWR	HII	12	[j]7/94	2000	1995
	Kashiwazaki Kariwa 6	Niigata	1,315	TP	ABWR	GE	0	[j]7/96	2005	2000
	Kashiwazaki Kariwa 7	Niigata	1,315	TP	ABWR	GE	0	[j]7/97	2005	2000
	Maki 1	Maki	825	TC	BWR	NA	0	[j]3/2000	2020	2010
	Maki 2	Maki	1,067	TC	BWR	NA	0	--	--	2020
	Monju	Tsuruga	280	PF	FBR	TOS	75	[j]1993	1995	1995
	Shika	Shika	500	HU	BWR	NA	7	[j]3/93	1995	1995
	Noto 2	Suzu	800	HU	BWR	NA	0	2003	2010	2005
	Ohi 3	Ohi-cho	1,127	KA	FWR	NA	44	[j]12/91	1995	1995
	Ohi 4	Ohi-cho	1,127	KA	PWR	NA	13	[j]2/93	1995	1995
	Ohra 1	Ohra	1,122	KA	PWR	NA	0	[j]11/97	2010	2005
	Ohra 2	Ohra	1,122	KA	PWR	NA	0	[j]2005	2010	2005
	Onagawa 2	Oshikagun	800	TC	BWR	NA	5	[j]7/95	2000	2000
	Tomari 2	Tomari-Hokkaido	579	HD	PWR	MHI	91	[h]6/91	1995	1995
Total	**26 Units**		**25,774**							

See footnotes at end of table

Table G1. Roster of Nuclear Generating Units in the Construction Pipeline as of December 31, 1989, in Foreign Countries with FME (Continued)

Country	Unit Name [a]	Location	Capacity [b] (Net MWe)	Utility [c]	Type [d]	Reactor Supplier [e]	% Complete	Expected Date of Operation: Published [f]	EIA [g]: LR	EIA [g]: UR
Korea, South	Yonggwang 3	Gyaema, near Kwang-Ju	900	KR	PWR	CE	0	[h]3/95	2005	2000
	Yonggwang 4	Gyaema, near Kwang-Ju	950	KR	PWR	CE	0	[h]6/96	2005	2000
Total	**2 Units**		**1,850**							
Mexico	Laguna Verde 2	Laguna Verde, Veracruz	654	FC	BWR	GE	50	[h]7/94	2000	1995
Total	**1 Unit**		**654**							
Pakistan	Chashma Barrage	Kundian	300	PA	PWR	NA	0	[h]1996	2010	2005
Total	**1 Unit**		**300**							
Spain	Cabo Cope	Cope, Murcia	930	HF	BWR	GE	0	[h]ID	--	--
	Regadola	Lugo	1,000	FE	PWR	SIEM/KWU	0	[h]ID	--	--
	Sayago	Sayago, Zamora	1,075	IB	PWR	WEST	0	[j]1999	--	--
	Trillo 2	Trillo, Guadalupe	997	UE	PWR	SIEM/KWU	[j]5	[j]1995	--	--
	Valdecaballeros 1	Badajoz	975	CS	BWR	GE	80	[j]1995	2000	1995
	Valdecaballeros 2	Badajoz	975	CS	BWR	GE	60	[j]1997	2005	2000
Total	**6 Units**		**5,952**							
Switzerland	Graben	Graben	1,140	BR	BWR	GET	0	[j]2007	2020	2015
Total	**1 Unit**		**1,140**							
Taiwan	Yenliao 1	Yenliao	950	TW	PWR	NA	0	[j]12/98	2000	2000
	Yenliao 2	Yenliao	950	TW	PWR	NA	0	[j]12/99	2010	2005
Total	**2 Units**		**1,900**							
United Kingdom	Hinkley Point C	Somerset	1,200	NE	PWR	WE		[j]1998	2005	2005
	Sizewell B	Sizewell	1,175	CG	PWR	NA	30	[h]1994	2010	2005
Total	**2 Units**		**2,375**							
Total Capacity in the Construction Pipeline in Foreign FME Countries (70 Units)			**64,503**							

[a]EIA's review of the latest data sources has resulted in revisions of names, capacities, and grid operation dates for some of the units listed in this table.

[b]Some nuclear units were rerated to reflect more current data.

[c]See Table F2 for key to abbreviations of utility names.

[d]Reactor Types: ABWR, advanced boiling-water reactor; AGR, advanced gas-cooled reactor; BWR, boiling-water reactor; FBR, fast breeder reactor; LMFBR, liquid metal fast breeder reactor; LHWR, light-water-cooled, heavy-water-moderated reactor; PHWR, pressurized heavy-water-moderated and cooled reactor; PWR, pressurized-water reactor.

[e]See Table F3 for key to abbreviations of utility names.

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

[g]EIA projections in the Lower Reference (LR) and Upper Reference (UR) cases, as described in the text, refer to the preceding 5-year period during which a nuclear unit is estimated to become operable. Units operable for all foreign countries are those that have generated electricity to the grid. A dash (--) indicates that the estimated year of operability is beyond 2010.

[h]Source: *Nuclear News*, "World List of Nuclear Power Plants" (February 1990), pp. 63-82; *Nuclear Engineering International*, "World Nuclear Industry Handbook 1990" (July 1989), pp. 25-40; International Atomic Energy Agency, *Nuclear Power Reactors in the World* (Vienna, Austria, April 1990).

[i]This unit was connected to the grid on this date.

[j]Source: Most of this information on foreign countries was derived in consultation with the DOE Office of Uranium Enrichment; a few dates were modified by EIA.

Note: NA = not available. ID = indefinitely deferred. FME = Free Market Economies.

Table G2. Final Periods of Pipeline Projections for Installed Nuclear Capacity in Foreign FME Countries

Country	Final Period of Pipeline Projection	
	Lower Reference Case	Upper Reference Case
OECD Countries		
Belgium	2010	2005
Canada	2000	1995
Finland	2005	2000
France	2010	2010
Germany, West	2010	2005
Italy	2010	2005
Japan	2015	2015
Netherlands	2005	2000
Spain	2005	2000
Sweden	2020	2015
Switzerland	2010	2005
Turkey	2015	2000
United Kingdom	2010	2005
Non-OECD Countries		
Argentina	2010	2005
Brazil	2015	2010
Egypt	2015	2015
India	2005	2005
Korea, South	2005	2005
Mexico	2015	2010
Pakistan	2010	2005
South Africa	2010	2005
Taiwan	2005	2000
Yugoslavia	2010	2005

OECD – Organization for Economic Cooperation and Development.
FME – Free Market Economies.

Appendix H

Foreign Nuclear Generating Units Operable as of December 31, 1989 in Countries with Regulated Market and Centrally Planned Economies

Foreign Nuclear Generating Units Operable as of December 31, 1989 in Countries with Regulated Market and Centrally Planned Economies

Table H1. Roster of Foreign Nuclear Generating Units Operable as of December 31, 1989, in Countries with Regulated Market and Centrally Planned Economies

Country	Unit Name [a]	Location	Capacity [b] (Net MWe)	Utility [c]	Reactor Type [d]	Reactor Supplier [e]	Date of Operation [f]
Bulgaria	Kozloduy 1	Kozloduy	408	EE	PWR	AEE	1974
	Kozloduy 2	Kozloduy	408	EE	PWR	AEE	1975
	Kozloduy 3	Kozloduy	408	EE	PWR	AEE	1980
	Kozloduy 4	Kozloduy	408	EE	PWR	AEE	1982
	Kozloduy 5	Kozloduy	953	EE	PWR	AEE	1987
Total	**5 Units**		**2,585**				
Czechoslovakia (Czech and Slovak Federal Republic)	Bohunice 1	Jaslove, Bohunice	408	CZ	PWR	AEE	1978
	Bohunice 2	Jaslove, Bohenice	408	CZ	PWR	AEE	1980
	Bohunice 3	Jaslove, Bohunice	408	CZ	PWR	AEE	1984
	Bohunice 4	Jaslove, Bohunice	408	CZ	PWR	AEE	1985
	Dukovany 1	Dukovany	408	CZ	PWR	AEE	1985
	Dukovany 2	Dukovany	408	CZ	PWR	AEE	1986
	Dukovany 3	Dukovany	408	CZ	PWR	AEE	1986
	Dukovany 4	Dukovany	408	CZ	PWR	AEE	1987
Total	**8 Units**		**3,264**				
Germany, East (German Democratic Republic)	Nord 1	Lubmin	408	DG	PWR	AEE	1973
	Nord 2	Lubmin	408	DG	PWR	AEE	1974
	Nord 3	Lubmin	408	DG	PWR	AEE	1977
	Nord 4	Lubmin	408	DG	PWR	AEE	1979
	Nord 5	Lubmin	408	DG	PWR	AEE	1989
	Rheinsberg	Rheinsberg	62	DG	PWR	AEE	1966
Total	**6 Units**		**2,102**				
Hungary	Paks 1	Paks	410	HN	PWR	AEE	1982
	Paks 2	Paks	415	HN	PWR	AEE	1984
	Paks 3	Paks	410	HN	PWR	AEE	1986
	Paks 4	Paks	410	HN	PWR	AEE	1987
Total	**4 Units**		**1,645**				
U.S.S.R. (Union of Soviet Socialist Republics)	Balakovo 1	Balakovo	950	UR	PWR	AEE	1985
	Balakovo 2	Balakovo	950	UR	PWR	AEE	1987
	Balakovo 3	Balakovo	950	UR	PWR	AEE	1988
	Beloyarsk 2	Sverdlovsk	146	UR	LGR	AEE	1967
	Beloyarsk 3	Sverdlovsk	560	UR	FBR	AEE	1980
	BN 350	Shevchenko	135	UR	FBR	AEE	1973
	Chernobyl 1	Kiev	925	UR	LGR	AEE	1977
	Chernobyl 2	Kiev	925	UR	LGR	AEE	1978
	Chernobyl 3	Kiev	925	UR	LGR	AEE	1981

See footnotes at end of table.

Table H1. Roster of Foreign Nuclear Generating Units Operable as of December 31, 1989, in Countries with Regulated Market and Centrally Planned Economies (Continued)

Country	Unit Name [a]	Location	Capacity [b] (Net MWe)	Utility [c]	Reactor Type [d]	Reactor Supplier [e]	Date of Operation [f]
U.S.S.R. (continued)	Ignalina 1	Ignalina, Lithuania	1,380	UR	LGR	AEE	1983
	Ignalina 2	Ignalina, Lithuania	1,380	UR	LGR	AEE	1987
	Kalinin 1	Kalinin	950	UR	PWR	AEE	1984
	Kalinin 2	Kalinin	950	UR	PWR	AEE	1986
	Khmelnitski 1	Khmelnitski, Ukraine	950	UR	PWR	AEE	1987
	Kola 1	Murmansk	411	UR	PWR	AEE	1973
	Kola 2	Murmansk	411	UR	PWR	AEE	1974
	Kola 3	Murmansk	411	UR	PWR	AEE	1981
	Kola 4	Murmansk	411	UR	PWR	AEE	1984
	Kursk 1	Kursk	925	UR	LGR	AEE	1976
	Kursk 2	Kursk	925	UR	LGR	AEE	1979
	Kursk 3	Kursk	925	UR	LGR	AEE	1983
	Kursk 4	Kursk	925	UR	LGR	AEE	1985
	Leningrad 1	Leningrad	925	UR	LGR	AEE	1973
	Leningrad 2	Leningrad	925	UR	LGR	AEE	1975
	Leningrad 3	Leningrad	925	UR	LGR	AEE	1979
	Leningrad 4	Leningrad	925	UR	LGR	AEE	1981
	Novovoronezh 2	Voronezh	336	UR	PWR	AEE	1969
	Novovoronezh 3	Voronezh	385	UR	PWR	AEE	1971
	Novovoronezh 4	Voronezh	385	UR	PWR	AEE	1972
	Novovoronezh 5	Voronezh	950	UR	PWR	AEE	1980
	Rovno 1	West Ukraine	361	UR	PWR	AEE	1980
	Rovno 2	West Ukraine	384	UR	PWR	AEE	1981
	Rovno 3	West Ukraine	950	UR	PWR	AEE	1986
	Smolensk 1	Smolensk	925	UR	LGR	AEE	1982
	Smolensk 2	Smolensk	925	UR	LGR	AEE	1985
	South Ukraine 1	Nikolaiev	950	UR	PWR	AEE	1982
	South Ukraine 2	Nikolaiev	950	UR	PWR	AEE	1985
	South Ukraine 3	Nikolaiev	950	UR	PWR	AEE	1989
	Zaporozhe 1	Energodar, Ukraine	950	UR	PWR	AEE	1984
	Zaporozhe 2	Energodar, Ukraine	950	UR	PWR	AEE	1985
	Zaporozhe 3	Energodar, Ukraine	950	UR	PWR	AEE	1986
	Zaporozhe 4	Energodar, Ukraine	950	UR	PWR	AEE	1987
	Zaporozhe 5	Energodar, Ukraine	950	UR	PWR	AEE	1989
Total	**43 Units**		**34,186**				
Total Operable Capacity in Foreign Countries With Regulated Market and Centrally Planned Economies (66 Units)			**43,782**				

[a]EIA's review of the latest data sources has resulted in revisions of names, capacities, and grid operation dates for some of the units listed in this table.
[b]Some nuclear units were rerated to reflect more current data. [c]Utility: CZ, Czechoslovakia Power Works (Czechoslovakia); DG, VUB Energieversorgung (East Germany); EE, State Economic Union, Energetics and Coal (Bulgaria); HN, Hungarian Electrical Works; UR, Ministry of Power Stations (U.S.S.R.).
[d]Reactor Type: BWR, boiling-water reactor; FBR, fast breeder reactor; GCHW, gas-cooled heavy-water reactor; LGR, light-water-cooled, graphite-moderated reactor; PWR, pressurized-water reactor.
[e]Reactor Supplier: AEE, Atomenergoexport (U.S.S.R.).
[f]Operable units for all foreign countries are those that have generated electricity to the grid.
Sources: International Atomic Energy Agency, *Nuclear Power Reactors in the World* (Vienna, Austria, April 1990); *Nuclear News*, "World List of Nuclear Power Plants" (February 1990), pp. 63-82; *Nuclear Engineering International*, "World Nuclear Industry Handbook 1990 (July 1989)," pp. 25-41.

Table H2. Roster of Foreign Nuclear Generating Units in the Construction Pipeline as of December 31, 1989, in Countries with Regulated Market and Centrally Planned Economies

Country	Unit Name [a]	Location	Capacity [b] (Net MWe)	Utility [c]	Reactor Type [d]	Reactor Supplier [e]	Percent Complete	Published Date of Operation
Bulgaria	Belene 1	Belene	953	EE	PWR	AEE	..	1992
	Belene 2	Belene	953	EE	PWR	AEE	..	1994
	Belene 3	Belene	953	EE	PWR	AEE	..	..
	Belene 4	Belene	953	EE	PWR	AEE	..	..
	Kozloduy 6	Kozloduy	953	EE	PWR	AEE		1990
Total	**5 Units**		**4,765**					
China	Guangdong 1	Daya Bay	930	RC	PWR	FRAM	40	10/92
	Guangdong 2	Daya Bay	930	RC	PWR	FRAM	30	7/93
	Qinshan 1	Shanghai	288	RC	PWR	NA	90	12/90
	Qinshan 2	Shanghai	600	RC	PWR	NA	..	..
	Qinshan 3	Shanghai	600	RC	PWR	NA	..	..
	North East China 1	Northeast China	900	RC	PWR	NA	..	ID
	North East China 2	Northeast China	900	RC	PWR	NA	..	ID
	Sunan 1	East China	900	RC	PWR	NA	..	ID
	Sunan 2	East China	900	RC	PWR	NA	..	ID
Total	**9 Units**		**6,948**					
Cuba	Juraguá 1	Cienfuegos	408	CU	PWR	AEE	..	1992
	Juragua 2	Cienfuegos	408	CU	PWR	AEE	..	..
Total	**2 Units**		**816**					
Czechoslovakia (Czech and Slovak Federal Republic)	Mochovce 1	Mochovce	388	CZ	PWR	AEE	..	1992
	Mochovce 2	Mochovce	388	CZ	PWR	AEE	..	..
	Mochovce 3	Mochovce	388	CZ	PWR	AEE	..	..
	Mochovce 4	Mochovce	388	CZ	PWR	AEE	..	..
	Temelin 1	Temelin	892	CZ	PWR	AEE	..	11/92
	Temelin 2	Temelin	892	CZ	PWR	AEE	..	6/94
	Temelin 3	Temelin	892	CZ	PWR	AEE	..	11/95
	Temelin 4	Temelin	892	CZ	PWR	AEE	..	6/97
Total	**8 Units**		**5,120**					
Germany, East (German Democratic Republic)	Stendal 1	Magdeburg	900	DG	PWR	AEE	..	1992
	Stendal 2	Magdeburg	900	DG	PWR	AEE	..	1994
	Stendal 3	Magdeburg	900	DG	PWR	AEE	..	ID
	Stendal 4	Magdeburg	900	DG	PWR	AEE	..	ID
	Stendal 5	Magdeburg	900	DG	PWR	AEE	..	ID
	Stendal 6	Magdeburg	900	DG	PWR	AEE	..	ID
	Nord 6	Lubmin	408	DG	PWR	AEE	..	1990
	Nord 7	Lubmin	408	DG	PWR	AEE	..	..
	Nord 8	Lubmin	408	DG	PWR	AEE	..	..
Total	**9 Units**		**6,624**					
Hungary	Paks 5	Paks	950	HN	PWR	NA	..	..
	Paks 6	Paks	950	HN	PWR	NA	..	..
Total	**2 Units**		**1,900**					
Poland	Kujawy 1	Kujawy	950	PO	PWR	AEE	..	ID
	Kujawy 2	Kujawy	950	PO	PWR	AEE	..	ID
	Kujawy 3	Kujawy	950	PO	PWR	AEE	..	ID
	Kujawy 4	Kujawy	950	PO	PWR	AEE	..	ID
	Warta 1	Klempicz	950	WO	PWR	AEE	..	ID
	Warta 2	Klempicz	950	WO	PWR	AEE	..	ID
	Warta 3	Klempicz	950	WO	PWR	AEE	..	ID
	Warta 4	Klempicz	950	WO	PWR	AEE	..	ID

See footnotes at end of table.

Table H2. Roster of Foreign Nuclear Generating Units in the Construction Pipeline as of December 31, 1989, in Countries with Regulated Market and Centrally Planned Economies (Continued)

Country	Unit Name [a]	Location	Capacity [b] (Net MWe)	Utility [c]	Reactor Type [d]	Reactor Supplier [e]	Percent Complete	Published Date of Operation
Poland (continued)	Zarnowiec 1	Zarnowiec	434	PO	PWR	AEE	40	ID
	Zarnowiec 2	Zarnowiec	434	PO	PWR	AEE	20	ID
	Zarnowiec 3	Zarnowiec	434	PO	PWR	AEE	..	ID
	Zarnowiec 4	Zarnowiec	434	PO	PWR	AEE	..	ID
Total	**12 Units**		**[illegible],336**					
Romania	Romania 1	Olt	440	CR	PWR	AEE	..	..
	Cernavoda 1	Cernavoda	625	CR	PHWR	AEC	60	1/93
	Cernavoda 2	Cernavoda	625	CR	PHWR	AEC	40	9/94
	Cernavoda 3	Cernavoda	625	CR	PHWR	AEC	20	1/97
	Cernavoda 4	Cernavoda	625	CR	PHWR	AEC	10	9/98
	Cernavoda 5	Cernavoda	625	CR	PHWR	AEC	5	9/99
Total	**6 Units**		**3,565**					
U.S.S.R. (Union of Soviet Socialist Republics)	Balakovo 4	Balakovo	950	UR	PWR	AEE	..	1990
	Balakovo 5	Balakovo	950	UR	PWR	AEE	..	1995
	Balakovo 6	Balakovo	950	UR	PWR	AEE	..	..
	Bashkir 1	Bashkir ASSR	950	UR	PWR	AEE	..	1990
	Bashkir 2	Bashkir ASSR	950	UR	PWR	AEE	..	1990
	Bashkir 3	Bashkir ASSR	950	UR	PWR	AEE	..	..
	Bashkir 4	Bashkir ASSR	950	UR	PWR	AEE	..	..
	Beloyarsk 4	Beloyarsk	750	UR	FBR	AEE	..	1993
	BN-1600	Beloyarsk	1,500	UR	FBR	AEE	..	..
	Ignalina 3	Ignalina, Lithuania	1,380	UR	LGR	AEE	..	..
	Ignalina 4	Ignalina, Lithuania	1,380	UR	LGR	AEE	..	ID
	Kalinin 3	Kalinin	950	UR	PWR	AEE	..	1990
	Kalinin 4	Kalinin	950	UR	PWR	AEE	..	1991
	Kharkov 1	Kharkov	950	UR	PWR	AEE	..	ID
	Kharkov 2	Kharkov	950	UR	PWR	AEE	..	ID
	Khmelnitski 2	Khmelnitski, Ukraine	950	UR	PWR	AEE	..	1990
	Khmelnitski 3	Khmelnitski, Ukraine	950	UR	PWR	AEE	..	1990
	Khmelnitski 4	Khmelnitski, Ukraine	950	UR	PWR	AEE	..	1993
	Kostroma 1	Kostroma	1,450	UR	LGR	AEE	..	1993
	Kostroma 2	Kostroma	1,450	UR	LGR	AEE	..	1994
	Kostroma 3	Kostroma	1,450	UR	LGR	AEE	..	1/90
	Kostroma 4	Kostroma	1,450	UR	LGR	AEE	..	1/91
	Kursk 5	Kursk	925	UR	PWR	AEE	..	..
	Nizhnekamsk 1	Nizhnekamsk	950	UR	PWR	AEE	..	1/89
	Nizhnekamsk 2	Nizhnekamsk	950	UR	PWR	AEE	..	1/90
	Nizhnekamsk 3	Nizhnekamsk	950	UR	PWR	AEE	..	1/91
	Nizhnekamsk 4	Nizhnekamsk	950	UR	PWR	AEE	..	1/92
	Privolzhskaya 1	Saratov	950	UR	PWR	AEE	..	..
	Privolzhskaya 2	Saratov	950	UR	PWR	AEE	..	..
	Privolzhskaya 3	Saratov	950	UR	PWR	AEE	..	..
	Privolzhskaya 4	Saratov	950	UR	PWR	AEE	..	..
	Rostov 1	Rostov-on-the-Don	950	UR	PWR	AEE	..	..
	Rostov 2	Rostov-on-the-Don	950	UR	PWR	AEE	..	..
	Rostov 3	Rostov-on-the-Don	950	UR	PWR	AEE	..	..
	Rostov 4	Rostov-on-the-Don	950	UR	PWR	AEE	..	..
	Rostov 5	Rostov-on-the-Don	950	UR	PWR	AEE	..	..
	Rostov 6	Rostov-on-the-Don	950	UR	PWR	AEE	..	..
	Rovno 4	West Ukraine	950	UR	PWR	AEE	..	1990
	Rovno 5	West Ukraine	950	UR	PWR	AEE	..	..
	Rovno 6	West Ukraine	953	UR	PWR	AEE	..	..

See footnotes at end of table.

Table H2. Roster of Foreign Nuclear Generating Units in the Construction Pipeline as of December 31, 1989, in Countries with Regulated Market and Centrally Planned Economies (Continued)

Country	Unit Name [a]	Location	Capacity [b] (Net MWe)	Utility [c]	Reactor Type [d]	Reactor Supplier [e]	Percent Complete	Published Date of Operation
U.S.S.R. (continued)	Smolensk 3	Smolensk	925	UR	LGR	AEE	--	
	Smolensk 5	Smolensk	1,450	UR	LGR	AEE		
	Smolensk 6	Smolensk	1,450	UR	LGR	AEE	--	--
	South Ukraine 4	Nikolaev	950	UR	PWR	AEE	--	--
	Tatar 1	Tatar ASSR	950	UR	PWR	AEE	--	1990
	Tatar 2	Tatar ASSR	950	UR	PWR	AEE	--	1993
	Tatar 3	Tatar ASSR	950	UR	PWR	AEE	--	1994
	Tatar 4	Tatar ASSR	950	UR	PWR	AEE	--	1995
	Tsimlyansk 1	Volgodonsk	950	UR	PWR	AEE	--	--
	Tsimlyansk 2	Volgodonsk	950	UR	PWR	AEE		--
	Tsimlyansk 3	Volgodonsk	950	UR	PWR	AEE	--	--
	Tsimlyansk 4	Volgodonsk	950	UR	PWR	AEE	--	--
	Zaporozhe 6	Energodar, Ukraine	950	UR	PWR	AEE	--	1991
Total	**53 Units**		**55,460**					
Total Capacity in the Construction Pipeline in Foreign Countries With Regulated Market and Centrally Planned Economies (106 Units)			**94,534**					

[a]EIA's review of the latest data sources has resulted in revisions of names, capacities, and grid operation dates for some of the units listed in this table.
[b]Some nuclear units were rerated to reflect more current data.
[c]Utility: CR, Romanenergo (Romania); CU, Operated by Cuban Government; CZ, Czechoslovakia Power Works; DG, VUB Energieversorgung (East Germany); EE, State Economic Union, Energetics and Coal (Bulgaria); HN, Hungarian Electrical Works; PO, Northern Power Authority and WO, Western Power Authority (both Poland); RC, Operated by Chinese Government; UR, Ministry of Power Stations (U.S.S.R.).
[d]Reactor Type: FBR, fast breeder reactor; LGR, light-water-cooled, graphite-moderated reactor; PHWR, pressurized heavy-water reactor; PWR, pressurized-water reactor.
[e]Reactor Supplier: AEC, Atomic Energy of Canada, Ltd. (Canada); AEE, Atomenergoexport (U.S.S.R.); FRAM, Framatome (France).
Note: NA = data not available; ID = indefinitely deferred.
Note: "Construction pipeline" in this report includes units in operation and those under construction and planned that currently are expected to be completed by 2010.
Sources: International Atomic Energy Agency, *Nuclear Power Reactors in the World* (Vienna, Austria, April 1990); *Nuclear News*, "World List of Nuclear Power Plants" (February 1990), pp. 63-82; *Nuclear Engineering International*, "World Nuclear Industry Handbook 1990 (July 1989)," pp. 25-41.

Appendix I

Annual Capacity and Generation Projections for U.S. Nuclear Power Supply Scenarios

Appendix I

Annual Capacity and Generation Projections for U.S. Nuclear Power Supply Scenarios

The projections contained in this appendix were developed in accordance with the assumptions detailed in Chapter 2 of this report. Table I1 provides the annual detail supporting the capacity projections for each nuclear power supply scenario shown in Table 5 and Table 8. Table I2 presents annual net generation projections for each nuclear power supply scenario.[70]

The post-2010 capacity projections are based on a linear interpolation of nuclear capacity requirements estimated at 5-year intervals beginning in 2011 for the Lower Reference and Upper Reference cases. Therefore, these projections should be regarded as annual averages.

[70]The values in this appendix are presented in terms of calendar years. The U.S. Department of Energy's Office of Civilian Radioactive Waste Management, for its purposes, converts the generation projections to fiscal years.

Table 11. Annual Projections of U.S. Operable Nuclear Capacity at the End of the Year

(Net Gigawatts-Electric)

Year	Scenario		
	No New Orders Case	Lower Reference Case	Upper Reference Case
1989[a]	98	98	98
1990	99	99	99
1991	99	99	99
1992	102	102	102
1993	102	102	102
1994	102	102	102
1995	103	103	103
1996	103	103	103
1997	103	103	103
1998	103	103	103
1999	103	103	103
2000	104	104	104
2001	104	105	105
2002	104	105	105
2003	104	105	105
2004	104	105	105
2005	104	105	105
2006	104	105	107
2007	103	105	109
2008	103	105	113
2009	102	105	118
2010	100	103	122
2011	96	105	124
2012	91	107	127
2013	82	104	124
2014	72	100	120
2015	69	103	124
2016	63	102	125
2017	59	105	129
2018	58	109	135
2019	58	114	143
2020	54	116	146
2021	51	121	153
2022	45	122	156
2023	41	124	161
2024	34	125	163
2025	28	126	166
2026	22	126	168
2027	14	124	168
2028	12	128	174
2029	8	130	178
2030	6	134	184

[a] Actual.

Sources: **1989-2010**--Energy Information Administration, *Annual Energy Outlook*, DOE/EIA-0383(90). **Post-2010**--WINES Model.

Table 12. Annual Projections of U.S. Nuclear Generation
(Net Terawatthours)

Year	Scenario		
	No New Orders Case	Lower Reference Case	Upper Reference Case
1989[a]	529	529	529
1990	[b] 541	541	541
1991	551	551	551
1992	554	559	559
1993	555	566	566
1994	557	565	565
1995	558	573	573
1996	562	575	575
1997	566	578	578
1998	572	583	583
1999	570	582	582
2000	572	586	586
2001	579	595	593
2002	582	598	598
2003	586	601	601
2004	589	606	606
2005	592	608	608
2006	595	611	619
2007	595	613	630
2008	595	616	642
2009	598	620	673
2010	595	620	714
2011	567	603	706
2012	544	612	726
2013	492	591	717
2014	425	572	700
2015	409	596	717
2016	373	598	735
2017	353	616	763
2018	344	644	800
2019	342	680	849
2020	320	694	875
2021	307	622	916
2022	268	738	932
2023	244	760	963
2024	205	766	978
2025	165	776	1,024
2026	131	759	1,015
2027	84	749	1,016
2028	70	776	1,076
2029	53	802	1,111
2030	40	852	1,171

[a] Actual.

[b] Value from the AEO was replaced by the value from the International Nuclear Model.

Sources: **Historical Generation Data**--Energy Information Administration, *Monthly Energy Review*, December 1988, DOE/EIA-0035 (88/12) (March 1989). **Projected Generation**--No New Orders Case--1990-2010, *Annual Energy Outlook (1990)*, DOE/EIA-0383(90); 2011-2030, International Nuclear Model (INM) (1989). Lower and Upper Reference Cases--1990-2030, INM.

Appendix J

Status of U.S. Nuclear Plant Construction

Status of U.S. Nuclear Plant Construction

Introduction

This Appendix presents construction cost and milestone data for nuclear units in the construction pipeline,[71] canceled, or in commercial operation as of December 31, 1989. The data in this appendix were collected from nuclear utilities on Form EIA-254, "Semiannual Report on Status of Reactor Construction."[72] In some instances, the data presented here may vary from that presented in the body of the report since the source there for the comparable data is the U.S. Nuclear Regulatory Commission.

Discussion

The construction costs reported in Tables J1 and J2 comprise the total cost of the nuclear plant and can be regarded as the fixed investment or capital costs of the plant. The requested cost estimates are disaggregated into direct costs, indirect costs, contingency costs, common facility costs, and Allowance for Funds Used During Construction (AFUDC). Estimates of direct costs are further disaggregated into the following categories:

- Land and land rights
- Structures and improvements
- Reactor plant equipment
- Turbogenerator units
- Accessory electric equipment
- Miscellaneous power plant equipment.

For each nuclear unit, the estimated cost data provide an indication of the total expected construction costs and a record of revised estimates. Reported costs are in mixed current dollars; that is, the costs are in current dollars of a number of different years.

During 1988, 5 units entered commercial operation, 8 units were under construction, and 7 were deferred.[73] The status as of December 31, 1989, is shown in Figure J1. Of the 8 units under construction in 1988, 2 entered commercial operation during 1989, and 5 units were still under construction. One unit, Shoreham, was deferred in 1989, and one unit, Grand Gulf 2, was canceled during 1989. There are currently 7 deferred units in the construction pipeline.

During 1989, two nuclear units entered commercial operation: Vogtle 2 (Georgia) and South Texas 2 (Texas). These units entered commercial operation in May and June 1989, respectively. These units have a net summer capability[74] of 2.3 GWe and a total construction cost of $4.2 billion.

For the five units remaining under construction as of December 31, 1989, the estimated net summer capability is 5.7 GWe and the total construction cost is estimated at $21.7 billion.

In Table J1, the five units actively under construction as of December 31, 1989, are grouped by year of commercial operation as reported by the utilities in the 1989 survey. Commercial operation dates are estimates by the utilities and are subject to change. These data show that three of the five units under construction were expected to be in commercial operation by the end of 1990, representing a total net summer capability of 3.4 GWe and estimated total construction expenditures of $13.5 billion (in mixed current dollars). Two units are expected to enter commercial operation in 1991 representing a total net summer capability of 2.3

[71] Units referred to as being "in the construction pipeline" are those in the process of power ascension, those actively under construction, those for which construction permits are under review, and those that have been suspended or deferred but not officially canceled.

[72] For a discussion of uses of the data and a detailed description of the data, see Energy Information Administration, *Nuclear Power Plant Construction Activity 1988*, DOE/EIA-0473 (Washington, DC, June 1989).

[73] The Tennessee Valley Authority revised its December 31, 1988, Form EIA-254 submission to reflect deferral of Watts Bar 2 in October 1988 instead of October 1989 as originally reported.

[74] Net Summer Capability is the steady hourly output that generating equipment is expected to supply to steam load, exclusive of auxiliary power, as demonstrated by testing at that time of summer peak demand. Source of data on net summer capability: Energy Information Administration, Form EIA-860, "Annual Electric Generator Report 1989."

GWe and estimated total construction expenditures of $8.3 billion.

Table J2 shows reactor-specific data as of December 31, 1989. Data on nuclear power plant construction activity are collected on Form EIA-254, "Semiannual Report on Status of Reactor Construction." Results of this survey were previously reported in a report titled, *Nuclear Power Plant Construction Activity*. However, because of slow construction activity and a diminishing survey frame, this report was discontinued after publication of the 1988 version. The results of the survey will be included in future issues of *Commercial Nuclear Power*.

Table J1. Total Net Summer Capability and Estimated Total Cost of U.S. Nuclear Units Actively Under Construction, by Year Expected by Utility to Enter into Commercial Operation

Expected Year of Entry Into Commercial Operation	Number of Units	Total Net Summer Capability (GWe)	Estimated Total Cost (billion dollars)
1990	[a] 3	3.4	[b] 13.5
1991	2	2.3	8.2
Total	5	5.7	21.7

[a] All three of those units actually entered commercial operation in the first half of 1990.
[b] Estimated total costs for one unit include AFUDC (Allowance for Funds Used During Construction) for the majority owner only.
Note. Costs are in mixed-current dollars.
Sources: Net Summer Capability - Energy Information Administration, Form EIA-860, "Annual Electric Generator Report 1989." Cost Data - Energy Information Administration, Form EIA-254, "Semiannual Report on Status of Reactor Construction," 1989.

Table J2. Reactor Specific Data for Nuclear Units as of December 31, 1989

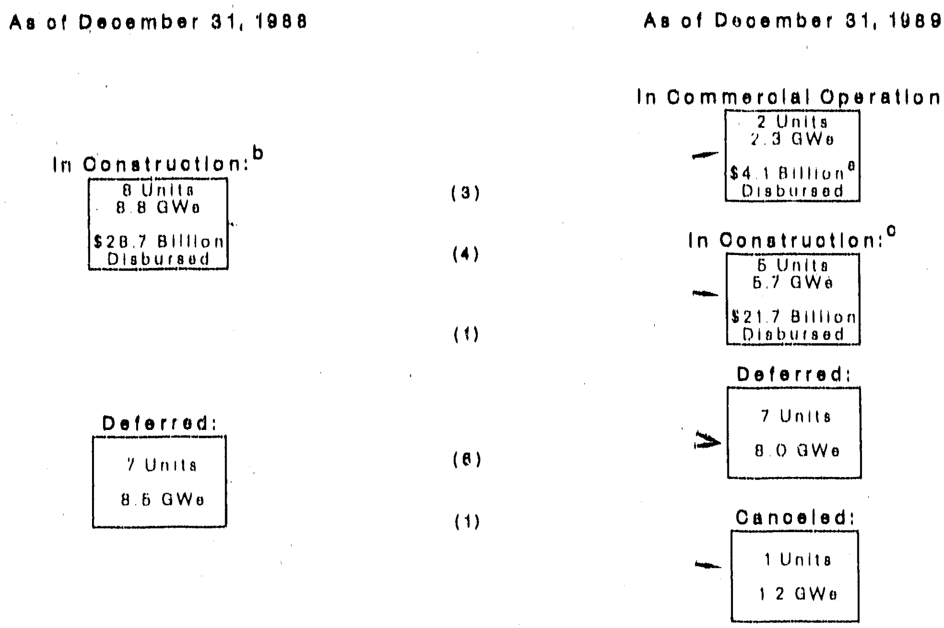
Unit Name	Units That Entered Commercial Operation in 1989			Canceled Units in 1989
	Commercial Operation Date	Net Summer Capability (MWe)	Final Cost (thousand dollars)	Date of Cancellation
Vogtle 2	May 1989	1,086	2,582,000	-
South Texas 2	June 1989	1,250	1,648,875	-
Grand Gulf 2		-		September 1989

Unit Name	Units Remaining Under Construction				
	Estimated Commercial Operation Date	Net Summer Capability (MWe)	Estimated Final Cost (thousand dollars)	Disbursed + AFUDC (thousand dollars)	Disbursed + Commitments (thousand dollars)
Limerick 2	January 1990	1,055	2,809,600	2,769,400	2,809,600
Comanche 1	March 1990	1,150	5,192,006	6,411,699	6,411,699
Seabrook 1	March 1990	1,150	5,490,549	5,490,549	5,490,549
Comanche 2	June 1991	1,150	3,599,752	2,681,056	2,681,056
Watts Bar 1	October 1991	1,170	4,616,606	4,296,113	4,324,913

Unit Name	Deferred Units			
	Date of Deferral	Net Summer Capability (MWe)	Disbursed + AFUDC (thousand dollars)	Disbursed + Commitments (thousand dollars)
WNP 1	April 1982	1,250	2,158,000	2,097,000
WNP 3	July 1983	1,250	3,013,000	2,591,000
Perry 2	August 1985	1,179	NR	NR
Bellefonte 1	June 1988	1,212	4,260,963	4,273,025
Bellefonte 2	June 1988	1,212	793,073	NR
Watts Bar 2	October 1988	1,170	1,623,262	1,642,462
Shoreham	June 1989	809	5,549,546	5,549,546

Note: AFUDC Allowance for Funds Used During Construction.
NR Not Reported.

Figure J1. Status of Nuclear Plant Construction as of December 31, 1988 and December 31, 1989



Note: GWe means electric gigawatts of net summer capability.

[a]Amount disbursed does not reflect the total cost of these units because not all funds were disbursed at the onset of commercial operation.

[b]Three units were reported completed but not yet in commercial operation. The Tennessee Valley Authority revised their December 31, 1988, submission of Form EIA-254, which reflects deferral of Watts Bar 2 in October 1988. This figure has been adjusted accordingly.

[c]Eight units were reported completed but not in commercial operation.

Source: Energy Information Administration, Form EIA-254, 1989.

Glossary

Availability Factor: A percentage representing the number of hours a reactor is available to generate power (regardless of the amount of power) in a given period, compared to the number of hours in the period.

Backfit: A term applied to the installation of a new system after an original system is in place, or the modification of the original system after it has been completed. This refers to changes mandated by the U.S. Nuclear Regulatory Commission or by safety agencies in foreign countries.

Balance-of-Plant: The components of a nuclear power plant outside the Nuclear Steam Supply System (NSSS).

Baseload: The minimum amount of electric power delivered or required over a given period of time at a steady state.

Baseload Capacity: The generating equipment normally operated to serve loads on a round-the-clock basis.

Baseload Plant: A plant, usually housing high-efficiency steam-electric or nuclear generating units, which is normally operated to take all or part of the minimum load of a system, runs continuously, and produces electricity at an essentially constant rate. 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.

Borated Water: Water containing a high concentration of boron, a neutron-absorbing element. The introduction of borated water into a reactor slows the reaction rate by absorbing free neutrons.

Breeder Reactor: A reactor that produces fissionable fuel as well as consuming it, 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.

CANDU: Canadian Deuterium-Uranium reactor. A nuclear reactor of Canadian design which uses natural uranium as a fuel and heavy water as a moderator and coolant.

Capacity: The full-load capability of a generating unit to produce electrical energy for a given time period and under specified conditions. The units of capacity are typically kilowatts or megawatts. In this report, U.S. "capacity" refers to net summer capability (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.

CPE: Centrally Planned Economies: (China, Cuba, North Korea and the USSR).

Commercial Operation: The phase of reactor operation that begins when power ascension ends and the operating utility formally declares the nuclear power plant to be 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.

Confinement: A reinforced building surrounding the reactor vessel and most or all of the primary radioactive circuits of a nuclear reactor, designed to withstand above-normal pressure and minimize radiation release in the event of a leak or rupture in the system. Less secure than a containment.

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 becomes operable. (See Operable.)

Containment: A massive steel-and-concrete structure surrounding the reactor vessel and most or all primary radioactive circuits of a nuclear reactor; designed to withstand extreme pressure and prevent the release of radiation in the event of a leak or rupture inside the system.

Control Rods: Rods inserted into the core of a reactor to absorb free neutrons and slow the rate of fission reactions.

Coolant: Material used to conduct heat away from the reactor core to the steam cycle of a nuclear power plant. Liquids, gases, and liquid metals can be used as coolants.

Core: The heat-generating component of a nuclear reactor, including the radioactive fuel, the fuel assemblies, and any other integral parts of the heat-generating mass (e.g., the graphite blocks in a gas-cooled reactor).

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

Cycle Length: The length of time a reactor is operated between refuelings, including the refueling time (typically, 14 to 18 months).

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.

Elasticity of Demand: The ratio of the percentage change in demand for a product to the percentage change in another variable, such as price or income. Demand is elastic when the absolute value of this ratio exceeds 1.0.

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 type of 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 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 (Fissionable) 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.

Fuel Cycle: The complete series of steps involved in supplying fuel for nuclear reactors, including mining, refining, enrichment, the original fabrication of fuel elements, their use in a reactor, and management of spent fuel and radioactive wastes. A closed fuel cycle includes chemical reprocessing to recover the fissionable material remaining in the spent fuel; an open fuel cycle does not.

FME: Free Market Economies: This group does not include countries with centrally planned or regulated market economies.

Full-Power Operation: Operation of a unit at 100 percent of its design capacity. Full-power operation precedes commercial operation. (See Operable.)

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

Generation (Gross): The total amount of electric energy produced by the generating units in a generating station or stations, measured at the generator terminals.

Generation (Net): Gross generation less the electrical energy consumed at the generating station for station use.

Gigawatt-electric (GWe): One billion watts. (See Watt.)

Graphite: A crystalline form of carbon used to moderate nuclear reactions.

Gross Domestic Product (GDP): A measure of the total final output of an economy within the geographic borders of the country by residents and nonresidents, regardless of the allocation to domestic and foreign claims.

Gross National Product (GNP): A measure of the final output of goods and services by citizens of a country, whether living at home or in foreign countries. GNP comprises GDP and factor incomes from abroad accruing to residents, less the income earned in the domestic economy accruing to citizens of other countries.

Halving Factor (Time): The time from the base year required for a variable to reach the midpoint between its base-year value and its asymptotic value.

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.

High-Temperature Gas-Cooled Reactor (HTGR): A reactor that is cooled by helium and moderated by graphite. The reactor is fueled with enriched uranium and with thorium, that can be transformed into useful fuel when it is irradiated.

Inherent Safety: Safety that is provided by the physical and chemical properties of a reactor system rather than mechanical or human safeguards. For example, a sodium-cooled reactor using metal fuel may be inherently safe because the reaction can be designed to stop itself without mechanical or human intervention in the event of a disturbance to normal reactor operations.

Isotope: One of two or more atoms having the same number of protons but different numbers of neutrons.

Kilowatt-electric (kWe): One thousand watts. (See Watt.)

Kilowatthour (kWh): One thousand watthours.

Lead-Time: The length of time from the start of construction of a nuclear unit until it becomes operable.

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.

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

Market (Logistic) Penetration Model: An exponential trend function in which the rate of growth begins at a low level, reaches a maximum, and then declines so that the increasing quantity approaches a maximum value (asymptote).

Maximum Dependable Capacity, Net: The gross electrical output measured at the output terminals of the turbine generator(s) during the most restrictive seasonal conditions, less the station service load.

Megawatt-electric (MWe): One million watts. (See Watt.)

Megawatthour (MWh): One million watthours.

Metal Fuel: A fuel made from metallic uranium rather than a uranium oxide. When overheated, metal fuels expand, producing a decline in reactivity; this expansion forms the basis for certain principles of inherently safe reactors.

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(s) by the fissioning of nuclear fuel is used to drive a steam turbine(s).

Nuclear Reactor: An apparatus in which the nuclear fission chain reaction 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.

Nuclear Steam Supply System (NSSS): The equipment used to supply nuclear-generated steam to the turbine-generator, consisting primarily of the reactor vessel and all internals; the primary coolant system and all associated pipes, valves, and pumps; and the steam generator and pressurizer for pressurized-water reactors.

Operable: A nuclear unit for the United States is "operable" after it completes low power testing and is issued a full power license by the Nuclear Regulatory Commission. For all foreign nuclear units, operable units are those that have generated electricity to the grid.

Passive Safety: See "Inherent Safety."

Plutonium (Pu): A heavy, fissionable, radioactive, metallic element (atomic number 94) that occurs naturally in trace amounts. It can also result 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.

Pressure Vessel: A massive steel vessel surrounding the reactor core that is used in all light-water reactors and in most other reactors.

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

RME: Regulated Market Economies (formerly centrally planned economies).

Senescence: Reactor aging, with resulting deterioration from wear and the effects of a harsh internal environment.

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 Fuel: Irradiated fuel that is permanently discharged from a reactor. 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 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 fuel before irradiation). The difference between these two quantities is the weight of the fission products.

Steam Generator: A component of pressurized-water reactors that transfers heat from the pressurized, nonboiling fluid circuit in the core to a separate steam circuit that drives the turbines.

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

Thorium (Th): A fertile element (Th-232) that can be bred into a fissile isotope (U-233) in certain reactors.

Turbine: A machine for producing rotary mechanical power from the energy in a stream of fluid (such as water, steam, or hot gas). Turbines convert the kinetic or thermal energy of the fluid to mechanical energy.

Uranium (U): A heavy, naturally radioactive, metallic element (atomic number 92) whose two principal 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.

Watt: The electrical unit of power. The rate of energy transfer equivalent to 1 ampere flowing under a pressure of 1 volt at unity power factor.

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