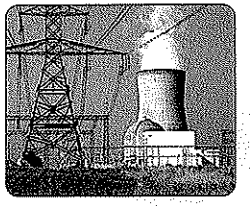
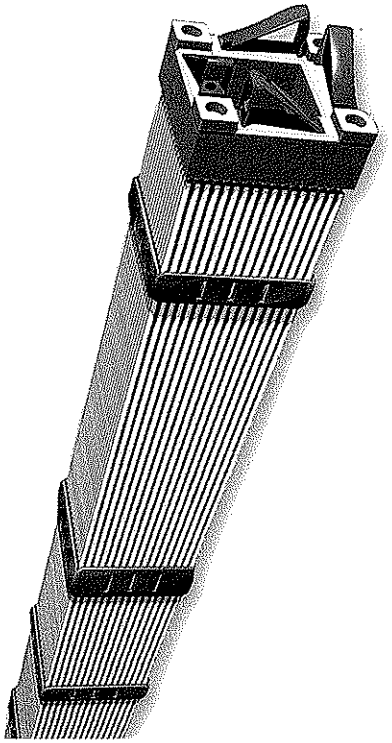
Nuclear Energy
Just the Facts



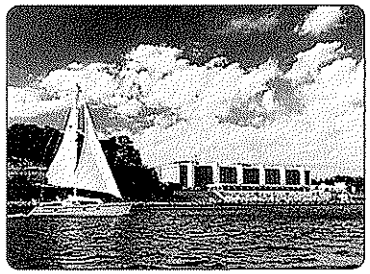


Nuclear Energy—Just the Facts

This booklet explains today's nuclear energy technology, the processes and safety practices associated with it, and the benefits it provides. It includes information about how nuclear power plants work, the cost of producing electricity, nuclear energy's environmental benefits, the mining and production of uranium fuel, the safe management of used nuclear fuel, nuclear plant security, and the economics of nuclear energy. Most of all, it provides "just the facts" for a quick study about nuclear energy.

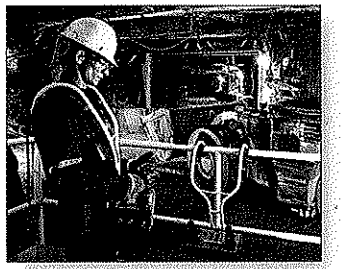
To learn about nuclear energy at a glance and the contents of this book, simply turn the page.

More detailed information on nuclear energy is available at ***www.nei.org.***

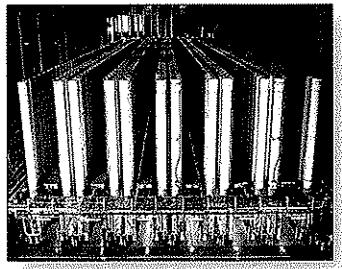


Nuclear Energy at a Glance

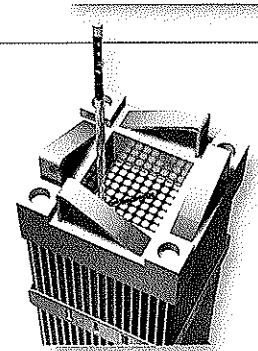
The U.S. Nuclear Regulatory Commission strictly **regulates** the commercial and institutional uses of nuclear energy, including nuclear power plants. Quality construction, continuous preventive maintenance and ongoing reactor operator training have contributed to the nuclear energy industry's excellent **safety record**.



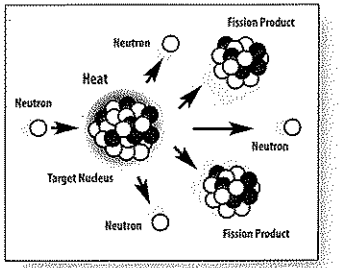
After mining, uranium is milled and processed to create **uranium oxide,** or **yellowcake**. *(Page 6)*



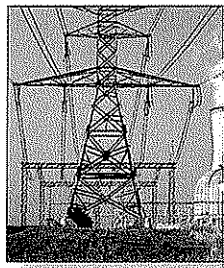
The conversion plant removes impurities and chemically converts the material. **Enrichment** makes the uranium usable as a fuel. *(Pages 6 and 7)*



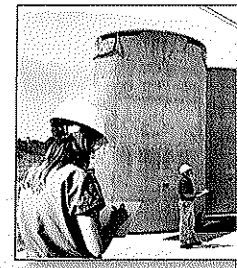
A fuel fabricator presses the uranium into solid ceramic **pellets** and inserts them into rods, making a **fuel assembly**. Assemblies are then transported to the nuclear plant and loaded into the **reactor**. *(Pages 6 and 7)*



In the reactor, **nuclear fission** produces energy to heat water and create steam that powers generators to produce electricity. *(Pages 4 and 5)*

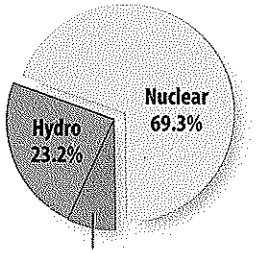


A nuclear reactor generate electricity around the cloc producing **greenhouse g** *(Pages 2 and 3)*



After a cooling period, nucl plants store used fuel **safel securely** on site in steel an vaults. *(Page 8)*

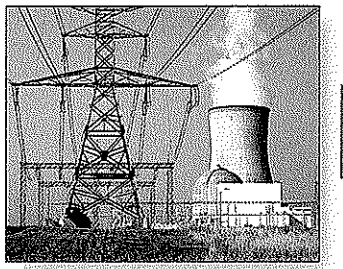
Emission-Free Power



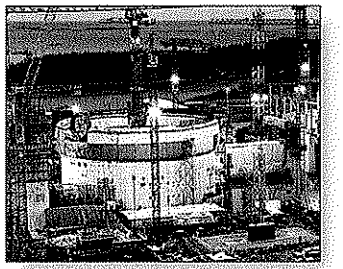
Nuclear energy is by far the largest source of **carbon-free** generation and provides 20 percent of U.S. electricity. By using nuclear instead of fossil fuel-based power plants, the industry prevents the emission of millions of tons of carbon dioxide and other greenhouse gases every year. *(Pages 2 and 3)*

Fuel Pellet (Actual Size)

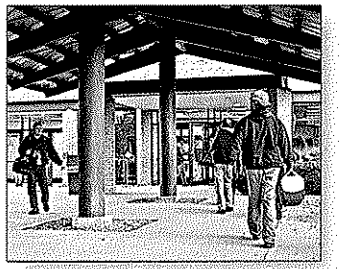
Because nuclear plants do not produce greenhouse gases, the amount of carbon emissions they prevent is greater than all other electricity sources combined. Also, nuclear plants have one of the smallest environmental "footprints" of any energy source.



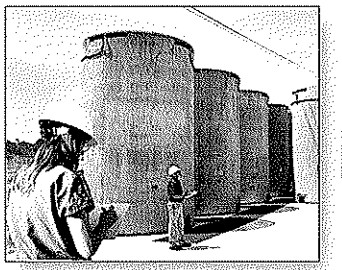
A nuclear reactor generates reliable electricity around the clock without producing **greenhouse gases**. *(Pages 2 and 3)*



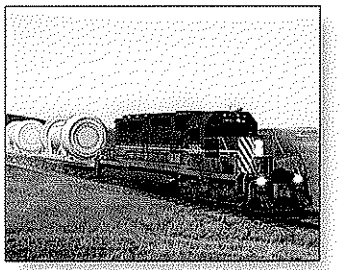
Building new nuclear plants is critical to meeting U.S. **environmental and energy** goals. *(Page 14)*



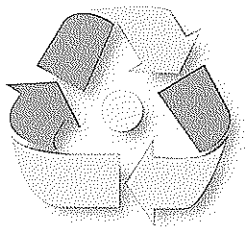
With up to 700 permanent jobs, a nuclear power plant provides significant **economic benefits** to local communities. *(Pages 16 and 17)*



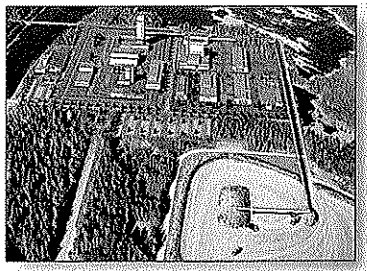
After a cooling period, nuclear power plants store used fuel **safely** and **securely** on site in steel and concrete vaults. *(Page 8)*



Used fuel containers will travel by **trains, trucks** or **barges** to a storage or recycling facility. *(Page 9)*



Development of advanced **fuel-cycle technologies** improves efficiency and reduces waste but does not preclude the need for a federal repository. *(Pages 10 and 11)*



A deep geologic repository is considered the best method of managing used nuclear fuel and recycling byproducts. Sweden is one country developing such a repository. *(Page 11)*

Nuclear Energy in the United States

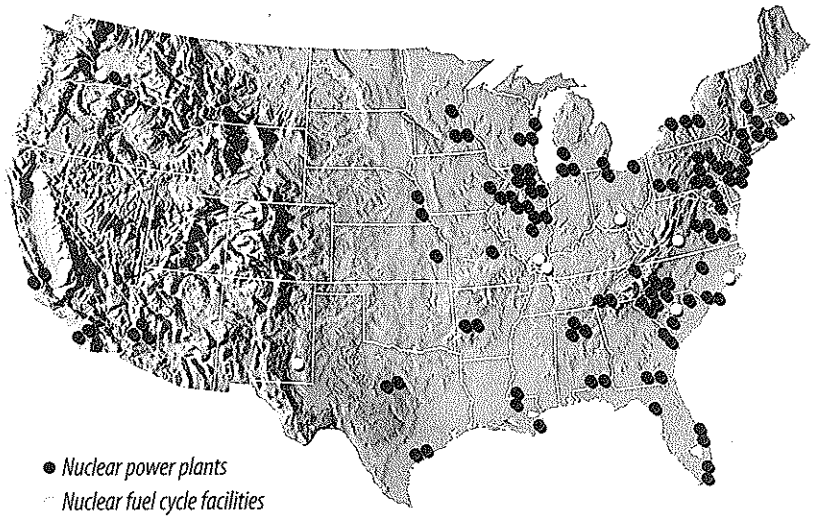
Just the Facts

- **Electricity is essential** to our everyday lives and to the nation's economy.
- Nuclear energy generates **20 percent** of U.S. electricity.
- Nuclear power plants produce **clean, reliable and affordable** electricity.

Electricity is vital to everyday life—powering everything from computers to server farms and air conditioners, lighting homes and running factories. Electricity generation and distribution are among the greatest achievements of the past century. With affordable power available to all, electricity fuels America's economy and has transformed the way we live and work.

Nuclear energy produces electricity for one in five homes and businesses across the United States, with 104 reactors in 31 states. The country's largest source of carbon-free electricity is nuclear energy, accounting for nearly 70 percent of all emission-free electricity generated. America's reactors operate around the clock, thereby stabilizing the entire country's electricity distribution system and electricity marketplace.

104 Reactors in 31 States

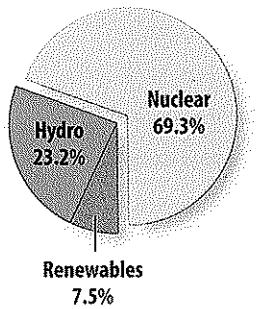


● *Nuclear power plants*
Nuclear fuel cycle facilities

Nuclear Energy Benefits the Environment

Nuclear power plants help mitigate climate change because they don't produce greenhouse gases while generating electricity.

U.S. Emission-Free Electricity Sources



Source: Ventyx/Energy Information Administration, 2009

About one-third of U.S. electricity comes from emission-free sources.

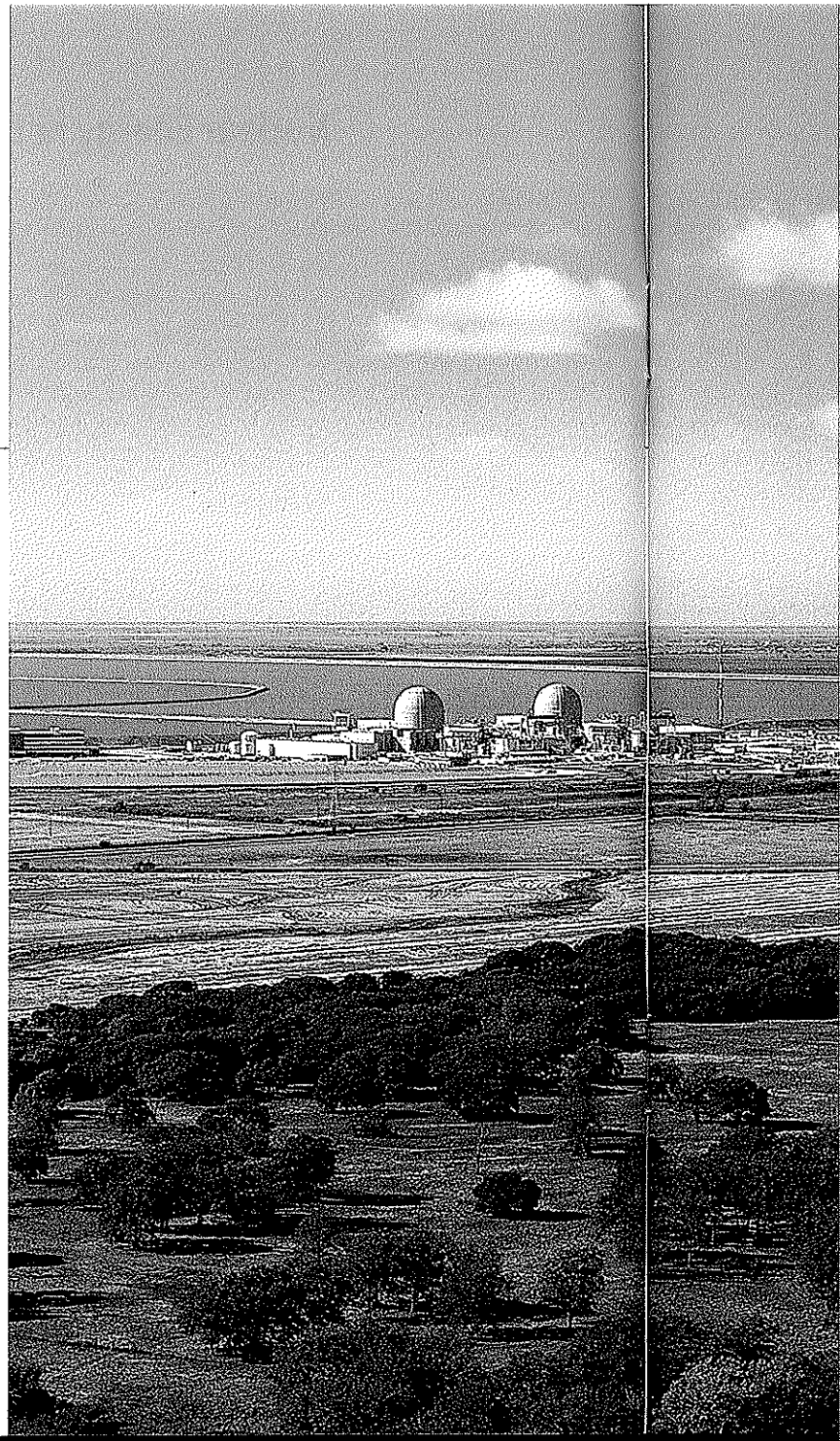
The United States generates most of its electricity by burning fossil fuels, a process that produces sulfur dioxide, nitrogen oxides and **carbon dioxide**. Emission-free sources provide 30 percent of America's electricity, and nearly 70 percent of that comes from nuclear power plants.

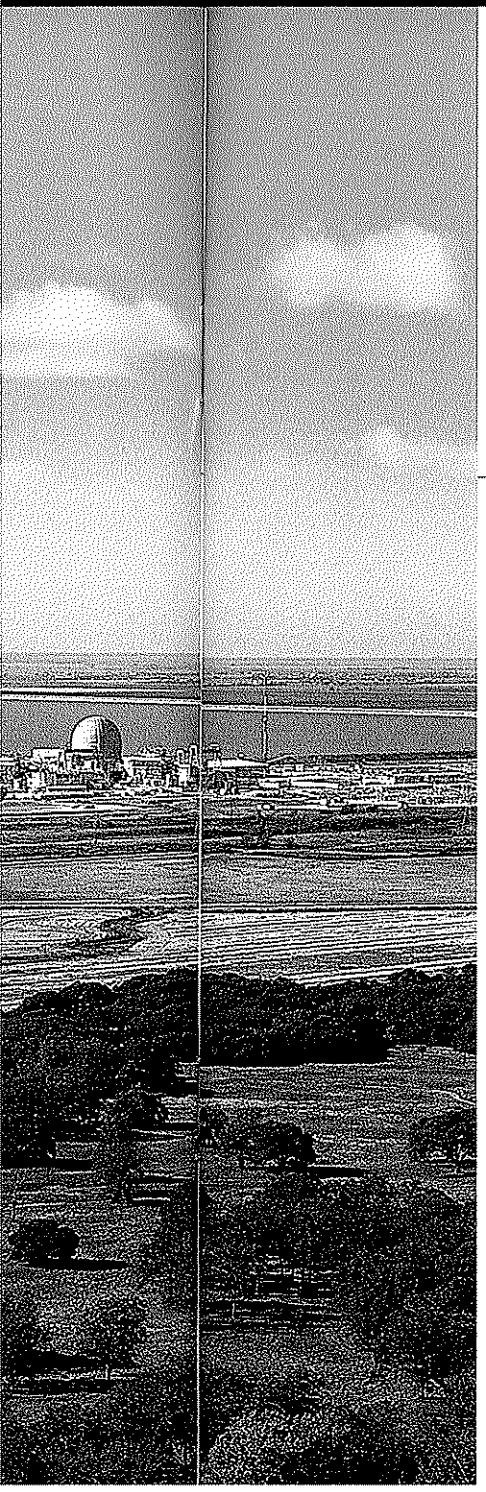
Nuclear power plants don't burn anything.

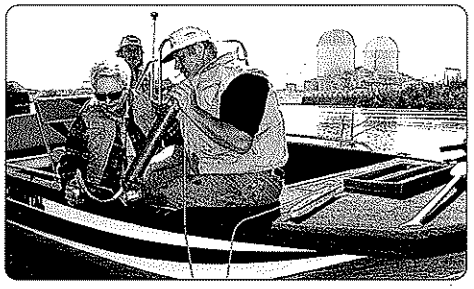
Nuclear power plants don't burn anything, so they produce no combustion byproducts. Nuclear plants help protect our air quality and have been an important tool in meeting **Clean Air Act** goals in many states. Coupled with renewable energy options, nuclear energy is critical to meeting the country's environmental and energy goals.

The United States needs abundant electricity and clean air.

Given the country's growing demand for new sources of electricity—as much as 28 percent by 2035, according to the Energy Information Administration's recent forecast—the United States will need all **new sources of electricity generation** available: renewables, coal, natural gas and nuclear energy. Nuclear energy is the only large-scale, emission-free energy source that can be widely expanded.







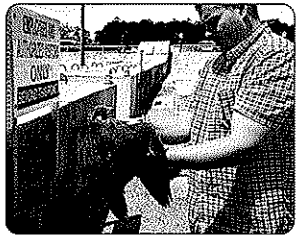
Environmental monitoring and protection programs are a hallmark of the nuclear industry.

Endangered species find sanctuaries at nuclear power plants.

Nuclear power plants are so clean and safe that they provide excellent habitat for wildlife and plants. Some nuclear energy companies have preserved environmentally rich wetlands, providing better nesting areas for waterfowl and other birds, new habitats for fish, and sanctuaries for other wildlife, flowers and grasses. "Residents" at nuclear power plant sites include many endangered and protected species, such as the American crocodile, manatee, shortnose sturgeon and sea turtle.

Nuclear power plants have won praise for their environmental activities.

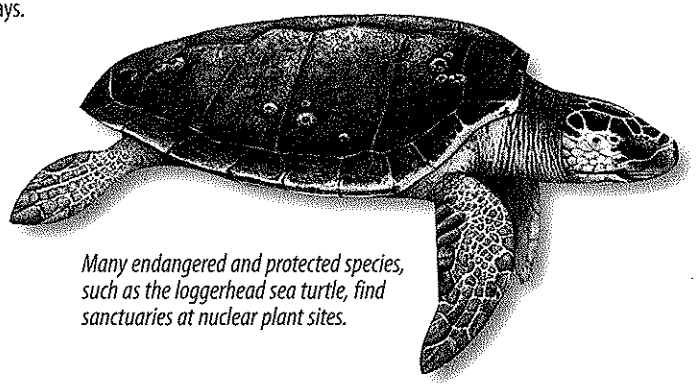
Environmental programs conducted by companies operating nuclear plants have been recognized by the nation's best-known **environmental organizations**, including the Audubon Society, Ducks Unlimited, the National Wildlife Federation, the Nature Conservancy, Trout Unlimited, the Wildlife Habitat Council, and the U.S. Fish and Wildlife Service.



Peregrine falcons, bald eagles and ospreys nest at the Three Mile Island nuclear plant in Pennsylvania.

Emissions prevented by nuclear power plants nearly equal those produced by all U.S. passenger cars.

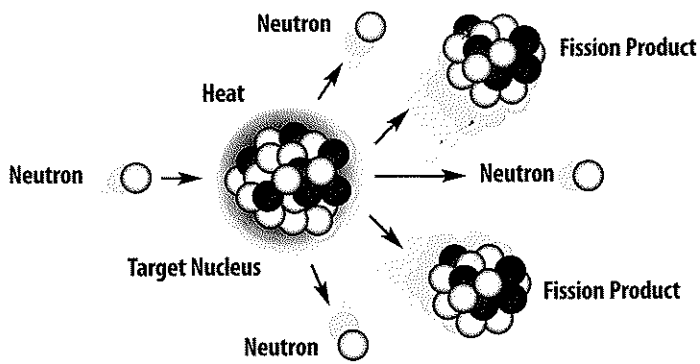
By using nuclear power instead of fossil fuel-based plants, the nuclear energy industry prevents millions of tons of carbon dioxide emissions every year. The volume of **greenhouse gas emissions** prevented at the nation's 104 nuclear power plants is equivalent to taking nearly **all passenger cars** off America's roadways.



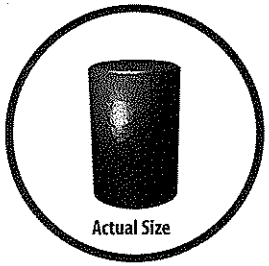
Many endangered and protected species, such as the loggerhead sea turtle, find sanctuaries at nuclear plant sites.

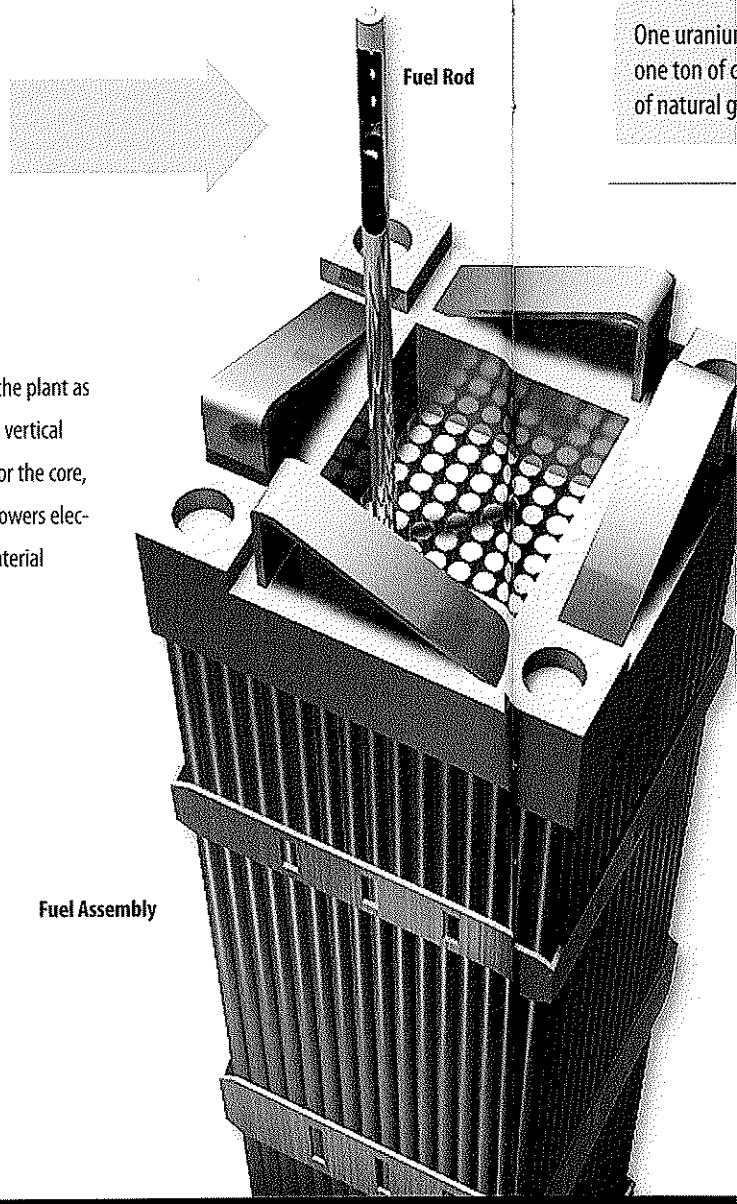
How Nuclear Power Plants Work

A nuclear plant produces steam using the heat produced by splitting atoms in uranium fuel. This steam drives a turbine to produce electricity.



*Nuclear reactors use enriched uranium for fuel. Uranium atoms make heat by **splitting**—the technical term is **fissioning**.*





Uranium fuel: solid ceramic pellets

The **uranium fuel** at nuclear power plants comes to the plant as small, **ceramic pellets** inserted and sealed into long, vertical metal alloy tubes or rods. Inside the **reactor vessel**, or the core, **nuclear fission** produces heat to create steam that powers electricity-producing generators. Nuclear fuel is a solid material enriched at a low level and cannot explode.

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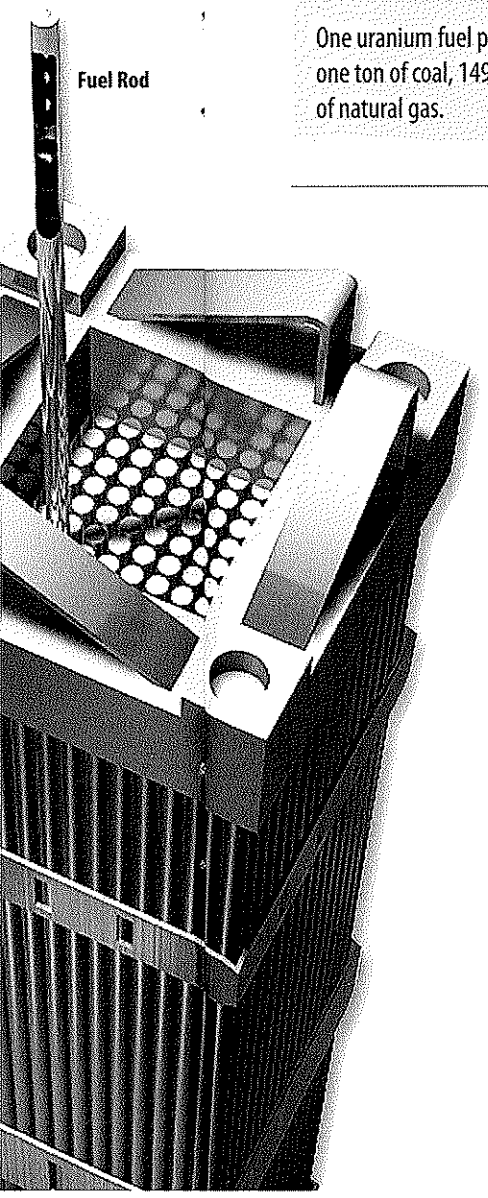


One uranium fuel pellet provides as much energy as one ton of coal, 149 gallons of oil or 17,000 cubic feet of natural gas.

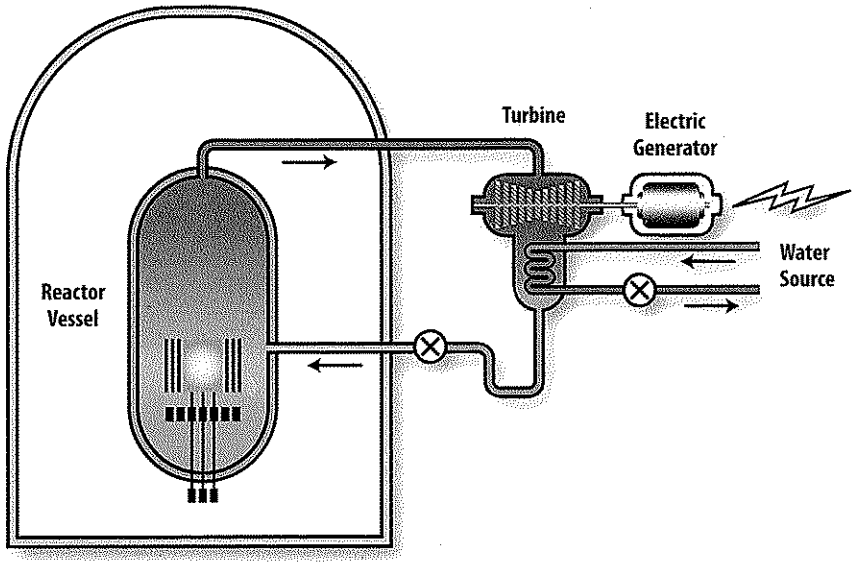
Types of nuclear power plants

There are two types of commercial nuclear power plants in the United States: boiling water reactors and pressurized water reactors. Ordinary water provides cooling for both types. Water is essential to the process that converts **fission energy** to **electrical energy**. Of the nation's 104 reactors, 69 are pressurized water reactors, while 35 are boiling water reactors.

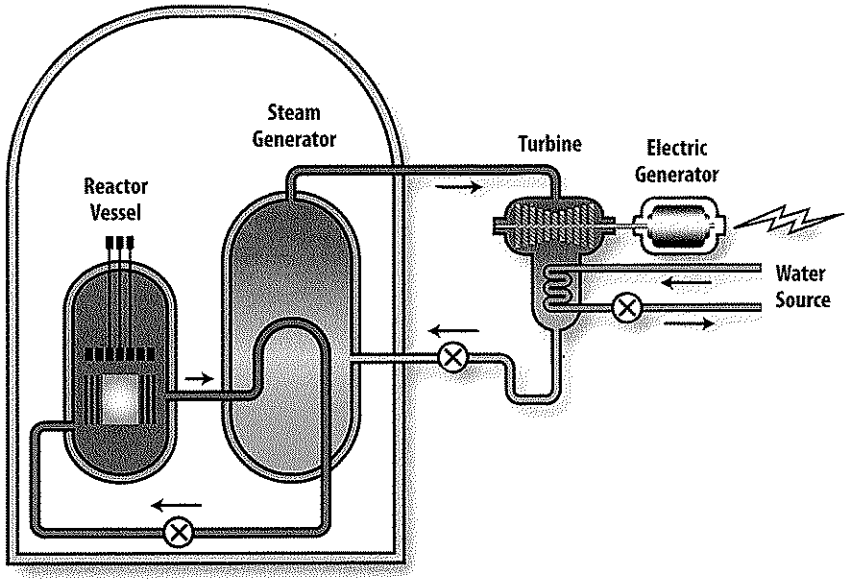
Boiling water reactors heat the water surrounding the nuclear fuel directly into steam in the **reactor vessel**. Pipes carry steam directly to the turbine, which drives the electric generator to produce electricity.

Pressurized water reactors heat the water surrounding the nuclear fuel in the **reactor vessel** but keep the water under pressure to prevent it from boiling. Pumps move the hot water from the reactor vessel to a **steam generator**. There, the water pumped from the reactor heats a second, separate supply of water, which boils to make steam. The steam spins the turbine, which drives the generator that produces electricity.

Boiling Water Reactor



Pressurized Water Reactor



How Nuclear Fuel Is Made

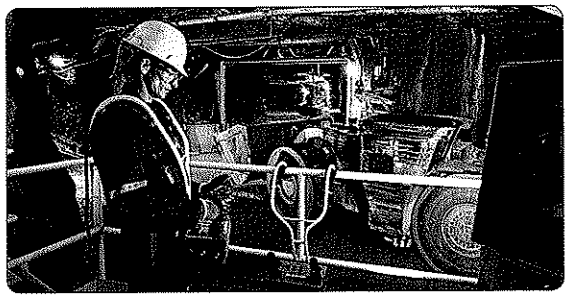
Uranium must undergo four processing steps to convert it from an ore to solid ceramic fuel pellets: mining and milling, conversion, enrichment, and fabrication.

Uranium miners use several techniques: surface, underground and in-situ recovery.

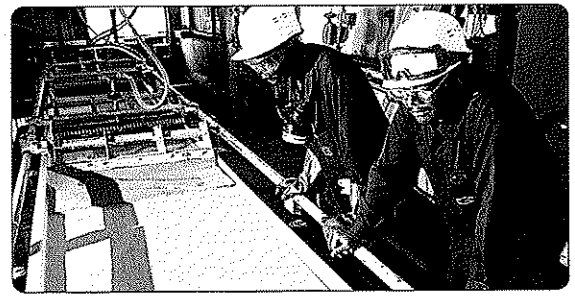
In-situ recovery uses water mixed with oxygen and baking soda to recover minerals from the underground ore. Uranium also can be a byproduct of other mineral processing operations. After mining, the material is milled and processed to create **uranium oxide**, or "**yellowcake**." Most uranium mining in the United States uses the in-situ process, whereas Canada and Australia primarily use the surface and underground approaches.

Yellowcake requires further processing before its use as a fuel.

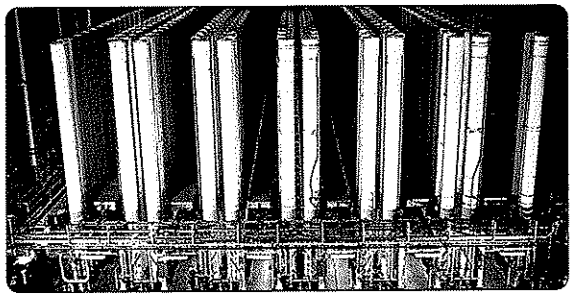
In the next step, the uranium oxide goes to a conversion plant, which removes impurities and chemically converts the material to **uranium hexafluoride**. The compound is heated to become a gas and is loaded into cylinders, where it cools and condenses into a solid. One of the world's five commercial conversion plants is in Metropolis, Ill. The others are in Canada, France, Russia and the United Kingdom.



Mining and Milling



Conversion of Yellowcake



Enrichment Centrifuges

Uranium
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Fuel Fab

Uranium fuel pellets are loaded into fuel rods. When grouped, they form fuel assemblies for insertion into the reactor.

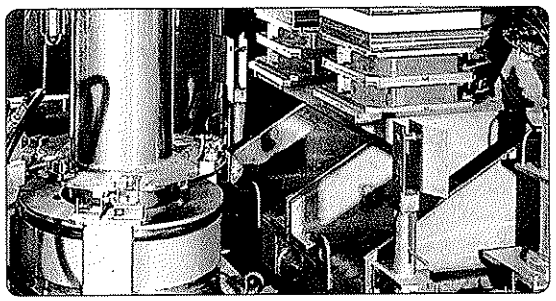
Utilities can buy uranium and have it enriched, or they can buy uranium already enriched.

Uranium hexafluoride contains two different forms, or **isotopes**, of uranium; one (U-238) is heavier than the other (U-235). The lighter U-235 is "fissionable" and typically makes up less than 1 percent of uranium by weight, while U-238 accounts for more than 99 percent. To make uranium usable as a fuel, its U-235 content must be increased to between 3 percent and 5 percent by weight through a process called **enrichment**.

The U.S.-Russia **"Megatons to Megawatts"** program downblends uranium from the Russian weapons program into commercial reactor fuel used in U.S. plants.

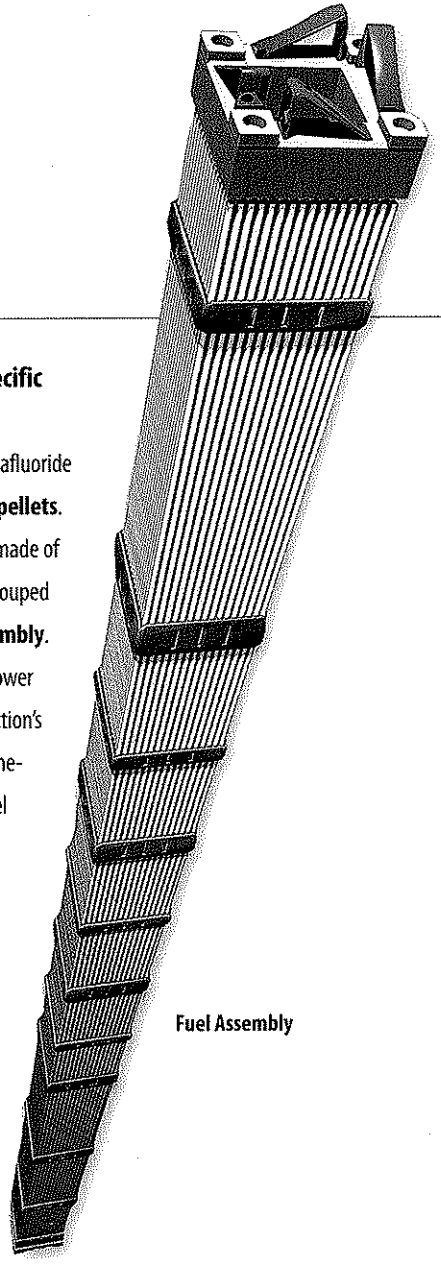
Fuel assemblies are designed to meet the specific requirements of each nuclear reactor.

After enrichment, a fuel fabricator converts uranium hexafluoride into **uranium dioxide** powder and presses it into **fuel pellets**. The fabricator loads the ceramic pellets into long tubes made of a noncorrosive material, usually zirconium alloy. Once grouped together into a bundle, these fuel rods form a **fuel assembly**. Multiple assemblies, which average 14 feet in length, power a reactor for 36 to 54 months, after which the chain reaction's efficiency begins to decrease. Operators replace about one-quarter to one-third of the fuel assemblies with new fuel every 18 to 24 months.



Fuel Fabrication

Fuel Pellet
(Actual Size)

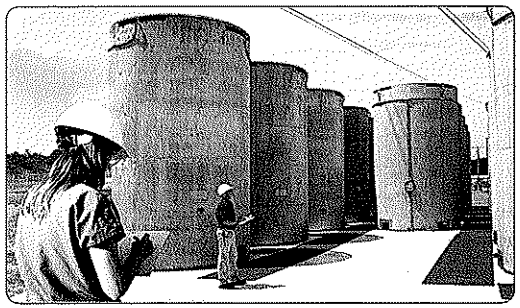


Fuel Assembly

Safely Managing Used Nuclear Fuel

FACT

Used nuclear fuel is a solid material safely stored at nuclear plant sites. Storage is one part of an integrated used fuel management system.



Nuclear power plants store used fuel safely and securely on site in steel and concrete vaults.

FACT

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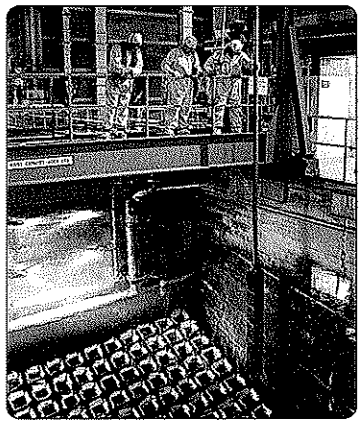
Nuclear power plants produce relatively little waste.

The nuclear energy industry takes full responsibility for all its byproducts and factors that into its production costs, while remaining the lowest-cost producer of baseload electricity.

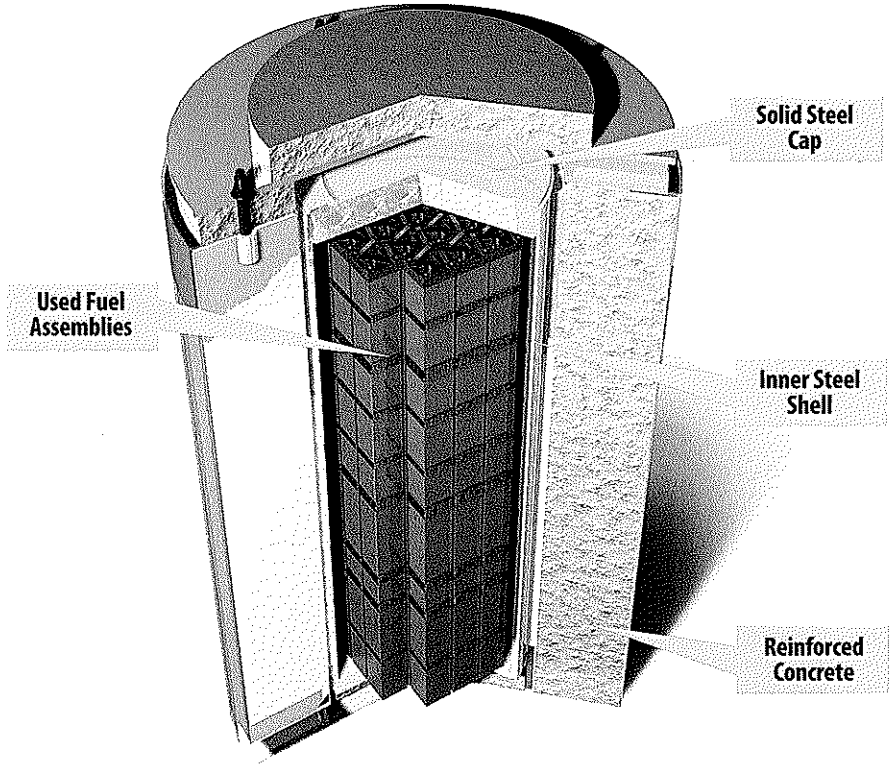


Used Fuel Pool

A typical large nuclear power plant produces enough electricity for more than 740,000 homes but only about 20 metric tons of **used uranium fuel** each year. In terms of volume, that is roughly equivalent to the cargo area of a small truck. All U.S. commercial reactors together produce about 2,000 metric tons of used fuel annually. The used fuel is highly radioactive and must be contained safely and securely.

Used fuel at nuclear plant sites is **managed securely** in special buildings that house the fuel in steel-lined concrete pools filled with water. Water both cools the fuel rods and shields workers from radiation in the fuel storage area. After the used fuel cools, it can be stored on plant property in huge steel or steel-lined concrete containers.

Typical Reactor Fuel Storage Container



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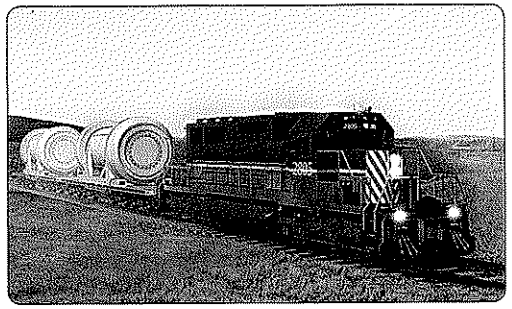
The nuclear industry has safely transported more than 3,000 shipments of used nuclear fuel over the past 40 years.



Used fuel containers will travel by train, truck or barge to a storage facility or recycling center.

Robust containers keep their contents safe.

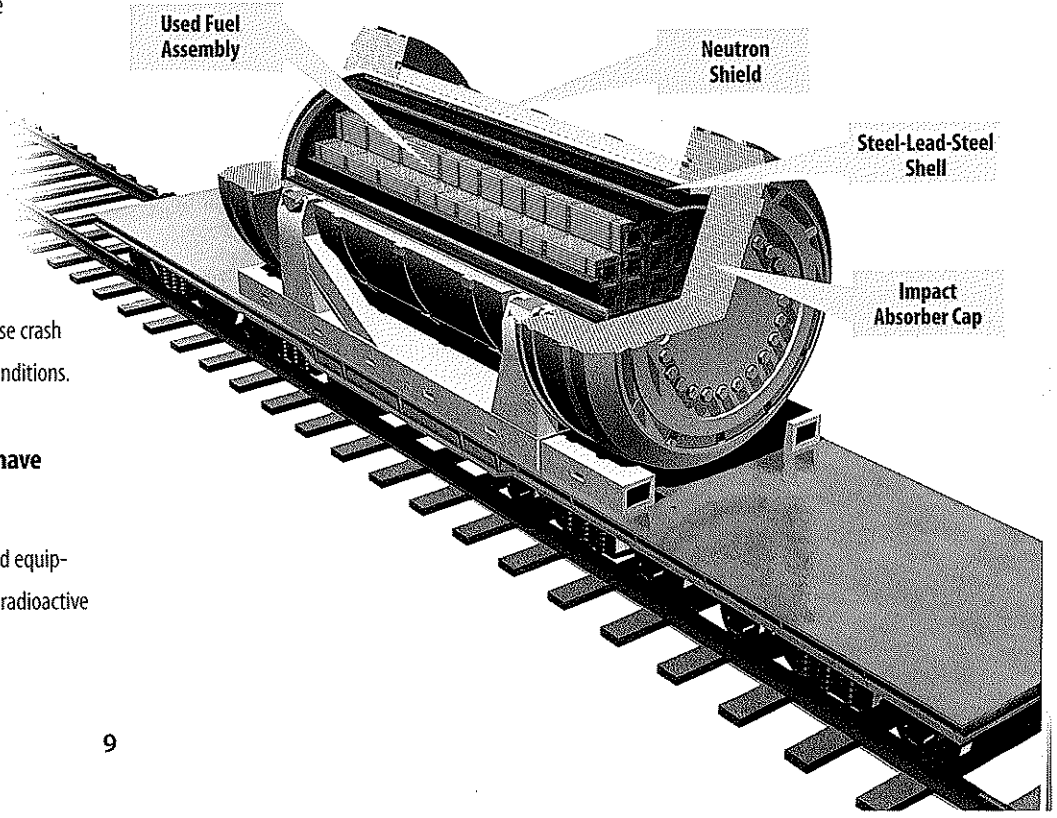
The industry has an **exemplary safety record** for used nuclear fuel transportation. These shipments have covered 1.7 million miles with no injuries, fatalities or environmental damage resulting from the radioactivity of the cargo.

Shippers, meeting rigorous regulatory standards, transport used nuclear fuel in special containers by rail, truck and sometimes barge. A container typically has about four tons of protective shielding for every ton of used fuel. The U.S. Nuclear Regulatory Commission and U.S. Department of Energy's national laboratories have subjected shipping containers to intense crash and fire tests to **ensure safe shipments** even under extreme conditions.

Nuclear power plants also manage byproducts that have low levels of radioactivity.

This material includes such things as protective clothing, tools and equipment used at nuclear power plants. Shippers transport low-level radioactive waste to federally licensed disposal facilities.

Train Container and Transport Car



Recycling and Advanced Fuel-Cycle Technologies

The U.S. government has a legal responsibility to manage used reactor fuel. As part of that law, electricity consumers have paid nearly $35 billion in special fees since 1983 to pay for the used nuclear fuel management program.

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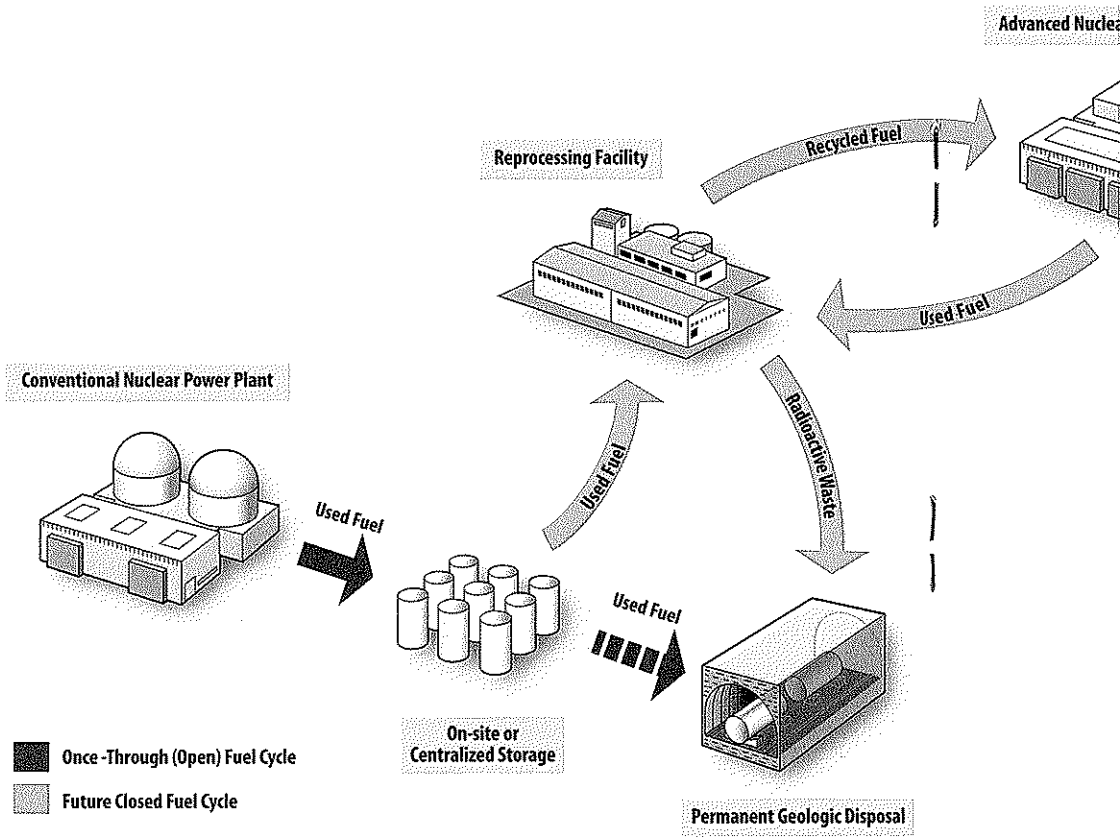
Used nuclear fuel should be managed through an integrated program.

The highest level of public safety and environmental protection is provided by an integrated program that includes temporary storage of used nuclear fuel, development of advanced fuel reprocessing facilities, and construction of a permanent disposal facility.

The United States uses a **once-through (open) fuel cycle** in which nuclear fuel is stored, ultimately for disposal, after one use. However, recycling can recover some of the energy that remains in used fuel and reduce the volume, heat and toxicity of the byproducts requiring permanent disposal. Although several countries recycle used nuclear fuel, U.S. policy prohibited it in the 1970s because of economic and proliferation concerns. This ban was overturned in 1981.

Today, advanced recycling technologies in a **closed fuel cycle** hold the promise of using nuclear fuel resources more efficiently. The expansion of nuclear energy also has prompted efforts to develop advanced fuel-cycle technologies.



The U.S. Nuclear Regulatory Commission has concluded that used nuclear fuel can be stored safely in temporary facilities for at least 100 years.

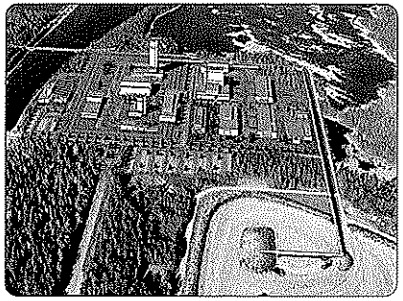
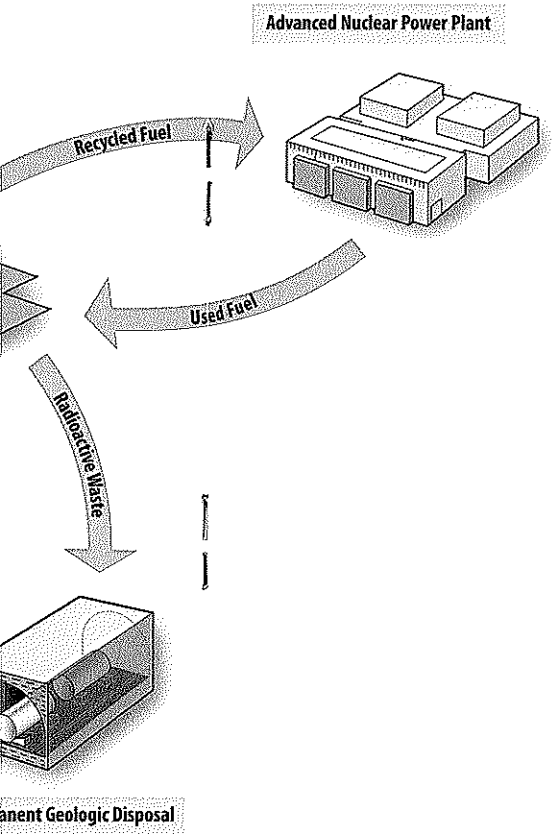


PHOTO COURTESY OF SKB/LAJ ILLUSTRATION

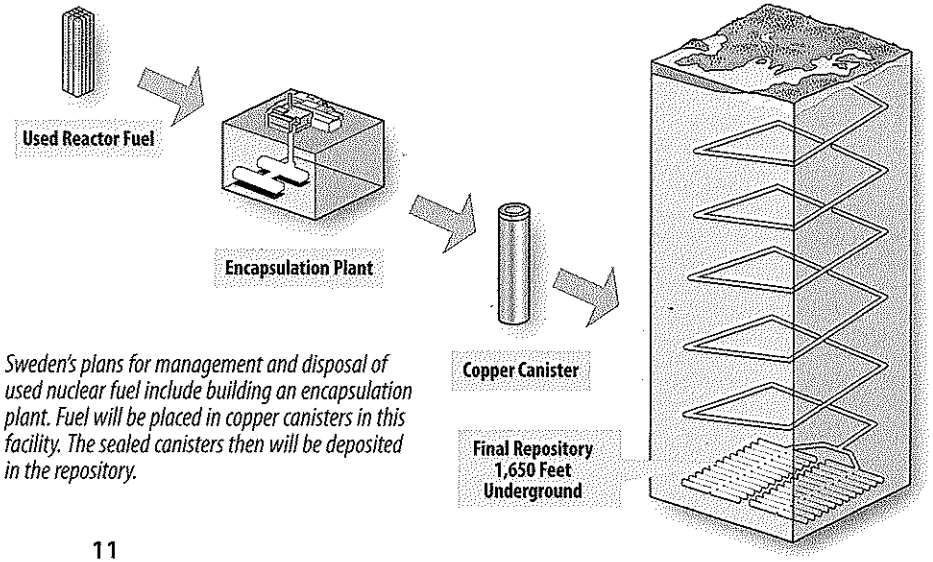
This shows how the final repository for used nuclear fuel in Sweden may look.



Used nuclear fuel and recycling byproducts will require permanent disposal.

There is scientific consensus worldwide that **disposal in a specialized facility** deep underground is the safest approach. "After four decades of study, geological disposal remains the only scientifically and technically credible long-term solution available to meet the need for safety without reliance on active management," according to the National Academy of Sciences.

Several nations, including Sweden and Finland, are developing geologic repositories for their used nuclear fuel. In the United States, after 20 years of study by the world's leading scientists, Yucca Mountain, Nev., was found to be a suitable location for a repository. The U.S. Congress and the president approved the site in 2002. The federal government is continuing to study and evaluate potential approaches for meeting its responsibility to manage used nuclear fuel.



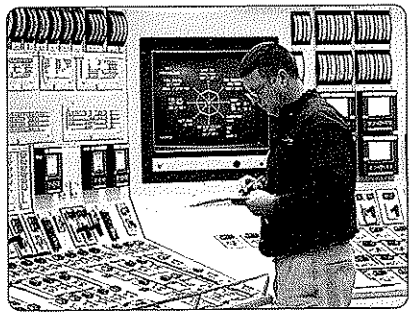
Sweden's plans for management and disposal of used nuclear fuel include building an encapsulation plant. Fuel will be placed in copper canisters in this facility. The sealed canisters then will be deposited in the repository.

ILLUSTRATION COURTESY OF SKB

Safety Is Paramount in Nuclear Plant Operations

FACT

Nuclear power plants are designed and operated safely, with multiple back-up safety systems, including automatic shutdowns.



Ongoing training for reactor operators and other key personnel has contributed to the nuclear energy industry's excellent safety record.

FACT

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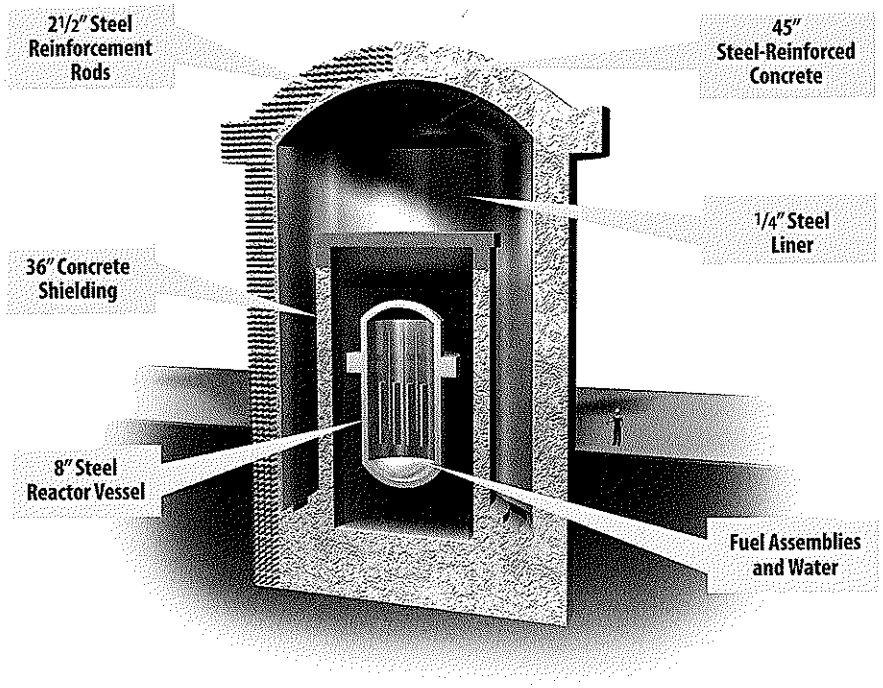
U.S.-Style Reactor Features Defense in Depth



The nation's nuclear power plants are among the safest and most secure industrial facilities.

Multiple automated safety systems, the industry's commitment to comprehensive safety procedures and stringent federal regulation keep nuclear power plants and neighboring communities safe.

The U.S. Nuclear Regulatory Commission, an independent federal agency, strictly regulates the commercial and institutional uses of nuclear energy, including nuclear power plants. The agency regulates plant performance according to three strategic areas: **reactor safety, radiation safety and security**. Independent NRC inspectors at each reactor provide oversight of plant operation, maintenance, equipment replacement and training. The NRC posts all performance results on its website *(www.nrc.gov)*.

The nuclear energy industry has an impeccable safety record.

Quality plant construction, continuous **preventive maintenance** and ongoing **reactor operator training** all have contributed to the nuclear energy industry's excellent safety record. Levels of safety in the nuclear energy industry exceed those of the overall electricity industry and of the manufacturing sector.

Accidents at Three Mile Island and Chernobyl, though serious events, led to significant improvements in nuclear plant safety.

All commercial nuclear plants have emergency response procedures in the event of an accident or security event.

These procedures are evaluated regularly during extensive drills involving plant personnel and local police, fire and emergency management organizations. NRC and Federal Emergency Management Agency expert teams evaluate some of these drills.

Nuclear plant staff and local emergency responders drill together to ensure close coordination.

Background on the accident at Three Mile Island

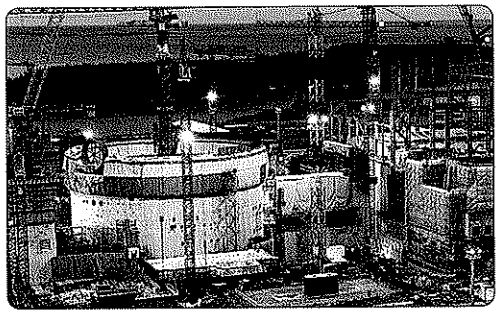
The accident at Three Mile Island (TMI) in 1979 was caused by a combination of equipment failure and the inability of plant operators to understand the reactor's condition at certain times during the event. A gradual loss of cooling water to the reactor's heat-producing core led to partial melting of the fuel rod steel cladding and the uranium fuel and the controlled release of a small amount of radioactive material. The TMI accident caused no injuries or deaths. Also, experts concluded that the amount of radiation released into the atmosphere was too small to result in discernible health effects to residents in the vicinity of the plant. A dozen epidemiological studies conducted since 1981 have confirmed this fact.

Background on the accident at Chernobyl

The 1986 accident at the Chernobyl nuclear power plant in Ukraine is the only accident in the history of commercial nuclear power to cause on-site fatalities from radiation. It was the product of a severely flawed Soviet-era reactor design combined with disregard of operating protocols. A Chernobyl-type reactor would not meet U.S. safety standards and could not be built in the United States.

Building New Nuclear Plants

Energy companies and consortia are pursuing plans to build as many as 30 new nuclear power plants to help meet projected increases in U.S. electricity demand.



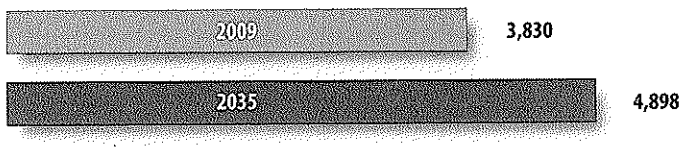
More than 60 nuclear power plants are under construction around the world.

The United States will need 28 percent more electricity by 2035.

The U.S. Department of Energy forecasts the United States will need about 250,000 megawatts of new electric generating capacity by 2035, equivalent to 250 new large power plants. This rising electricity demand, along with concerns about greenhouse gases and pollution, make new nuclear plants vital to our **energy mix**. Energy companies are developing **license applications** to build as many as 22 new commercial reactors. Several companies already have submitted applications for new reactors that the NRC is reviewing under its new licensing process.

U.S. Electricity Demand Will Increase 28 Percent by 2035

(in billion kilowatt-hours)



Source: Energy Information Administration

The federal government is planning for future electricity needs.

A loan guarantee program established by the Energy Policy Act of 2005 is helping companies build clean energy facilities, including nuclear power and renewable energy facilities. The government uses loan guarantees widely to ensure investment in critical national needs—for example, transportation infrastructure. Unlike other loan guarantee programs, however, companies awarded loan guarantees for nuclear power plant projects pay for all costs associated with the program, including a fee to cover any business risks associated with the loan.

U.S. companies are rebuilding infrastructure for new reactors.

Suppliers expect they can meet the needs of the first few new reactors. They have launched new initiatives, however, to develop the **manufacturing base** for new plants and to ensure the industry has the right construction management, engineering expertise and skilled labor needed for the future. New-plant construction will provide **thousands of additional jobs**. Building a new nuclear plant will create 1,400 to 1,800 jobs during construction, with peak employment as high as 2,400 jobs.

The industry is recruiting and training the nuclear work force of the future.

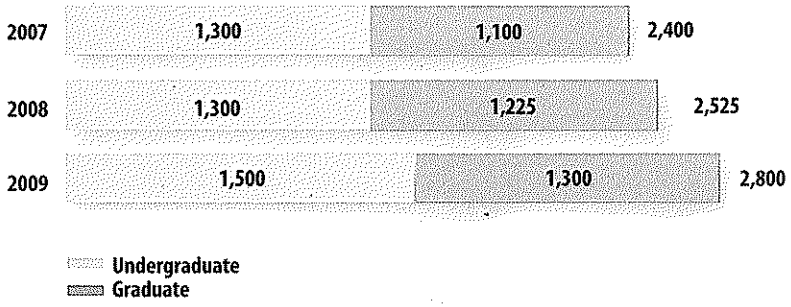
Because 35 percent of workers in the nuclear energy industry will be eligible to retire within five years, the industry is focusing on staffing and recruitment issues to retain a **high-quality work force**. The industry has intensified its recruiting efforts to address ethnic diversity issues, expand opportunities for women and attract talented employees needed in specific professions, such as **nuclear engineering** and **health physics**.

Nuclear energy's expansion in the United States will require thousands of new workers.

Industry efforts to increase the work force are showing results.

The number of students enrolled in four-year nuclear engineering programs increased to 1,500 in 2009—the highest number reported since the mid-1980s. The industry also has partnered with local technical and community colleges and organized labor to develop **technicians** and **craft personnel**. Nonetheless, the industry still faces a critical shortage of skilled workers to build the next generation of nuclear plants.

Nuclear Engineering Enrollment



Source: Oak Ridge Institute for Science and Education

Economic Benefits

Nuclear power plants create hundreds of high-paying jobs at the plants and in the surrounding communities.

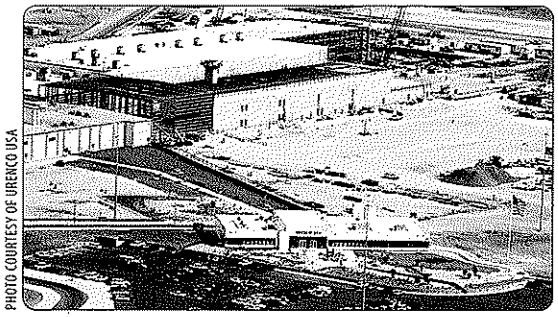


PHOTO COURTESY OF URENCO USA

Louisiana Energy Services opened a state-of-the-art uranium enrichment facility in Eunice, N.M, that employs 300 workers.

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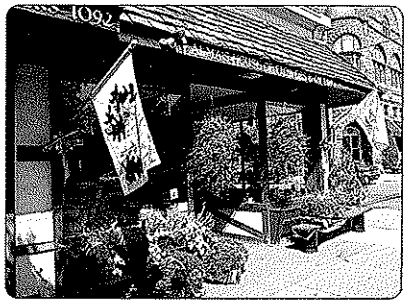
Operation of a U.S. nuclear plant generates up to 700 permanent jobs.

The up to 700 permanent jobs at a nuclear plant pay 36 percent more than average salaries in the local area. The plant also creates an equivalent number of additional jobs in the **local area** to provide the goods and services necessary to support the nuclear plant work force.

Nuclear plants provide economic benefits to their local communities.

Each year, a typical nuclear plant generates approximately $430 million in sales of goods and services in the local community and nearly $40 million in total labor income. These figures include both **direct** and **secondary effects**. The direct effects reflect the plant's expenditures for goods, services and labor. The secondary effects include subsequent spending attributable to the presence of the company and its employees as plant expenditures filter through the local economy. The average nuclear plant generates total state and local **tax revenue** of almost $20 million each year. These tax dollars benefit schools, roads, and other state and local infrastructure. Each nuclear plant generates federal tax payments of approximately $75 million each year.



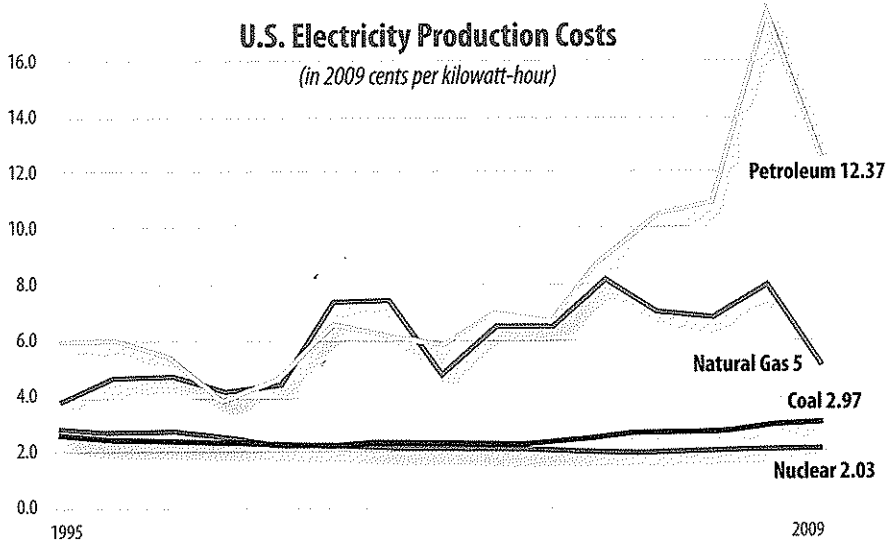
Additional jobs are created to provide goods and services like grocery stores, dry cleaners and car dealers.

Nuclear power has a lower production cost than coal or natural gas, so it helps reduce the price of electricity for consumers.

Nuclear energy provides reliable electricity around the clock to power our digital world.

Nuclear power is the lowest-cost producer of baseload electricity.

Average **electricity production costs** at nuclear power plants have declined more than 30 percent in the past 10 years to an average of 2 cents per kilowatt-hour. This includes the costs of operating and maintaining the plant, purchasing nuclear fuel, and managing used fuel. Electricity generated from nuclear power also has tremendous forward **price stability** because only about one-quarter of production costs are fuel costs. Fuel accounts for 80 percent to 90 percent of the cost of electricity produced by fossil fuel-fired generation, making it highly susceptible to fluctuations in coal and natural gas prices.



Source: Ventyx

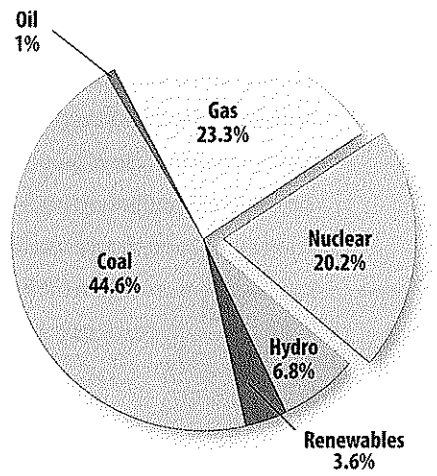
Nuclear Energy Key Statistics

Improvements in nuclear power plant efficiency since 1990 have raised total electricity output by an amount equal to building 28 new reactors.

The United States has the world's largest commercial nuclear energy program.

Each year, America's 104 nuclear power plants **alone** produce more electricity than does any single country from **all generating sources** except China, Japan and Russia. Efficiency gains have enabled nuclear plants to increase output by 40 percent since 1990. Because nuclear plants do not produce greenhouse gases, the amount of carbon dioxide emissions they prevent is more significant than all other electricity sources combined. As a result of these factors, public opinion surveys show a **steady increase in support** for nuclear energy. The following graphs illustrate nuclear energy's increasing value to consumers and importance to our nation's electricity supply.

U.S. Electricity Generation by Fuel Type



Source: Ventyx/Energy Information Administration, 2009

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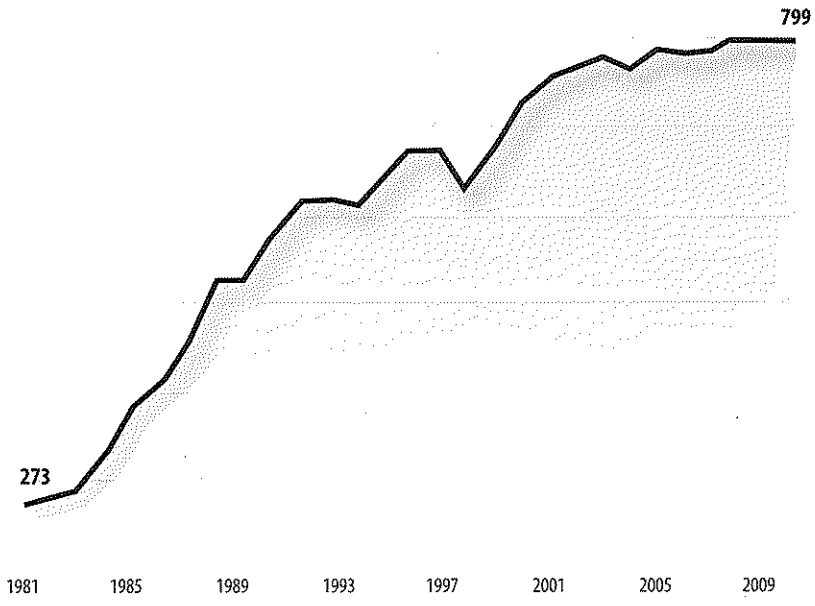
Source: Ventyx,

In seven states, nuclear energy makes up the largest percentage of electricity production. These include Vermont (72.3%), New Jersey (55.1%), Connecticut (53.4%), South Carolina (52%), Illinois (48.7%), New Hampshire (44.1%) and Virginia (39.6%).

Nuclear Energy Output at Near-Record Level

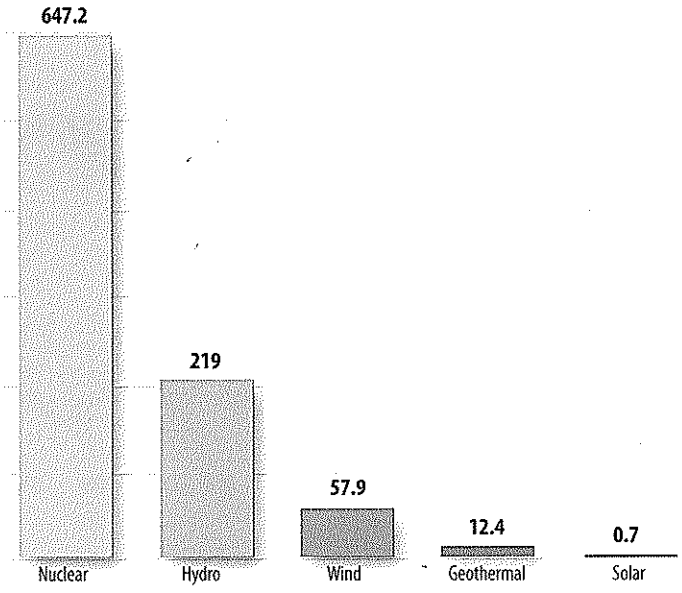
(in billions of kilowatt-hours)



Source: Ventyx/Energy Information Administration, 2009

Carbon Dioxide Prevented by U.S. Electric Power Industry

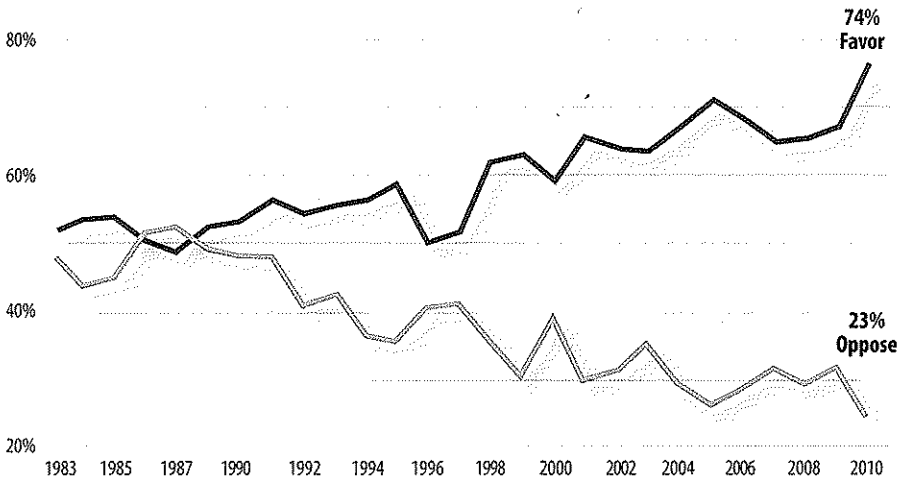
(in million metric tons of CO_2)



Source: Environmental Protection Agency/Energy Information Administration, 2009

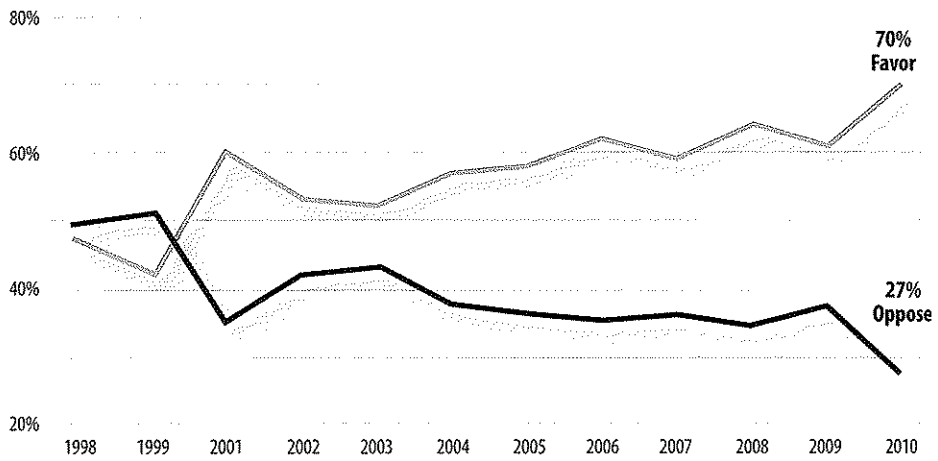
Nuclear Energy Key Statistics

Steady Growth in Public Support for Nuclear Energy

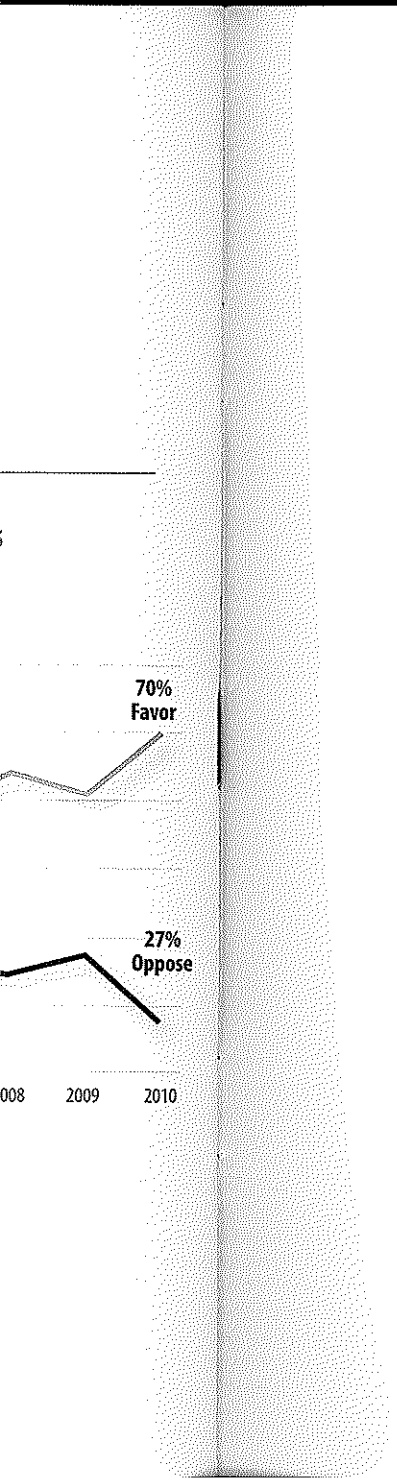


Source: Bisconti Research Inc.

Support for Building More Nuclear Power Plants



Source: Bisconti Research Inc.



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NEI improves the environment by reducing its carbon footprint.

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The Institute's members include companies that operate commercial nuclear power plants, their suppliers and labor unions, as well as leading universities, research laboratories, radiopharmaceutical and radioisotope manufacturers, and others.

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trees	water	energy	solid waste	greenhouse gases
47 fully grown	28,864 gallons	34 million BTU	8,316 pounds	6,028 pounds

Calculated based on research done by Environmental Defense and other members of the Paper Task Force.

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