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Nuclear Power

Nuclear power is projected to represent a shrinking share of the world's electricity consumption from 2001 through 2025, despite a net increase in world nuclear capacity as a result of new construction and life extensions.

In the *International Energy Outlook 2003* (*IEO2003*) reference case, the nuclear share of the world's total electricity supply is projected to fall from 19 percent in 2001 to 12 percent by 2025. The reference case assumes that the currently prevailing trend away from nuclear power in the industrialized countries will not be reversed, and that retirements of existing plants as they reach the end of their designed operating lifetimes will not be balanced by the construction of new nuclear power capacity in those countries. In contrast, rapid growth in nuclear power capacity is projected for some countries in the developing world.

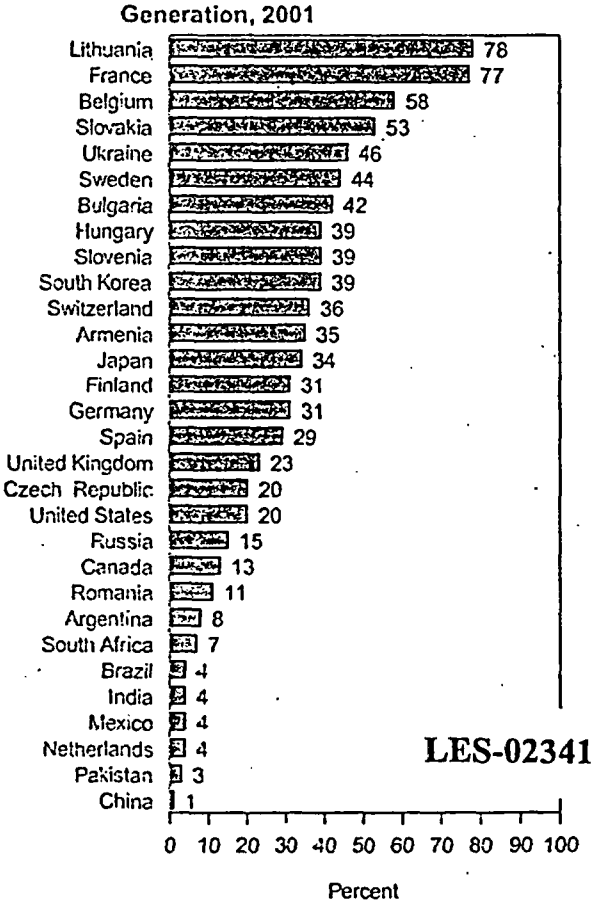
For the most part, and under most economic assumptions, nuclear power is a relatively expensive option for electricity generation when compared with natural gas or coal, particularly for nations with access to inexpensive sources of coal and natural gas. In addition, there is strong public sentiment against nuclear power in many parts of the world, based on concerns about plant safety, radioactive waste disposal, and the proliferation of nuclear weapons. The economics of nuclear power may be more favorable in other countries where for new nuclear construction capital costs can be relatively low, discount rates low, and construction times potentially short, and where other energy fuels (mostly imported) are relatively expensive.

Nineteen countries depended on nuclear power for at least 20 percent of their electricity generation in 2001 (Figure 66). In absolute terms the world's total nuclear power capacity is projected to increase from 353 gigawatts in 2001 to 366 gigawatts in 2025 in the reference case (Table 20). Most nuclear capacity additions are expected to be in Asia, where China, India, Japan, and South Korea are projected to add a combined total of approximately 45 gigawatts of nuclear capacity between 2001 and 2025, while the rest of the world sheds some 32 gigawatts of existing capacity. In addition, life extensions, higher capacity factors, and capacity uprates are expected to offset some of the capacity lost through plant retirements in other parts of the world. Life extension and higher capacity factors will play a major role in sustaining the U.S. nuclear industry throughout the forecast period. Russia also has an ambitious life extension program. Thus, despite a declining share of global electricity production, nuclear power is projected to continue in its role as an important source of electric power.

At the end of 2002 there were 441 nuclear power reactors in operation around the world (Figure 67). Another 33 nuclear power plants were under construction (Figure 68). Six new nuclear power plants began operation in 2002—four in China and one each in South Korea and the Czech Republic [1].

Nuclear power projections are subject to considerable uncertainty, both economic and political. The *IEO2003* high and low nuclear growth cases illustrate a range of possible outcomes, based on more optimistic and more pessimistic assumptions than in the reference case. On

Figure 66. Nuclear Shares of National Electricity Generation, 2001



Source: International Atomic Energy Agency, Reference Data Series 2, "Power Reactor Information System," web site www.iaea.org/programmes/a2/.

Table 20. Historical and Projected Operable Nuclear Capacities by Region, 2001-2025
(Net Gigawatts)

Region	2001[a]	2005	2010	2015	2020	2025
Reference Case						
Industrialized	278.7	283.9	290.7	288.5	279.4	260.9
United States	98.2	100.2	99.3	99.5	99.6	99.6
Other North America	11.4	14.6	15.9	15.9	15.9	13.0
Japan	43.2	45.0	49.4	52.2	52.2	51.9
France	63.1	63.5	66.6	66.6	66.6	64.7
United Kingdom	12.5	11.0	11.1	7.0	6.0	5.4
Other Western Europe	50.3	49.7	48.4	47.3	39.1	26.3
EE/FSU	46.3	46.6	46.4	45.0	39.9	34.7
Eastern Europe	11.6	11.8	10.7	10.7	11.3	11.3
Russia	20.8	22.0	23.5	22.5	16.7	14.5
Ukraine	11.2	11.3	11.9	11.9	11.9	8.9
Other FSU	2.7	1.6	0.4	0.0	0.0	0.0
Developing	27.6	37.9	44.7	59.6	63.2	70.4
China	2.2	7.6	8.6	16.6	16.6	19.6
South Korea	13.0	16.9	18.0	20.9	23.6	27.6
Other	12.4	13.3	18.1	22.2	23.1	23.2
Total World	352.6	368.4	381.8	393.1	382.5	366.0
Low Growth Case						
Industrialized	278.7	281.1	278.9	259.9	224.8	185.2
United States	98.2	100.2	99.3	99.5	99.6	99.6
Other North America	11.4	14.6	15.2	12.3	10.7	9.8
Japan	43.2	43.9	49.4	48.6	41.6	35.8
France	63.1	63.5	66.6	64.7	54.3	33.2
United Kingdom	12.5	11.0	7.0	3.6	1.3	1.3
Other Western Europe	50.3	47.9	41.4	31.2	17.3	6.5
EE/FSU	46.3	45.0	43.0	36.4	30.1	17.3
Eastern Europe	11.6	11.0	10.7	10.7	11.3	8.4
Russia	20.8	21.6	22.5	16.7	12.8	7.9
Ukraine	11.2	11.3	9.8	9.1	6.0	1.0
Other FSU	2.7	1.2	0.0	0.0	0.0	0.0
Developing	27.6	35.6	41.6	48.3	52.1	50.6
China	2.2	6.6	8.6	9.6	12.6	12.3
South Korea	13.0	16.0	17.1	19.9	20.2	21.3
Other	12.4	13.0	16.0	18.7	19.2	17.0
Total World	352.6	361.7	363.5	344.6	306.9	253.1
High Growth Case						
Industrialized	278.7	288.1	298.3	314.5	335.8	351.6
United States	98.2	100.2	99.3	99.5	99.6	99.6
Other North America	11.4	14.6	15.9	16.6	18.3	20.0
Japan	43.2	47.0	51.6	60.0	70.4	73.7
France	63.1	63.7	66.6	69.5	72.4	75.3
United Kingdom	12.5	11.9	11.1	14.0	16.2	17.0
Other Western Europe	50.3	50.8	53.8	55.0	58.9	66.0
EE/FSU	46.3	49.6	56.7	64.9	78.2	96.3
Eastern Europe	11.6	12.6	12.6	16.2	19.7	25.7
Russia	20.8	22.9	28.8	33.6	39.9	43.1
Ukraine	11.2	11.3	13.8	13.8	15.7	17.7
Other FSU	2.7	2.7	1.6	1.4	2.9	9.9
Developing	27.6	39.4	56.0	71.6	97.6	119.0
China	2.2	8.6	11.7	17.7	20.7	22.7
South Korea	13.0	16.9	20.5	24.9	30.3	34.4
Other	12.4	13.9	23.8	29.0	46.6	62.6
Total World	352.6	377.1	411.0	451.0	511.5	566.9

[a]Status as of December 31, 2001. Data are preliminary and may not match other EIA sources.

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Totals may not equal sum of components due to independent rounding.

Sources: United States: Energy Information Administration, *Annual Energy Outlook 2003*, DOE/EIA-0383(2003) (Washington, DC, January 2003). Foreign: Based on detailed assessments of country-specific nuclear power programs.

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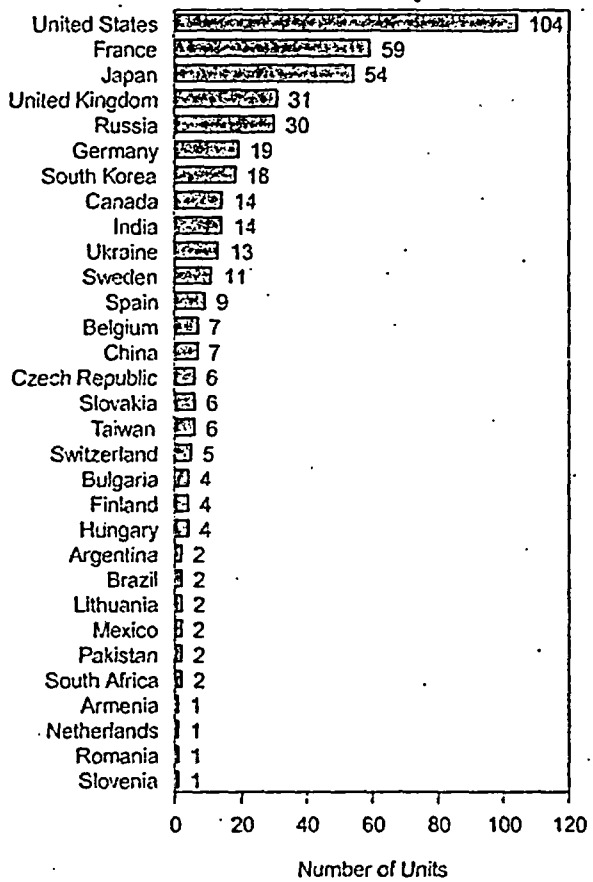
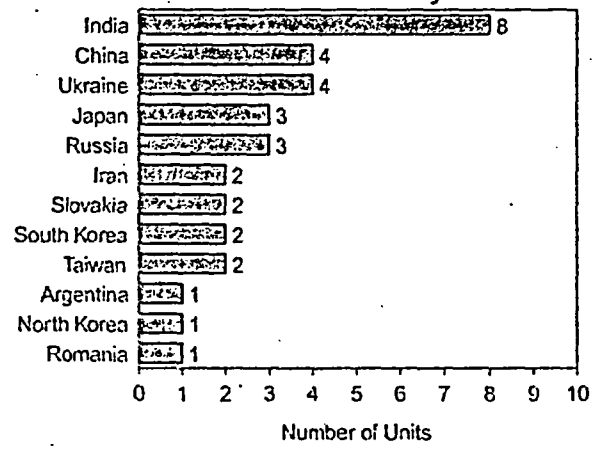
Figure 67. Operating Nuclear Power Plants Worldwide as of February 2003



Source: International Atomic Energy Agency, Reference Data Series 2, "Power Reactor Information System," web site www.iaea.org/programmes/a2/ (February 15, 2003).

Figure 68. Nuclear Power Reactors Under Construction as of January 2003



Source: International Atomic Energy Agency, Reference Data Series 2, "Power Reactor Information System," web site www.iaea.org/programmes/a2/ (January 1, 2003).

the optimistic side, for example, emerging technologies could change the economics and perceived safety of nuclear power plants, as well as public sentiment about radioactive waste disposal and nuclear weapons proliferation. In the high nuclear growth case, world nuclear capacity is projected to grow from 353 gigawatts in 2001 to 567 gigawatts in 2025 (Table 20).

On the pessimistic side, whatever public support for nuclear power is currently in evidence could be eroded quickly if a serious nuclear mishap occurred anywhere in the world; expected technology breakthroughs might not materialize; and future delays or cost overruns on nuclear power construction projects could adversely affect economics. In fact, there have been no new orders for nuclear power plants since 1978 in the United States and none since 1993 in the European member countries of the Organization for Economic Cooperation and Development (OECD). Nuclear power development generally depends on government support or sanction, and political developments can bring into power political parties that are opposed to the nuclear option, as has happened in Western Europe in recent years. In the low nuclear growth case, world nuclear capacity is projected to shrink from 353 gigawatts in 2001 to 253 gigawatts in 2025 (Table 20). The low nuclear growth case does, however, include new builds in other regions, specifically Asia. The following paragraphs discuss in more detail some of the uncertainties that could affect the future of nuclear power around the world.

The nuclear accidents at Three Mile Island in the United States in 1979 and at Chernobyl in the Soviet Union in 1986 did serious damage to nuclear prospects during the 1980s and 1990s. More recently, however, significant improvements in operating and safety performance have improved the image of nuclear power and its future global prospects. For instance, the average world nuclear power plant availability factor has improved from 73 percent in 1990 to 83 percent in 2001 [2], and average U.S. capacity factors have improved from 71 percent in 1992 to 89 percent in 2001 [3]. Greater capacity utilization has allowed the U.S. nuclear power industry to increase its net generation by 19 percent between 1991 and 2001,[21] despite a nearly 2-percent decrease in operable nuclear capacity over the same period [4]. At the same time, both overseas and in the United States, safety measures have shown considerable improvement. Nuclear power has also become a more desirable option from the perspective of meeting the carbon dioxide emission reduction targets of the Kyoto Protocol.

Nowhere is the decision to build nuclear power capacity left entirely to corporations or utilities that would base their decisions solely on economic grounds. In general,

[21] Measured as the net summer capability of operating units.

LES-02343

government policy (with an eye to public opinion) guides the development of nuclear power. National policies have evolved considerably since the first nuclear power reactors were connected to the grid in the United Kingdom, United States, and Soviet Union during the 1950s. Shortly after the first oil crisis exposed the vulnerability of world economies to petroleum price shocks, nations attempted to increase their access to more secure sources of fuel, and subsequent oil price shocks tended to reinforce their desires. As a result, many nations pursued nuclear power programs aggressively during the 1970s, in most cases with strong public support.

Subsequently, however, accidents at Three Mile Island in the United States in 1979 and at Chernobyl in the Soviet Union in 1986 pushed public opinion and national energy policies away from nuclear power as a source of electricity. In the United States, massive cost overruns and repeated construction delays—both caused in large part by regulatory reactions to the accident at Three Mile Island—essentially ended U.S. construction of nuclear power plants. Similarly, both before and after the Chernobyl accident, several European governments have announced their intentions to withdraw from the nuclear power arena. Sweden committed to a phaseout of nuclear power in 1980 after a national referendum. Both Italy and Austria have abandoned nuclear power entirely, and Austria has also been a strong opponent of nuclear power programs in Eastern Europe that it considers to be unsafe. Belgium, Germany, and the Netherlands have committed to gradual phaseouts of their nuclear power programs, although in some cases such commitments have proven difficult to carry through. Moreover, "committed" can be an ambiguous term, given that political parties with different views on nuclear power are periodically voted in or out of national office.

In large part, government support for nuclear power has waxed and waned with the changing of governing regimes, depending on whether the nation's ruling party is liberal or conservative. In recent years public officials and industry representatives from various nations have called for a reevaluation of nuclear power. For example, France, the Netherlands, Italy, and the United States have recently elected conservative governments more favorably inclined to nuclear options. In 2001, the interim head of the Italian environmental protection agency stated that the country should review its nuclear energy options and consider the potential national benefits of new generation technologies [*5*]. In the Netherlands, representatives of the ruling coalition have proposed construction of a new plant [*6*]. In the United States, the Bush Administration's energy plan calls for the expansion of nuclear energy "as a major component of our national energy policy." Current U.S. energy goals include an intended new build by the end of the current decade. Further, the Bush Administration budget proposal for 2003 included a provision to increase spending on nuclear technology research to $46.5 million from $12 million in 2002 [*7*].

In contrast, liberal governments in Sweden and Germany have committed both nations to the early retirement of their nuclear power sectors, and their recent successes at the ballot box (in September 2002) may lower the odds of reviving nuclear power programs in both countries. Since June 2000, Germany has been committed to the shutdown of its nuclear power industry by the mid-2020s, or after German reactors have been operational for an average of 32 years. Germany's current Social Democratic chancellor, Gerhard Schröder, with the strong backing of political allies in the environmentalist Green Party, negotiated the terms of the nuclear phaseout with Germany's electricity industry. It remains unclear, however, whether the goals will be met. Shortly after the September election, the German nuclear supply industry showed some hesitancy about meeting the agreed target date. In October, Energie Baden Warttemberg AG (EnBW) applied for government permission to delay the scheduled closure of its Obrigheim nuclear power station for 5 years [*8*]; and the Chief Executive Officer of E.ON, Germany's second largest electricity company, has called for the retention of nuclear power [*9*].

If the closely decided German election in September 2002 had gone the other way, Germany might well have reversed its commitment to a nuclear shutdown. Schröder's opponent, the Christian Democratic leader Edmund Stoiber, and his Free Democrat allies had adopted a platform that included a more accommodating view of nuclear power. A Stoiber government might have delayed, tabled, or reversed the ambitious nuclear shutdown plan. In Lithuania, not long after the previous government had committed to a scheduled shutdown of its existing nuclear power industry, the newly elected president, who assumed office in February 2003, stated that Lithuania must retain its nuclear power program "for definite" [*10*].

Political and economic considerations clearly can affect national plans for moving away from nuclear power. For instance, Sweden is committed to closing down its nuclear power industry entirely by the time the youngest of its nuclear power reactors reaches the end its expected lifespan—which was generally assumed to be around the year 2010—but the first two plant closures in the nuclear phaseout plan were repeatedly delayed [*11*]. Barsebäck 1, originally scheduled for shutdown in July 1998, continued operating until November 1999; and Barsebäck 2, originally scheduled for closure in 2001, remains in operation. Only 2 months after the Swedish elections in November 2002, two reports commissioned

by the government pointed to the difficulties that might arise from closing Barsebäck 2 on schedule [12]. In March 2003, the Swedish government admitted that the necessary conditions for closing Barsebäck 2 (i.e., finding an alternative source of power) could not be met.

Sweden's goal of phasing out its nuclear generation and simultaneously attempting to meet its commitment to greenhouse gas reductions following its ratification of the Kyoto Protocol in March 2002 poses a particular dilemma for this resource-intensive nation [13]. Energy-intensive industries, such as forest products and iron and steel, contribute a sizable sum to Sweden's gross domestic product (GDP) and exports, and it has been estimated that 5 percent of the nation's GDP could be lost when nuclear power is phased out entirely. Combining a nuclear phaseout with climate change commitments could cost Sweden roughly one-third of its annual GDP [14].

Another factor being weighed by European nations in deciding whether to abandon, continue, or expand their nuclear power programs is the influence of the multilateral European Union (EU). Although the EU does not set the energy policies of its members, its voice can influence the debate. European Commission Vice President (and also Transport and Energy Commissioner) Loyola de Palacio has stated that it would be "irresponsible" for countries to ignore nuclear power [15], and in mid-2002 the Commission published a report that called for keeping the nuclear option open [16].

The political divisions between pro- and anti-nuclear advocates is particularly sharp in Taiwan. When the Democratic Progressive Party of Taiwan was elected to power in March 2000, President Chen Shui-bian promised a phaseout of nuclear power and an emphasis on liquefied natural gas (LNG) as a future source of electricity. Before the election, the Kuomintang (KMT) party had ruled Taiwan since the fall of Nationalist China in 1949. A multi-party democracy emerged in Taiwan during the mid-1980s, along with a strong anti-nuclear movement. In October 2000, in pursuit of his goal of making Taiwan nuclear free, President Chen announced a decision to cancel construction of the Lungmen nuclear power station after the project had been one-third completed, which led to a major row with the more conservative parliament. Opposition parties, led by the KMT, control the parliament and were strongly opposed to the cancellation of Lungmen 1 and 2, viewing such a step as unconstitutional. In February 2001, President Chen reached an agreement with the parliamentary opposition to complete Lungmen but also to continue the pursuit of a non-nuclear Taiwan.

Finally, the on-again off-again history of Labor Party support for a nuclear phaseout in the United Kingdom suggests that opposing views on nuclear policy may exist not only across parties but also within a single party and, perhaps, within a single politician over time. In 1986, the Labor Party voted to phase out the nation's nuclear power plants gradually over a period of decades [17]. More recently, in 1997, its general election manifesto opposed adding to the country's nuclear power industry. Since the Labor Party's Prime Minister Tony Blair came into office in 2001, however, several energy policy statements from the government have suggested that the Prime Minister's office may have significantly softened its previous opposition to nuclear power. There has even been speculation that the Blair government could eventually come out in support of new builds. Then, in January 2003, the government appeared to reverse course again, when the allegedly pro-nuclear energy policy minister, Brian Wilson, called for a 5-year moratorium on construction of new nuclear power capacity [18].

Regional Developments

Asia

In Asia, nuclear power plants are currently under construction in China, South Korea, India, Taiwan, and Japan. In contrast to most of the rest of the world, developing Asia, in particular, still supports a buoyant nuclear power plant construction industry. For the developing countries of Asia (excluding Japan, which is part of the industrialized Asia country grouping), the *IEO2003* reference case projects a 17-percent share of the world's total nuclear power capacity in 2025, up from 7 percent in 2001.

China

In 2001, China had only three nuclear power units in operation: Guangdong 1 and 2 (944 megawatts each) and Qinshan 1 (279 megawatts). Four new units were opened in 2002, adding a total of 3,151 megawatts of nuclear capacity: Lingao 1 and 2 (938 megawatts each), Qinshan 2 unit 1 (610 megawatts), and Qinshan 3 unit 1 (665 megawatts). In the *IEO2003* reference case, China's nuclear capacity is projected to grow from 2,167 megawatts in 2001 to 19,593 megawatts in 2025—the largest increase projected for any country in the world.

China has been attempting to develop an indigenous nuclear technology base for some time. Thus far, China's nuclear power program has used a variety of nuclear technologies, some imported and some domestic. A goal of the program, as stated by the chairman of China's Atomic Energy Authority, is to "attain independence in the design, manufacture and operation of large nuclear power units on the basis of learning [from the] advanced experience of other countries" [19]. China's first reactors, Guangdong 1 and 2, were designed by French Framatome ANP and came on line in 1993 and 1994. Qinshan 1, which came on line in 1991, was China's first

domestically designed unit, and its design was scaled up for Qinshan 2 units 1 and 2 [20]. Qinshan 3 unit 1 is China's first reactor based on Canadian Candu technology. The two Lingao reactors that came on line in 2002 use French technology supplied by Framatome ANP.

South Korea

South Korea's nuclear power capacity is projected to grow from 12,990 megawatts in 2001 to 27,607 megawatts in 2025 in the reference case. Two 960-megawatt units, Ulchin 5 and 6, are currently under construction [21]. The country has pursued an aggressive nuclear power program since the late 1970s and has announced plans to build 10 new nuclear power reactors by 2025 (see box below).

Japan

Japan is one of the few advanced industrialized nations projected to build additional reactors over the 2001-2025 time frame. Japan—the world's third largest producer of nuclear power, after the United States and France—completed its fifty-third nuclear reactor in 2001, the 798-megawatt Onagawa 3. In the *IEO2003* reference case, Japan's nuclear power capacity is projected to grow from 43,245 megawatts in 2001 to 51,899 megawatts in 2025.

Recent events could stall Japan's effort to expand its nuclear power industry. A scandal of major proportions emerged in August 2002, when it was disclosed that Japan's largest nuclear power company, Tokyo Electric

The South Korean Standard Nuclear Plant Design

Nuclear power currently provides South Korea with 39 percent of its electricity supply. Because it lacks indigenous energy resources, South Korea was eager to develop nuclear power for its electricity sector and began a nuclear power program with the assistance of the United States in the 1950s. With U.S. aid, South Korea constructed a nuclear research reactor that was completed in 1962.

In the early 1970s, South Korea was virtually entirely reliant on oil for electricity generation, a reliance that left the nation particularly vulnerable to the first oil price shock in 1973. In the early 1970s, South Korea's nuclear power program went into full swing, and its first nuclear power plant, Kori 1, was completed in 1978. Between 1983 and 1989, eight new plants were added, and by 1989 nuclear accounted for 51 percent of South Korea's electricity generation.[a]

The purpose of South Korea's nuclear power program was in part to encourage self-reliance in nuclear power plant construction, operation, and maintenance. It was also to achieve a high degree of standardization in order to reduce costs and make operations easier. South Korea (along with China and India) is one of a number of developing nations attempting to develop indigenous nuclear power plant designs. In 1987, ABB Combustion Engineering and the Korean nuclear power industry agreed on a 10-year program (which was extended for another 10 years in 1997) aimed at transferring nuclear technology to the Korean nuclear power industry.[b]

South Korea completed its tenth and eleventh nuclear power units when Yonggwang units 3 and 4 came on line in 1995 and 1996. Both of the 960-megawatt units were based on ABB Combustion Engineering's System 80 design, in collaboration with the Korea Power Engineering Company (KOPEC). KOPEC's role grew with the construction of subsequent units. Yonggwang units 5 and 6, completed in 2002 and 2003, represent the culmination of the South Korean standard nuclear plant (KSNP) design.

The KSNP program began in 1984 as part of the government's effort to increase South Korea's technological self-reliance in nuclear energy. The KSNP was developed from incremental design improvements, which built on the safety and reliability of earlier proven designs. The Ulchin 3 and 4 units in the North Kyungsang Province of South Korea, completed in 1998 and 1999, were the first KSNPs. Their design was in turn derived from the Yonggwang 3 and 4 power plants, which were modeled on the reactors at the Palo Verde nuclear generating station in the United States.[c] The basis for all these plants is ABB's System 80 design.

The next step in South Korea's nuclear power program is the development of the advanced Korea Next Generation Reactor (KNGR). In 1992, South Korea began developing designs for a standard Advanced Power Reactor 1400 (APR1400), with a goal of design certification occurring by the end of 2002.[d]

[a]Energy Information Administration (EIA). *International Energy Annual 2001*. DOE/EIA-0219 (Washington, DC, various issues). web site www.eia.doe.gov/iea/.

[b]A. Matzie and K.I. Han, "The Evolutionary Development of Advanced Reactors," in *The Uranium Institute's Twenty Third Annual International Symposium 1998*, web site www.world-nuclear.org/sym/1998/matzie.htm.

[c]Korea Institute of Nuclear Energy, "Korea Power Program," web site www.kins.re.kr/eng/databank_7.html.

[d]E.S. Young, "RIC 2001 Recent Safety Issues and Perspectives in Korea Session TH3," Korea Institute of Nuclear Safety (March 15, 2001).

Power Co. (Tepco), had filed falsified inspection documents for 13 reactors [22]. The documents concealed from government regulators knowledge about cracks in structures holding nuclear fuel in place in reactor cores at several Tepco power plants. As a result of the disclosures, several senior Tepco executives, including the company's president, were forced to resign.

Japan's Nuclear and Industrial Safety Agency ordered the shutdown of Tepco's Fukushima plant for up to 1 year [23], and by early 2003 Tepco had suspended operations at all of its 17 nuclear reactors [24]. Several of the other nine nuclear utilities in Japan also reported similar wrongdoings. In September 2002, two of Japan's producers of nuclear power, Chubu Electric Power Co. and Tohoku Electric Power Co., reported "questionable handling of nuclear reactor inspections" [25], and by the end of 2002 a reported 13 nuclear reactors had been shut down [26]. In reaction to the falsification of inspections and repairs, the Japanese Minister of Economy, Trade and Industry stated, "It is absolutely abominable that this incident caused the people's confidence to be largely lost in nuclear power" [27].

These industrial improprieties have heightened public concern over the reporting practices at Japan's nuclear power plants and the integrity of its nuclear industry. Whether they will result in a major reevaluation of the country's nuclear power future by Japanese policymakers and industry is uncertain.

India

India's installed nuclear power capacity is projected to increase from 2,503 megawatts in 2001 to 6,986 in 2025. Currently, India has 14 nuclear power reactors in operation, which make up 4 percent of the nation's electricity generation capacity. Another 7 nuclear power reactors are in various stages of construction. Two 450-megawatt nuclear power reactors, the Tarapur 3 and 4 units, are expected to become operational by 2009, and the two 960-megawatt Kundankulam 1 and 2 units are expected to come on line in 2010 and 2011. The 3 remaining reactors now under construction are not expected to be completed during the *IEO2003* forecast period. Construction has also been started on a large prototype fast breeder reactor.

Middle East and Africa

Iran

Russia is currently working to complete a nuclear power plant at Bushehr, Iran. Initial construction of two reactors at the site was undertaken by Germany in 1974 but was suspended in 1979 (after 85 percent of the construction had been completed) in the midst of the Iranian revolution. During Iran's war with Iraq in the 1980s, Iraqi warplanes attacked Bushehr repeatedly. In 1995, Iran signed an agreement with Russia to complete the two 1,000-megawatt plants at Bushehr. Although both the United States and Israel have expressed strong opposition to Iran's nuclear power program, in July 2002 the Russian Ministry of Atomic Energy (Minatom) proposed the construction of six additional 1,000-megawatt units for Iran [28].

South Africa

South Africa, with two 900-megawatt units located at Koeberg, is the only country in Africa with nuclear power. No new additions to South Africa's nuclear capacity are expected in the *IEO2003* reference case.

South Africa's state utility, Eskom, along with South Africa's Industrial Development Corporation, has been planning to build a pebble bed modular reactor (PBMR). To date, Eskom and the Industrial Development Corporation have a joint shareholding of more than 50 percent in the PBMR project. Eskom's partners in the project originally included BNFL and U.S.-based Exelon; however, Exelon pulled out of the project in April 2002 [29], stating that:

> *Becoming a reactor supplier is no longer consistent with Exelon's strategy. Exelon continues to believe that the PBMR technology has the potential to be viable and successful. Exelon's economic and professional support has done a great deal to advance this technology's development to the point where there is a defined path to the completion of the commercialization of the technology. The project is now positioned for other companies with the appropriate expertise and core business experience to deliver the PBMR plants to power generators such as Exelon Generation.*

The move followed discussions at the end of 2001 between the PBMR Company—set up by the international consortium behind the project to build and market the reactors—and Exelon concerning the estimated cost of a PBMR unit.

At present there is a great deal of uncertainty as to whether the PBMR project will ever reach fruition. In November 2001, the PBMR consortium announced that construction of the first pilot plant would be delayed by up to 12 months [30]. In addition, earlier expectations that PBMRs would achieve revolutionary economic improvements over most existing nuclear technologies have been dampened. David Nicholls, the PBMR consortium's chief executive officer, has stated that the cost of a PBMR will not reach $1,000 per kilowatt of capacity until 32 modules have been constructed [31]. He remains optimistic, however, that the PBMR project will be completed, stating in June 2002 that he had hoped to receive approval from South Africa's government for a test reactor and to complete a pilot unit by 2007 [32].

Western Europe

Nuclear power capacity in Western Europe is projected to decline from 126 gigawatts in 2001 to 96 gigawatts in

2025 in the reference case. The projected loss would amount to 23 percent of the region's total nuclear capacity. Several Western European nations remain committed to their plans to phase out nuclear power; however, those commitments could be modified in view of their emission reduction commitment obligations under the Kyoto Protocol. Finland is the only Western European nation that is committed to the construction of additional nuclear power plants.

Belgium

It appears that Belgium has joined Germany and Sweden in adopting a commitment to phase out nuclear power. In March 2002, Belgium's inner cabinet voted to approve legislation aimed at phasing out the nation's nuclear power plants between 2015 and 2025. Individual plants would be phased out after 40 years of service [*33*]. At the same time, the Belgium Council of Ministers decided to phase out the commercial production of nuclear power in Belgium. In December 2002, Belgium's House of Representatives passed legislation to close the nation's 7 reactors after 40 years of operation, with the first one going out of service in 2015 and the last in 2025. In January 2003, the Belgian Senate voted to phase out all of the nation's nuclear power units not longer than 40 years after their entry into service [*34*]. Belgium's efforts to close its nuclear units could prove difficult, however, in that nuclear power currently provides more than 50 percent of its electricity production. No other nation as dependent on nuclear power as Belgium is has committed to a complete phaseout of its nuclear plants.

United Kingdom

Nuclear power provided 25 percent of the United Kingdom's electricity supply in 2001, but that share is projected to fall to 10 percent by 2025 in the *IEO2003* reference case. Like Japan, the United Kingdom may be approaching a watershed in its nuclear power program (see discussion earlier in this chapter). In February 2002, the government's Performance and Innovation Unit[22] issued a review of UK energy [*35*] which suggested that the government had adopted a more nuanced view of the future role for nuclear power:

> *Nuclear power: a role that cannot yet be defined, since concerns about radioactive waste and low probability but high consequence hazards may limit or preclude its use. Costs of production could fall substantially if new modular designs are effective. Unlikely to compete with fossil fuels in power generation on cost alone, but might have a significant role if low carbon emissions are required. If renewable costs do not fall as anticipated, and/or concerns surrounding waste and risks can be resolved, nuclear would be an obvious candidate for delivering low carbon electricity . . . .*

The report went on to state that any decision to construct new nuclear capacity would be largely an economic one, relying on private investors and new technology that would make the reactors competitive with other generating sources. In January 2003, however, the allegedly pro-nuclear energy minister, Brian Wilson, called for a 5-year moratorium on the construction of new nuclear power plants. An official white paper on energy policy from the prime minister's office was released in early 2003, representing the prime minister's official policy. The document included the following statement: "This white paper does not contain specific proposals for building new nuclear power stations. However, we do not rule out the possibility that at some point in the future new nuclear power builds might be necessary if we are to meet our carbon targets. Before any decision to proceed with the building of new power stations, there will need to be the fullest public consultation and the publication of a further white paper setting out our proposals" [*36*].

Relying more heavily on nuclear power is one means by which the United Kingdom could better meet its Kyoto Protocol commitments. In addition, concerns about energy security may favor the nuclear option. Domestic natural gas production began a downward trend in 2001, and concerns have been raised about the future availability of natural gas supplies, which are expected to come increasingly from foreign sources. On the other hand, possible difficulties in financing future nuclear power projects may have forced the energy minister's hand. The United Kingdom has two domestic nuclear power companies, the government-owned BNFL and the recently privatized British Energy (BE),[23] both of which have had financial difficulties.

Over the past year, BE has encountered several operational and financial difficulties. An unplanned shutdown of BE's Torness 1 nuclear unit in Scotland and operational difficulties at its Torness 2 and Dungeness B units precipitated a decline in BE's share price value [*37*]. In 2001, BE faced insolvency and reported losses of

[22]The Performance and Innovation Unit (PIU) was created in 1998 to review the effectiveness of the central government. The purpose of the PIU is to "improve the capacity of government to address strategic, cross-cutting issues and promote innovation in the development of policy and in the delivery of the Government's objectives." The unit reports directly to the Prime Minister.

[23]When the British government set about privatizing its nuclear power assets, it decided that only the country's most advanced nuclear power reactors could be sold to the public successfully. These included five advanced gas-cooled reactors (AGRs) in England, two AGRS in Scotland, and one pressurized-water reactor in England. Older gas-cooled reactors (GCRs), using MAGNOX technology, were to be retained by the UK government as a public corporation and operated by BNFL, the state-owned nuclear fuel cycle and waste disposal company. In 1996, the more modern reactors were auctioned off in the creation of BE. BE is the largest privately owned nuclear power company in the world.

$778 million for the year [38]. As a consequence, the UK government provided BE with a loan of $640 million to avoid bankruptcy. Concerns over BE's financial health caused three major credit-rating agencies to lower the company's debt rating to below investment grade [39]. BE has said that it is "in preliminary steps of exploring the possibility of selling its interest in Amergen—a 50-50 joint venture with Exelon of the U.S." [40].

BNFL has also encountered operational difficulties. Like BE, BNFL has made overseas investments in nuclear power, including a financial stake in Eskom's PBMR project in South Africa. It is possible that, if future UK government policy turns decidedly pro-nuclear, financial support for nuclear plant construction (with loan guarantees being one of several possible measures) might be forthcoming.

Another factor that may have motivated the moratorium on nuclear plant construction is a sharply reduction in electricity prices under the New Electricity Trading Arrangement (NETA), a power pool reorganization that was adopted by the United Kingdom in 2001. Between March 2001, when NETA was adopted, and March 2002, baseload electricity prices declined by 20 percent and peak prices by 27 percent [41]. Lower electricity prices were blamed for the early closure of the nation's two oldest nuclear plants, Calderhall and Chapelcross [42]. Further, in October 2002, low prices forced PowerGen, the United Kingdom's second largest electricity producer, to announce that it would idle 1,800 megawatts of capacity—26 percent of the company's total generating capacity and 2.5 percent of UK capacity [43].

Finland

Finland is the only advanced industrialized nation, outside of Japan, projected to build new nuclear power reactors. After considering an application made in November 2000 by Finnish utility TVO, the government in January 2002 approved by a 10-6 cabinet vote the building of a new nuclear unit. Finland is governed by a five-party coalition that includes the Green Party, which opposes nuclear power. In May 2002, the Finnish Parliament authorized the construction of a fifth new reactor by a vote of 107 to 92. The reactor is to be in operation in 2009. This is the first authorized construction of a nuclear power plant facility in Europe since the 1986 Chernobyl accident.

In 1993, Parliament rejected a similar proposal, but Finland appears to have adopted a more favorable view toward nuclear energy since then [44]. In a May 2002 Gallup poll, 54 percent of Finns canvassed approved the construction of a fifth unit [45]. In September 2002, TVO announced its specifications for bids to build a new nuclear reactor. Two sites are being evaluated, TVO's existing Loviisa and Olkiluoto nuclear power plant sites [46].

Eastern Europe and the Former Soviet Union

Nuclear power capacity in Eastern Europe and the former Soviet Union (EE/FSU) is projected to decline from 46,321 megawatts in 2001 to 34,722 megawatts in 2025 in the reference case. In Eastern Europe, nuclear power capacity is expected to grow slightly after 2015, with new plants expected to offset the closure of several reactors, many of which are scheduled to be shut down early in response to safety concerns. Since the breakup of the Soviet Union in the early 1990s, the European Union (EU) and the EE/FSU nations have engaged in protracted negotiations to determine the conditions under which several reactors, deemed dangerous by the EU, would be decommissioned early. Table 21 provides a listing of plants for which early closures are being negotiated.

Thus far, both Armenia and Lithuania have been able to negotiate the shutdown of their nuclear power industries with the EU. Lithuania, which relies on nuclear for 78 percent of its electricity supply agreed to shut down Ignalina unit 1 in 2005 and unit 2 by 2009. The Lithuanian parliament agreed to the shutdown of both of the country's nuclear units, with the proviso that there be "sufficient foreign aid" to support closure and that closure should not present "an unbearable burden for the national economy" [47]. A large portion of Lithuania's electricity production is exported and hence a major source of foreign exchange earnings, and the government has asserted that it might build new plants in the future [48]. Lithuania was promised 200 million euros

Table 21. European Union Schedule for Nuclear Reactor Shutdowns in Eastern Europe

Country	Plant Name	Reactor Type[a]	Expected Shutdown
Lithuania...	Ignalina 1	RBMK 1500	2005
Lithuania...	Ignalina 2	RBMK 1500	2009
Slovakia ...	Bohunice 1	VVER 440/230	2006
Slovakia ...	Bohunice 2	VVER 440/230	2008
Bulgaria ...	Kozloduy 1	VVER 440/230	2003[b]
Bulgaria ...	Kozloduy 2	VVER 440/230	2003[b]
Bulgaria ...	Kozloduy 3	VVER 440/230	2006
Bulgaria ...	Kozloduy 4	VVER 440/230	2006

[a]VVER, water-cooled water-moderated energy reactor (Russian version of pressurized-water reactor); RBMK, Soviet-designed pressurized-water reactor using ordinary water as coolant and graphite as moderator, intended and used for both plutonium and power production.

[b]Kozloduy 1 and 2 were officially closed on December 31, 2002.

Sources: European Commission, "Forecasted Shutdown Dates for Certain Nuclear Power Plants in the EU Candidate Countries," web site http://europa.eu.int/comm/energy/nuclear/decomm7.htm (March 19, 2002); and "Bulgaria Shuts Kozloduy 1 & 2 As Promised, But Not Happily," *Nucleonics Week*, Vol. 44, No. 2 (January 9, 2003), p. 10.

(about $180 million) in grants from the European Commission and 12 other nations to help ease the financial burden of shutting down its Ignalina I power plant.

Armenia, which operates one nuclear power reactor, Metsamor II, agreed with the EU in 1999 to close the plant in 2004, on the condition that the EU provide Armenia with funds to operate the plant safely during the interim. In 2001, both sides agreed to postpone the shutdown until 2006-2007. The Soviet Union had built two nuclear power reactors in Armenia, Metsamor I (now retired) and Metsamor II, both with 376 megawatts of capacity. Metsamor I and II were shut down in 1989 after sustaining earthquake damage. Metsamor II came back on line in 1995. The international community has since pressed Armenia to close Metsamor II. The EU has promised support of 100 million euros and the European Bank for Reconstruction and Development (EBRD) has promised 138 million euros for Armenia to find substitute sources of electric power when Metsamor II is closed [*49*].

Bulgaria and Slovakia have also been involved in negotiations with the EU over the shutdown of their nuclear power reactors. The EBRD has targeted the Kozloduy plant in Bulgaria and the Bohunice plant in the Slovak Republic for early shutdown. In 1999, the EU and Slovakia negotiated an agreement whereby Slovakia is committed to closing down the Bohunice plant between 2006 and 2008. Thus far, negotiations with Bulgaria have been inconclusive.

Recent negotiations between the EU and Bulgaria highlight the difficulty that Eastern European nations and the EU have had in closing nuclear power plants. Nuclear power accounts for nearly one-half of Bulgaria's electricity supply. Bulgaria's nuclear power industry consists of four 408-megawatt nuclear power reactors, Kozloduy 1 through 4, and two 953-megawatt units, Kozloduy 5 and 6. Kozloduy units 1 through 4 are Russian-built VVER 440/230 reactors that were completed in 1974, 1975, 1981, and 1982. The International Atomic Energy Agency (IAEA) declared in 1991 that Kozloduy 1 and 2 were the most dangerous nuclear power units in Europe, but that assessment has been strongly denied by the Bulgarian government [*50*].

In 1999, in an effort to gain entry into the EU, the former Bulgarian prime minister Ivan Kostov and the EU pledged to close units Kozloduy 1 and 2 before 2003 and to agree on a final date for closure of units 3 and 4 by the end of 2002. The EU has taken the position that units 3 and 4 must be closed no later than 2006 [*51*]. At the same time, Bulgaria announced that it intended eventually to restart construction at Belene, where work was stopped in 1990 [*52*]. The EU committed 200 million euros to help Bulgaria close Kozloduy units 1 and 2, and in February 2001 Westinghouse announced that it will modernize Kozloduy units 5 and 6. Bulgaria began the shutdown of Kozloduy units 1 and 2 on December 31, 2002 [*53*].

In 2002, after a series of upgrades on Kozloduy 3 and 4, the IAEA declared that "the safety of units 3 and 4 corresponds widely to the safety levels of plants of the same vintage worldwide" and that "the life of the units could be lengthened by an additional 35-40 years" [*54*]. For several years, Bulgaria has tried to renegotiate the shutdown of Kozloduy 3 and 4. Calling for a peer review by EU member states, the Bulgarian foreign policy minister stated that "should this review reveal that reactors 3 and 4 have not reached the necessary level of nuclear safety for reactors of the same vintage in the member states... we shall close them unconditionally. However, if the review shows that the reactors are in a new design condition and can function fully safely for years ahead, if they meet the requirements of the national regulator, the member states shall modify their position paper on the energy chapter, and delete the two units from the list of reactors subject to early closure" [*55*]. In October 2002, Minister of Energy Milo Kovachev stated that the government did not intend to close units 3 and 4.

Russia

Nuclear power capacity in Russia is projected to fall from 20,793 megawatts in 2001 to 14,463 megawatts in 2025 in the *IEO2003* reference case. In 1997, the Russian government approved a nuclear power construction program that would expand capacity to 29,200 megawatts by 2010. It is Russia's announced intention to replace retired nuclear capacity by new construction at the same site, to optimize the use of established infrastructure and personnel. Three advanced reactor designs are envisaged in the program. All this is seen as a precursor to large-scale nuclear energy development after 2010. Russia also plans to refurbish and extend the lives of existing reactors [*56*].

Ukraine

Ukraine has also undergone protracted negotiations with the EU over the fate of the nation's nuclear power industry. Much of the finance for completing two stalled but largely built reactors has recently been pledged. The two units will replace lost output from Chernobyl. Although the units—Khmelnitsky 2 and Rovno 4 (K2 and R4)—today are 80 percent complete, it is not clear that either unit will ever be connected to the grid. Construction on both units was aborted in 1991 after the breakup of the Soviet Union. In 1995, the EBRD and the Group of Seven (G7) signed a memorandum of understanding with Ukraine's government. An important goal of the EBRD and G7 was to encourage Ukraine to shut down its remaining Chernobyl vintage reactors. As a form of compensation, the EBRD agreed to fund the completion of K2 and R4. An understanding was reached that K2 and R4 would be operated at "western safety levels."

The $1.48 billion in funding for the completion and safety upgrade of K2 and R4 was to have come from a number of sources: $580 million from Euratom, $348 million from export credit agencies, $215 million from the EBRD, $123 million from Russia, $159 million from Energoatom (the Ukraine nuclear power utility), and $50 million from the Ukrainian government. As coordinator of the loan package, EBRD's funding became critical to the future of the project. Energoatom and the EBRD had a difficult time negotiating a loan agreement. Initially, the EBRD approved a $215 million loan in December 2000, pending certain conditions involving safety and funding availability. In December 2001, however, loan negotiations foundered over an inability to agree on a future rate structure for sales of electricity from the two plants. Since the beginning of 2002, the negotiations have shown little progress.

Throughout 2002, Ukraine also negotiated with Russia to provide funding for the completion of the K2 and R4 units. Inasmuch as Russian equipment is expected to be used, Russia has an incentive to see the projects through to completion. In mid-2002 Russia agreed to provide 50 percent of the funding for R4 [57], and in October 2002 Ukrainian government officials stated that the EBRD had indicated that it was ready to resume talks on project financing [58]. In November 2002, Ukraine's Parliament ratified a state loan agreement with Russia, and in December it was signed by the Ukrainian president, Leonid Kuchma [59, 60].

North America

Canada

Canada's nuclear power capacity is projected to grow from 10,018 megawatts in 2001 to 11,576 megawatts in 2025 in the *IEO2003* reference case. Seven of Canada's nuclear power units were shut down in 1998, and the prospects for bringing them back into service are mixed. In 1997, Ontario Hydro commissioned an analysis of the operating performance of its nuclear reactors, the results of which led Ontario Hydro to retire or suspend the operation of seven units at its Bruce and Pickering nuclear power plants. As a result of the closures—the largest nuclear shutdown in history—Canada lost more than 5,000 megawatts, or one-third, of its total nuclear electricity capacity [61].

In July 2000, Ontario Power Generation leased the Bruce A and B power plants until at least 2018 to Bruce Power Partnership, which is owned by British Energy (95 percent) and the power plant employees (5 percent). Bruce Power Partnership also acquired an option to extend the lease to 2043. As of late 2002, Bruce Power was expected to restart Bruce 4 in April 2003 and Bruce 3 in June 2003 [62]. Also, in October 2002, Ontario Power Generation announced its intention to bring Pickering 4 back on line by July 2003 [63]. Ontario Hydro had initially intended to bring Pickering A's first four units back on line by 2001, but the costs of restarting them mushroomed from $800 million to more than $2 billion [64].

United States

Installed nuclear generating capacity in the United States is projected to increase from 98.2 gigawatts in 2001 to 99.6 gigawatts in 2025 in the reference case. The increase is expected to result not from new construction but from uprates of existing capacity. In general, the *IEO2003* forecast views the construction of nuclear power plants in the United States as unlikely, because they are less economical to construct than plants fired by natural gas or coal. In 2001, the U.S. Nuclear Regulatory Commission (NRC) authorized uprates at 22 nuclear power plants, which would increase nuclear capacity in the United States by 1,111 megawatts—the equivalent of adding an additional large nuclear power unit [65]. U.S. nuclear facilities also reported a record high average capacity utilization rate of 89.3 percent in 2001, as compared with 66 percent in 1990.

The Bush Administration's energy plan calls for the expansion of nuclear energy "as a major component of our national energy policy" [66]. Current U.S. energy goals include an intended new build by the end of the current decade. The Administration's National Energy Policy, released in May 2001 [67], supports an expanded role for nuclear power, including the following recommendations:

- Encourage the NRC to expedite applications for licensing new advanced-technology reactors
- Encourage the NRC to facilitate efforts by utilities to expand nuclear energy generation by uprating existing plants
- Encourage the NRC to relicense existing nuclear plants
- Direct the Secretary of Energy and the Administrator of the Environmental Protection Agency to assess the potential of nuclear energy to improve air quality
- Provide a deep geologic repository for nuclear waste
- Support legislation to extend the Price-Anderson Act, which places financial limits on the liability of a nuclear power operator in the event of an accident.

Also in 2001, in a separate measure, the U.S. Department of Energy (DOE) solicited proposals from the civilian nuclear electricity industry to conduct scoping studies "of potential sites for the deployment of new nuclear power plants" [68].

Several developments in 2002 showed additional promise for the U.S. nuclear industry:

- In May 2002, the Board of Directors of the Tennessee Valley Authority (TVA) voted to restart Browns

Ferry 1, which has been shut down for 17 years. TVA plans to bring the unit back on line in May 2007, at an estimated cost of $1.7 to $1.8 billion. In October 2002, TVA reached an agreement with Bechtel Power to provide engineering and technical services for the restart. Bechtel stated that it intended to complete the restart by the 2007 deadline [69].

- In June 2002, DOE announced the selection of three U.S. electric utilities "to participate in a joint government/industry projects to evaluate and obtain NRC approval for sites where new nuclear power plants could be built" [70]. Dominion Resources, Entergy Nuclear, and Exelon have announced plans for early site permit applications. Entergy is focusing on four nuclear plants sites in the South, with particular emphasis on River Bend and Grand Gulf as potential locations for additional reactors.
- In July 2002, President Bush signed legislation designating Yucca Mountain as a site for the disposal of nuclear waste.
- The President's budget proposal for 2003 included a provision to increase spending on nuclear technology research to $46.5 million, from $12 million in 2002.
- The Omnibus Appropriations Resolution signed by President Bush on February 20, 2003, included a provision to extend the Price-Anderson Act. Final approval is dependent on congressional approval of a comprehensive energy bill or a vote on Price-Anderson as a separate piece of legislation.

Not all recent events have been promising for nuclear power in the United States, however. In February 2002, the Davis-Besse reactor in Ohio was shut down after significant corrosion damage to the reactor vessel head was discovered. A hole was found in the reactor's pressure vessel, the result of boric acid seeping through cracks in two of the control rod drive mechanism nozzles. The discovery prompted the NRC to order the inspection of vessel heads in all U.S. pressurized-water reactors [71].

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Appendix E

Projections of Nuclear Generating Capacity

- Reference
- High Growth
- Low Growth

LES-02355

Table E1. World Nuclear Generating Capacity by Region and Country, Reference Case, 1999-2025
(Megawatts)

Region/Country	History			Projections				
	1999	2000	2001	2005	2010	2015	2020	2025
Industrialized Countries								
North America	112,446	109,353	109,530	114,758	115,163	115,353	115,468	112,611
United States	97,470	97,975	98,152	100,152	99,288	99,479	99,593	99,593
Canada	13,616	10,018	10,018	13,232	14,433	14,433	14,433	11,576
Mexico	1,360	1,360	1,360	1,374	1,442	1,442	1,442	1,442
Western Europe	124,902	125,882	125,882	124,185	126,101	120,913	111,721	96,355
Belgium	5,712	5,712	5,712	5,769	6,055	5,639	4,204	0
Finland	2,656	2,656	2,656	2,656	3,656	3,656	3,656	3,656
France	61,623	63,073	63,073	63,468	66,610	66,610	66,610	64,681
Germany	21,345	21,345	21,345	21,558	18,831	18,153	12,685	5,690
Netherlands	450	450	450	450	450	450	0	0
Spain	7,524	7,524	7,524	7,599	7,813	7,813	7,341	7,341
Sweden	9,432	9,432	9,432	8,466	8,249	8,249	8,249	7,321
Switzerland	3,192	3,192	3,192	3,224	3,384	3,384	2,997	2,242
United Kingdom	12,968	12,498	12,498	10,994	11,053	6,959	5,979	5,424
Industrialized Asia	43,491	43,245	43,245	44,958	49,398	52,238	52,238	51,899
Japan	43,491	43,245	43,245	44,958	49,398	52,238	52,238	51,899
Total Industrialized	280,839	278,480	278,657	283,900	290,662	288,504	279,426	260,865
EE/FSU								
Eastern Europe	10,292	10,680	11,592	11,805	10,659	10,659	11,309	11,309
Bulgaria	3,538	3,538	3,538	2,749	2,020	2,020	2,020	2,020
Czech Republic	1,648	1,648	2,560	3,507	3,680	3,680	3,680	3,680
Hungary	1,755	1,755	1,755	1,773	1,860	1,860	1,860	1,860
Romania	655	655	655	662	694	694	1,344	1,344
Slovakia	2,020	2,408	2,408	2,432	1,688	1,688	1,688	1,688
Slovenia	676	676	676	683	717	717	717	717
Former Soviet Union	34,704	33,779	34,729	34,814	35,745	34,364	28,546	23,412
Armenia	376	376	376	376	376	0	0	0
Lithuania	2,370	2,370	2,370	1,185	0	0	0	0
Russia	19,843	19,843	20,793	21,951	23,507	22,504	16,685	14,463
Ukraine	12,115	11,190	11,190	11,302	11,861	11,861	11,861	8,949
Total EE/FSU	44,996	44,459	46,321	46,619	46,404	45,024	39,855	34,722

See notes at end of table.

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Table E1. World Nuclear Generating Capacity by Region and Country, Reference Case, 1999-2025 (Continued)
(Megawatts)

Region/Country	History			Projections				
	1999	2000	2001	2005	2010	2015	2020	2025
Developing Countries								
Developing Asia	21,861	22,767	22,969	32,323	39,077	51,535	55,485	61,695
China	2,167	2,167	2,167	7,603	8,603	16,603	16,603	19,593
India	1,695	2,301	2,503	2,413	4,153	5,886	6,536	6,986
Pakistan	125	425	425	425	425	300	900	900
South Korea	12,990	12,990	12,990	16,949	18,007	20,857	23,557	27,607
Taiwan	4,884	4,884	4,884	4,933	7,889	7,889	7,889	6,609
Middle East	0	0	0	915	915	2,111	2,111	3,111
Iran	0	0	0	915	915	2,111	2,111	2,111
Turkey	0	0	0	0	0	0	0	1,000
Africa	1,800	1,800	1,800	1,818	1,908	1,908	1,908	1,908
South Africa	1,800	1,800	1,800	1,818	1,908	1,908	1,908	1,908
Central and South America	1,561	2,836	2,836	2,836	2,836	4,065	3,730	3,730
Argentina	935	935	935	935	935	935	600	600
Brazil	626	1,901	1,901	1,901	1,901	3,130	3,130	3,130
Total Developing	25,466	27,403	27,605	37,892	44,736	59,619	63,234	70,444
Total World	349,233	350,342	352,583	368,411	381,802	393,147	382,516	366,030

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Totals may not equal sum of components due to independent rounding.
Sources: **History:** International Atomic Energy Agency, *Nuclear Power Reactors in the World 2001* (Vienna, Austria, April 2002). **Projections:** Energy Information Administration (EIA), *Annual Energy Outlook 2003*, DOE/EIA-0383(2003) (Washington, DC, January 2003), Table A9; and EIA, Office of Coal, Nuclear, Electric and Alternate Fuels, based on detailed assessments of country-specific nuclear power plants.

Table E2. World Nuclear Generating Capacity by Region and Country, High Growth Case, 1999-2025
(Megawatts)

Region/Country	History			Projections				
	1999	2000	2001	2005	2010	2015	2020	2025
Industrialized Countries								
North America	112,446	109,353	109,530	114,758	115,163	116,053	117,868	119,568
United States	97,470	97,975	98,152	100,152	99,288	99,479	99,593	99,593
Canada	13,616	10,018	10,018	13,232	14,433	15,133	15,833	16,533
Mexico	1,360	1,360	1,360	1,374	1,442	1,442	2,442	3,442
Western Europe	124,902	125,882	125,882	126,351	131,447	138,531	147,539	158,293
Belgium	5,712	5,712	5,712	5,769	6,055	6,055	6,055	8,055
Finland	2,656	2,656	2,656	2,656	3,656	4,656	4,656	5,656
France	61,623	63,073	63,073	63,704	66,610	69,510	72,410	75,310
Germany	21,345	21,345	21,345	21,558	22,265	22,265	23,200	23,284
Italy	0	0	0	0	0	0	1,000	2,000
Netherlands	450	450	450	450	450	450	450	1,450
Spain	7,524	7,524	7,524	7,599	7,975	8,813	9,813	10,813
Sweden	9,432	9,432	9,432	9,526	9,998	9,362	9,362	10,362
Switzerland	3,192	3,192	3,192	3,224	3,384	3,384	4,384	4,384
United Kingdom	12,968	12,498	12,498	11,864	11,053	14,036	16,209	16,979
Industrialized Asia	43,491	43,491	43,245	46,974	51,645	59,956	70,356	73,706
Japan	43,491	43,491	43,245	46,974	51,645	59,956	70,356	73,706
Total Industrialized	*280,839*	*278,726*	*278,657*	*288,083*	*298,254*	*314,541*	*335,762*	*351,567*
EE/FSU								
Eastern Europe	10,292	10,680	11,592	12,629	12,607	16,165	19,688	25,688
Bulgaria	3,538	3,538	3,538	3,573	2,885	3,838	3,973	4,973
Czech Republic	1,648	1,648	2,560	3,507	3,680	3,680	4,680	5,680
Hungary	1,755	1,755	1,755	1,773	1,860	1,860	2,860	3,860
Poland	0	0	0	0	0	0	1,000	3,000
Romania	655	655	655	662	1,344	1,994	1,994	2,994
Slovakia	2,020	2,408	2,408	2,432	2,120	4,076	4,464	4,464
Slovenia	676	676	676	683	717	717	717	717
Former Soviet Union	34,704	33,779	34,729	36,924	44,118	48,713	58,487	70,600
Armenia	376	376	376	376	376	376	0	2,000
Belarus	0	0	0	0	0	0	0	2,000
Estonia	0	0	0	0	0	0	0	1,000
Kazakhstan	0	0	0	0	0	0	1,920	2,880
Lithuania	2,370	2,370	2,370	2,370	1,185	1,000	1,000	2,000
Russia	19,843	19,843	20,793	22,876	28,796	33,576	39,906	43,058
Ukraine	12,115	11,190	11,190	11,302	13,761	13,761	15,661	17,661
Total EE/FSU	*44,996*	*44,459*	*46,321*	*49,553*	*56,725*	*64,878*	*78,175*	*96,288*

See notes at end of table.

Table E2. World Nuclear Generating Capacity by Region and Country, High Growth Case, 1999-2025 (Contniued)
(Megawatts)

Region/Country	History			Projections				
	1999	2000	2001	2005	2010	2015	2020	2025
Developing Countries								
Developing Asia	21,861	22,767	22,969	33,863	47,834	63,271	83,002	98,160
Bangladesh	0	0	0	0	0	0	0	600
China	2,167	2,167	2,167	8,603	11,703	17,703	20,703	22,703
India	1,695	2,301	2,503	2,953	6,721	8,791	12,691	13,799
Indonesia	0	0	0	0	0	0	2,000	3,000
Malaysia	0	0	0	0	0	0	1,000	2,000
Pakistan	125	425	425	425	1,025	1,625	2,700	4,700
Philippines	0	0	0	0	0	0	0	2,000
South Korea	12,990	12,990	12,990	16,949	20,496	24,907	30,307	34,357
Taiwan	4,884	4,884	4,884	4,933	7,889	9,245	10,601	10,601
Thailand	0	0	0	0	0	1,000	2,000	3,000
Vietnam	0	0	0	0	0	0	1,000	2,000
Middle East	0	0	0	915	2,111	2,111	5,111	7,111
Iran	0	0	0	915	2,111	2,111	3,111	4,111
Turkey	0	0	0	0	0	0	1,000	1,000
Syria	0	0	0	0	0	0	1,000	2,000
Africa	1,800	1,800	1,800	1,818	2,038	2,168	3,428	6,688
Egypt	0	0	0	0	0	0	0	2,000
Morocco	0	0	0	0	0	0	1,000	2,000
South Africa	1,800	1,800	1,800	1,818	2,038	2,168	2,428	2,688
Central and South America	1,561	2,836	2,836	2,836	4,065	4,065	6,065	7,065
Argentina	935	935	935	935	935	935	1,935	1,935
Brazil	626	1,901	1,901	1,901	3,130	3,130	4,130	5,130
Total Developing	25,466	27,403	27,605	39,432	56,048	71,615	97,606	119,024
Total World	349,233	350,588	352,583	377,068	411,027	451,034	511,544	566,879

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Totals may not equal sum of components due to independent rounding.
Sources: **History:** International Atomic Energy Agency, *Nuclear Power Reactors in the World 2001* (Vienna, Austria, April 2002). **Projections:** Energy Information Administration (EIA), *Annual Energy Outlook 2003*, DOE/EIA-0383(2003) (Washington, DC, January 2003), Table A9; and EIA, Office of Coal, Nuclear, Electric and Alternate Fuels, based on detailed assessments of country-specific nuclear power plants.

Table E3. World Nuclear Generating Capacity by Region and Country, Low Growth Case, 1999-2025
(Megawatts)

Region/Country	History			Projections				
	1999	2000	2001	2005	2010	2015	2020	2025
Industrialized Countries								
North America	112,446	109,353	109,530	114,758	114,490	111,824	110,308	108,392
United States	97,470	97,975	98,152	100,152	99,288	99,479	99,593	99,593
Canada	13,616	10,018	10,018	13,232	13,760	10,903	9,273	7,357
Mexico	1,360	1,360	1,360	1,374	1,442	1,442	1,442	1,442
Western Europe	124,902	125,882	125,882	122,408	114,986	99,539	72,868	40,962
Belgium	5,712	5,712	5,712	5,769	4,204	4,204	0	0
Finland	2,656	2,656	2,656	2,656	2,656	3,656	2,328	1,000
France	61,623	63,073	63,073	63,468	66,610	64,681	54,283	33,242
Germany	21,345	21,345	21,345	19,327	14,021	5,690	0	0
Netherlands	450	450	450	450	450	0	0	0
Spain	7,524	7,524	7,524	7,599	7,341	7,341	7,341	3,219
Sweden	9,432	9,432	9,432	8,920	9,362	7,321	5,416	0
Switzerland	3,192	3,192	3,192	3,224	3,384	2,997	2,242	2,242
United Kingdom	12,968	12,498	12,498	10,994	6,959	3,649	1,259	1,259
Industrialized Asia	43,491	43,491	43,245	43,891	49,398	48,561	41,582	35,814
Japan	43,491	43,491	43,245	43,891	49,398	48,561	41,582	35,814
Total Industrialized	280,839	278,726	278,657	281,057	278,874	259,923	224,757	185,168
EE/FSU								
Eastern Europe	10,292	10,680	11,592	10,981	10,659	10,659	11,309	8,360
Bulgaria	3,538	3,538	3,538	2,749	2,020	2,020	2,020	2,020
Czech Republic	1,648	1,648	2,560	3,507	3,680	3,680	3,680	3,244
Hungary	1,755	1,755	1,755	1,773	1,860	1,860	1,860	930
Romania	655	655	655	662	694	694	1,344	1,344
Slovakia	2,020	2,408	2,408	1,608	1,688	1,688	1,688	823
Slovenia	676	676	676	683	717	717	717	0
Former Soviet Union	34,704	33,779	34,729	34,049	32,351	25,748	18,805	8,924
Armenia	376	376	376	0	0	0	0	0
Lithuania	2,370	2,370	2,370	1,185	0	0	0	0
Russia	19,843	19,843	20,793	21,562	22,504	16,685	12,763	7,917
Ukraine	12,115	11,190	11,190	11,302	9,847	9,063	6,042	1,007
Total EE/FSU	44,996	44,459	46,321	45,030	43,010	36,408	30,115	17,284

See notes at end of table.

Table E3. World Nuclear Generating Capacity by Region and Country, Low Growth Case, 1999-2025 (Continued)
(Megawatts)

Region/Country	History			Projections				
	1999	2000	2001	2005	2010	2015	2020	2025
Developing Countries								
Developing Asia	21,861	22,767	22,969	30,063	36,315	42,905	45,533	46,012
China	2,167	2,167	2,167	6,603	8,603	9,593	12,593	12,314
India	1,695	2,301	2,503	2,113	2,466	4,616	4,616	6,986
Pakistan	125	425	425	425	300	900	1,500	2,700
South Korea	12,990	12,990	12,990	15,989	17,057	19,907	20,216	21,300
Taiwan	4,884	4,884	4,884	4,933	7,889	7,889	6,609	2,712
Middle East	0	0	0	915	915	915	2,111	2,111
Iran	0	0	0	915	915	915	2,111	2,111
Africa	1,800	1,800	1,800	1,818	1,908	1,908	1,908	0
Egypt	0	0	0	0	0	0	0	1,000
South Africa	1,800	1,800	1,800	1,818	1,908	1,908	1,908	0
Central and South America	1,561	2,836	2,836	2,836	2,501	2,501	2,504	2,504
Argentina	935	935	935	935	600	600	0	0
Brazil	626	1,901	1,901	1,901	1,901	1,901	2,504	2,504
Total Developing	25,466	27,403	27,605	35,632	41,639	48,229	52,056	50,627
Total World	349,233	350,588	352,583	361,718	363,523	344,560	306,928	253,080

Notes: EE/FSU = Eastern Europe/Former Soviet Union. Totals may not equal sum of components due to independent rounding.
Sources: **History:** International Atomic Energy Agency, *Nuclear Power Reactors in the World 2001* (Vienna, Austria, April 2002). **Projections:** Energy Information Administration (EIA), *Annual Energy Outlook 2003*, DOE/EIA-0383(2003) (Washington, DC, January 2003), Table A9; and EIA, Office of Coal, Nuclear, Electric and Alternate Fuels, based on detailed assessments of country-specific nuclear power plants.