

# Guide To Nuclear Energy



Prepared by  
The Nuclear Energy Institute

The Nuclear Energy Institute (NEI) is privileged to make available to you this *Guide to Nuclear Energy*. I hope and believe that it will prove to be a useful resource to further your understanding and consideration of nuclear energy issues. Because the guide is intended as a starting point to a more complete understanding of nuclear technologies, their benefits and their place in society, I encourage you to contact NEI representatives directly, or visit the Institute's web site (<http://www.nei.org>) for more information.

As the nuclear energy industry's policy organization, NEI considers the communication of accurate and timely information to policymakers, the news media and the public to be among its primary responsibilities. Nuclear technologies provide many benefits in the lives of billions of people. Nuclear power plants generate electricity without polluting the air. Radioactive materials are widely used in the field of medicine, and they are used for such purposes as developing hardier, more disease-resistant crops, and checking the structural integrity of bridges. Radioactive materials also provide benefits in everyday consumer goods and services.

The men and women in this industry are proud of the work they do and the benefits they provide to our daily lives. This guide is part of our effort to inform the public of these industry achievements and to make it possible for the industry to build upon its contributions to society. I invite your feedback on the usefulness of the guide in meeting your needs.



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January 2001



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# Nuclear Energy for the 21st Century

**N**uclear energy is the second-largest source of electricity in the United States, after coal (see Fig. 1). Importantly, nuclear energy is the largest emission-free source of electricity, because it does not burn anything to produce energy.

The United States has more than 100 licensed nuclear plants that provide about one-fifth of the nation's electricity. These nuclear plants have a capacity of more than 97,000 megawatts, and they provided 728 billion kilowatt-hours in 1999. That was almost as much electric energy as our entire national electric system was generating when nuclear energy was introduced in 1957 with the startup of the first commercial nuclear generating station in the western Pennsylvania town of Shippingport. Today, almost every American home, business and industry receives part of its electricity from nuclear power plants through a nationwide, interconnected transmission system (see Fig. 2).

Because of a lack of demand for new large-scale electricity supply, the last nuclear power plant to be completed in the United States came on line in 1996. In recent years, however, electricity supplies have become increasingly tight. The greatly improved performance of nuclear power plants during the 1990s has provided energy equivalent to the addition of 19 new nuclear plants. Moreover, during extreme cold spells, when coal piles are frozen and river transportation is halted, the value of having nuclear plants in the energy mix as a reliable alternative to fossil-fueled generation is even more apparent. Due primarily to nuclear plants, U.S. electric utilities were able to reduce their dependence on imported oil dramatically through the 1970s and 1980s. And because the plants do not emit greenhouse gases or air pollution, they help to improve our air quality and the environment.

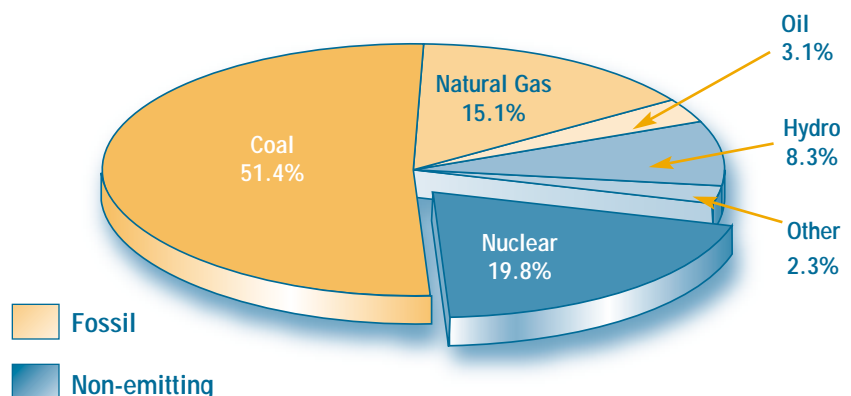
Nuclear energy's future in the United States is not assured, however. These accomplishments could be jeopardized unless there is a redoubling of efforts to achieve centralized storage of high-level nuclear waste and to remove regulatory obstacles to the full use of nuclear energy.

Consider nuclear energy's benefits to the United States over the past four decades:

**Competitive production costs.** Average nuclear production costs are declining and have been for more than 10 years. In 1987, they hit a high of nearly three cents per kilowatt-hour, on average. Production costs were down to less than two cents by 1996, and are still falling. Today, it's not uncommon for production costs at nuclear plants to be 1.5 cents per kilowatt-hour or lower. Even as the electric utility industry restructures, the majority of nuclear plants are competitive with the most efficient new combined-cycle gas plants. Recent decisions by electric utilities to pursue license renewal of nuclear plants bear this out. A deregulated, competitive electric generating business creates a powerful

## Second Largest Source of Electricity in the U.S.

Figure 1



Source: Department of Energy/Energy Information Administration

*“I believe very firmly that nuclear has to be a significant part of our energy future and a large part of the Western world, if we’re going to meet these [emission reduction] targets.”*

— Stuart Eizenstat,  
Under Secretary of State  
for economic, business  
and agricultural affairs,  
the lead U.S. envoy  
at the Buenos Aires Summit  
on climate change,  
November 1998

business incentive to keep a nuclear plant operating safely and reliably beyond its initial 40-year licensing period. With deregulation, a fully depreciated nuclear plant is a tremendous asset. It can sell energy at marginal cost. Even when some plants have investment costs that are not fully recovered in the transition to a deregulated electricity system, improved performance and reliability have enabled them to be among the nation’s least-cost electricity producers.

As 2000 drew to a close, utilities running five of the nation’s 103 operating reactors had received 20-year extensions to those units’ operating licenses from the Nuclear Regulatory Commission. The owners of another five reactors had filed license renewal applications with the NRC, and the owners of another 28 reactors had notified the agency of plans to file similar applications by 2004.

**Major environmental advantages.** Nuclear power plants avoid air pollution, clearly a prerequisite in our environmentally attuned society. Between 1973 and 1996, for example, nuclear energy met 40 percent of the increased demand for electricity in the United States without emitting chemicals that produce acid rain and ozone smog or jeopardize public health. Each year, our nuclear plants avoid the emission of 5.3 million tons of sulfur dioxide, 2.5 million tons of nitrogen oxides, and 168 million metric tons of carbon. These numbers are not trivial. As state and federal governments prepare to meet new air quality restrictions, nuclear energy will be even more vital. For example, the yearly carbon avoided by U.S. nuclear plants amounts to almost 60 percent of the target level required in the Kyoto Protocol on climate change. The carbon avoided is equivalent to the carbon emissions that would result from 170 coal-fired power plants with generating capacities of 500 megawatts or from 300 gas-fired plants of the same size.

The U.S. Department of Energy estimates that the operating licenses of nuclear power plants will need to be renewed and another 40,000 megawatts of new nuclear capacity built in order for the United States to

meet its Kyoto commitments. Nuclear energy in the U.S. today keeps as much carbon dioxide out of the atmosphere as taking 94 million cars off the road. Globally, 432 nuclear power plants generate 16 percent of the world’s electricity (*see Fig.3*), while avoiding 500 million tons of carbon annually. Nuclear energy’s contributions will become even more significant, as global electricity demand is expected to grow 75 percent by 2020 and could triple by 2050. Although solar energy and other non-hydro renewables are important alternatives, nuclear energy will remain the primary large-scale source to meet increasing electricity needs and emission-reduction goals.

**Steadily improving safety and operating performance.** The safety record of nuclear power plants in the United States is outstanding by any measure—including the plant performance indicators tracked by the U.S. Nuclear Regulatory Commission and the World Association of Nuclear Operators. A steady reduction in the number of unplanned plant shutdowns at America’s nuclear plants and a plunging workplace accident rate since the Three Mile Island accident in 1979 reflect the industry’s commitment to safety. A recent analysis of operational data conducted by the Nuclear Regulatory Commission confirmed the industry’s improved safety performance. The analysis showed that the number of severe accident precursors recorded in 1997—none with a damage probability greater than one in 10,000—reached its lowest level since 1970, when only one-sixth as many reactors were operating.

Along with the constant gains in safety performance, the average capacity factor (a measure of efficiency) has improved steadily. In 1999, it hit a record high of 86.8 percent, up from 67.5 percent as recently as 1990. Through the first nine months of 2000, the average capacity factor increased 4.4 percent from the same period in 1999. Nationally, each percentage point increase in capacity factor is roughly equivalent to bringing another 1,000 megawatts of generating capacity on line. Improved nuclear plant performance

thus helps meet the growing demand for electricity even without building new plants. The rise in capacity factor over the past decade is the result of plant modifications, improved operating and maintenance practices, and ongoing training of nuclear plant personnel.

**Greater national energy security.** In electricity production, nuclear energy essentially has replaced the use of oil. Between 1973 and the early 1990s, nuclear energy's share of U.S. electricity increased from 4 percent to 20 percent. Oil's share dropped from 17 percent to 4 percent. The shift to nuclear-generated electricity has saved American consumers \$65 billion since 1973 by avoiding the cost of using oil. And nuclear electricity is replacing the direct burning of oil in many other areas of our economy, making the U.S. less vulnerable to sudden price hikes and supply interruptions.

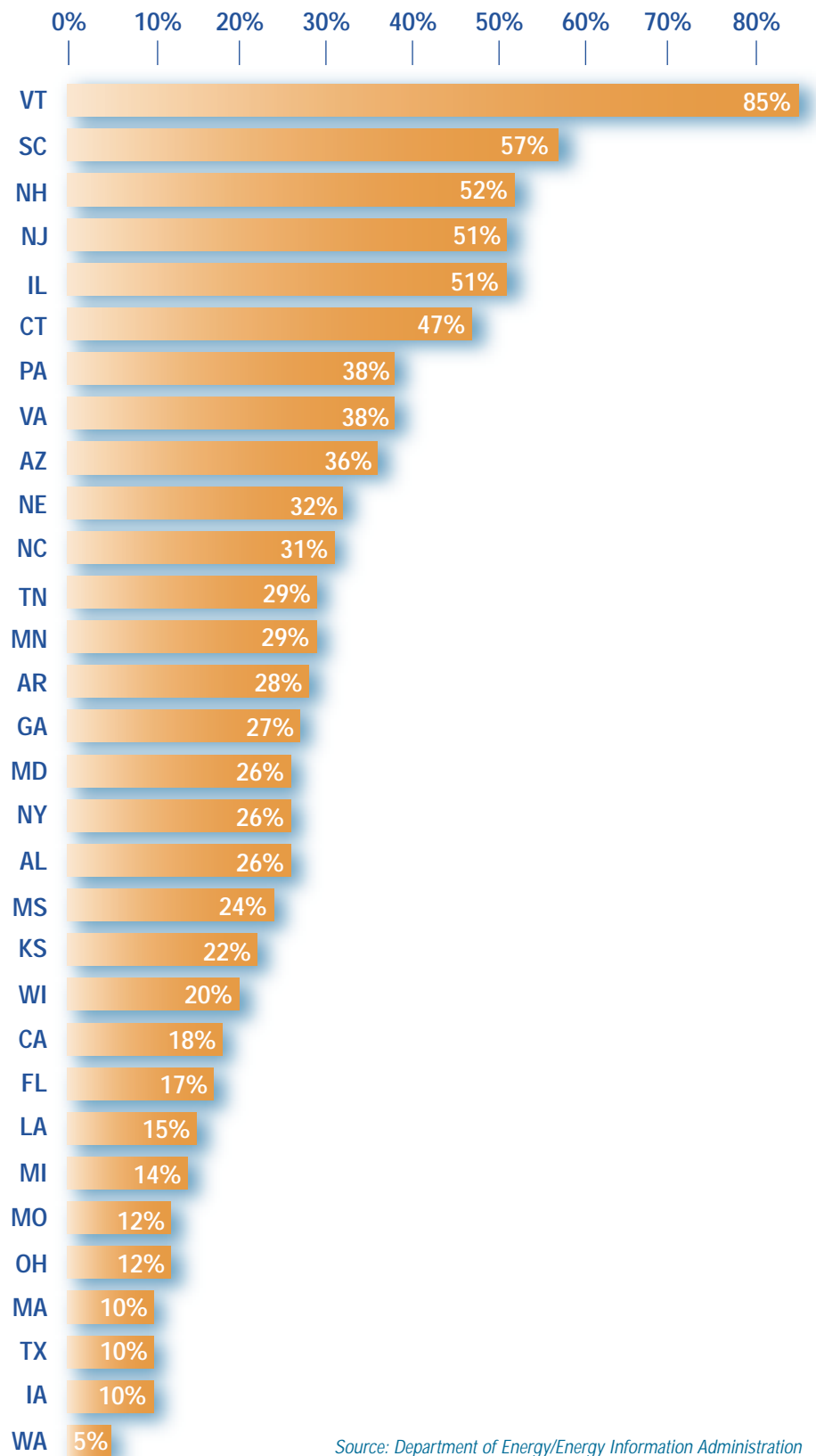
But the U.S. electric supply system is aging. In 1970, 83 percent of the U.S. baseload power plants were less than 20 years old; only 9 percent were more than 30 years old. At the turn of the century, however, only one-quarter of the baseload power plants are under 20 years old, while more than one-third of them—about 140,000 megawatts—are more than 30 years old. Conservation and energy efficiency can help, but they cannot eliminate the need for new generating capacity to meet annual growth in energy demand. If the United States expects to ensure energy reliability and meet its air-quality commitments, some portion of that new generating capacity must be nuclear energy.

### NUCLEAR SWORDS INTO PLOWSHARES

Without any fanfare, many U.S. nuclear power plants are using fuel derived from Russian weapons-grade uranium to generate electricity, earning back most if not all of the purchase price, while destroying fissile material from warheads that once were aimed at U.S. cities. U.S. experts say the equivalent of more than 1,800 nuclear warheads already have been destroyed by blending down weapons-grade uranium to the very dilute fuel used for energy production. President

## Nuclear Power Produced in 1999

Figure 2



Source: Department of Energy/Energy Information Administration



## Nuclear Power Worldwide

Figure 3

Top Ten Countries by Number of Operating Reactors in 2000		Top Ten Countries by Percentage of Electricity Supplied by Reactors in 1999	
United States	103	France	75%
France	59	Lithuania	73%
Japan	53	Belgium	58%
United Kingdom	35	Bulgaria	47%
Russia	29	Slovak Republic	47%
Germany	19	Sweden	47%
South Korea	16	Ukraine	44%
Canada	14	South Korea	43%
Ukraine	13	Hungary	38%
Sweden/India	11	Armenia	36%

Source: International Atomic Energy Agency

Clinton in 1998 proposed a plan to build on that success and move ahead with a two-track system for immobilizing U.S. weapons plutonium—converting some surplus plutonium into mixed oxide fuel and encasing the rest in glass “logs” for burial at an underground facility. Mixed oxide, or MOX, fuel includes a blend of plutonium and uranium. The value of the generated electricity from burning MOX fuel in nuclear power plants could reach billions of dollars. Russia has agreed to remove some of the surplus military plutonium from its stockpile, process it as MOX fuel, and use the fuel in commercial nuclear power plants.

### QUALITY OF LIFE

Nuclear technology provides benefits to our society in a myriad of critical areas. It is an essential component in medical, scientific, industrial and agricultural research and applications. For instance, nuclear medicine saves lives every day through its application in both diagnostic and treatment uses. Every year, more than 12 million Americans—including one

of every three hospital patients—benefit from the use of radiation or radioactive materials as part of their medical diagnosis or treatment. Breakthroughs in medical research and pharmaceutical drugs would be impossible without the benefits of nuclear materials, and food irradiation is becoming an important means of preserving food and protecting human life. Entire areas of research and development in chemistry, metallurgy, genetics, biotechnology and engineering would not exist without nuclear materials. In space exploration to distant planets and many other missions, there is no alternative to radioisotope-generated electricity.

The United States faces major energy challenges in the early years of the 21st century, and the nation's electric energy industry faces a future filled with change. There are unanswered questions about the evolving competitive environment for electricity; and uncertainty about the future price and supply of natural gas, the dominant fuel for new smaller-scale electric generating plants in the United States. There are questions about the economic viability of solar and other renewable energy sources, and questions about the success of programs to manage growth in electricity demand by increasing the efficiency of use, and the very real possibility of increasingly stringent environmental restrictions on the burning of fossil fuels.

Many complex factors will shape decisions on the type of generating capacity that must be built in the years ahead. Those decisions will require the balancing of benefits, uncertainties and competing interests. No single energy source can satisfy all circumstances. Energy diversity is one of the great strengths of the U.S. electric supply system, and nuclear energy has a vital role to play in the future. Rather than an option, it is a necessity.

# Plant Safety

**A**nuclear power plant is a way to boil water to generate steam without the use of fossil fuels. The steam turns a turbine to produce electricity, just as it does in any power plant. The difference is that in a nuclear plant, the heat used to generate steam is produced by a nuclear reaction involving uranium, instead of by the combustion of fossil fuel. The reactor's uranium is manufactured in solid pellets, each about a half-inch long. The pellets are stacked by the hundreds into long, thin fuel rods bundled to form fuel assemblies, with the number of assemblies in the typical reactor ranging from 550 to 800. All the fuel assemblies together are referred to as the reactor "core."

In the United States, there are two main types of light water reactors: the pressurized water reactor (PWR) and the boiling water reactor (BWR). Pressurized water reactors outnumber boiling water reactors by 2-1. Both types operate on basically the same principles, and both are cooled using ordinary water.

In a PWR, heated water passing through the core is kept under high pressure so that it will not boil. The water is piped to a steam generator, a kind of heat exchanger, and the steam thus formed drives the turbine. After the steam passes through the turbine, it then passes through a heat exchanger called a condenser. Water circulates through tubes in the condenser, cooling the used steam and converting it to water again. The condensed water is then returned to the steam generator and the cycle is repeated.

In a BWR, heated water passing through the core is allowed to boil after it leaves the core. The boiling water produces steam that drives the turbine. After the steam passes through the turbine and the condenser, it is reused in the reactor.

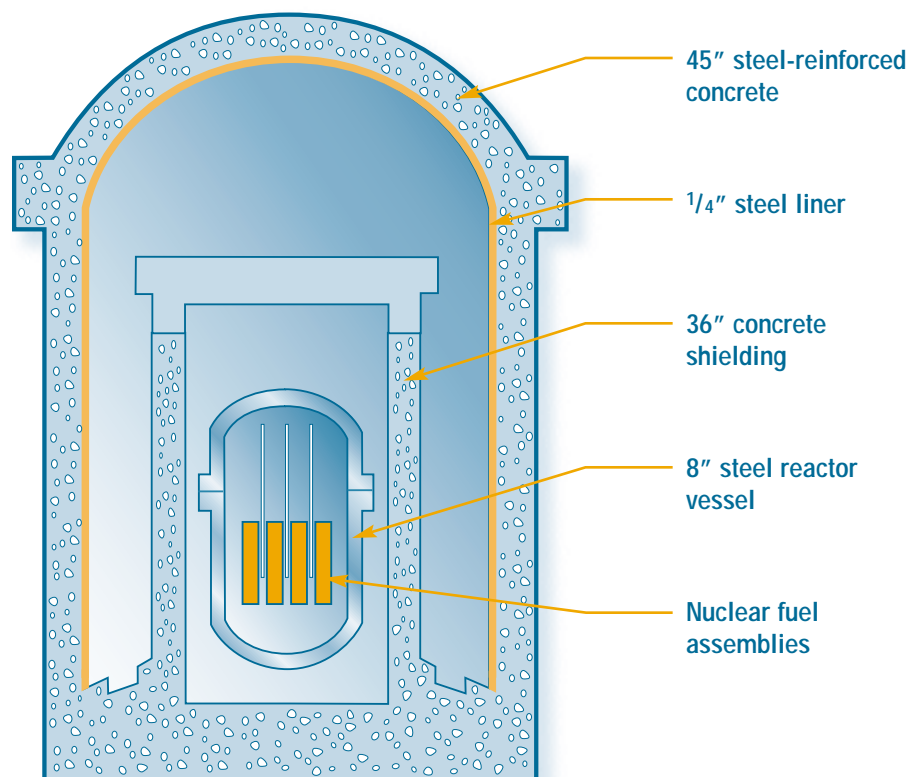
A nuclear plant in the United States has multiple backup safety systems to provide (see Fig. 4) "defense in depth." Safety features are built in to control the

chain reaction. Control rods absorb tiny subatomic particles called neutrons and control the reaction. The reactor core itself is contained within a steel pressure vessel with very thick walls.

Water helps moderate the reaction inside the reactor. Although the control rods are the main way to control the nuclear reaction, the water helps, too. The greater the nuclear reaction, the more heat is produced. The increasing heat turns more water to steam, which slows down the nuclear reaction. So the water works like a brake. It prevents the nuclear reaction from running out of control. If the water were ever lost, multiple emergency cooling systems would keep the reactor from overheating.

## *U.S. Style Nuclear Reactor—Defense In Depth*

*Figure 4*





The “defense in depth” philosophy recognizes that equipment can fail and that operators can make mistakes. So the plant has built-in sensors to watch temperature, pressure, water level and other indicators that are important to safety. These sensors are linked to control systems that adjust or shut down the plant—immediately and automatically—at the first sign of trouble. These safety mechanisms operate independently, and each has one or more backups: If one set fails, another is available for safe shutdown of the reactor.

U.S. nuclear power plants also use a series of physical barriers to make sure that radioactive material does not escape. The first barrier is the composition of nuclear fuel itself. The radioactive byproducts of the fission process remain locked inside the fuel pellets. These pellets are sealed inside rods made of special metal. The fuel rods are positioned inside a large steel vessel, which has walls about eight inches thick. At most plants, the reactor and vessel are enclosed in a large, leak-tight shell of steel plate. All this is contained inside a massive, reinforced-concrete structure—called the containment—with walls that are typically three to four feet thick.

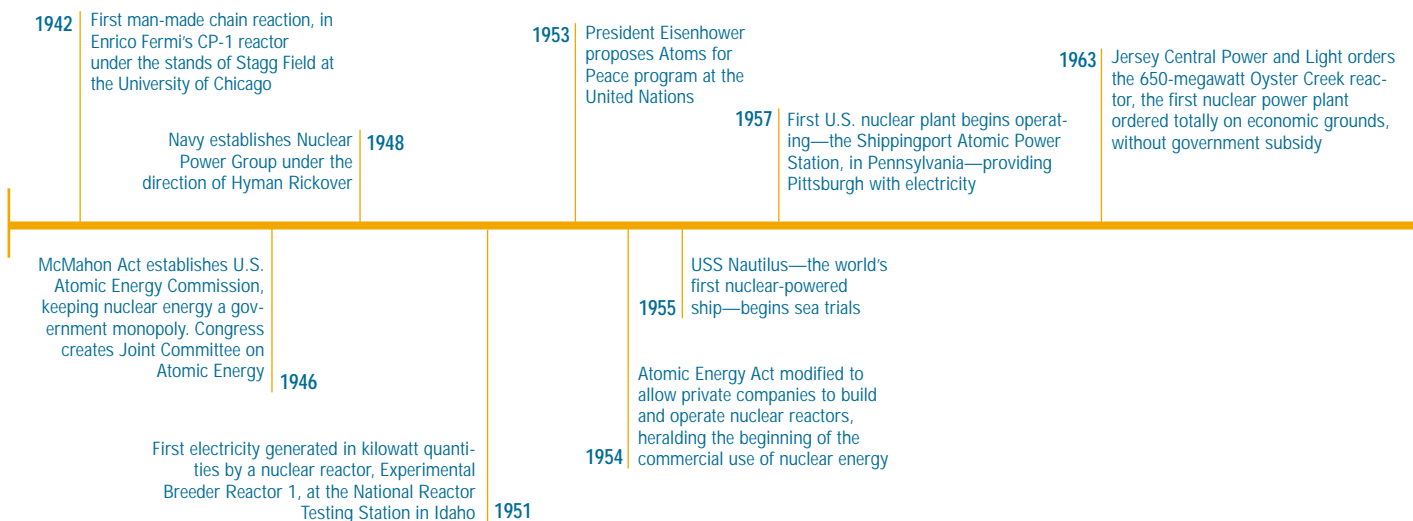
The many thick layers of the containment building keep radioactive materials safely inside. Without question, the 1986 accident at Chernobyl in the former Soviet Union could not happen in the United States. That basic design would not be licensed by the U.S. Nuclear Regulatory Commission. The Chernobyl reactor had no containment structure, so radioactivity did escape. The Chernobyl plant also had other design flaws. And safety systems that, at a minimum, could have reduced the severity of the accident had been ordered shut off while a test of plant equipment was conducted. Ukraine closed the last operating Chernobyl reactor in December 2000.

### THREE MILE ISLAND: LEARNING FROM EXPERIENCE

The U.S. nuclear energy industry learned many lessons from the Three Mile Island accident near Harrisburg, Pa., in March 1979. Although it did not result in a single injury, the accident aroused public fears concerning nuclear safety.

Health experts concluded that the amount of radiation released into the atmosphere was too small to result in discernible direct health effects to the

## Nuclear Energy's History



population in the vicinity of the plant. At least a dozen epidemiological studies conducted between 1981 and 1991 have borne this out.

The incident taught power plant operators a lot about how to improve reactor safety. According to the President's Commission on the Accident at Three Mile Island, headed by John G. Kemeny, the accident began with a single pump failure. As the operators addressed this rather routine problem, an important valve failed to work the way it was designed, causing a leak in the reactor's cooling system. More than two hours passed before the faulty valve was discovered and shut.

During this time, thousands of gallons of radioactive water passed into the reactor building, but still within the containment. Some of the water was pumped to storage tanks in an auxiliary building, but these tanks quickly spilled over.

Meanwhile, the plant's operators were being misled by inadequately designed instrumentation that provided ambiguous indications of plant conditions. The operators believed the cooling system contained too much water, when in fact there was far too little. Because of this faulty reading, the operators took actions that essentially eliminated the system's ability

to remove heat from the reactor core. Although the nuclear reaction had ceased, heat in the fuel continued to increase, causing the metal grid work and supports that hold the fuel in place to melt and, according to research commissioned by the U.S. Department of Energy, the pellets themselves began to disintegrate.

The impact of the accident on improved reactor safety was enormous. It led to greater understanding of potential risks, improved regulation, improved safety systems, and improved operator training and supervision. For instance, since Three Mile Island, U.S. nuclear power plant operators continually train on plant-specific simulators for accidents as well as routine operation.

In addition, the industry demonstrated a long-lasting commitment to safety and to excellence in nuclear power plant operation by establishing the Institute of Nuclear Power Operations. INPO, which is based in Atlanta, continues to examine the operation of all nuclear power plants in the United States and identifies any aspects that are not up to its standards of excellence. Its evaluations are important to all utilities, and all utilities work to achieve INPO's high standards.

*"The lesson of Chernobyl is not an indictment of nuclear power as such. Nuclear power, designed well, regulated properly, cared for meticulously, has a place in the world's energy supply."*

— Vice President Al Gore  
in a statement at the  
Chernobyl nuclear plant  
in July 1998

<p>1975 Congress eliminates the Atomic Energy Commission and, in its place, establishes the Nuclear Regulatory Commission and the Energy Research and Development Authority</p>	<p>1977 The Energy Research and Development Authority is abolished and the Department of Energy organized</p>	<p>1983 For the first time, nuclear energy produces more electricity in the U.S. than natural gas, using 76 reactors with a generating capacity of 59,283 megawatts</p>	<p>1992 Energy Policy Act amends licensing process to expedite the construction and operation of new nuclear power plants using standardized designs</p>	<p>1999 Entegy Nuclear's acquisition of Boston Edison's Pilgrim Station marks the first completed sale of a U.S. nuclear power plant</p>
<p>1973 Arab oil embargo creates crisis in energy supply and cost, underscoring dangerous U.S. dependence on oil and the need for energy diversity</p>	<p>1977 The Joint Committee on Atomic Energy in the U.S. Congress is abolished and its functions divided among other congressional committees</p>	<p>1979 Accident occurs at Three Mile Island in Pennsylvania</p>	<p>1984 Nuclear energy produces more electricity than hydropower, leaving it second in the U.S. only to coal</p> <p>Three advanced reactor designs are approved by the Nuclear Regulatory Commission</p> <p>Baltimore Gas and Electric and Duke Power become the first utilities to apply for renewal of nuclear plant licenses at the two-unit Calvert Cliffs plant in Maryland and the three-unit Oconee plant in South Carolina</p>	<p>1997-1998 Constellation Energy, Duke Power receive license extensions for Calvert Cliffs and Oconee plants</p> <p>1998 NRC begins implementing a new nuclear power plant oversight process</p> <p>2000</p>

Another organization that was established in the aftermath of Three Mile Island—the National Academy for Nuclear Training—continues to check all plant design, testing, operations and training. All of this is in addition to strict regulation by the U.S. Nuclear Regulatory Commission.

### THREE MILE ISLAND UNIT 1: A WORLD-CLASS NUCLEAR POWER PLANT

Since the accident at Three Mile Island Unit 2, the remaining operating reactor (Unit 1) of that plant has achieved an extraordinary operating record. TMI-1, which was closed pending the outcome of extensive NRC hearings, remained off line for six years. It restarted in 1985 and began its climb to world-class performance immediately. For example, in 1989,

TMI-1's capacity factor—a measure of reliability and safe operation—reached 100.03 percent, the best in the world. In cool weather, the plant can safely exceed its rated output and therefore boost its capacity factor above 100 percent. By 1991, TMI-1 set a world record for the longest operating cycle in the history of U.S. commercial energy: 479 consecutive days. In June 1997, TMI-1 completed the longest operating run of any light-water reactor worldwide: 616 days and 23 hours of continuous operation. The run also qualified as the longest of any steam-driven plant in the U.S., including fossil-fuel plants. And in September 1999, TMI-1 established its third world record of the decade, at 668 days of continuous operation. The plant's average capacity factor over the past five years is 96 percent, among the best in the world.

## Tough Controls on Radiation

The Nuclear Regulatory Commission enforces strict standards to protect the public from radiation.

These tough regulations are based on recommendations from two respected scientific groups: the U.S. National Academy of Sciences' Committee on Biological Effects of Ionizing Radiation (BEIR) and the National Council on Radiation Protection and Measurements.

Scientists have been studying radiation for more than 100 years. They know how to detect, measure and control even the smallest amounts. The beneficial uses of radiation—nuclear energy, medical diagnosis and treatment, agricultural and scientific research, and many others—have enriched our lives for decades.

Radiation is measured in units called rem or millirem (1/1,000 of a rem). Natural background radiation (from the sun's cosmic rays, rocks, soil, and radon in the air) accounts for an

average of 300 millirem annually. The average American gets about 80 millirem a year from X-rays and radioactive materials used for medical diagnosis and therapy. Another 10 millirem come from consumer products like smoke detectors and color television sets. Doses above 10,000 millirem can be harmful, sometimes even fatal. But scientists have never been able to detect any adverse health or safety effects below 10,000 millirem. The average annual exposure from nuclear power plants is only 0.02 millirem, or one twelve-thousandth of natural background, according to an October 2000 report issued by the United Nations Scientific Committee on the Effects of Atomic Radiation. Health experts agree that even the Three Mile Island accident caused an average exposure of just 1.5 millirem to people within 50 miles of the plant—less than what they would receive from a cross-country airplane flight.

All radioactive materials at nuclear power plants are handled in strict compliance with federal standards, so both the public and plant workers are protected. To make sure, the NRC has inspectors at each plant to monitor operations every day. Among the activities that the NRC regulates is the transport by rail and truck of used nuclear fuel.

According to the NRC, the dose from used fuel containers at a distance of six feet can be no greater than 10 millirem per hour, or about the same exposure an individual receives from a chest X-ray. In actual practice, the dose is lower than the regulatory limit. Since the dose is reduced greatly as distance from the source increases, even at the regulatory limit, the dose will be less than 1 millirem at distances greater than 65 feet. Hence, health effects along the transportation corridors will be very small—essentially negligible.

# The Next Generation of Advanced Nuclear Power Plants

**A**s we usher in a new century, our nation faces energy and environmental challenges that rival any experienced in the past. The U.S. Department of Energy projects that the United States will need 403,000 megawatts of new generating capacity by 2020 to meet even modest annual growth in energy demand of 1.5 percent and to replace electric generation capacity that has reached the end of its useful life. This electricity must be produced while implementing more stringent national and international environmental goals, particularly the need for cleaner air and the need for substantial reductions in greenhouse-gas emissions. Without nuclear energy, the United States cannot successfully meet those challenges.

To ensure a strong role for nuclear energy, the U.S. nuclear industry, in cooperation with the federal government, has completed design and engineering work on three advanced design nuclear power plants using proven light water reactor technology. Designs for these standardized plants have received final approval from the Nuclear Regulatory Commission, a milestone in the effort to build and operate light water reactors that are even safer and more efficient.

- Two of these “evolutionary” plant designs are large reactors—the General Electric Advanced Boiling Water Reactor (ABWR) and the Westinghouse System 80+. The two designs are 1,350-megawatt plants.
- The third plant design is the Westinghouse AP600, a 600-megawatt pressurized water reactor that incorporates safety systems that rely on natural forces rather than more complex “active” systems. Natural forces include gravity, convection, evaporation and condensation.

These advanced-design reactors will be standardized to an unprecedented extent. They represent a major departure from today’s custom-designed nuclear

power plants. For example, the AP600 is conceived on a modular design concept. Large components of the plant can be prefabricated and shipped to any location worldwide. Another advantage is improved quality assurance, since welds can be checked during factory construction instead of at the plant site. Westinghouse officials estimate that a twin-unit AP600 can be built in 36 months at a cost 30 percent below most conventional nuclear plants.

The plant designs are based on detailed owner/operator specifications covering all levels of design and construction, and many aspects of operation and maintenance. Since they will have NRC design certification, utilities will be able to apply for combined construction/operating licenses. However, such certification imposes high barriers and regulatory controls for any proposed design changes that would affect safety levels or the approved certified design.

Building upon the design specifications and details locked in by NRC certification, additional engineering—known as first-of-a-kind engineering—will bring the entire plant design to sufficient completion to provide a dependable cost and construction schedule estimate. At that time, some 80 percent of the design details will be complete, leaving only site-specific engineering to be done by a potential customer. This is in sharp contrast to past nuclear plant construction practices, when major design changes were made as plants were being built, stretching out construction schedules and therefore raising costs.

Importantly, standardization applies to every aspect of a plant. Standardized procedures will be used in areas, such as operations, maintenance, training and work control. This commitment will help nuclear plant owners to realize the full benefits of standardization in maintaining high levels of safety, sim-

*“There is no other zero-emission source that could supply as much electricity as nuclear power supplies today.”*

— *The Business Roundtable,*  
July 1999

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plicity of operation, and enhanced cost competitiveness of future U.S. nuclear plants.

In addition to the technical design issues, a new federal and state licensing framework provides customers and investors with a predictable process that resolves safety and siting issues before a substantial investment has been made. And it thoroughly addresses public concerns with design safety, site suitability, and adequacy of plant “defense-in-depth” design.

The new approach differs from the one used for the currently operating U.S. nuclear power plants, which were licensed by the NRC in a two-stage process. In the first stage, a construction permit was issued and construction began, even as the plant design was evolving and new regulatory requirements were being issued. Under these circumstances, construction costs and schedules were often exceeded. In the second stage, another round of technical reviews and public hearings was conducted before a plant received a license to operate. Because the plant was essentially complete, significant issues raised at this point concerning the site or design were very difficult and expensive to address.

In contrast, future U.S. nuclear power plants will be licensed under a new regulation. The new process offers four major improvements:

- NRC certification of a design assures that a thorough technical review and approval of the design have occurred. It documents the safety findings and, importantly, imposes a high threshold for proposed changes to that design over time, either by NRC regulation or by the nuclear industry.
- Early site permitting allows for a similar federal pre-approval of a nuclear plant site, again resolving plant concerns well in advance of a proposal to build a plant on that site.
- A combined construction permit and operating license, issued before construction begins, captures the resolution of all design, site, plant operation and environmental issues. It establishes the specific tests, inspections, analyses and acceptance criteria

that will be used to verify that the completed plant conforms to the certified design and the license requirements.

- Public involvement is enhanced in this new, multi-stage process by allowing opportunities for hearings and resolution of safety concerns at every stage.

The new nuclear plants that serve America will be cheaper and more efficient to build than today’s—and simpler and even safer to operate.

### **U.S. NEW REACTOR TECHNOLOGY APPLIED ABROAD**

Already, two General Electric advanced boiling water plants very similar to the U.S.-certified design are operating at Tokyo Electric Power Co.’s Kashiwazaki site along the Sea of Japan. And according to Japanese officials, 20 more are soon likely to be built. Eight South Korean nuclear plants incorporate advanced features of the Westinghouse System 80+ design, and the System 80+ is the technology base for the next generation of Korean plants. China has announced tentative plans to order as many as 30 advanced light water reactors over the next three decades.

### **PROGRESS ON OTHER TYPES OF REACTORS**

In the summer of 2000, PECO Energy Co. (now part of Exelon Corp.) took a 20 percent stake in the pebble bed modular reactor project being pursued by the South African utility, Eskom. The pebble bed concept, which has a short construction lead time and low operating costs, among other attributes, is an inherently safe helium-cooled reactor. It uses silicon carbide-coated particles of enriched uranium oxide encased in graphite to form a fuel sphere, or “pebble,” about the size of a tennis ball. The consortium in which Exelon invested aims to build and operate a single module to serve as a demonstration plant and a launch platform for local and international sales.

# Nuclear Regulation

U.S. nuclear power plants are performing at exceptional levels of safety and reliability, and all trends indicate continued improvements in plant performance. Although our nation's regulatory system for ensuring the safe operation of nuclear plants has been remarkably successful—and is emulated worldwide—improvements in its implementation are due. That's particularly true with regard to the Nuclear Regulatory Commission's regulations. Even though the nuclear energy industry now has a combined 2,000 reactor-operating years of experience, NRC regulations still derive from oversight of the emerging industry of the 1950s and 1960s.

The regulations were largely written to regulate the design and initial licensing of nuclear plants, but have been modified repeatedly to fit the operation of the plants. In some cases, the requirements are inconsistent and needlessly burdensome, with duplicative new requirements often layered on top of old ones. The bulk of NRC regulations are contained in 10 CFR Part 50, which spans nearly 800 pages. And Part 50 itself is dwarfed by guidance, inspection procedures and other regulatory elements that support its implementation and enforcement.

NRC's regulatory procedures are largely deterministic and prescriptive—a process rooted in the 1950s, when knowledge about nuclear safety and nuclear plant operating experience was evolving. The emphasis on strict adherence to requirements that lack safety significance has created a regulatory environment that suffers from a lack of prioritization. This approach leaves little flexibility for either utilities or the NRC to take actions commensurate with actual safety significance. A case in point is the enforcement process, which for years consumed inordinate regulatory and utility resources on minor (Level IV) violations of little or no safety significance. The process penalized nuclear plant operators on a zero-defect

threshold even as industry safety, reliability and economic performance climbed to all-time highs.

In effect, the regulatory threshold was continually raised even though objective data show that plants today surpass even the industry's top plants of years gone by. Today's top plants are performing at five times the level that the average plant did in the mid-1980s, and even the inconsistent-performing plants of recent years are operating at safety levels three times greater than the industry average from 1985. Just as the nuclear industry has improved its operations, the NRC has recognized the need to replace its outdated, cumbersome regulatory framework with one that is focused on those issues most important to safety. Only since 1998, when the NRC began instructing its resident inspectors to focus activity on more risk-significant areas, has the level of Level IV violations fallen. And, the decline has been dramatic.

The commission should take a safety-focused approach through which it establishes basic requirements and sets overall performance goals, then leaves plant management to decide how best to meet those goals. A good start would be the increased use of computer-based analyses of each plant. Every U.S. nuclear power plant has conducted some type of probabilistic risk assessment, which gauges the relative risk significance of various system and equipment conditions. Based on these insights, the plants have voluntarily implemented hundreds of design and operational improvements.

Instead of an emphasis on compliance with rules that sometimes have little real bearing on safety, regulators could increase the use of probabilistic risk assessments in combination with safety goals to judge whether a plant is operating safely. And plant operators would like to be able to use this valuable information to support regulatory improvements—targeting their resources where a direct benefit to safety exists.

*“The NRC should continue to pursue and complete on a priority basis its proposed program to move to risk-informed regulations in parallel with the development of a clearly defined safety philosophy that can be consistently applied to all nuclear plants.”*

— *The Regulatory Process for Nuclear Power Reactors*,  
CSIS Panel Report,  
August 1999



To its credit, the NRC has acknowledged the need for reform. It has responded to increased congressional oversight and its own internal examinations by developing objective safety goals for the operation of nuclear plants and by initiating programs to implement risk-informed regulation, inspection and enforcement. The NRC also has recognized that its process for evaluating nuclear plant performance needs to be improved. In 1999, it eliminated the Systematic Assessment of Licensee Performance (SALP) process that fundamentally was a subjective assessment that lacked scrutable, objective measurement criteria directly tied to plant safety.

In April 2000, the NRC implemented an industry-wide new plant assessment process aimed at giving utilities and the public a more accurate view of safety performance (See Fig. 5). It employs quantitative safety and performance measures, and provides clear thresholds for plant action and regulatory intervention. Reforms such as these are key to the development of a more effective regulatory process that focuses industry resources on those items most related to safety as plants strive to further improve reliability and efficiency in a competitive marketplace.

The goal of the Nuclear Regulatory Commission's new, safety-focused approach to assessing nuclear power plant performance is greater emphasis on

objective, safety-significant criteria with less reliance on subjective evaluations. The agency also wants to make clearer to utilities and the public what the NRC expects of a nuclear plant, and what agency actions will be taken if performance declines. Pilot testing of the new process was completed in November 1999 at nine nuclear plants.

As with the regulatory process from which it evolves, the new oversight system requires NRC inspections of every nuclear energy facility. Good performers receive the baseline inspections—an estimated 1,800 hours per year. Other plants are subject to additional inspection, targeted to address specific issues.

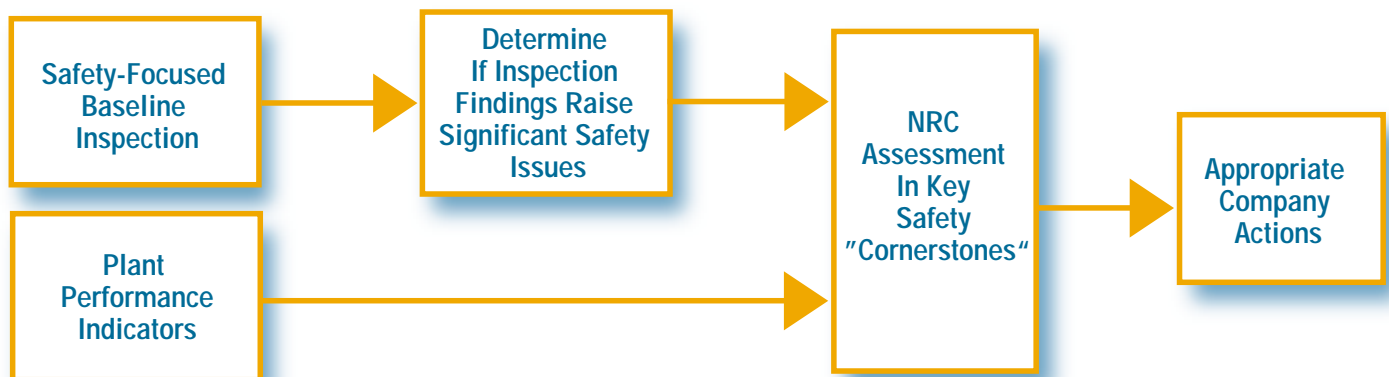
Objective measures of plant performance are a key element of the process. The NRC assesses performance in three major areas: reactor safety, radiation protection and security.

These areas are supported by seven NRC "cornerstones":

- Challenges to plant safety systems
- How well safety systems respond to challenges
- Integrity of barriers to the release of radiation
- Emergency preparedness
- Public radiation safety
- Occupational radiation safety
- Security

### *Nuclear Plant Assessment Process*

*Figure 5*



## Managing Used Nuclear Fuel

Used nuclear fuel is stored at nuclear power plants in 34 states. From the beginning of commercial nuclear energy, it has been national policy that the federal government has responsibility for retaining control and disposing of used fuel. But more than 18 years after Congress created this requirement, the U.S. Department of Energy has refused to meet its contractual obligation to take possession of used fuel beginning Jan. 31, 1998. The used fuel is still being stored at more than 75 nuclear power plant sites around the country, despite a U.S. Court of Appeals ruling affirming this legal federal responsibility. The Energy Department claims that it cannot take the used fuel because the federal government has no place to store it. Hence, a vigorous effort to ensure action on the part of the federal government is the key to maximizing the benefits that society derives from commercial nuclear power plants in the 21st century. This will guarantee that plants will not have to be shut down prematurely because a utility has run out of space to store used fuel.

The long-lived elements in used nuclear fuel constitute the high-level radioactive wastes that must be disposed of permanently. Some of these radioactive isotopes—plutonium-239 and iodine-129, for example—have half-lives that are measured in many centuries. (A half-life is the amount of time it takes for half the atoms of a radioactive substance to decay away.) Because it is a solid, used fuel is easy to manage and control. It can't spill or leak the way a liquid or a gas can. And because of its physical and chemical characteristics, used fuel cannot explode.

Considering that nuclear power plants provide roughly one-fifth of the nation's electricity, there is less used fuel than people might imagine. A typical nuclear power plant produces about 20 tons of used fuel each year. All the used fuel produced by U.S.

nuclear plants since the first commercial units began operating in the early 1960s—almost 40,000 tons—would cover an area the size of a football field to a depth of about five yards.

At present, the used fuel removed from utility reactors is stored at the plant sites, either in steel-lined, concrete vaults filled with water or in stainless steel or concrete containers. Temporary at-plant storage is safe and is continually monitored. But permanent disposal in a centralized facility would be more efficient, less costly and even safer. After all, nuclear plants were designed to produce electricity, not to store used fuel indefinitely.

For many years, the National Academy of Sciences and other scientific and technical organizations have examined the issue of used fuel management. The consensus is that used fuel from nuclear power plants and high-level radioactive waste from federal defense sites can be disposed of safely deep underground. In 1990, the National Research Council's Board on Radioactive Waste Management said, "There is no scientific or technical reason to think that a satisfactory geological repository cannot be built." Other organizations that reached the same conclusion include the U.S. Office of Technology Assessment, the International Atomic Energy Agency, and the Organization for Economic Cooperation and Development's Nuclear Energy Agency.

Although computer modeling techniques used to develop the concepts for a repository scheme are extremely sophisticated, they alone cannot provide absolute guarantees that any repository can successfully retain radioactive material for thousands of years. But nature provides compelling evidence that these byproducts can be contained geologically for hundreds of thousands, even millions, of years. In fact, nature provides us with a site where this has already happened.

*"...for the foreseeable future, geologic disposal represents the only truly available option for assuring safety and security over several tens of thousands of years and more."*

— Organization for Economic Cooperation and Development, Nuclear Energy Agency, 1999

Several years ago, the remains of a “natural” nuclear reactor were discovered in the West African republic of Gabon, in an area that has rich uranium ore, with concentrations of between 20 and 60 per cent. Millions of years ago, a self-sustaining chain reaction began in this uranium ore deposit. Like reactors, this one created its own radioactive waste—12,000 pounds of uranium byproducts. The chain reaction occurred intermittently for more than 500,000 years. Despite their location in a wet, tropical climate, the uranium deposit and high-level radioactive waste have remained securely locked in this natural repository for the past 200 million years. By analyzing samples of the soil, French radiochemists have found that most of the fission fragments have scarcely moved in the nearly two billion years since they were formed. For example, plutonium moved less than one millimeter from the time of its formation. Many of the waste products

either stayed where they were created or moved only a few inches before decaying into harmless products.

U.S. policy on the safe isolation and disposal of high-level nuclear waste was established by Congress in the Nuclear Waste Policy Act of 1982 and in its 1987 amendments. To finance the management program it authorized, Congress created a federal Nuclear Waste Fund as part of the 1982 legislation. Since 1983, consumers of nuclear-generated electricity have paid into the fund a fee of one-tenth of a cent for every nuclear-generated kilowatt-hour consumed. Through June 2000, electricity users had committed more than \$17 billion, including interest, to the fund (*see Fig. 6*).

The 1987 amendments to the Nuclear Waste Policy Act identified Yucca Mountain—a wind-swept, barren ridge in the Nevada desert—as the best candidate site for the repository. In 1991, the Energy Department began “site characterization,” a compre-

## Consumer Commitments to Federal Nuclear Waste Fund (through June 2000)

Figure 6

Contributing State	Total NWF Contributions (Millions \$)	Contributing State	Total NWF Contributions (Millions \$)
Alabama	703.2	Mississippi	171.0
Arizona	440.6	Missouri	176.1
Arkansas	402.0	Nebraska	267.8
California	796.2	New Hampshire	110.4
Colorado	0.3	New Jersey	640.4
Connecticut	710.9	New York	1,056.7
Florida	751.5	North Carolina	738.8
Georgia	600.6	Ohio	289.2
Illinois	2,243.1	Oregon	111.1
Iowa	110.0	Pennsylvania	1,431.9
Kansas	164.6	South Carolina	1,190.8
Louisiana	270.0	Tennessee	349.0
Maine	239.9	Texas	425.7
Maryland	350.0	Vermont	195.1
Massachusetts	169.3	Virginia	692.7
Michigan	752.8	Washington	129.2
Minnesota	407.0	Wisconsin	374.5

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hensive scientific investigation of the site's hydrology, geology and other characteristics to determine Yucca Mountain's suitability. The site characterization will cost more than \$6 billion and involve more than 500 scientists, engineers and technicians.

Despite delays caused by Nevada politicians who oppose a repository, enough data on three key subjects—earthquakes, volcanoes, and water movement through the rock—had been gathered by December 1998 for the Energy Department to release its long-awaited “viability assessment” report on the site. Based on data gathered from DOE's underground laboratory, dozens of trenches and hundreds of bore holes at Yucca Mountain, the agency said there are no “show-stoppers” that would suggest it should stop investigating the site. The agency, which was supposed to have begun accepting used reactor fuel waste in January 1998, said it would continue the research through 2001, when it is required to make a recommendation on the site to the president. Some of the remaining research will focus on the performance over time of the canisters holding the fuel.

If the president approves the construction of the repository, the Energy Department will apply to the NRC for a license to build it. At this point, the state of Nevada may submit a “notice of disapproval,” which can only be overruled by a simple majority vote in Congress.

The NRC's review of the Energy Department's application, which is expected to take at least three years, includes the participation of individuals and interested organizations. Additional NRC approval is required before the Energy Department can begin operating the repository. NRC would approve or disapprove the Energy Department's application to build the repository by 2004. Construction is slated to be completed by 2010, when the repository would begin accepting used fuel.

Meanwhile, the Energy Department has a legal obligation to begin taking the used fuel from nuclear power plants. In November 1997, the U.S. Court of

Appeals ordered the Energy Department “to proceed with contractual remedies in a manner consistent with the [Nuclear Waste Policy Act's] command that it undertake an unconditional obligation to begin disposal of the [fuel] by January 31, 1998.” The court also “preclude[s] the Energy Department from concluding that its delay is unavoidable on the ground that it has not yet prepared a permanent repository or that it has no authority to provide storage in the interim.”

In 1982, Congress provided a blueprint for the government to begin managing fuel by the 1998 deadline and utilities signed contracts with the Energy Department to codify this commitment. The deadline passed with the fuel still at nuclear plant sites in 34 states. The fact is many nuclear power plants are running out of storage capacity. Most have expanded the capacity of their steel-lined water pools, while some have built additional storage using steel or concrete containers. Time is running out for a few nuclear plants that are unable to do either and may be forced to shut down prematurely. Meanwhile, electricity consumers in many places must pay twice for used fuel storage: once, through payments to the Nuclear Waste Fund, and a second time for expanded at-reactor storage. If this additional storage were not available, many nuclear plants would have to shut down.

As a result, a major dispute has developed over the Energy Department's inaction. Utilities point out that the government is legally obligated to move fuel from nuclear plants and are seeking action by DOE, or billions of dollars in damages for the additional cost of storing fuel. In December 1998, a federal judge for the U.S. Court of Federal Claims in Washington, D.C., in a breach of contract case involving three closed New England reactors, ruled that the government is liable for monetary damages for failing to dispose of the reactor fuel. Many other utilities also are seeking damages. If the lawsuits succeed, the government could be liable for about \$56 billion.

## Safely Transporting Used Nuclear Fuel

*Since 1965, there have been more than 2,500 shipments of spent nuclear fuel in the United States without injury or environmental consequences as a result of the radioactive nature of the cargo.*

— U.S. Department of Energy, 1999

It would be hard to find anyone better prepared than the people who package, ship and monitor the transportation of used fuel from nuclear power plants. Over the past 45 years, more than 20,000 shipments of spent fuel have traveled throughout the world—including approximately 3,000 commercial shipments in the United States—with no radiation-related injuries or deaths. A key reason behind the safety record: training and preparation.

Fuel containers—thick steel cylinders consisting of tons of shielding material to prevent release of radiation—are built to take the toughest punishment, and must prove it before the Nuclear Regulatory Commission will certify and license the designs. A series of rigorous tests demonstrates they can withstand severe impact, flames, submersion or a possible puncture.

The structural integrity of shipping containers has been verified in a number of tests, including tests required by the Department of Transportation and the Nuclear Regulatory Commission. The packaging and shipping standards for used fuel are more stringent than for any other hazardous material. In tests, the used fuel containers have been able to withstand the following events:

- Loaded onto a truck that was made to crash, first at 60 miles per hour and then at 80 mph, into a 700-ton concrete wall backed with 1,700 tons of dirt
- Hit broadside by a 120-ton locomotive traveling at 80 mph
- Dropped from a height of 2,000 feet onto extremely hard ground
- Burned in a pool of aviation fuel for an hour and a half at temperatures of more than 2,000 degrees Fahrenheit.

Although dented, the casks neither ruptured nor sustained significant damage that would jeopardize their integrity.

Accidents, of course, happen on all of America's transportation routes, and the shipment of used fuel is no exception. But in more than four decades, only eight accidents in the United States have involved spent fuel containers. None has ever resulted in a release of radioactivity or caused harm to the public. No shipping container has ever leaked or cracked. The worst of the eight accidents occurred in 1971 in Tennessee. A tractor-trailer carrying a 25-ton shipping container packed with used fuel swerved to avoid a head-on collision. As the truck overturned, the trailer—with the fuel container still attached—skidded into a ditch. The container suffered minor damage but released no radioactive material.

The impressive safety record during these shipments is no accident. A proven system of precautions, regulations, checks and counter-checks has led to the unblemished safety record.

That fact is becoming more significant as communities begin to coordinate with the federal government prior to used fuel shipments. When a central storage facility for used fuel becomes available, up to 300-500 shipments a year are planned. Fuel shipments from nuclear power plants to a storage facility are likely to rely heavily on rail transport, because rail containers (at up to 125 tons) are bigger and can transport more fuel than the 25-ton truck containers.

Despite scenarios designed to scare the public conjured up by some anti-nuclear activists, experts agree there would be almost no radiation-related consequences—even in the event that a shipment of used fuel was in a vehicular accident. That's largely because of the solid, non-explosive nature of the fuel and the robust design of the shipping containers. But if radiation were released, local emergency responders at the

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scene minutes after the accident would cordon off the shipping container and keep bystanders at a safe distance. Then, a state or federal hazardous materials team would clean up the accident. They would follow proper response and cleanup procedures, having already gone through advance training and preparation in programs sponsored by the U.S. Department of Energy and the Federal Emergency Management Agency.

For example, FEMA offers a series of courses in radiation monitoring and emergency response for local law enforcement officials, firefighters and emergency rescue squads. DOE also has developed several radiological emergency training courses for local responders, and has radiological assistance teams in each of its regional offices. In recent years, DOE has provided extra training for local officials along a shipping route for used fuel containers from European research reactors, which were being returned to the United States and delivered to DOE's Savannah River Site in South Carolina.

Nevertheless, before used fuel is moved anywhere, the nuclear plant owners and shippers meticulously follow numerous safety procedures and regulations. Coordination of this endeavor requires the expertise of companies that specialize in nuclear transportation services. For a highway shipment, they must plan a route that fulfills regulations set by the Federal Highway Administration, a branch of the Department of Transportation. The rules call for the most direct interstate route, avoiding large cities when an interstate bypass or beltway is available. States can get approval from the Department of Transportation to designate preferred routes as an alternative; a number of states currently have registered preferred routes. The Nuclear Regulatory Commission must approve the shipping routes.

Highly specialized trucking companies handle most of the shipments of radioactive materials in the United States—not only used fuel but also medical and research materials such as cobalt and cesium sources.

These specially licensed and qualified transporters, with a combined 700-plus drivers, travel more than 50 million miles yearly. They are expert at hauling hazardous materials—largely explosives, arms and ammunition for the Department of Defense. But no other shipments are as regulated and safeguarded as nuclear fuel. For trucking companies, that requires extra training and certification of drivers, state-of-the-art vehicles, satellite tracking of the cargo and much more planning and preparation.

### **FEDERAL AND STATE COOPERATION IN SHIPPING USED NUCLEAR FUEL**

No other shipments are as regulated and safeguarded as used nuclear fuel. The U.S. Department of Energy is developing guidance for used fuel routing plans for both highways and railroads. Groups such as the National Conference of State Legislatures and a Nationwide Transportation Coordinating Group that includes representatives of state, regional and national organizations are working with DOE on these issues.

For a highway shipment, DOE must plan a route that fulfills regulations set by the Federal Highway Administration, an arm of the U.S. Department of Transportation. The rules call for the most direct interstate route, avoiding large cities when an interstate bypass or beltway is available. States can get approval from DOT to designate their own preferred routes as an alternative; about 10 states currently have registered preferred routes. The Nuclear Regulatory Commission has final approval on routes, and the commission checks for law enforcement and emergency response capability.

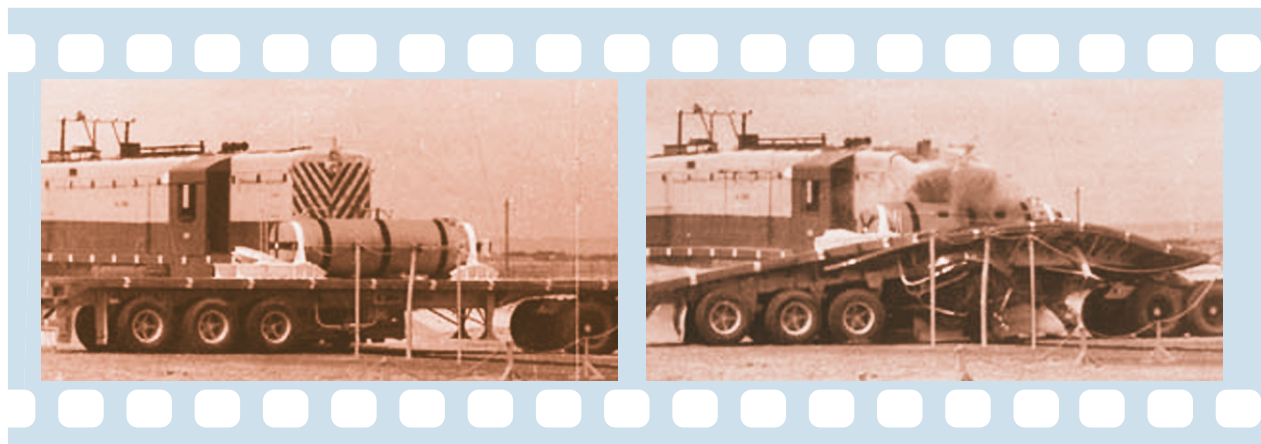
Several days before each shipment begins, the shipper has to notify the governor's office, or designated agency, of each state on the route. Sometimes arrangements have to be made for escort vehicles, typically from local or state police. The NRC requires external escorts for used fuel shipments when they pass through a city with more than 100,000 population.



When a truck is carrying radioactive material for DOE, that agency also monitors the shipment via a satellite tracking system called TRANSCOM. All communications go through a TRANSCOM Control Center in Oak Ridge, Tenn. The tracking system also will be used for railroad shipments when DOE begins transporting used fuel from nuclear power plants to a federal disposal facility.

DOE has provided extra training for local officials along shipping routes for used nuclear fuel from foreign research reactors, which were being returned to the United States and delivered to the DOE's Savannah River Site at Aiken, S.C. Training programs like these will be used before DOE begins extensive shipping of used fuel from commercial power plants.

### *Guarding Against the Unexpected—Testing of Used Fuel Transport Containers* *Figure 7*



Transportation containers for used fuel are designed to withstand accidents more serious than they will ever likely face without breaking open.

To test integrity, the container was loaded on a truck and broadsided by a 120-ton locomotive traveling at 80 miles per hour.



As with all of the tests, the transportation containers retained their integrity and would have kept the radioactive cargo locked safely inside.

# Low-Level Radioactive Waste Management

Two U.S. facilities are in operation for disposal of low-level radioactive waste from nuclear power plants, which typically includes plant hardware, filters, tools, personal protective equipment and other materials with comparatively low levels of radioactivity. Other low-level radioactive wastes are produced from the use of radioisotopes in medicine and industry. One disposal site, at Richland, Wash., serves 11 states in the Pacific Northwest and Rocky Mountain regions. The Barnwell, S.C. site accepts most of the rest of the nation's low-level radioactive waste, but South Carolina has taken steps to limit volume to preserve the facility's remaining capacity for in-state users—making disposal uncertain for most out-of-state users after 2008. A third disposal site at Utah's Envirocare facility accepts only the most short-lived radioactive waste, which is mostly medical waste; it has applied to take all types of waste.

Despite the long-term need for new sites, not one has opened since enactment of the Low-Level Radioactive Waste Policy Act of 1980 and amendments of 1985, which were meant to compel states without low-level waste disposal facilities to assume responsibility for their own waste. The reasons why no facility has been developed vary. In the most notable case, the U.S. Department of Interior's repeated delays in transferring a parcel of Mojave Desert land to the state of California stymied an effort to develop a new low-level waste facility at Ward Valley, even though the state had issued a license for the facility. Efforts to develop the facility were abandoned in 1999.

Escalating disposal costs and uncertainty over the future availability of these facilities provide additional impetus to the successful efforts to reduce the volume of low-level waste generated at nuclear power plants. Electric utilities use advanced methods to compact the

waste. This has greatly reduced the amount of material requiring disposal. For example, the volume of solid low-level waste at pressurized water reactors, as measured in cubic meters per unit, dropped from a median 500 cubic meters in 1980 to 18 cubic meters in 1997, and is still falling. For boiling water reactors, the median dropped from 950 cubic meters in 1980 to 77 cubic meters in 1997, and is also falling.

Ironically, as generators have struggled to keep costs down by reducing waste volumes, their success has increased the per-cubic-foot costs of disposal as the site operators seek to recoup operating costs.

The higher costs have forced a number of nuclear power plants, as well as hospitals and other generators, to store low-level waste at on-site facilities. Many forecasters predict a serious shortage of disposal space and rising costs for the nation's 12,000 generators of low-level radioactive waste. The effects are likely to be serious for nuclear medicine, industry, agriculture and scientific research. Medical low-level waste consists of such things as syringes, needles, bandages, alcohol sponges, protective clothing, plastics and glassware.

For nuclear energy, the ability to predict the cost of low-level waste disposal is critically important. As some electric companies begin to plan for plant decommissioning, access to safe, predictable, cost-effective low-level waste disposal capacity is essential.

Another consideration is that the very nature of the low-level waste generated by nuclear power plants will shift over the next 10-15 years. As some plants close, the decommissioning process will greatly increase the volume of low-level wastes. This waste will include parts of large plant components, such as steam generators, pressurizers and reactor vessels. How and where to dispose of this additional low-level waste has yet to be resolved by states.

*“Many people inside and outside the environmental community believe nuclear power deserves another look.”*

— John Holdren, chair of the President's Council of Science and Technology and President Clinton's adviser on global warming, Nov. 3, 1997

## The Economic Value of Emission-Free Nuclear Power

*“It is difficult to envision a competitive electricity market without nuclear being a key element.”*

— Steven M. Fetter,  
managing director of the  
Global Power Group,  
Fitch IBCA Inc.,  
July 30, 1998

**N**uclear power plants provide unique environmental advantages by avoiding air pollution and greenhouse gas emissions. Because they produce electricity by the fissioning of uranium, not the burning of fossil fuels, they do not emit sulfur dioxide, nitrogen oxides, particulate soot, or greenhouse gases, such as carbon dioxide, into the air. Nuclear energy is the largest source of emission-free electric generation in the United States and many other countries. As state and federal governments consider implementing new air-quality restrictions, the continued operation of nuclear power plants is even more critical.

For example, making one million kilowatt-hours of electricity in a power plant fueled with natural gas produces 550 tons of carbon dioxide. Producing the same amount of electricity at an oil-fired plant produces 850 tons of carbon dioxide; in a coal-fired plant, 1,100 tons. But producing one million kilowatt-hours of electricity at a nuclear power plant produces no carbon dioxide. Renewable energy sources, such as hydro, solar and wind power, are carbon-free alternatives and have a role to play in our energy mix. However, nuclear energy will remain the primary large-scale source to meet increasing electricity needs and requirements to improve our air quality.

According to the President’s Council of Advisors on Science and Technology, since 1973, the generation of electricity by U.S. nuclear power plants has resulted in approximately two billion fewer metric tons of carbon emissions than if the same amount of energy had been produced by coal plants. Nuclear energy accounted for 90 percent of all carbon emission reductions achieved by the electric utility industry. Without nuclear energy, carbon emissions just from generating electricity would be 30 percent higher. Nuclear power

plants also have put a lid on emissions of sulfur dioxide, which some scientists believe causes acid rain.

Between 1973 and 1996, U.S. nuclear power plants met 40 percent of the increased demand for electricity in the United States. At the same time, they were responsible for avoiding the emission of 80.2 million tons of sulfur dioxide and 34.6 million tons of smog-causing nitrogen oxides. In 1996 alone, nuclear plants avoided the emission of 5.3 million tons of sulfur dioxide—or greater than 50 percent of the sulfur dioxide cap established by the 1990 amendments to the Clean Air Act.

A 1998 Department of Energy report\* on the potential economic impact of the Kyoto protocol on global climate change says that the United States must extend the operating licenses of nuclear power plants and build 40,000 megawatts of new nuclear capacity if it hopes to meet commitments for carbon reductions. Another Energy Department report\*\* issued in October 2000 cited “an increase in electricity generation from nuclear power plants” as one of the two major reasons that U.S. greenhouse gas emissions rose only 0.8 percent from 1998 to 1999.

Increased capacity and improved efficiency at nuclear power plants since 1993 represent about one-third of voluntary carbon reductions achieved by U.S. electric companies under the Climate Challenge program (see Fig. 8). The clean air benefits of nuclear energy will become more vital in the years ahead as the United States strives to meet more stringent Clean Air Act requirements and as the world moves to reduce emissions of carbon dioxide and other greenhouse

\* “Impacts of the Kyoto Protocol on U.S. Energy Markets and Economic Activity,” Energy Information Administration, Oct. 9, 1998.

\*\* “Emissions of Greenhouse Gases in the United States 1999,” Energy Information Administration, Oct. 31, 2000.

gases. That's why it is so important, with the introduction of competition in the electricity market, to make rational decisions that recognize the inescapable link between nuclear energy and environmental protection.

Accordingly, there must be a broader recognition by Congress, the administration and state policymakers of the environmental contributions made by nuclear energy. Nuclear power plants should receive economic credit for the emissions avoided through their operation. The regulations implementing the Clean Air Act have never explicitly recognized the value of the displacements of sulfur dioxide, nitrogen oxides, particulates, mercury, ground-level ozone, and carbon dioxide achieved by nuclear power plants and other non-emitting sources. As a result, the benefits and economic value associated with nuclear power plants never have been fully recognized.

That approach is shortsighted. A case in point is the sulfur dioxide "cap and trade" system. Fossil-fuel plants targeted by the Environmental Protection Agency for sulfur dioxide reductions have been allowed to claim not only their cuts; they've also accumulated future credits for discharges avoided because of increased generation by emission-free nuclear plants. This is allowed under EPA's cap-and-trade compliance system for sulfur dioxide emissions. Emissions beyond the specified "caps" must be offset by reductions in sulfur dioxide emissions from other sources using a sulfur dioxide allowance system. In other words, if a company wants to exceed its pollution limit, it can purchase the right to do so from companies that have reduced emissions.

There is irony in this approach because in order to participate, a company must actively pollute the air. Because nuclear plants do not emit air pollutants, they are not participants in the cap-and-trade process. A study by Energy Resources International has shown that the sulfur dioxide emissions avoided because of nuclear energy's increased electricity generation between 1990 and 1995 allowed coal-fired plants to effectively bank about 480,000 tons of sulfur

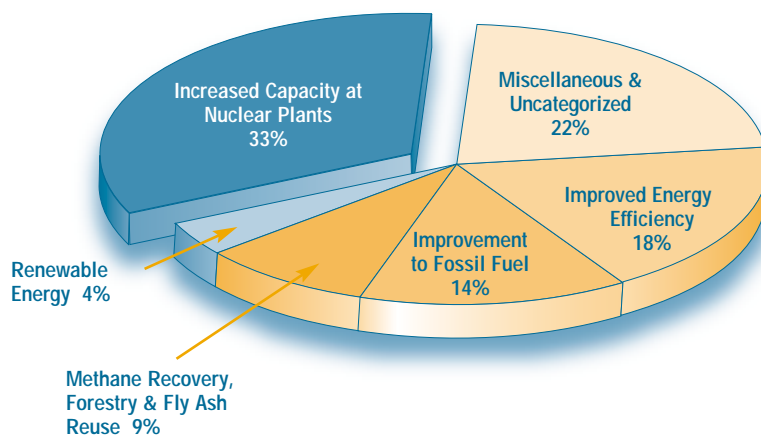
allowances, with a 1999 market value of about \$60 million.

This wealth transfer to fossil-fuel plants undervalues nuclear energy and other non-carbon energy sources. As with sulfur dioxide, nuclear energy also stands to receive short shrift when it comes to reducing nitrogen oxides. However, the financial gains nuclear energy could make by being recognized for sulfur dioxide and nitrogen oxides avoidance pale in comparison to those garnered by reducing carbon dioxide emissions.

At the very least, existing and emerging clean air requirements will tend to both remove from service some existing fossil-fuel power plants and increase the cost of operations for coal-, gas-, and oil-fired generation, possibly by a significant amount, and thus make existing nuclear power plants more competitive. For example, a recent Resource Data International, Inc. study on the impact of federal environmental regulations in a competitive electricity marketplace stated, "a number of the power plants that might otherwise undertake investments for emission controls may not be able to recover these costs in the deregulated marketplace."

### Voluntary Carbon Reduction Achievements by U.S. Electric Companies

Figure 8



Source: Department of Energy's Climate Challenge Program

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