CQ Researcher

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Nuclear Energy

Should the U.S. build more nuclear power plants?

President Bush has recommended building more nuclear energy plants in response to high oil and natural gas costs and continuing concern about global warming. Advocates say nuclear power is the only large-scale energy source that does not contribute to global climate change. The Energy Department is working with industry to find sites for new, safer reactors, and Congress has approved subsidies for companies that build the first plants. Opponents fear that accidents or terrorist strikes on reactors could contaminate large areas, and that nuclear fuel could be stolen and used for weapons. They also argue the United States does not have an acceptable, long-term policy for managing nuclear waste and that renewable energy is safer, cleaner and more affordable. Meanwhile, critics say a nuclear pact recently proposed by Bush between India and the United States undercuts nuclear nonproliferation efforts.

More than 25 years ago, fears sparked by an accident at the Three Mile Island nuclear plant in Pennsylvania stalled U.S. development of nuclear power. Now energy companies are again considering building new nuclear plants.

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NUCLEAR ENERGY

Cover: More than 25 years ago, fears sparked by an accident at the Three Mile Island nuclear plant in Pennsylvania stalled U.S. development of nuclear power. Now energy companies are again considering building new nuclear plants. (Lonna M. Malmsheimer)

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Nuclear Energy

BY JENNIFER WEEKS

THE ISSUES

Critics scoffed when plans were announced in 2002 to spend $1.8 billion upgrading the Browns Ferry nuclear power plant in northern Alabama, which had been sitting idle since a 1985 fire and a series of operating problems.

"For the same amount of money, they could build a brand-new reactor that's safer and has a longer life," said David Lochbaum, director of the Union of Concerned Scientists' (UCS) Nuclear Safety Project and a former Browns Ferry engineer. "It's like trying to dust off an eight-track tape player rather than buying a DVD system." [1]

But after extensive modifications, the 25-year-old plant is scheduled to restart in May 2007, and with a higher power output. "This investment will pay dividends for the families, businesses and industry of the [Tennessee] Valley in the forms of low-cost power, cleaner air and economic growth," said Bill Baxter, director of the Tennessee Valley Authority (TVA). [2]

Nuclear advocates see the resurrection of Browns Ferry as a sign that nuclear power, which has produced about 20 percent of U.S. electricity annually since 1990, is poised for new growth. They say it offers the best option for addressing the nation's converging challenges of rising energy demand, high fossil-fuel prices, unreliable foreign energy suppliers and concerns about air pollution and climate change.

In his 2006 State of the Union address, President Bush complained that America is "addicted" to oil and proposed increasing research on energy sources, including nuclear power, to reduce U.S. reliance on imported oil. "By applying the talent and technology of America, this country can dramatically improve our environment, move beyond a petroleum-based economy and make our dependence on Middle East oil a thing of the past," said Bush.

"The United States needs more electricity production capacity starting after 2010," says Marvin Fertel, senior vice president of the Nuclear Energy Institute (NEI). Congress is considering new restrictions on the amount of pollutants — including sulfur dioxide, nitrogen oxide, mercury and carbon dioxide — power plants can emit after that date. That would severely limit energy companies' ability to use coal, even as dwindling supplies have driven up natural gas prices. What the nation needs is other options, he adds. "Nuclear plants are performing well, and the industry has consolidated and become more efficient, so they offer operating certainty and price stability."

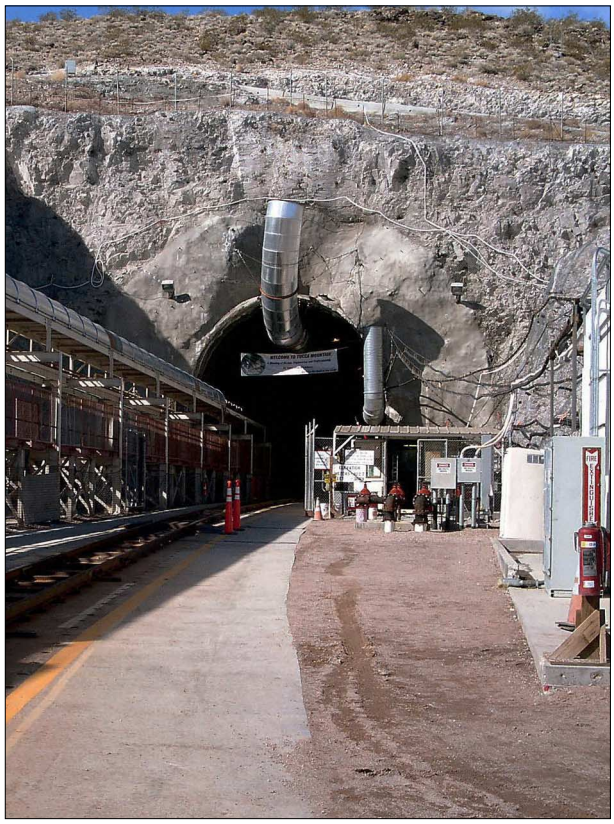
But before nuclear power can become a more important source of non-polluting energy, the industry and policymakers must first figure out how to lower the cost of building and operating modern nuclear plants, reduce the risk of nuclear accidents, manage radioactive waste and prevent nuclear proliferation. [3]

"We can't assume that society will continue to accept nuclear energy unless we can sufficiently reduce its proliferation, waste, safety and terrorism liabilities — and it's an open question as to whether we can manage those risks," says John Holdren, a professor of environmental policy at Harvard University and co-chair of the National Commission on Energy Policy.

But the rewards of successfully expanding nuclear energy would be far-reaching, according to Holdren, helping to address both global climate change and the growing competition for natural gas. [4] "It can't be the whole solution, but it would help," he says.

The threat of nuclear-weapons development by Iran and North Korea and the recent controversy over U.S. nuclear assistance to India underscore the concern about proliferation. (*See sidebar, p. 228.*)

On March 2, Bush proposed helping India meet its growing civilian energy needs while allowing it to

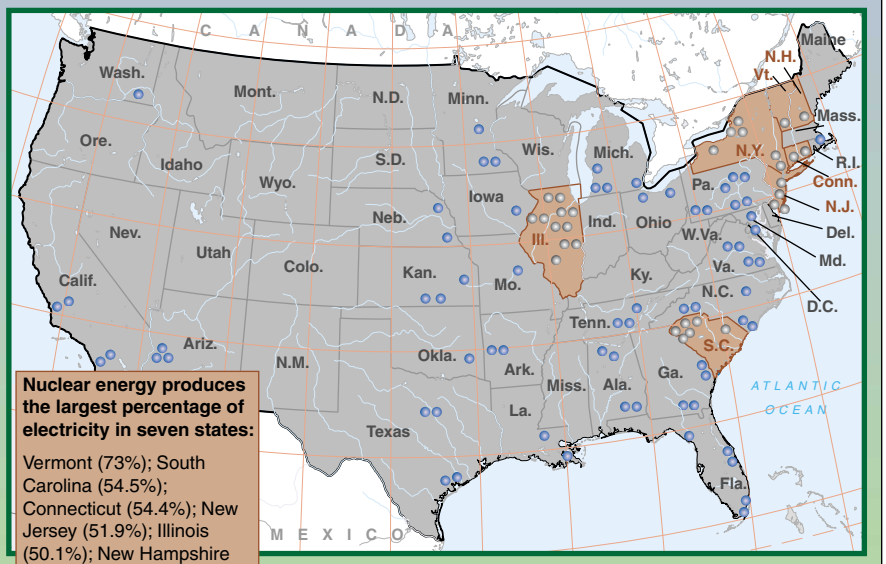


Getty Images/Maxim Kniazkov

Construction of the Department of Energy's nuclear-waste repository inside Nevada's Yucca Mountain is far behind schedule. If licenses are granted and the facility is completed, it will store sealed casks containing 70,000 tons of high-level radioactive waste from commercial power plants as well as atomic fuel from nuclear ships.

Nuclear Plants Operate in 31 States

The 103 commercial nuclear power plants operating in 31 states produce about 20 percent of the nation's electricity. The newest plant is Tennessee's 1996 Watts Bar 1; the oldest plant is Nine Mile 1 in New York state, built in 1969.



Nuclear energy produces the largest percentage of electricity in seven states:

Vermont (73%); South Carolina (54.5%); Connecticut (54.4%); New Jersey (51.9%); Illinois (50.1%); New Hampshire (43%), New York (29.8%).

Source: Nuclear Energy Institute, March 2, 2006

continue developing nuclear weapons. Supporters said the pact was essential to maintaining nuclear stability in the region, but critics said it undermined nuclear non-proliferation efforts.

"I'm trying to think differently," Bush said in New Delhi. "Not to stay stuck in the past, and recognize that by thinking differently, particularly on nuclear power, we can achieve some important objectives: one of which is less reliance on fossil fuels, second, to work with our partners to help both our economies grow and thirdly is to be strong in dealing with non-proliferation issues." [5]

In 2004, the nation's 103 existing nuclear plants — down from 111 in 1990 — were producing power at a record 90.5 percent of total licensed capacity, up from 66 percent in 1990. [6] With power consumption projected to rise sharply in the next several decades, nuclear advocates say it's time for expansion.

"In the 21st century, our nation will need more electricity, more safe, clean, reliable electricity," said Bush while visiting Maryland's Calvert Cliffs nuclear plant in June 2005. "It is time for this country to start building nuclear power plants again." [7]

No new nuclear plants have been ordered in the United States since 1979, when an accident at the Three Mile Island plant near Middletown, Pa., triggered a partial meltdown. There were no injuries, but the resulting opposition to new plants continues today. "Nuclear energy is too expensive, it's unsafe and we don't have a good solution for handling high-level waste," says Anna Aurilio, legislative director of the U.S. Public Interest Research Group (US PIRG). Moreover, she says, the industry's optimistic cost estimates for new plants "are not borne out by the facts."

Nuclear-energy critics say the Nuclear Regulatory Commission (NRC) is not aggressive enough at regulating the industry, citing the 2002 discovery that corrosion at Ohio's Davis-Besse nuclear plant had nearly eaten through the steel around the reactor's radioactive core. The General Accounting Office (now the Government Accountability Office) called the incident the most serious at a U.S. commercial reactor since Three Mile Island. The NRC failed to detect the corrosion because its oversight "did not produce accurate information on plant conditions," said the GAO. [8]

For its part, the NRC levied a record $5.45 million fine against the plant's owners in 2005. In early 2006 the owners agreed to pay a $28 million fine to escape criminal prosecution for providing false information to the NRC about the reactor; three former plant employees eventually were indicted by a federal grand jury. [9]

Lochbaum says plant owners should be required to fix known safety problems more quickly and the NRC should have more sophisticated ways to monitor reactors as they age. "Surprises keep coming up," he says. "We haven't done a good job of picking the most vulnerable areas to monitor for aging, and sometimes inspections look at the right areas but don't catch problems." (*See "At Issue," p. 233.*)

While the NRC describes itself as "a pain in the neck" regulator forbidden by law from promoting nuclear power, Lochbaum also says the NRC is under pressure to do just that. "Congress and the administration have been hammering the NRC to get out of the industry's way and not be a regulatory burden, and the commission has heard the message," he says. For example, he says, before the problems at Davis-Besse were uncovered, the NRC had diverted personnel from inspections there to work on extending reactor licenses, a contention the NRC denies.

Overall safety at U.S. nuclear plants has improved dramatically since the 1980s. "There's no such thing as perfect safety, but the probability of an

accident is far smaller today than it was 10 or 20 years ago," says Robert Budnitz, head of the Nuclear and Risk Science Group at Lawrence Livermore National Laboratory and former NRC research director. "Significant events," such as reactor shutdowns and problems with important safety equipment, fell from an average of 0.9 per year per plant in 1989 to 0.02 in 2003, and unplanned automatic shutdowns declined nearly tenfold from 1980 through 2004. [10]

"The industry is proud of this improvement, and it has a right to be proud," says Budnitz. "Nuclear operators have analyzed the causes of failures at reactors and reduced accidents and safety events significantly. Better training has made the work-force culture at nuclear plants more professional and respectful of rules, and the industry has become much more responsible about policing itself."

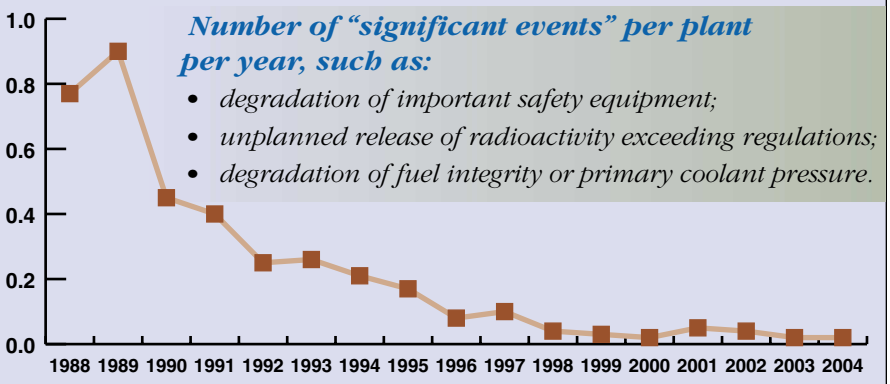
But an even more ominous cloud has descended over nuclear safety since the terrorist attacks of Sept. 11, 2001. Many Americans now worry that terrorists might target nuclear reactors, especially since the 9/11 hijackers reportedly discussed crashing jet planes into a nuclear facility near New York City. [11]

Although the NRC has tightened security requirements, ordered more frequent and realistic attack training and insists there are multiple, redundant layers of safety and security to protect against even a large commercial aircraft, critics say plants still are vulnerable. Officials in communities surrounding nuclear plants now worry that residents cannot be evacuated quickly in emergencies, especially if populations have increased since the plants were built. (While the NRC evaluates evacuation plans, primary off-site evacuation responsibility lies with local authorities.)

As lawmakers and communities debate the need for more nuclear power plants, here are some issues they will consider:

Industry Safety Has Improved

The decreasing number of so-called significant events at U.S. nuclear plants each year is one of many indicators of the industry's improving safety record, according to the Nuclear Regulatory Commission.



Source: Nuclear Regulatory Commission, "NRC Information Digest," December 2005

Can nuclear power "solve" the global-warming problem?

Now that scientific consensus affirms that greenhouse-gas emissions from human activities are warming Earth's climate, the nuclear industry contends that nuclear power is the best option for meeting rising energy demand without exacerbating climate problems. Nuclear reactors generate electricity without emitting carbon dioxide and other pollutants — called greenhouse gases — that hold heat in the atmosphere. Power plants burning coal, oil and natural gas produced 39 percent of U.S. carbon dioxide emissions in 2003. [12]

But nuclear-power capacity would have to expand dramatically to eliminate enough greenhouse emissions to make a difference. Nuclear plants generated 789 terawatt-hours * of electricity in 2004 — or about 22 percent of the nation's electrical power. By 2030 the U.S. Energy Information Administration (EIA) predicts that nuclear plants will generate only about 871 terawatt-hours — and that's if six new 1,000-megawatt reactors are built and 2,000 megawatts of uprates (capacity increases) are made at existing plants. But demand will have risen so sharply by then, says the EIA, that nuclear power will end up providing only about 16 percent of total U.S. power generation — a smaller share than it provides today. [13]

To significantly reduce climate change, according to a 2003 Massachusetts Institute of Technology (MIT) study, world nuclear capacity would have to roughly triple by 2050, with the United States adding 200 or more new reactors. [14] Industry representatives admit that growth on anything approaching this scale would be a serious challenge.

Even so, some prominent environmentalists have called recently for rethinking the issue of nuclear power in view of the potential threat from climate change. "Renewable energies, such as wind, geothermal and hydro are part of the solution," wrote Greenpeace co-founder Patrick Moore in early 2005. "Nuclear energy is the only non-greenhouse-gas-emitting power source that can effectively replace fossil fuels and satisfy global demand." [15]

* A terawatt is equivalent to 1 trillion watts.

However, most environmental organizations remain strongly opposed to nuclear energy because of unresolved concerns about safety and radioactive waste. Bishop Hugh Montefiore, former chairman of the British group Friends of the Earth, was forced to leave the board in late 2004 because of his support for nuclear power. [16]

In June 2005, Sens. John McCain, R-Ariz., and Joseph I. Lieberman, D-Conn., put the issue to a test when they offered a revised version of their Climate Stewardship Act, which would require the United States to cut its greenhouse-gas emissions. The measure had been supported by 43 senators when it was first offered in 2003, but McCain and Lieberman added federal loan guarantees for construction of advanced nuclear reactors and other zero-greenhouse-gas energy plants to the 2005 version. "The idea that a zero-emission technology such as nuclear has little or no place in our energy mix is just as antiquated, out-of-step and counterproductive as our continued dependence on fossil fuels," said McCain. [17]

However, the measure was defeated by a wider margin than in 2003 after nearly all major environmental groups opposed the inclusion of nuclear power. "Adding expensive and unnecessary subsidies to a global-warming bill doesn't increase support for doing something about the issue," argues US PIRG's Aurilio.

The United States has limited options for meeting rising electricity demand without increasing greenhouse emissions. Environmentalists want investments in energy conservation and renewable fuels such as wind and solar energy. Renewable sources other than hydropower generated about 2 percent of U.S. electricity supplies in 2004, and the EIA says this share will increase only slightly by 2030. But policy choices could substantially increase renewable energy's market share, according to the bipartisan National Commission on Energy Policy, which estimated that with more funds for research and development and binding limits on greenhouse-gas emissions, non-hydro renewable-energy sources could generate up to 10 percent of U.S. electricity supplies by 2020. [18]

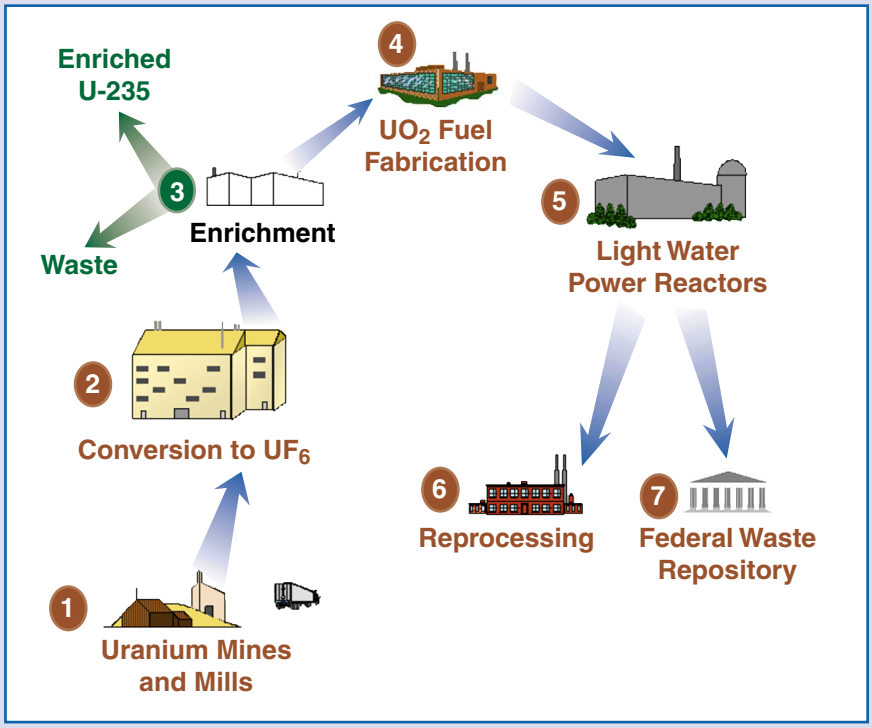
But even though oil and gas prices have risen sharply since 2000, fossil fuels today are still cheaper than many renewables. Coal is generally still the cheapest fuel for electricity generation, "especially since carbon dioxide emissions are not subject to any kind of nationwide cap," says Karen Palmer, an economist at the environmental group Resources for the Future.

National limits on emissions — like those proposed by McCain and Lieberman — would make renewable fuels and nuclear power more competitive with coal and natural gas, because fossil-fuel-burning plants would have to buy allowances for emissions that exceed their limits, increasing the cost of their electricity. "Even a small carbon tax

Producing Electricity From Nuclear Fuel

Processing uranium to produce fuel to generate electricity is known as the "nuclear fuel cycle." It involves converting the mined uranium into a gas, which is then "enriched" through a physical-separation process into nuclear fuel. Since only 1 percent of natural uranium contains uranium-235 (U-235), with atoms that are easily split and thus is useful for producing energy, the processing requires that the U-235 be extracted from the 99 percent of the ore that contains uranium-238 (U-238) — which is not useful for producing electricity.

The Nuclear Fuel Cycle



Source: U.S. Nuclear Regulatory Commission

Steps in the Nuclear Fuel Cycle

1. Uranium Mining and Milling: Uranium is mined using either surface or underground techniques, depending on the depth of the ore. A mill then grinds the ore and separates out concentrated uranium oxide, called "yellowcake." (It takes about 200 tons of yellowcake to produce the fuel needed to run a large 1,000-megawatt reactor for a year.)

2. Conversion: The yellowcake is converted into a gas, uranium hexafluoride (UF_6).

3. Enrichment: The UF_6 gas is enriched through a physical process, typically diffusion through a membrane or separation in a centrifuge, to raise the amount of "fissile," or splittable, uranium-235 (U-235) in the gas from its natural level of 0.7 percent to about 3.5 percent or more. The enriched gas then moves to the next stage of the fuel cycle, fuel fabrication. The waste material — known as depleted uranium, tails or tailings — contains less than 0.25 percent U-235 and cannot be used for energy. Nearly twice as dense as lead, depleted uranium has other commercial uses.

4. UO_2 Fuel Fabrication: The enriched uranium gas is converted into uranium dioxide (UO_2) powder and pressed into fuel pellets, which are inserted into thin tubes to form fuel rods. The sealed rods are assembled into clusters to form fuel assemblies that are used in the core of the nuclear reactor.

5. Light Water Power Reactors: Hundreds of fuel assemblies make up the core of a nuclear reactor, where the U-235 isotope splits in a chain reaction that produces heat used to produce steam for driving an electric generator. In U.S. reactors, the core is cooled by normal, or "light," water. Some foreign reactors use "heavy" water, which has more deuterium and tritium, to both cool the core and help support the chain reaction. After the fuel is consumed, or "spent," it is removed from the reactor and stored in on-site ponds or air-cooled facilities for several years while its radioactivity and heat subside.

6. Reprocessing: About 1 percent of the spent fuel is fissionable U-235 and about 1 percent is plutonium that was produced in the reactor. Reprocessing separates the uranium and plutonium from waste products. The recovered uranium can be returned to the conversion plant to be reconverted to UF_6. The plutonium can be blended with enriched uranium to produce a mixed oxide fuel in a fuel-fabrication plant. The remaining high-level radioactive wastes can be stored in liquid form and subsequently solidified. Currently, reprocessing occurs in Europe and Russia, but not in the United States.

7. Federal Waste Repository: Unreprocessed spent fuel eventually will be encapsulated in sturdy, stainless steel canisters and buried in stable rock structures deep underground. Several countries are working on creating federal waste repositories, but a final disposal of spent fuel has not yet occurred. The Department of Energy is attempting to license a permanent disposal site at Yucca Mountain, in Nevada.

would benefit nuclear, although it probably won't be enough by itself to be a deciding factor in building new nuclear plants," says Palmer. But the Bush administration strongly opposes mandatory limits on greenhouse-gas emissions, which it says would increase energy prices and harm the economy.

Similarly, building more nuclear power plants will do little to reduce current U.S. dependence on imported oil in the short term because petroleum products are used mainly in the transportation sector (oil only produces about 3 percent of the nation's electricity supply). However, over the long term nuclear power could help facilitate a shift to a hydrogen-based economy, particularly in transportation. In 2003 the Bush administration launched a Hydrogen Initiative aimed at reducing U.S. oil consumption and pollution from motor vehicles by commercializing hydrogen fuel-cell vehicles and other hydrogen applications. [19]

Using hydrogen as fuel does not produce greenhouse gases if the hydrogen is made using a carbon-free electricity source. If hydrogen is made by chemically separating it from natural gas or coal, carbon dioxide is produced as a byproduct that can either be captured and stored or released into the atmosphere.

Hydrogen can also be extracted from water, using electricity; if the electricity comes from a plant powered by fossil fuel, the process still produces greenhouse-gas emissions. Nuclear reactors can provide the electricity needed for hydrogen extraction without emitting carbon dioxide, although the process is more expensive than separating hydrogen from fossil fuels. But advanced "Generation IV" reactors being developed for deployment after 2030 could produce hydrogen from water more efficiently. [20]

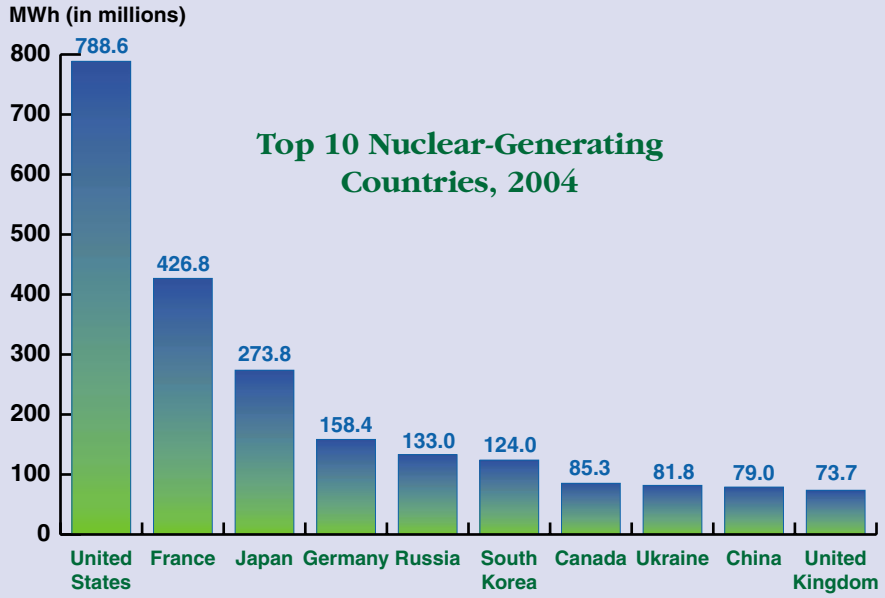
In any case, hydrogen production is not a factor in near-term decisions on nuclear power because other major elements of a hydrogen economy, such as distribution systems and cheaper fuel cells, have yet to be developed. "It's not going to happen tomorrow, but if we're going to go to large-scale hydrogen, then we should produce it with non-emitting technologies, and if nuclear plants can do it efficiently and economically, we should look at that," says NEI's Fertel.

Does the U.S. have a viable program for managing nuclear waste?

For more than 30 years, U.S. policy for managing high-level nuclear waste has centered on a "once-through" fuel cycle in which fuel is irradiated once in a reactor, then disposed of permanently in an underground repository. Today, frustration with the slow progress of the government's efforts to build a repository for the nuclear waste is undermining some policymakers' support for this approach. [21]

U.S. Is Top Nuclear-Energy Producer

U.S. nuclear plants generate nearly 800 million megawatt hours (MWh) of electricity — nearly twice as much as France.



Source: World Nuclear Association, June 2005

The Nuclear Waste Policy Act of 1987 directed the Department of Energy (DOE) to build a repository deep inside Nevada's Yucca Mountain to store 70,000 tons of high-level nuclear waste, mainly from commercial nuclear power reactors. DOE was to devise a repository capable of containing spent fuel for tens of thousands of years while its radioactive emissions decay to natural background levels.

After more than 20 years and $4 billion of scientific analysis, Energy Secretary Spencer Abraham in February 2002 formally recommended Yucca Mountain as a suitable site for the repository, and both Congress and President Bush approved the recommendation.

"A repository at Yucca Mountain will bring together the location, natural barriers and design elements necessary to protect the health and safety of the public, including those Americans living in the immediate vicinity, now and long into the future," Abraham said in a letter to Bush. [22]

Since then, however, the project has hit several new roadblocks. Until recently, DOE estimated that the site would be ready to start accepting waste by 2010 (well past its original target date of 1998), but now the department has stopped forecasting an official opening date. [23]

Environmental groups and Nevada officials say the waste could leach from the repository during the thousands of years it would be stored, exposing people nearby to dangerous radiation. In July 2004, the U.S. Circuit Court of Appeals rejected the Environmental Protection Agency's (EPA) proposed standard for radiation exposure in the area surrounding Yucca Mountain. [24] The EPA had proposed an overall dose of no more than 15 millirem per year (about equal to three chest X-rays) for 10,000 years after the repository closes. But Congress had directed EPA to conform its standard to the National Academy of Sciences' estimated time of peak exposure risk, which was hundreds of thousands of years into the future. [25]

EPA then proposed adding a limit of 350 millirem per year for the period lasting from 10,000 years after the repository is closed up to 1 million years. Lawrence Livermore's Budnitz says DOE was prepared to meet EPA's original standard for protecting the public from radiation for 10,000 years, but that the revised standard will require further study.

"We have a very strong understanding of doses for the first 10,000 years, and we should be able to meet those criteria," he says. "But until EPA's new analysis of doses over 1 million years is done and evaluated, it's premature to say whether we have that understanding. Whatever the final standard is, the NRC will have to approve the license, and it will carry out a stringent review of the repository so the public can have confidence in the decision."

However some experts question the EPA's revised standard. "It's a cop-out," says Allison Macfarlane, a senior research associate and nuclear waste expert at MIT. "The waste canisters will fail after about 100,000 years, so the radiation doses increase significantly after that point, but you can't estimate doses a million years out."

Nevada is challenging the EPA standards in court, along with the DOE's plan to designate federal lands in Nevada for a rail line to ship waste to the site. Some nuclear critics argue that moving spent fuel cross-country could lead to accidental releases of radiation, but a 2006 study by the National Academy of Sciences found "no fundamental technical barriers to the safe transport of spent nuclear fuel and high-level radioactive waste in the United States." [26] Nuclear-waste shipments would cross some 43 states.

Robert Loux, director of the Nevada nuclear projects office, says the DOE is redoing its Yucca Mountain hydrology model — showing how water moves through the site — because of data-

quality questions and is launching a broader re-evaluation of the entire program that may last for several years.

"The program at DOE is in chaos, and the regulatory foundation will probably be uncertain for a very long time because EPA's standards have been repeatedly thrown out of court," says Loux. "Our view is that the project is dead, and that sooner or later the industry will recommend that Congress pull the plug. Congress could legislate standards, but that doesn't improve the site or DOE's competence to develop a repository."

But the DOE insists that Yucca Mountain will be licensed and constructed. "This project will fulfill a government obligation to the commercial nuclear power industry, and it will remove what has been a major impediment to new nuclear construction in this country. And we are committed to completing this important project," Energy Secretary Samuel Bodman said in May 2005. [27]

However, Congress has underfunded administration requests for research and development for the Yucca Mountain project. Work on a nuclear-waste repository is funded partly by a user fee of 0.1 cents per kilowatt-hour on nuclear electricity, paid into a Nuclear Waste Fund that can only be used for work on a repository. Since the fund was created in 1982, electricity customers have paid more than $24 billion into the fund, and the balance is growing at more than $1 billion annually, plus interest.

But Congress frequently appropriates less for the fund than DOE requests, because under current budget procedures payments into the fund are treated as general revenues that go into the federal treasury, not as collections to offset spending on a repository. Thus Congress has little incentive to spend all of the money on the repository.

Since the fund currently stands at just over $16 billion, nuclear industry and state energy officials argue that Congress has been using the money to offset federal budget deficits in other areas and have demanded assurances the funds are spent only on the repository. DOE has also called on Congress to revise its budgeting practices so that enough funds will be appropriated to carry out work on Yucca Mountain. [28]

"The nation's electric ratepayers have been paying for a nuclear-waste repository for over 20 years," Robert Garvin, chairman of the Wisconsin Public Service Commission, told the House Energy and Commerce Committee in March 2005. "It is past time for ratepayers to get what they have paid for." [29]

The DOE is required to report to Congress between January 2007 and 2010 on whether the nation needs a second repository to handle high-level waste. Yucca Mountain is legally limited to storing 70,000 metric tons of spent fuel, but DOE has estimated that up to 105,000 tons of commercial spent fuel and other radioactive waste may require disposal by 2035. [30]

"Yucca Mountain is basically full today because of the substantial quantities of spent waste that [already] exist around our country" and are waiting to be transferred to Yucca, Bodman said recently. [31]

Congress has several options for addressing this dilemma, including increasing the limit on Yucca Mountain storage (which DOE has said is technically possible), or directing DOE to begin looking for a second repository site. The Bush administration, however, supports a third, more controversial and costly option: reprocessing spent fuel to reduce the volume that must be stored. (*See sidebar, p. 228.*)

Should the United States subsidize new nuclear reactors?

According to a study published in 2000, the nuclear power industry received $145 billion worth of federal subsidies from 1943 to 1999, including both direct benefits, such as research-and-development funding, and indirect benefits such as liability limits that reduce plant owners' insurance premiums. [32] But critics question whether new nuclear plants should receive further federal subsidies, given the scope of past government support and the fact that the industry is now developing its fourth generation of reactors.

In the Energy Policy Act of 2005, Congress approved several additional incentives for building advanced nuclear plants, including $2 billion in risk insurance to compensate for construction delays at up to six new reactors; a tax credit of 1.8 cents per kilowatt-hour for electricity generated by the first new reactors; and loan guarantees for innovative technologies that reduce air pollution and greenhouse-gas emissions, including advanced, new nuclear plants. It also extended the federal cap on nuclear plant liability through 2025.

"With the practical steps in this bill, America is moving closer to a vital national goal," said President Bush in signing the bill on Aug. 8, 2005. "We will start building nuclear plants again by the end of this decade."

Nuclear advocates point out that reactor owners pay all or part of many costs that other energy sources are not required to cover, such as waste disposal and decommissioning closed plants. And incentives for the first, few nuclear power plants are justified, they argue, because of the enormous amounts of capital involved and the history of long regulatory delays in the 1970s and '80s.

A "systematic, disciplined program to build nuclear power plants" is justified, the NEI's Fertel told Congress in April 2005, because nuclear power is "a strategic national asset." Thus, a comprehensive program is needed to address the business concerns — including licensing and regulatory issues, development of new plant designs and financing — that could block new plant construction, he said. [33]

Many energy experts agree that some support for new nuclear plants is justified. Both the 2003 MIT nuclear power study and the 2004 report of the National Commission on Energy Policy recommended that the government

share costs with industry for designing and licensing a few, new advanced-design reactors. "Government subsidies for first movers in a new generation of reactor construction are the entry fee that will give us a chance to show whether we can build cheaper and safer reactors," says energy commission co-chair Holdren.

Fiscal conservatives argue that the nuclear industry itself should bear the financial risks of building new plants. When the Senate was debating the 2005 Energy Policy Act, Sen. John E. Sununu, R-N.H., unsuccessfully tried to strike loan guarantees for new reactor construction, which he said would set "a terrible precedent, putting the taxpayers on the hook for billion-dollar loans to successful, private, profitable corporations." Although he supports nuclear power, Sununu said, the measure would leave the federal government liable for the full value of the loans if the projects failed.

The Nuclear Energy Institute points out in a recent report that government-industry partnerships frequently have been used to strengthen the nation's infrastructure: "This approach has worked to bolster the country's transportation, rural electrification, telecommunications, land and water projects," the institute said, noting that similar approaches were used to promote merchant marine modernization and to help the airlines survive the economic downturn that ensued after the 9/11 terrorist attacks. [34]

That may be true, say opponents, but nuclear power has already received enough support. "These measures are simply corporate welfare," says Jill Lancelot, president of Taxpayers for Common Sense. "This is a mature industry — it's over 50 years old, and it's had cradle-to-grave subsidies that distort price signals and undermine the natural market forces of the energy industry. It's time for the industry to stand on its own feet — innovation should be a cost of doing business for nuclear power."

Other energy industries, including oil, gas, coal and renewable energy, receive various forms of government support ranging from research and development funds to tax credits and "portfolio standards" that require electricity suppliers to generate a specific fraction of their energy from specified fuels. The effectiveness of any of these measures depends in large part on how they are designed. [35]

In any case, nuclear plant owners want federal and state regulations to treat nuclear energy the same as other non-polluting energy sources. Under so-called "cap-and-trade" regulations, traditional energy producers receive credits that allow them to produce specific levels of emissions each year. Sources that produce less pollution than they are allowed can sell their extra credits to other plants that emit more than their allowances.

Nuclear advocates say nuclear plants that do not produce emissions should be rewarded with allowances that they can sell, which would reduce their cost of producing power and make them more competitive with polluting plants.

In 2003, New Hampshire revised its regulations controlling emissions of nitrogen oxides (NOx), a primary ingredient of smog, so that the Seabrook nuclear plant could receive NOx emission credits if it is allowed to increase its power output because nuclear plants generate power without emitting NOx. Other states have been reluctant to let nuclear plants receive this kind of credit for "avoided" emissions, but the industry argues that any plant that produces emission-free energy — whether it uses wind, solar energy or nuclear power — should be credited. [36]

Most environmentalists support awarding credits for emission-free electricity generation to renewable-energy sources but argue that nuclear power is a well-established industry that does not need this type of support to gain market share, and that nuclear energy has negative environmental impacts that should not be rewarded with subsidies.

In a 2004 report, the National Association of State PIRGs predicted that the Seabrook nuclear plant might receive up to one-third of the allowances that New Hampshire had set aside under its NOx-control program to encourage cleaner power sources. "The risk of catastrophic radiation release due to accident or sabotage, the dangers posed by routine emissions of radiation and the as-yet unresolved problems surrounding the long-term storage of nuclear waste mean that nuclear power cannot be considered an environmentally acceptable solution to the problem of climate change," the association argued. [37] ■

BACKGROUND

A New Industry

Civilian nuclear power emerged after World War II as a spin-off from the top-secret atomic bomb program. In 1946 Congress placed nuclear-research facilities under civilian control and created the Atomic Energy Commission (AEC) to manage the new industry. [38]

But while politicians saw nuclear energy as an important symbol of American scientific and technical leadership, private firms had little interest in what they viewed as a risky, new field. Early U.S. nuclear-energy research was driven mainly by scientists and the armed forces: *Business Week* reported in 1950 that "AEC people have had to beat on desks in order to find a company willing to take on projects." [39]

To increase business interest, Congress in 1954 allowed private companies to own nuclear-power reactors, and in 1957 the Price-Anderson Act capped private liability for reactor accidents at $560 million, allaying utilities' fears that they would be unable to obtain insurance for the potentially

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Chronology

1970s *Nuclear power expands following oil shocks.*

October 1973
Arab members of the Organization of Petroleum Exporting Countries (OPEC) embargo oil shipments to the United States. . . . U.S. utilities order 41 new nuclear reactors.

1974
India detonates a "peaceful" nuclear weapon, raising global concern over nuclear proliferation.

1977
President Jimmy Carter declares a national energy crisis, introduces measures to reduce U.S. dependence on oil imports and bans reprocessing of spent nuclear fuel to avoid stockpiling weapons-grade plutonium.

1979
A partial meltdown at the Three Mile Island nuclear plant near Middletown, Pa., triggers cancellations of plans for new plants and tighter regulations on reactors.

1980s *An explosion at a nuclear plant in Chernobyl, Ukraine, increases concern about nuclear power safety.*

Jan. 7, 1983
Nuclear Waste Policy Act directs Department of Energy (DOE) to take charge of spent nuclear fuel by Jan. 31, 1998.

April 26, 1986
An explosion at the Chernobyl nuclear power plant kills 50 emergency workers and causes thousands of cases of radiation illness in Ukraine and surrounding countries.

1987
Congress directs DOE to research underground storage of nuclear waste at Nevada's Yucca Mountain.

1990s *Nuclear reactor performance improves as regulators take steps to support new plant construction.*

1991
Inspections after the first Persian Gulf War reveal a massive, secret, nuclear-weapons program in Iraq, prompting the International Atomic Energy Agency (IAEA) to seek stronger powers to inspect nuclear facilities worldwide.

1992
Energy Policy Act revises U.S. reactor-licensing rules to reduce construction delays by awarding single licenses to construct and operate nuclear reactors.

1995
Nuclear Non-Proliferation Treaty of 1968, now with 177 member countries, is extended and made permanent.

1997
The U.S. and more than 150 other nations sign the Kyoto Protocol, which sets targets and timetables for cutting industrialized countries' greenhouse-gas emissions to slow global climate change.

1998
Baltimore Gas and Electric applies for 20-year license extension at its Calvert Cliffs plant. . . . DOE misses its deadline for beginning to store commercial nuclear fuel wastes. . . . India and Pakistan test nuclear weapons from materials obtained for peaceful purposes.

2000s *Energy companies become more positive about building new nuclear plants.*

2001
President Bush's energy policy calls for expanding nuclear power.

2002
Opposition group reveals that Iran is building a uranium-enrichment plant that could be used for civilian or military purposes. IAEA reveals Iran has carried out secret nuclear research for 18 years.

2003
New Hampshire awards economic credits to the Seabrook nuclear power plant as a non-polluting energy source. . . . North Korea withdraws from Nuclear Non-Proliferation Treaty.

2004
Nine U.S. nuclear energy companies form the NuStart consortium to seek licenses for advanced nuclear reactors at two sites by 2011.

2005
Energy Policy Act of 2005 provides loan guarantees and tax credits for new, advanced nuclear reactors and extends liability protection for the nuclear industry. . . . DOE delays the opening date for the nuclear waste repository at Yucca Mountain.

2006
In his State of the Union address, President Bush calls for more reliance on nuclear power to break America's "addiction" to oil. . . . On March 2 Bush agrees to a controversial plan to end a decades-long moratorium on sales of nuclear fuel and reactor components to India, allowing it to expand its nuclear power while continuing to develop nuclear weapons.

India and the Challenge of Non-Proliferation

The recent announcement of what President Bush called a "historic" nuclear pact between the United States and India has generated concern about continuing nuclear weapons proliferation and the threat of nuclear terrorism.

"This deal not only lets India amass as many nuclear weapons as it wants, it looks like we made no effort to try to curtail them," said George Perkovich, vice president for studies at the Carnegie Endowment for International Peace." [1]

Under the agreement, announced on March 2, the United States would end its longstanding ban on the sale of civilian nuclear fuel and reactor components to India — which has refused to sign the Nuclear Non-Proliferation Treaty (NPT) — while allowing it to continue developing nuclear weapons. [2]

Supporters said the deal would help India fulfill its civilian energy needs while creating a strategic partner for the United States in a volatile region. Critics say it sets a dangerous precedent that may undermine efforts to prevent other nations, such as Iran and North Korea, from developing nuclear weapons in defiance of international treaties.

The proposed deal is "an absolute torpedo aimed at the midship of the whole nuclear non-proliferation regime," says Jonathan Schell, author of *The Unconquerable World: Power, Nonviolence, and the Will of the People*. It paves the way for the "new nuclear world order" of unlimited and unconstrained proliferation heralded by Indian Prime Minister Manmohan Singh, he said. [3]

But supporters of the deal say Bush is merely being a realist, acknowledging that India has had nuclear weapons for 30 years. "This deal brings a country that's been developing nuclear programs . . . into the non-proliferation mainstream," said Richard Boucher, the new assistant secretary of State for South and Central Asian Affairs. "As they develop nuclear power, it's better for us to be cooperating with them than not." The deal would increase the percentage of India's nuclear capacity that is under international safeguards from the current 19 percent to 65 percent, he said, and "over time . . . up to 90 percent." [4]

Besides being a realist, Bush is being a pragmatist, said Ashton Carter, co-director of the Preventive Defense Project at Harvard's Kennedy School of Government and a former assistant secretary of Defense. Bush wants a "strategic partnership" in a region where two of India's neighbors, China and Pakistan, have nuclear weapons. India can serve as "a counterweight to China if one is required sometime in the future," Carter said. And "if something goes wrong in Pakistan, we want to have neighbors who help us." [5]

Nevertheless, he said, "avoiding nuclear terrorism and nuclear proliferation is the most important security objective of the United States." Terrorists are most likely to seek nuclear weapons, but they also can use nuclear materials produced in nuclear power programs.

Since the Soviet Union's breakup in 1991, the three non-Russian republics where nuclear weapons had been stored — Ukraine, Belarus and Kazakhstan — have returned those weapons to Russia and joined the NPT as non-nuclear states. Now, the United States and other countries are helping to upgrade security for Russia's thousands of nuclear weapons and radioactive materials — reportedly about 180 tons of separated plutonium and 1,100 tons of highly enriched uranium (HEU), which is used for nuclear weapons. But security has only been upgraded at half of Russia's nuclear-materials storage sites. [6]

In December 2005, the federal commission appointed to analyze the Sept. 11, 2001, terrorist attacks gave the U.S. government a "D" grade on its efforts to secure weapons of

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severe damage that a major nuclear accident might cause. [40]

These and other federal incentives gradually stimulated private investments in nuclear power. By 1960, only three commercial nuclear plants had been licensed, but applications increased through the decade, spurred by sharply rising demand for electricity. By 1970, 20 reactors were operating, and dozens more were under construction. However, opponents blocked several projects they claimed were unsafe, including two plants in California and Oregon that were located on earthquake faults. Meanwhile, some facilities experienced serious accidents — including partial meltdowns at a prototype mobile reactor at Idaho Falls in 1961 and an experimental breeder reactor — for plutonium production — near Detroit in 1966.

However, these events received little media coverage, and public views of nuclear energy remained positive. [41]

Limiting Nuclear Weapons

Scientists and U.S. leaders recognized from the outset that civilian nuclear reactors and facilities for processing uranium and spent nuclear fuel could be used to produce highly enriched uranium or plutonium, both of which could be used to make nuclear weapons. To prevent this, the U.S. proposed in the 1946 Baruch Plan that an international organization be established to control nuclear weapons and nuclear power activities — from mining uranium to operating nuclear reactors. The Soviet Union, which wanted to develop nuclear weapons, rejected the plan. [42]

In 1953 President Dwight D. Eisenhower again called for peaceful cooperation on nuclear energy. In his "Atoms for Peace" speech, Eisenhower proposed creating an agency at the United Nations to promote civilian applications of nuclear technology worldwide. Eisenhower's initiative led to the establishment in 1957 of the International Atomic Energy Agency (IAEA), which was charged with ensuring that nuclear plants were not producing nuclear weapons. [43]

mass destruction, noting, "Countering the greatest threat to America's security is still not the top national-security priority of the president and the Congress." [7] In fact, in his 2005 budget, Bush requested cuts in funds to safeguard nuclear weapons in Russia. [8]

Under the NPT, non-nuclear weapons states that sign the pact have an "inalienable right" to develop peaceful nuclear energy. Honoring this commitment while limiting the spread of nuclear weapons has been a longstanding U.S. challenge. [9]

Since 1978, the United States has required non-nuclear weapons countries to open their entire nuclear programs to "full-scope" International Atomic Energy Agency (IAEA) monitoring before they can receive nuclear exports from the United States. But by the time those conditions were imposed, several countries had developed or researched nuclear weapons using materials and technologies imported from abroad — often after pledging to use the equipment for peaceful purposes. Three such countries — India, Israel and Pakistan — refused to sign the NPT and thus remain outside of the pact.

Today, with Iran and North Korea suspected of carrying out nuclear weapons research at civilian facilities, persuading their leaders to give up their nuclear programs is widely considered the world's foremost non-proliferation challenge.

Because many countries have cheated on non-proliferation commitments, experts say access to the nuclear fuel cycle should be restricted. In 2004, President Bush urged major nuclear-supplier countries to stop selling enrichment and reprocessing technology to countries that did not already have them. [10] And IAEA Director General Mohamed ElBaradei, upon accepting the 2005 Nobel Peace Prize, recommended establishing an international fuel bank and a multinational system for producing, supplying and disposing of nuclear fuel so countries would not have to develop enrichment and reprocessing facilities on their own. [11]

ElBaradei also stressed the need to strengthen international safeguards and verification systems. The United States, however, spent less than $5 million on technical-safeguards research and development in 2005. [12] "The IAEA has inspectors deployed throughout the world at nuclear facilities, and some relatively modest investments in better technologies would make them much more effective," says Steve Fetter, dean of the University of Maryland's School of Public Policy.

[1] Quoted in Steven R. Weisman, "Dissenting on Atomic Deal," *The New York Times*, March 3, 2006, p. A10.

[2] Elisabeth Bumiller and Somini Sengupta, "Bush and India Reach Pact That Allows Nuclear Sales," *The New York Times*, March 3, 2006, p. A1.

[3] Quoted from WBUR's OnPoint Show, "Nuclear Ambitions," March 7, 2006. Also see David Von Drehle, "The Multipolar Unilateralist," *The Washington Post*, March 5, 2006, p. B2.

[4] WBUR, *ibid.*

[5] *Ibid.*

[6] "The Security of WMD Related Material in Russia," Annual Report for the NATO Parliamentary Assembly, December 2005, www.nato-pa.int/Default.asp?SHORTCUT=695.

[7] 9/11 Public Discourse Project, "Final Report on 9/11 Commission Recommendations," Dec. 5, 2005, p. 4.

[8] Miles A. Pomper, "Bush Stresses Importance of Nunn-Lugar Programs but Cuts Funds in 2005 Budget Request," Arms Control Association, March 2004.

[9] For background, see Mary H. Cooper, "Nuclear Proliferation and Terrorism," *CQ Researcher*, April 2, 2004, pp. 297-320.

[10] "President Announces New Measures to Counter the Threat of WMD," Feb. 11, 2004, www.whitehouse.gov.

[11] "Nobel Lecture by IAEA Director General and Nobel Peace Prize Laureate 2005 Dr. Mohamed ElBaradei," www.iaea.org.

[12] American Physical Society, *op. cit.*, pp. 6-13.

By this time, though, the nuclear club was already growing. Britain exploded its first atomic bomb in 1952, followed by France in 1960. In 1963 President John F. Kennedy predicted that within a decade the U.S might face "a world in which 15 or 20 or 25 nations may [have] these weapons. I regard that as the greatest possible danger and hazard." [44] China tested its first weapon the following year.

These steps lent urgency to talks that had been in process since 1958 on a treaty to limit the spread of nuclear weapons. [45] Under the Nuclear Non-Proliferation Treaty, signed by 98 countries in 1968, all members other than the five declared nuclear-weapons states pledged never to develop nuclear weapons. In return, the treaty guaranteed signatories access to peaceful nuclear materials and technologies. [46]

Momentum Stalls

A series of upheavals in the 1970s sharply undercut public support for nuclear power and halted new reactor orders by 1980. [47]

When Arab oil-producing states embargoed oil exports to the United States in 1973 to protest American support for Israel, the resulting spike in energy prices made nuclear power more competitive with fossil fuels — at least in the short term. But households and businesses responded by conserving energy, reducing demand for electric power. State regulators became less willing to approve rate hikes or let companies pass costs through to customers. As a result, many utilities ran short of cash and had to borrow money at high interest rates, increasing the already steep costs of building new reactors.

The emergence of an environmental movement helped to blunt nuclear power's growth. New laws such as the National Environmental Policy Act of 1970 subjected reactors to environmental reviews, further prolonging the licensing process and driving up construction costs. [48]

Activists also began to question the safety of nuclear power. For example, the Union of Concerned Scientists asserted in 1971, citing information from

government researchers, that the Atomic Energy Commission was not looking closely enough at possible flaws in reactors' emergency core-cooling systems and called for a halt to licensing new nuclear plants. [49]

Nuclear waste also became an issue in the 1970s. U.S. policy called for reprocessing spent fuel, recycling plutonium in reactors and putting remaining wastes in an underground repository. But in 1972 work on a Kansas repository was canceled after the site proved geologically unsuitable. Instead, the commission proposed building a surface interim-storage facility, but it was unclear whether or when it would be ready. With public concern growing, several states barred construction of new reactors until a permanent solution was found for managing nuclear waste. [50]

As questions mounted, critics charged that the AEC was paying more attention to expanding nuclear power than to safety and waste-management issues. In 1974 President Gerald R. Ford abolished the AEC and replaced it with two agencies: the Energy Research and Development Agency (which later became the Energy Department) to promote nuclear power, and the Nuclear Regulatory Commission (NRC) to regulate it. Three years later Congress abolished its Joint Committee on Atomic Energy, which was viewed as highly secretive and too supportive of the nuclear industry. Many other committees began holding open hearings that further publicized nuclear controversies.

Concerns increased during this period that nuclear-power programs abroad were furthering the spread of nuclear weapons. In 1974 India tested what it called a "peaceful" atomic weapon that was fueled with plutonium made in a civilian reactor, and a 1975 CIA report described Taiwan, South Korea, Pakistan, Argentina, Brazil, Libya, South Africa, Iran, Egypt and Spain as "threshold states" that could produce nuclear weapons by 1985. [51]

In 1977, President Jimmy Carter indefinitely deferred reprocessing and commercial development of breeder reactors — used to create plutonium — in an effort to discourage other countries from developing plutonium stockpiles. This meant the United States would only follow a "once-through" fuel cycle, sending spent fuel directly to a repository after using it once in a reactor.

On March 28, 1979, a reactor at the Three Mile Island plant near Middletown, Pa., suffered a partial core meltdown after a stuck valve drained too much cooling water from the reactor. [52] Although the accident was ultimately found to have released only small amounts of radiation, it sharply increased public fear of nuclear power. Many standing reactor orders were canceled, and new orders ceased completely. New safety requirements led to expensive modifications at operating reactors and plants under construction.

For the next decade, the nuclear industry struggled to regain momentum. President Ronald Reagan lifted the ban on commercial reprocessing, but private industry did not pursue the technology because of its high cost. The Nuclear Waste Policy Act of 1982 set timetables for developing two underground waste repositories, but the Energy Department was unable to find communities willing to host them. [53]

In 1987 Congress designated Yucca Mountain as the only site to be studied, drawing protests from Nevada that it had been chosen because of its small population, not because it was technically suitable. [54]

Against this backdrop the number of U.S. reactors grew from 71 in 1980 to 111 in 1990 as projects were completed, but many were finished far behind schedule and over budget. After an explosion at Ukraine's Chernobyl reactor in May 1986 killed dozens and sent a radioactive cloud across Western Europe, concerns about safety increased, although utilities stressed that the Chernobyl reactor had a different and riskier design than U.S. nuclear plants.

One of the most controversial projects, the Shoreham reactor on Long Island, was shut down in 1988 without ever going online after New York Gov. Mario M. Cuomo refused to certify that the region could be safely evacuated in an emergency. The $5.3 billion loss was absorbed by utility investors and electricity customers on Long Island.

A New Era?

In the 1990s, nuclear advocates began laying the groundwork for a new generation of reactors. The Energy Policy Act of 1992 streamlined licensing procedures by creating a combined license to build and operate nuclear plants. [55] Formerly, utilities had to obtain construction licenses and then apply for operating licenses, giving opponents two chances to block new plants and often leading to design changes during construction. The new approach also allowed the NRC to pre-approve reactor sites and standardize plant designs.

The 1992 law also spurred a major restructuring of the electric-power industry, leading many states to begin deregulating their retail power markets, opening them up to competition. [56] Although many observers predicted that nuclear plants would close because reactors' high capital costs made them unable to compete with cheaper fuels, nuclear power survived deregulation handily. Many utilities that owned only one or two reactors sold them to larger power companies that could run them more efficiently. Power output at U.S. reactors rose from 66 percent of total licensed capacity in 1980 to 88.1 percent in 2000 as operators reduced shutdowns for maintenance and unplanned safety problems. [57]

Deregulation gave nuclear power operators "an incentive to improve their performance," says economist Palmer

of Resources for the Future. "It's one of the success stories of competition."

As nuclear plants' performance improved, NRC approvals of applications for power uprates rose from 13 in the 1980s to 33 in the 1990s. [58] These increases in licensed reactor output allowed nuclear plants to maintain their share of the electric-power market even though several older reactors closed in the 1990s. In 1998, reactor owners began applying to extend their 40-year operating licenses for another 20 years. The NRC approved each of these requests after conducting thorough plant-safety reviews. To date, over 100 power uprates have been granted, often in the form of multiple, incremental increases at a single site. The NRC is required to grant the increase if a plant meets safety and environmental requirements. The same holds true for the 39 license extensions granted so far.

In his 2001 energy plan, President Bush strongly endorsed expanding nuclear power, but the 9/11 terrorist attacks raised questions about whether nuclear reactors might be similarly targeted. [59] NRC Chairman Richard Meserve stated in September 2002 that it would be prudent "to presume that al Qaeda may consider nuclear facilities as potential targets." [60] The commission tightened security requirements at nuclear plants and increased the size of a likely attacking force in contingency plans.

In 2004, the National Academy of Sciences (NAS) warned Congress that if terrorist attacks partially or totally drained pools at reactor sites, where highly radioactive spent fuel rods are stored underwater, the fuel's zirconium cladding could catch fire and release large amounts of radiation. The report recommended steps to make spent fuel pools less vulnerable, such as rearranging the fuel to distribute heat loads evenly and adding water-spray systems to cool the fuel if pools were damaged. [61]

Over the next several years, fossil fuel prices rose sharply as oil and gas supplies tightened, improving the competitive position of nuclear plants. Additionally, because world uranium supplies were plentiful and distributed among many supplier countries, advocates contended that increased use of nuclear power would help insulate the U.S. economy against unstable fuel prices.

But as work on the Yucca Mountain repository lagged farther behind schedule, the problem of managing nuclear waste remained the industry's Achilles' heel. The DOE missed its 1998 deadline for starting to accept spent fuel from nuclear plant owners, forcing a growing number of energy companies to store spent fuel at their reactor sites in dry casks, once the fuel had cooled enough to be removed from cooling pools.

By the end of 2004, a total of 49 reactors were storing spent fuel onsite in casks, and another 45 facilities were building or planning to build onsite storage. [62] Three courts had found DOE in breach of its contractual responsibility to accept spent fuel, creating major potential liabilities for taxpayers. ■

CURRENT SITUATION

Licensed to Build

Encouraged by NRC's streamlining of the licensing process and nuclear power's improving economics, energy companies are edging closer to building new reactors, although none have made firm commitments yet.

Exelon, Entergy and Dominion Resources have applied for early permits to build new reactors at existing nuclear plant sites in Illinois, Mississippi and Virginia, respectively, and Southern Company plans to apply for an early site permit at its Vogtle, Ga., nuclear plant this year. [63] If the applications are approved, the companies can bank the licenses while they decide whether to build new units.

As many as seven other companies and groups of companies are preparing to apply for licenses to build "Generation III" advanced nuclear plants at other existing reactor sites, mainly in the South. [64] The new plants would be simpler, more rugged and have more safety features than 1970s- and '80s-era Generation II reactors now operating in the United States and most other nuclear countries. [65] The NRC has certified four Generation III designs and is reviewing others. Certification, which is valid for 15 years, means the NRC has approved the reactor designs as safe for general use, so their safety features cannot be challenged during licensing of specific projects.

While no application to the NRC is expected until well into 2007, the companies have indicated plans to build as many as 17 new reactors.

The Department of Energy's Nuclear Power 2010 program, which aims to reduce barriers to construction of new nuclear plants, is paying half of the cost of first-time demonstrations of NRC's new combined construction/operating license process at two sites, a project expected to cost about $1.1 billion. [66]

"Showing the new plants can be built on schedule and on budget, including licensing, is one of the nuclear industry's biggest challenges, given some of the cost overruns that occurred in the 1980s," says NEI's Fertel. "The 1992 reforms to the licensing process do a lot to address past risks and should provide investors with a high degree of certainty at the time when they will be required to commit capital."

Reprocessing Used Nuclear Fuel

There are two ways to handle nuclear waste — store it or reprocess it. Neither alternative comes without risks and costs, and the Bush administration proposes reprocessing — the more controversial approach.

Commercial nuclear-reactor fuel consists of enriched-uranium pellets, which are sealed in long metal rods. The fuel rods are packaged in assemblies (bundles) that can weigh more than 1,000 pounds. Used or "spent" fuel assemblies are removed from reactors when they have absorbed so many neutrons that they can no longer sustain a chain reaction, although they still contain substantial amounts of uranium and plutonium. They are highly radioactive and must be cooled underwater in pools for at least several years before they can be processed.

Countries that practice a "once-through" fuel cycle, like the United States, Canada and Sweden, send spent fuel to a final disposition site or store it until a site is ready. Others, including France, Russia and Japan, reprocess it. Reprocessing involves breaking down used fuel and using various chemical methods to separate its components, after which the uranium and plutonium can be re-fabricated into new fuel. The remaining waste includes actinides (long-lived radioactive substances such as americium and neptunium) and fission products (shorter-lived, highly radioactive substances such as iodine, cesium and strontium). Countries that reprocess need disposal sites for these high-level radioactive wastes.

Today, commercial reprocessing is done using the PUREX process, which was developed during World War II to separate plutonium for use in nuclear weapons. PUREX involves dissolving spent fuel in nitric acid and then adding a solvent to recover uranium and plutonium from the solution. Because it produces separated plutonium that can be used for nuclear weapons, PUREX is viewed as a proliferation risk and is done under strict safeguards to prevent plutonium from being stolen or diverted. According to the Department of Energy, nuclear weapons can be made using as little as 4 kilograms (about 10 pounds) of plutonium, a mass roughly the size of a soft drink can. [1] Commercial reprocessing plants typically process several tons of plutonium each year.

DOE is researching two new approaches to reprocessing that advocates believe are more "proliferation-proof" than PUREX because they produce plutonium that is mixed with highly radioactive elements and therefore is less usable for weapons. [2] The UREX+ method is similar to PUREX but leaves the plutonium mixed with neptunium and other elements. Another technique, pyroprocessing, uses molten salt instead of acid to dissolve the fuel and passes an electric current through the solution to separate out plutonium, other actinides and some fission products.

In countries using PUREX, reprocessing has consistently cost more than a once-through fuel cycle because reprocessing spent fuel and fabricating plutonium into reactor fuel are more expensive than making new fuel from fresh uranium. [3] Reprocessing U.S. spent fuel and recycling the long-lived transuranic elements in reactors would cost between $50 billion and $100 billion more than disposal in underground repositories. [4]

The Bush administration's proposed Global Nuclear Energy Partnership (GNEP) program would use UREX+ or pyroprocessing to reprocess spent fuel, then recycle the actinides in reactors that use fast-moving neutrons to break these products down to shorter-lived substances. The cost of this approach remains highly uncertain: In a February budget briefing, Deputy Energy Secretary Clay Sell said, "[W]e are seeking to develop these technologies; we are seeking to lessen the amount of uncertainty as to what it would cost to build these facilities on a commercial scale, and ultimately we hope to be in a position to make a judgment about the commercial viability of this approach in the coming years." Sell acknowledged, however, that the administration's $250 million funding request for fiscal 2007 "is expected to increase dramatically in the coming years." [5]

[1] U.S. Department of Energy, "Restricted Data Declassification Decisions, 1946 to the Present (RDD-7)," Jan. 1, 2001, online at www.fas.org/sgp/ othergov/doe/rdd-7.html#I23, item II-L-33.

[2] U.S. Department of Energy, Global Nuclear Energy Partnership, "Why Do We Need Advanced Fuel Separation Techniques?", www.gnep.energy.gov/pdfs/factSheetPrimerAdvSseperation.pdf.

[3] Steve Fetter and Frank von Hippel, "Is U.S. Reprocessing Worth the Risk?" *Arms Control Today*, September 2005.

[4] National Academy of Sciences, *Nuclear Wastes: Technologies for Separation and Transmutation* (1996), p. 7.

[5] DOE press briefing on the Global Nuclear Energy Partnership, Feb. 6, 2006, www.energy.gov/print/3171.htm.

Reprocessing Ban

While momentum may be building for construction of new nuclear plants, the slow progress at the Yucca Mountain repository has prompted calls to revisit the U.S. ban on reprocessing commercial spent fuel. Reprocessing could buy extra time for work on the repository and might mean that more nuclear waste could be stored there over the long term, but this step is controversial because past U.S. reprocessing activities at civilian and military facilities have run over budget and generated large quantities of highly radioactive waste.

DOE's Advanced Fuel Cycle Initiative (AFCI), part of its nuclear energy research program, is studying ways to treat spent fuel and recycle plutonium. This research "could provide an alternative to building multiple Yucca Mountains while still supporting an expanding role for nuclear power in this country," William Magwood, director of DOE's Office of Nuclear Energy, told Congress in March 2005. Reprocessing could not only extend the useful life of the Yucca repository, Magwood says, but also reduce the radiotoxicity of the wastes stored there, cutting to less than 1,000 years the time needed for the wastes to decay to the relatively harmless toxicity of natural

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At Issue:

Do aging nuclear reactors pose higher safety risks?

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WRITTEN FOR THE *CQ RESEARCHER*, MARCH 2006

A product's chance of failure over its lifetime is represented by what is called the "bathtub curve." Failure is most likely early in life, the break-in phase, and late in life, the wear-out phase. The break-in portion of nuclear power's bathtub curve is labeled with names like Sodium Reactor Experiment, SL-1, Fermi Unit 1, Three Mile Island and Chernobyl — serious reactor accidents in the first months of operation. The wear-out portion of nuclear power's bathtub curve has no labels — yet.

The average age of the nuclear power reactors operating in the United States is more than 26 years. Over half have had their 40-year operating licenses extended for another 20 years, and most of the rest are in line for extensions. All U.S. nuclear power reactors are heading toward — if not already in — the wear-out phase of their lifetimes.

While nuclear reactors are operating with an increasing risk of failure, policies have diminished the chances for early detection and correction of aging problems. Reactor owners, citing low failure rates occurring during the flat portion of the bathtub curve, have successfully petitioned the Nuclear Regulatory Commission (NRC) for significant reductions in the scope and frequency of safety tests and inspections. Checks that had been performed on a monthly basis are now being performed quarterly. Other checks that had been conducted annually are now being done biannually, or even less frequently. Thus, U.S. nuclear reactors are moving closer to the wear-out phase of the bathtub curve with a strobe light, rather than a spotlight, on their safety levels.

This disturbing trend is exacerbated by another recent development. The NRC has approved increases of up to 20 percent in the maximum power levels at which nuclear reactors can operate. The higher temperatures and flows occurring at increased power levels cause equipment to wear out faster. For example, flow vibrations at the Quad Cities nuclear plant in Illinois caused a large metal component above the reactor core to shake itself apart — twice.

Operating aging nuclear reactors at increased power levels with fewer safety checks is a recipe for disaster. To avoid balancing the nuclear bathtub curve with reactor names on the wear-out phase, prompt steps must be taken to ensure there is a powerful spotlight on safety, not a weak strobe light.

Sadly, last year's energy bill contained ample provisions for more nuclear plants but nothing to remedy the NRC's flickering focus on safe reactor operation.

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An industry commitment to safety and training, combined with a system of close monitoring and strict regulation, has placed nuclear power plants among the nation's safest industrial facilities.

The Nuclear Regulatory Commission (NRC) regulates commercial and institutional uses of nuclear energy. As part of this oversight, the NRC assigns at least two full-time resident inspectors to each nuclear plant site. They conduct daily inspections, providing close surveillance of the plant, its equipment and operations. In addition, the typical nuclear plant site undergoes about 2,500 hours of inspections per reactor each year.

The NRC developed a new reactor-oversight process that was implemented industrywide in April 2000. This process is more sharply focused on areas of plant operation that are most important to safety and provides the public, the government and the industry timely, understandable and meaningful assessments of plant performance.

The NRC also reviews applications for nuclear plant license renewals. This is a stringent process that takes into account numerous factors regarding a reactor's ability to continue operation, including the effectiveness and safety of existing equipment.

The industry's overarching commitment to safety extends beyond meeting federal regulations. This desire to maintain the highest level of safety and efficient operation of nuclear plants motivates the industry's investment in sound systems and properly functioning equipment.

Companies operating nuclear power plants have an integrated plan for managing the condition of plant systems, structures and components. That includes monitoring the integrity of primary system materials and maintaining the condition of plant equipment. With more than 40 years of experience, companies have learned how equipment wears, and they can refurbish or replace the vast majority of equipment before it fails. When the operation of an important component degrades or fails, companies make detailed root-cause analyses and take corrective actions.

It is for these reasons that the so-called bathtub curve does not appropriately apply to America's existing nuclear power plants. Clearly, these plants already have safely surpassed the first phase, or break-in period. Given that the speculative back end of the bathtub curve would be due to fatigue or depletion of materials, the ongoing preventative and corrective maintenance performed at nuclear plants addresses these issues.

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uranium ore. [67] This would allow more waste to be stored at Yucca Mountain, advocates argue, because the heat of the waste determines how far apart canisters need to be spaced in the repository. To accelerate this process, Congress added $50 million to the fiscal 2006 energy appropriations bill for DOE to develop a plan to reprocess all U.S. commercial spent nuclear fuel and recycle its plutonium content, with instructions to start finding sites for the facilities by mid-2006. "It is essential to continue development of the Yucca Mountain repository," said the bill's sponsor, Rep. David Hobson, R-Ohio, "but it is also essential to pursue alternative approaches to spent nuclear fuel so that we do not have to develop eight more Yucca Mountains by the end of this century." [68]

The Bush administration has requested $250 million in its fiscal 2007 budget to launch a Global Nuclear Energy Partnership (GNEP), under which the U.S. would lease fresh nuclear fuel to other countries and take back spent fuel for disposition (which the U.S. already does with fuel it supplies to scientific-research reactors around the world to prevent the spent fuel from being used for weapons).

Using technologies currently under development, the United States would reprocess both the foreign and domestic spent fuel, using the resulting plutonium and other actinides (long-lived radioactive elements) as fuel for advanced "burner" reactors that would break them down into shorter-lived materials. [69]

The partnership would enable expansion of nuclear power in the United States and around the world, promote non-proliferation and help resolve nuclear waste disposal issues, Energy Secretary Bodman told the Senate Energy Committee on Feb. 9. "[T]he United States will work with key international partners to develop and demonstrate new proliferation-resistant technologies to recycle spent nuclear fuel to reduce waste," he said. And new technologies developed through the project would reduce the volume and radiotoxicity of nuclear waste, greatly reducing the amount of waste needing permanent storage at Yucca Mountain and delaying the need for an additional repository indefinitely, he said.

The Energy Department has not released long-term cost estimates for GNEP, but developing new reprocessing plants and fast reactors to break down transuranic wastes could cost $40 billion or more over the next several decades. [70] "These advanced reprocessing techniques and fast reactors have not been commercially deployed, so we don't know whether they are technically feasible or how much they'll cost, although they are almost certain to cost more than conventional reprocessing," says physicist Steve Fetter, dean of the University of Maryland's School of Public Policy.

The Bush administration wants private companies and foreign governments to contribute, but early reactions from U.S. nuclear plant owners were lukewarm because executives reportedly did not see GNEP as helping to build support for new power plants. "We'll all cheer DOE from the sidelines," said one utility official in early February. [71]

The trade newsletter *Electricity Daily* called a resumption of reprocessing "an entirely bad idea" and predicted that it would be "wildly uneconomic," noting that DOE has been working to clean up a civilian reprocessing site at West Valley, N.Y., since 1980 and does not expect to be finished until 2008. [72]

Many energy experts argue that because spent nuclear fuel can be stored in dry casks at reactors for at least 50 years, there is no need to make a near-term commitment to an expensive reprocessing program. They further argue that since plutonium separated during reprocessing can be stolen or diverted for use in nuclear weapons, the United States should not resume reprocessing any earlier than necessary because it could spur proliferation threats around the globe.

The Bush administration argues that reprocessing techniques envisioned for GNEP will produce plutonium unsuitable for nuclear weapons because it would be mixed with other actinides. But some scientists doubt the new techniques would be proliferation-proof. "Almost all of these elements are usable for nuclear weapons, although they may complicate the design issues," says Fetter. "And other countries might alter the technologies to produce materials that could be used in nuclear weapons. GNEP raises more questions than it answers."

A May 2005 report by the American Physical Society on resolving nuclear power's proliferation problem concluded that it was not "urgent" for the United States to initiate reprocessing or develop additional repositories. The panel recommended refocusing the Advanced Fuel Cycle Initiative — away from reprocessing and onto proliferation-resistant fuel cycle options.

"We should not be stampeded into anything," says Ernest Moniz, a professor of physics at MIT and former Energy under secretary. "The right course is long-term surface or sub-surface storage of spent fuel." The nuclear industry continues to press for licensing of the Yucca Mountain repository and to criticize Congress for appropriating less money out of the Nuclear Waste Fund than consumers have paid into it. NEI's Fertel says nuclear owners view reprocessing as a long-term strategy, not as an alternative to geologic disposition.

"If we're going to build a large number of nuclear plants in the coming decades," says Fertel, "then it makes sense to look at whether we're going to close the fuel cycle, and to do research and development on some key questions: What technology is the safest, most efficient and most proliferation-resistant, what kind of fuel would be used, and what kind of reactor would we use? But our timeline is 30 to 50 years, and whether you close the fuel cycle and move to reprocessing or not, you still need a repository." ■

OUTLOOK

Doubts About Expansion

While conditions for building new nuclear plants appear to be improving, experts outside the nuclear industry remain skeptical that a major nuclear expansion is on the horizon.

Based on the subsidies included in the 2005 Energy Policy Act, the Energy Information Administration predicts that 9,000 megawatts of new nuclear capacity will be added through 2030, including 3,000 megawatts of uprates at existing plants and 6,000 megawatts of new plants (about six large reactors). [73] Energy analysts agree that even though streamlined licensing regulations have lowered the barriers to building new plants, lingering issues — especially waste management — could still undercut support for new reactors.

Incentives in the new law should resolve the financial risk issues, says MIT's Moniz, but until there is a "near-term prospect" of disposing of spent fuel at Yucca Mountain, it could be very complicated to get a new plant licensed.

Reprocessing advocates appear ready to press for a change in U.S fuel-cycle policy, if only to move spent fuel somewhere soon. "Yucca Mountain started out as something everybody thought could stay on time, stay within budget and get done," said Sen. Pete Domenici, R-N.M., a leading congressional reprocessing advocate. "It turns out none of that is true — it's not on time, we still haven't cleared some of the worst hurdles. So we have to stick with it, [but] what role it will inevitably play is still undetermined, in my opinion." [74]

Most environmentalists maintain that conservation and renewable energy are the safest and cheapest ways to keep the lights on and the air clean. They view reprocessing as expensive and a proliferation threat, and oppose the Bush administration's Global Nuclear Energy Partnership proposals. "It's the height of hypocrisy to support activities that will make energy and environmental problems worse at a time when funds are being cut for energy programs that help people, like weatherization and efficiency," says US PIRG's Aurilio.

Plant security could also fuel new concerns about expanding nuclear power, especially if any incidents take place at operating plants or it becomes clear that terrorists are targeting reactors. Details of the new design-basis threat (DBT) — the minimum size of an attacking force that commercial reactor owners must be ready to fight off — implemented by the NRC in 2004 are classified, but the standard reportedly directs nuclear plant owners to maintain enough security to defend against a force less than the size of the 9/11 attackers. The commission is currently reviewing the DBT and putting the new standards into regulations after taking public comments, says NRC public affairs Director Brenner. [75]

"Every nuclear power plant in the United States meets the requirements for providing assurance that their activities . . . do not constitute an unreasonable risk to the public health and safety," said NRC Chairman Nils Diaz on Dec. 2, 2004. "However, the NRC continues to be vigilant, cognizant of the threat and of the need to ensure that every one of our licensees is performing at the levels needed for . . . the protection of the public." [76]

Critics argue that the NRC is overly focused on how much security the industry can afford, citing examples such as a June 2005 agency staff paper, which stated the revised design-basis threat "is not based on worst-case scenarios but rather on actual adversary characteristics demonstrated worldwide and a determination as to those characteristics against which a private security force could reasonably be expected to provide protection." [77]

"That's backwards," says Danielle Brian, director of the Project on Government Oversight. "What we really need is an assessment of the threat and what it takes to handle it. If this is the best that industry can do on security, then we should rethink whether industry should be in charge of security."

The privately owned plants are guarded by well-trained private security forces, often staffed with ex-military personnel, and all have arrangements with local law-enforcement agencies for supplemental assistance, Brenner says. An attacking force larger than the DBT is considered by NRC regulation to be "an enemy of the United States" that would call into play additional federal assets.

Meanwhile, reactors are continuing to win approvals for uprates and license extensions. Most local communities seem willing to live with existing reactors, but winning public approval and millions of dollars in federal support to build the first next-generation reactors will be a much higher hurdle. "That's where the rubber will meet the road," says Aurilio. "Will Congress spend hundreds of millions of dollars more on this industry when budgets are tight?"

Furthermore, even if new plants can be built safely in the United States, a nuclear disaster abroad — like Chernobyl in 1986 — would quickly sour domestic opinion on nuclear energy again. The fate of nuclear power in the United States thus is tightly linked to the adoption of stronger safety requirements and barriers against proliferation worldwide.

"Many nuclear energy proponents don't recognize that one accident or proliferation incident anywhere will shut down an expansion of nuclear power worldwide," says Harvard's Holdren. "If we're going to do this, it's important to do it right." ■

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Wilkie, Dana, "Nuclear Power Poised For Comeback," *The San Diego Union-Tribune*, July 31, 2005, p. A1.

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Wald, Matthew L., "Scientists Try to Resolve Nuclear Problem With an Old Technology Made New Again," *The New York Times*, Dec. 27, 2005, p. F3.

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Weir, Fred, and Howard LaFranchi, "Russia and U.S. As Global Nuclear Waste Collectors?" *The Christian Science Monitor*, Feb. 7, 2006, p. 1.

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National Security and Nuclear Power

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A senior official at Connecticut's Millstone Nuclear Power Station was removed from his job after he complained that the plant's electronic security system was seriously flawed.

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Executives at Florida Power and Light have turned the Turkey Point nuclear plant into a heavily guarded encampment.

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