Nuclear Energy

Just the Facts

NEI

NUCLEAR ENERGY INSTITUTE

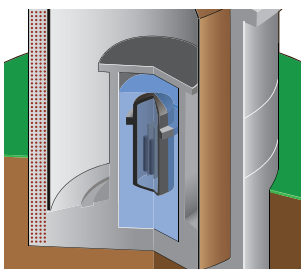
Nuclear Energy

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 energy facilities 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

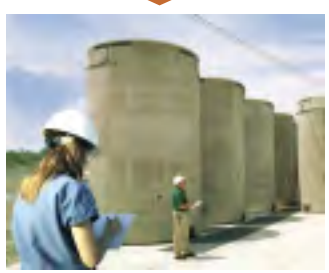


*Nuclear energy facilities have **layer upon layer** of safety measures. (Pages 2 and 3)*

*With up to 700 permanent jobs, a nuclear energy facility provides significant **economic benefits** to local communities. (Pages 4 and 5)*

*A nuclear reactor generates reliable electricity around the clock without producing **greenhouse gases**. (Pages 6 and 7)*

*Building new nuclear energy facilities is critical to meeting U.S. **environmental and energy** goals. (Page 16)*



*After a cooling period, nuclear energy facilities store used fuel **safely** and **securely** on site in steel and concrete containers. (Page 12)*

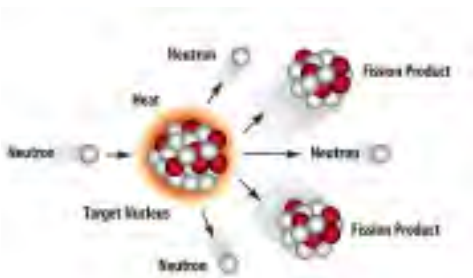
*Used fuel will travel by **train, truck** or **barge** to a consolidated storage facility or disposal facility. (Page 13)*

FACT *The U.S. Nuclear Regulatory Commission, an independent government watchdog,* ***strictly regulates*** *the commercial and industrial uses of nuclear technology, including nuclear energy facilities. The industry has a* ***commitment to safety****, including quality construction, continuous preventive maintenance and ongoing reactor operator training.*

After mining, uranium is milled and processed to create ***uranium oxide,*** *or* ***yellowcake.*** *(Page 10)*

The conversion plant removes impurities and chemically converts the material. ***Enrichment*** *makes the uranium usable as a fuel. (Page 10)*

A fuel fabricator presses the uranium into solid ceramic ***pellets*** *and inserts them into rods. The rods are then bundled into* ***fuel assemblies.*** *Assemblies are then transported to the nuclear facility and loaded into the* ***reactors.*** *(Page 11)*



In the reactor, ***nuclear fission*** *produces energy to heat water into steam that powers generators to produce electricity. (Pages 8 and 9)*

Development of ***advanced fuel cycle technologies*** *improves efficiency and reduces waste but does not preclude the need for a federal repository. (Page 14)*

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 15)*

Fuel Pellet (Actual Size)

Nuclear Energy in America

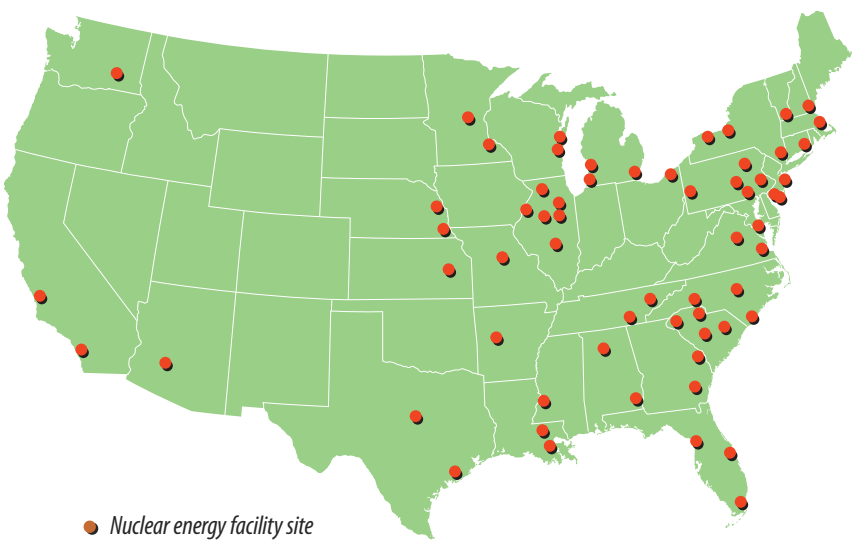
Just the Facts

- **Electricity is essential** to our everyday lives and to America's economy.
- Nuclear energy generates nearly **20 percent** of U.S. electricity.
- Nuclear energy facilities 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 has transformed the way we live and work and continues to fuel America's economy.

Nuclear energy produces electricity for one in five homes and businesses across the United States, with 104 reactors at 65 sites in 31 states. The country's largest source of carbon-free electricity is nuclear energy, accounting for nearly two-thirds of all carbon emission-free electricity generated. America's reactors operate around the clock, thereby stabilizing the entire country's electricity distribution system and electricity marketplace.

America's Nuclear Energy Facilities

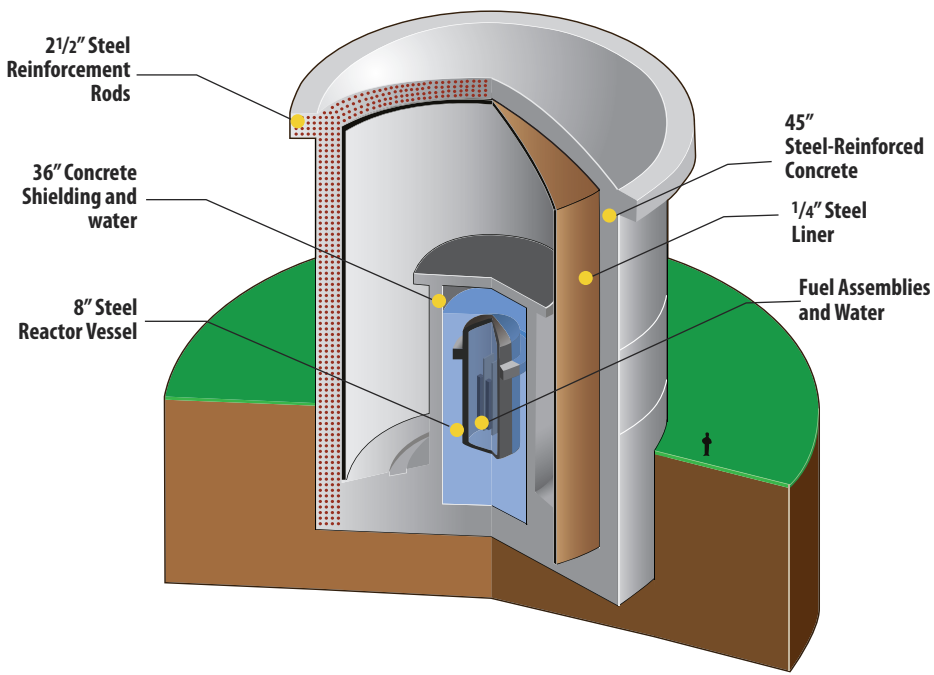


Safety Is the Highest Priority

FACT Nuclear energy facilities are designed and operated safely, with multiple backup safety systems that can automatically shut down the reactor.

Continuous training for reactor operators and other key personnel helps ensure that America's nuclear energy facilities operate safely.

U.S.-Style Reactor Features Multiple Layers of Safety



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

The nuclear energy industry is relentless in its pursuit of safety through high-quality facility construction, continuous **preventive maintenance** and **reactor operator training.** This approach doesn't just meet the standards created by the federal government—it exceeds them.

Multiple automatic safety systems, the industry's commitment to comprehensive safety procedures and stringent federal regulation keep nuclear energy facilities 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 electricity-generating facilities. The agency regulates facility performance in three strategic areas: **reactor safety, radiation safety and security.** NRC inspectors at each reactor provide oversight of facility operation, maintenance, equipment replacement and training. If the NRC believes a facility is unsafe, it will order remedies, including shutting it down.

FACT The industry analyzes operational events worldwide to incorporate lessons learned that will make our nuclear energy facilities even safer.

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

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

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

Commitment to Safety The companies that operate nuclear energy facilities are committed to safe operations. They also anticipate the worst and plan for it. Their facilities have multiple layers of safety, including backup safety equipment, detailed emergency operating procedures and onsite emergency response plans. Workers are trained and drilled so they can implement backup safety measures quickly and efficiently, if needed.

Regulatory Oversight The NRC is the lead agency for coordinating federal actions in response to an event at a commercial nuclear energy facility. The agency maintains a headquarters incident response center, where operations officers are on duty around the clock. NRC inspectors at each reactor site have full access to the facility at all times. FEMA establishes standards for off-site emergency preparedness programs and assists state and local governments in developing these programs.

Continuous Improvement Emergency plans for nuclear energy facilities continually evolve and improve. Changes have included incorporating lessons learned from accidents at the Three Mile Island, Chernobyl and Fukushima Daiichi nuclear energy facilities. The industry also enhanced security and emergency preparedness following the terrorist attacks of Sept. 11, 2001.

Economic Benefits

FACT Nuclear energy facilities create hundreds of high-paying jobs at the facilities 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.

Operation of a nuclear energy facility generates up to 700 permanent jobs.

Up to 700 permanent jobs at a nuclear energy facility pay 36 percent more than average salaries in the **local area.** Each facility also creates an equivalent number of additional jobs in the local area, providing goods and services necessary to support the nuclear facility workforce.

A typical nuclear energy facility provides 400 to 700 permanent jobs.

Nuclear energy facilities provide economic benefits to their local communities.

Each year, a typical nuclear energy facility generates approximately $470 million in sales of goods and services in the local community and $40 million in total labor income. These figures include both **primary** and **secondary effects.** Primary effects reflect the facility's expenditures for goods, services and labor. Secondary effects include subsequent spending attributable to the presence of the company and its employees as facility expenditures filter through the local economy. The average nuclear facility generates total state and local **tax revenue** of $16 million each year. These tax dollars benefit schools, roads, and other state and local infrastructure. Each nuclear energy facility also generates federal tax payments of approximately $67 million each year.

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

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

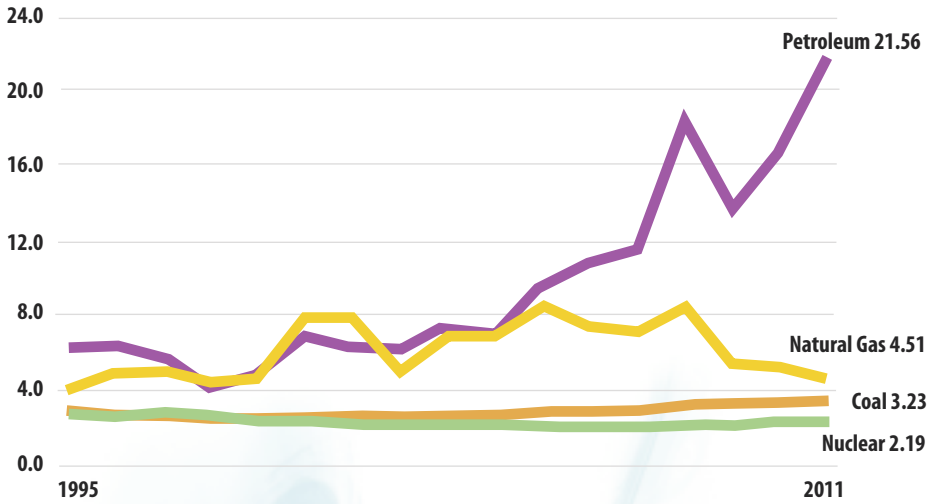
Nuclear energy facilities generate electricity around the clock, 365 days a year, helping to maintain the reliability of America's energy supply.

Nuclear energy is a low-cost producer of baseload electricity.

The average electricity production costs at nuclear energy facilities are about 2 cents per kilowatt-hour. This includes the costs of operating and maintaining the facility, purchasing nuclear fuel and managing used fuel. Electricity generated from nuclear energy also has tremendous **price stability** because only one-quarter of production costs are for fuel. 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.

U.S. Electricity Production Costs

(in 2011 cents per kilowatt-hour)



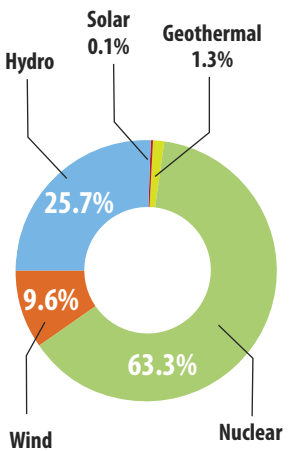
Source: Ventyx Velocity Suite

Nuclear-generated electricity powers America's homes at a price we can afford.

Nuclear Energy Benefits the Environment

FACT Nuclear energy facilities help mitigate climate change because they don't produce greenhouse gases while generating electricity.

Emission-Free Electricity Sources



Source: Energy Information Administration, 2011

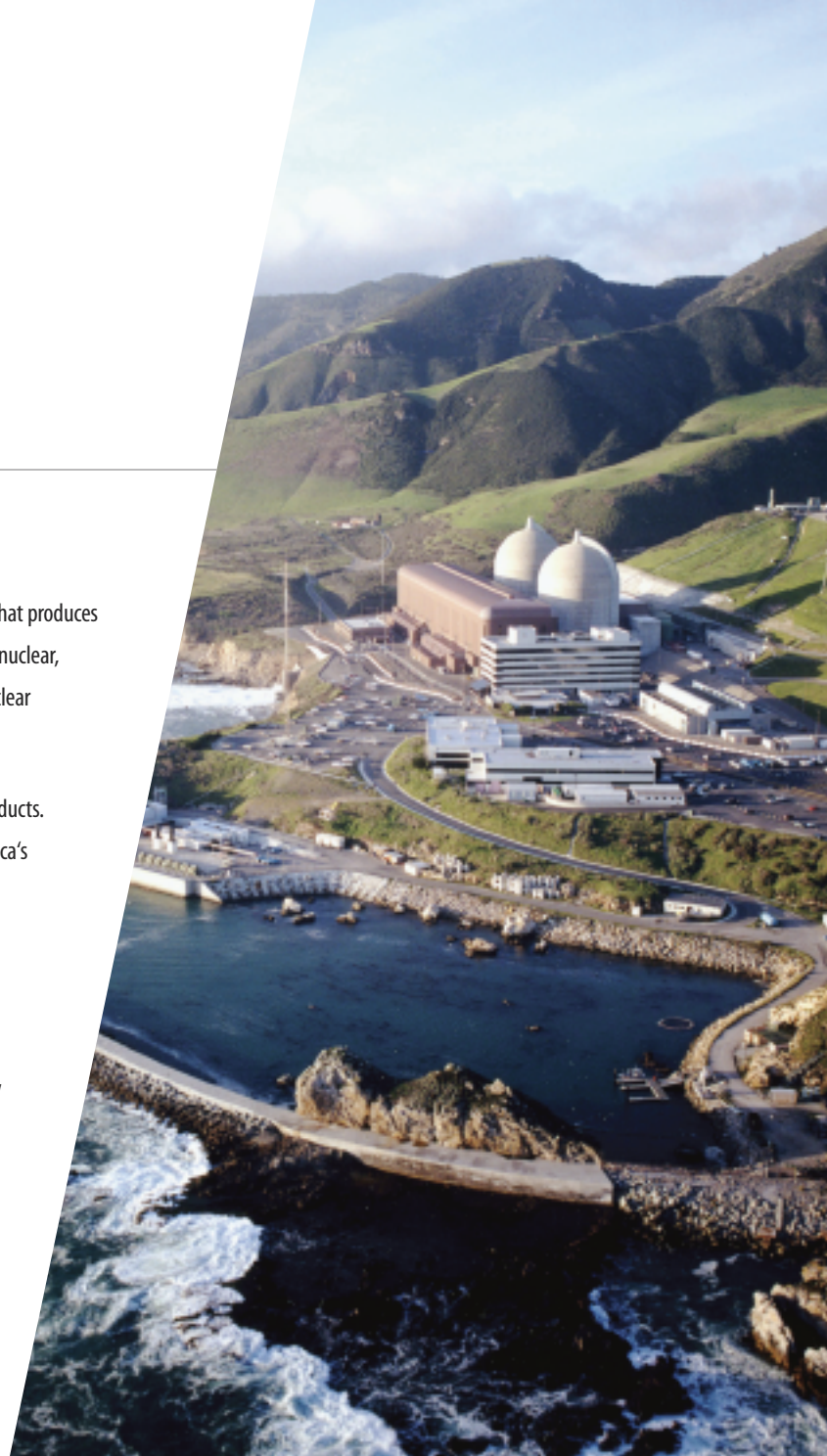
About one-third of America's electricity comes from carbon-free sources.

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, including nuclear, provide 30 percent of America's electricity. Nearly two-thirds of that comes from nuclear energy.

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

Americans need abundant electricity and want clean air.

With nuclear energy, they can have both. Given the country's growing demand for new sources of electricity—as much as 22 percent by 2035, according to the Energy Information Administration's latest forecast—the United States will need all sources of electricity generation available: renewables, coal, natural gas and nuclear energy. Nuclear energy is the only large-scale, carbon-free energy source that can be widely expanded.



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

Endangered species find sanctuaries at nuclear energy facilities.

Nuclear energy facilities are so clean and safe that they provide excellent habitats 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 facilities include many endangered and protected species, such as the American crocodile, manatee, shortnose sturgeon and sea turtle.

Nuclear energy facilities have won praise for their environmental activities.

Environmental programs conducted by companies operating nuclear energy facilities 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.

Emissions prevented by nuclear energy facilities nearly equal those produced by all U.S. passenger cars.

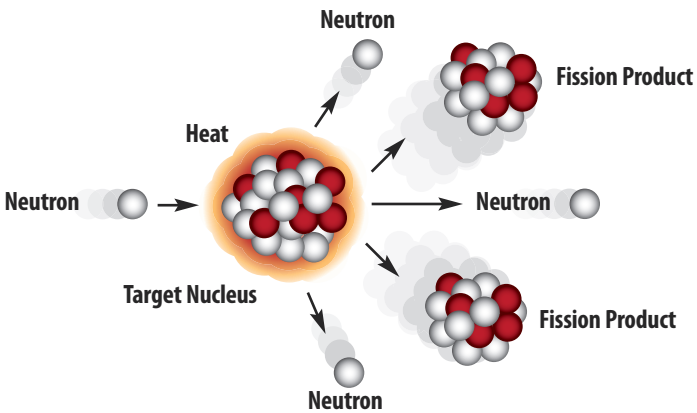
By using nuclear energy instead of fossil fuel-based generating facilities, the nuclear energy industry prevents millions of tons of carbon dioxide emissions every year. The volume of **greenhouse gas emissions** prevented at 104 nuclear energy facilities is equivalent to taking nearly **all passenger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

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

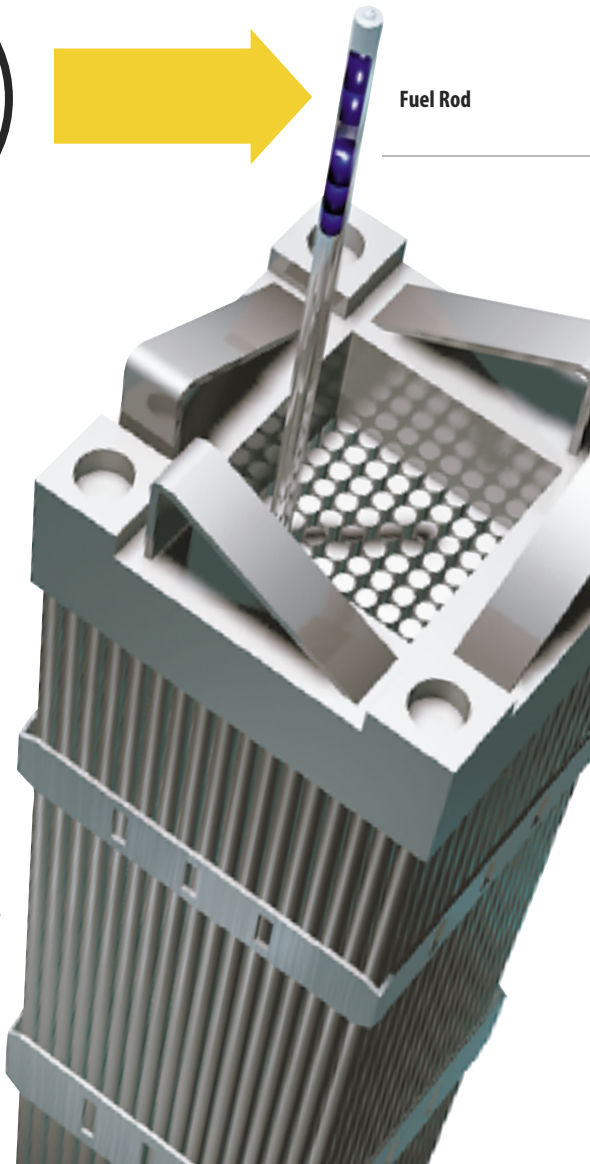
Peregrine falcons, bald eagles and ospreys nest at the Three Mile Island nuclear energy facility in Pennsylvania.

How Nuclear Energy Facilities Work

FACT A nuclear energy facility 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 energy facilities arrives 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. Uranium fuel is a solid material and cannot explode.

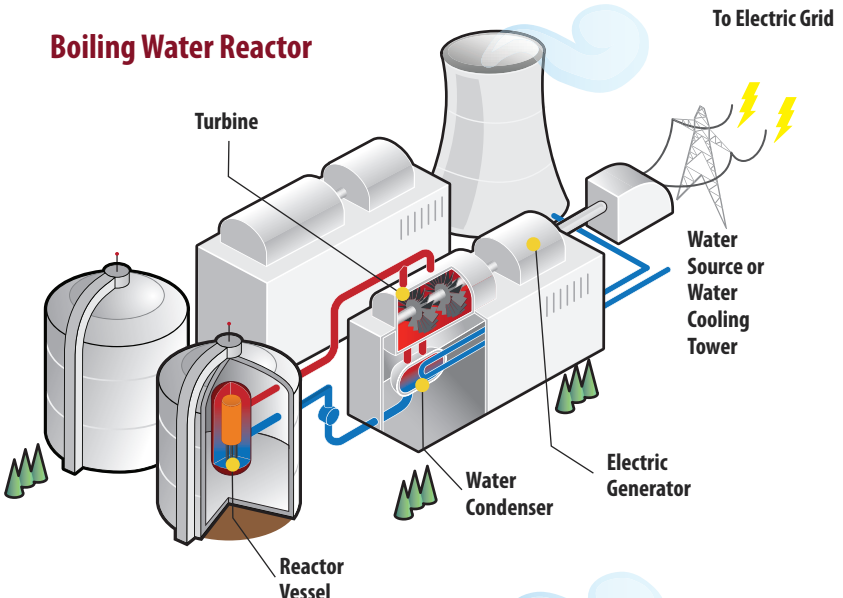
FACT One uranium fuel pellet provides as much energy as one ton of coal, 149 gallons of oil or 17,000 cubic feet of natural gas.

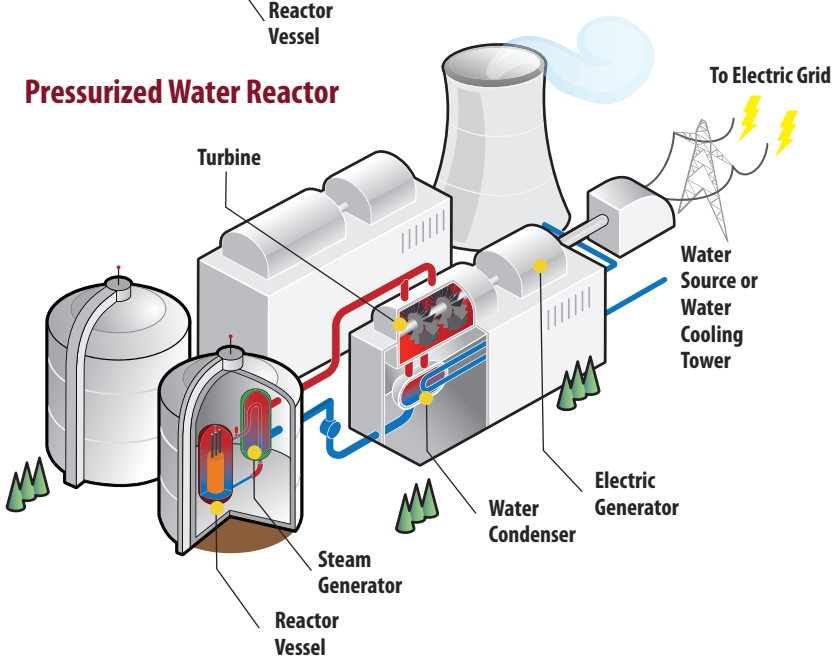
Types of nuclear energy facilities

There are two types of commercial nuclear energy facilities 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.





How Nuclear Fuel Is Made

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

Mining Uranium

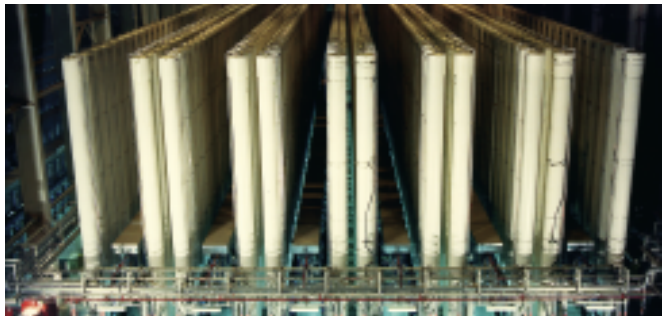
Uranium miners use several techniques: surface, underground and in-situ recovery.

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.

Milling to Create Yellowcake

Yellowcake requires further processing before its use as a fuel.

In the next step, the uranium oxide goes to a conversion facility, 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 facilities is in Metropolis, Ill. The others are in Canada, France, Russia and the United Kingdom.



Enrichment Centrifuges

FACT 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 that is already enriched.

Uranium 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**.

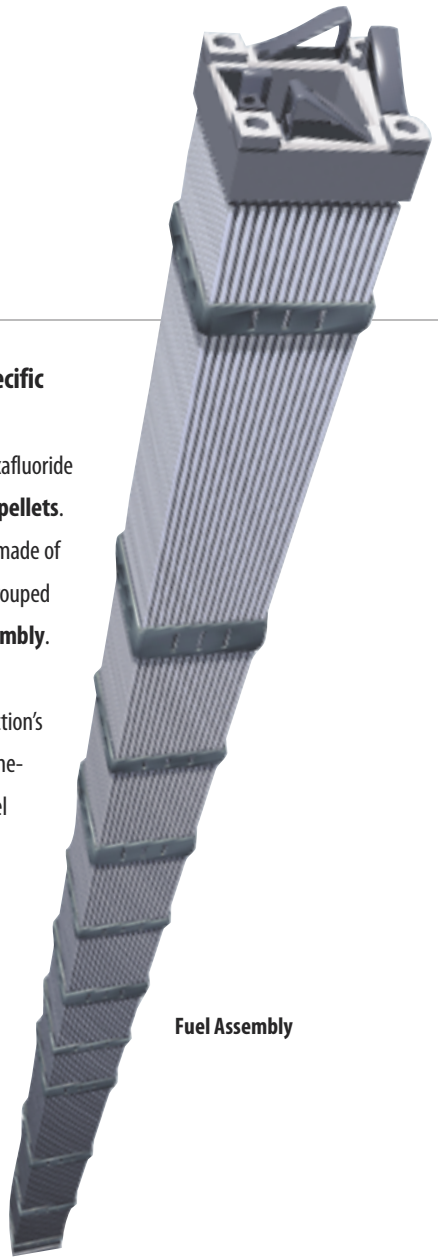
In one program, the U.S.-Russia **"Megatons to Megawatts"** agreement downblends uranium from thousands of Russian weapons into half of the commercial reactor fuel used in U.S. facilities.

Fuel assemblies are designed to meet the specific requirements of each 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, typically 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

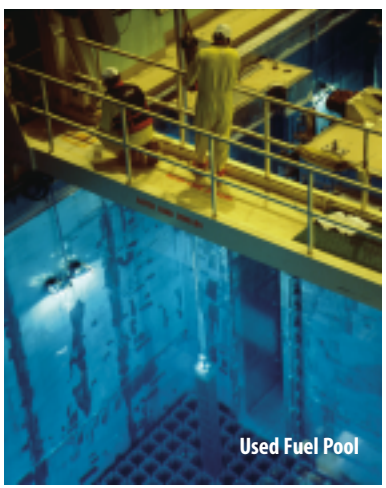
Safely Managing Used Nuclear Fuel

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

Nuclear energy facilities store used fuel safely and securely on site in steel and concrete containers.

Nuclear energy facilities produce relatively little waste.

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

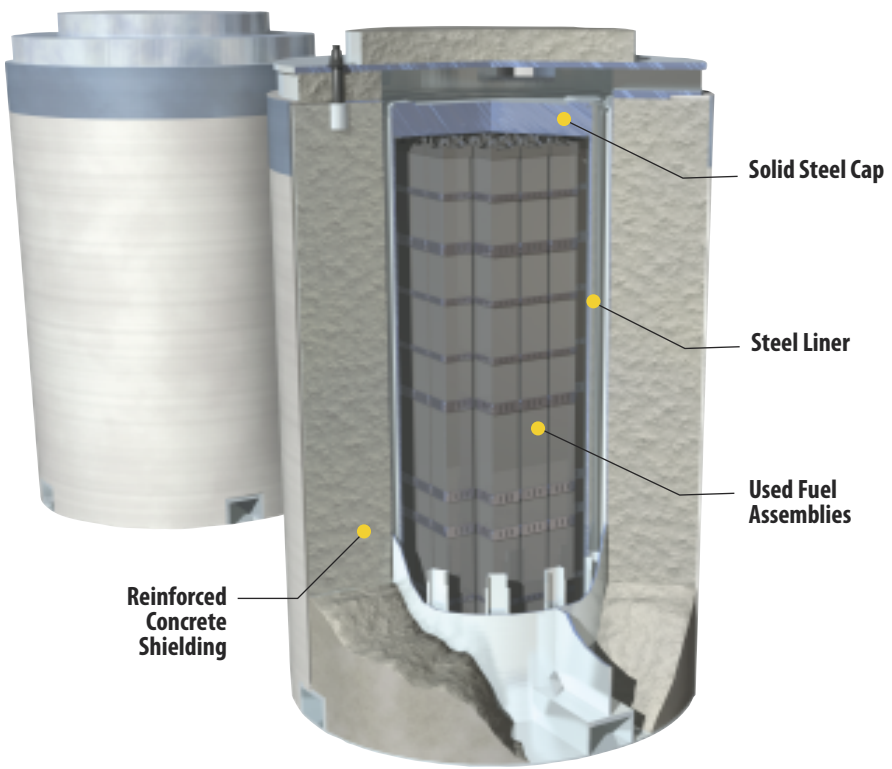


The water in storage pools shields workers from radiation from used fuel, allowing them to wear light protective clothing.

A typical large nuclear energy facility produces enough electricity for more than 690,000 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. Used fuel is highly radioactive and must be contained safely and securely.

Used fuel at nuclear energy facilities is **managed securely** 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 sufficiently, it can be stored on facility property in huge steel or steel-lined concrete containers.

Typical Reactor Fuel Storage Container



FACT The nuclear industry has safely transported more than 3,000 shipments of used nuclear fuel over the past 50 years.

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

Robust containers keep their contents safe.

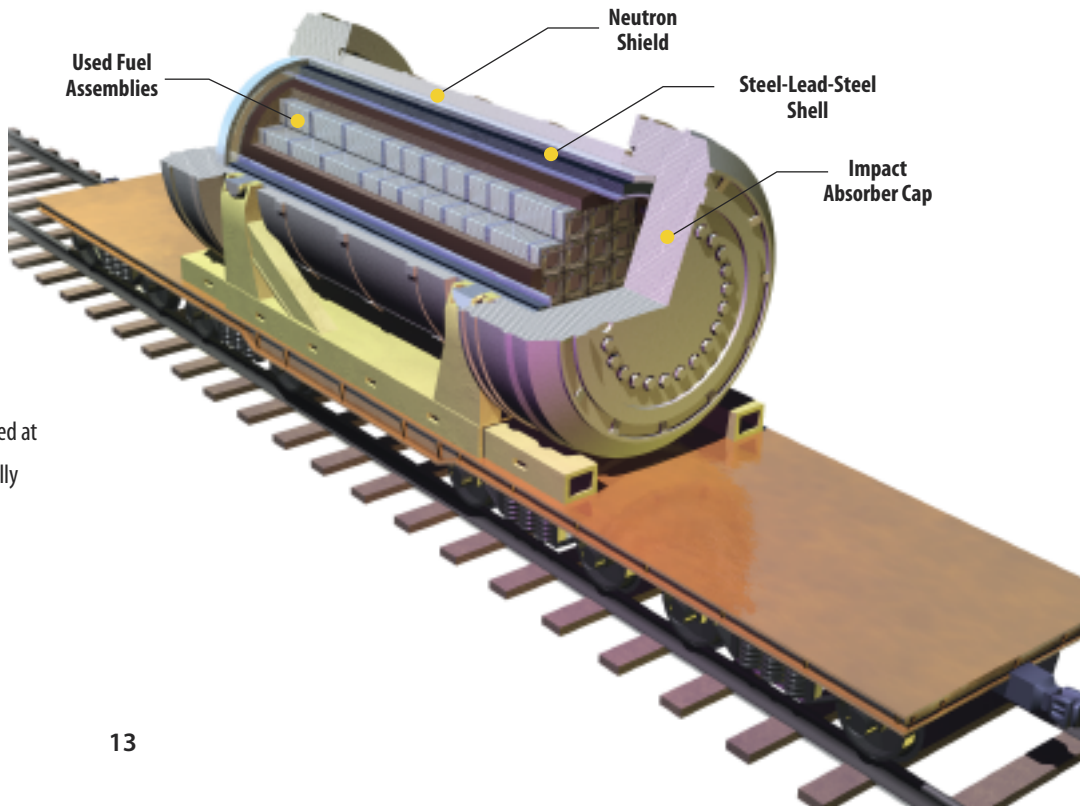
The industry has an **exemplary safety record** in transporting used nuclear fuel. These shipments have covered 1.7 million miles with no injuries, fatalities or environmental damage resulting from the radioactivity of the cargo.

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 energy facilities also manage byproducts that have low levels of radioactivity.

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

Train Container and Transport Car



Recycling and Advanced Fuel-Cycle Technologies

FACT The U.S. government has a legal responsibility to dispose of used reactor fuel. As part of that law, electricity consumers have paid $36 billion in fees since 1983 specifically for the used nuclear fuel management program.

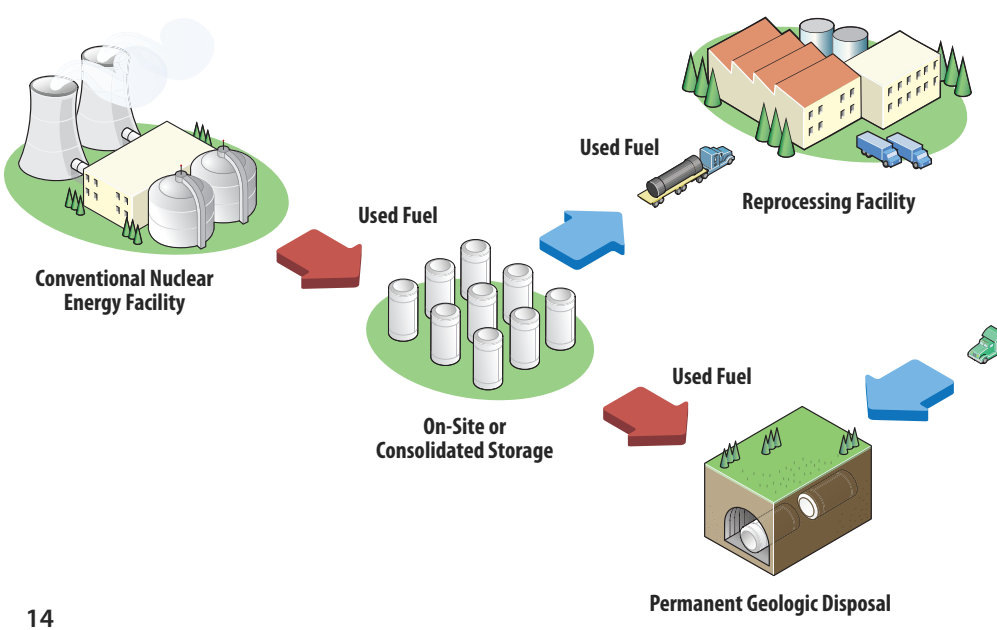
Used nuclear fuel should be managed through an integrated program.

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 consolidated storage facilities and 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.

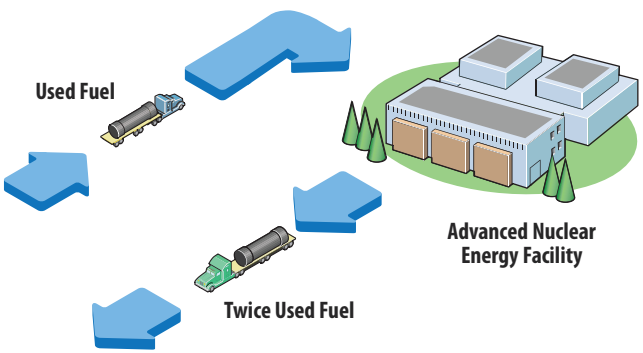
Advanced Nuclear Fuel Cycle



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

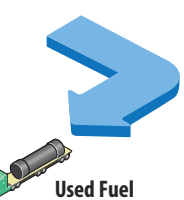
ILLUSTRATION COURTESY OF SKB/LAJ

Sweden is developing a final repository for used nuclear fuel about 1,650 feet underground.



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 used nuclear fuel. In the United States, the federal government is continuing to study and evaluate potential approaches for meeting its responsibility to manage used nuclear fuel. In 2012, the Blue Ribbon Commission on America's Nuclear Future made eight recommendations. They include adapting a consent-based approach for siting nuclear waste management facilities and establishing a new independent organization to manage the program.

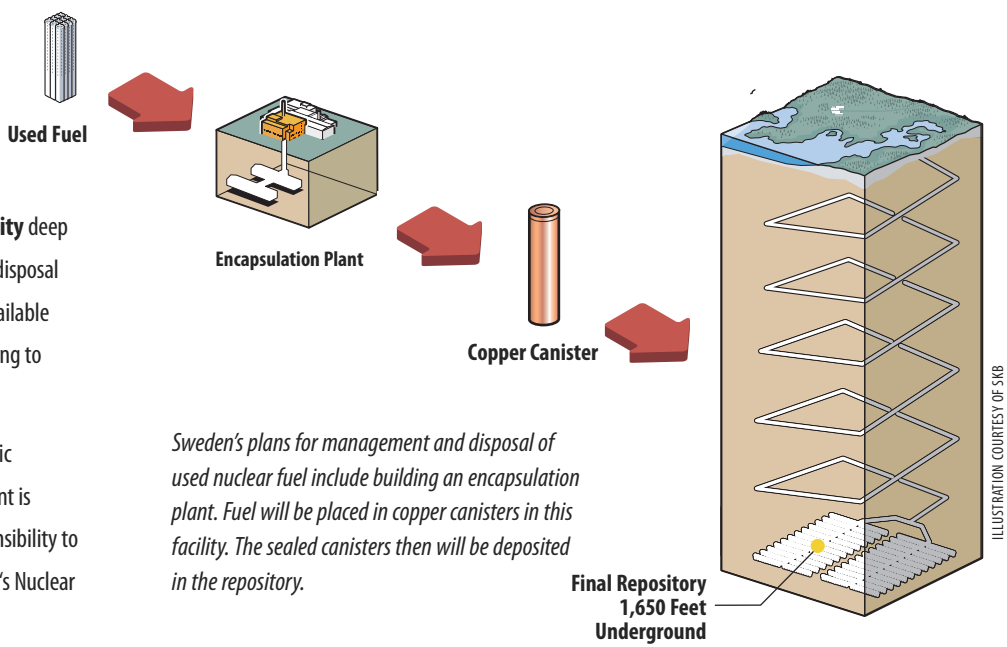


ILLUSTRATION COURTESY OF SKB

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.

Building New Nuclear Energy Facilities

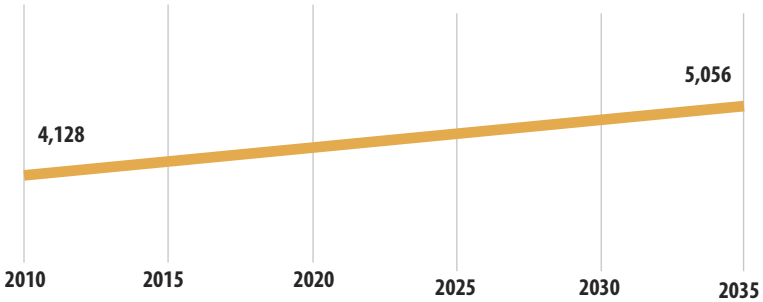
FACT Energy companies and consortia are pursuing plans to build nuclear energy facilities to help meet projected increases in U.S. electricity demand.

The United States will need 22 percent more electricity by 2035.

The U.S. Department of Energy forecasts the United States will need about 220,000 megawatts of new electric generating capacity by 2035, equivalent to 222 new large generating facilities. This rising electricity demand, along with concerns about greenhouse gases and air quality, makes new nuclear energy facilities vital to our **energy mix.** Five reactors are under construction in the United States, and the NRC is reviewing applications to build and operate 16 more reactors.

U.S. Electricity Demand Will Increase 22 Percent by 2035

(in billion kilowatt-hours)



Source: Energy Information Administration

America will need hundreds of new generating facilities to meet growing electricity demand.

More than 65 nuclear energy facilities are under construction around the world, including this Westinghouse AP1000 in China.

The federal government is planning for future electricity needs.

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

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

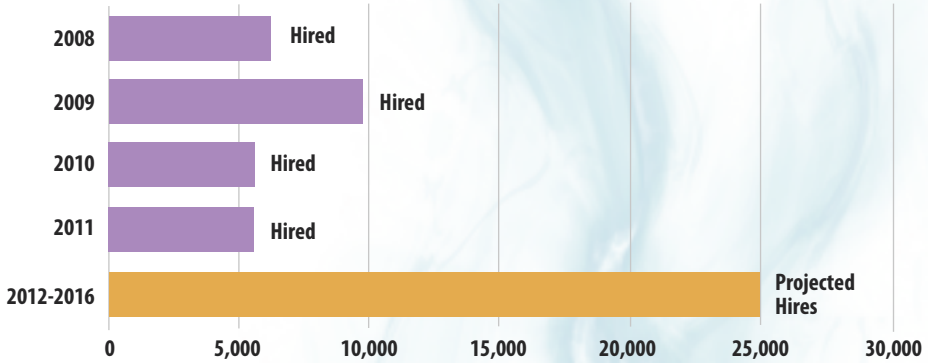
Suppliers expect they can meet the needs of the first few new reactors. They have launched new initiatives, however, to develop the **manufacturing base** for new facilities and to ensure the industry has the right construction management, engineering expertise and skilled labor needed for the future. New-reactor construction already has created **thousands of additional jobs**. Building each new nuclear energy facility will create up to 3,500 jobs at peak construction.

A steel liner for one of two reactors is being assembled at Georgia Power's Vogtle site located near Augusta.

The industry is recruiting and training the nuclear workforce of the future.

Because 39 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 workforce**. The industry has intensified its recruiting efforts to expand opportunities for women and ethnic minorities attract talented employees needed in specific professions, such as **nuclear engineering** and **health physics**.

The Nuclear Energy Industry Expect to Hire about 5,000 Workers Per Year from 2012-2016



Source: Nuclear Energy Institute

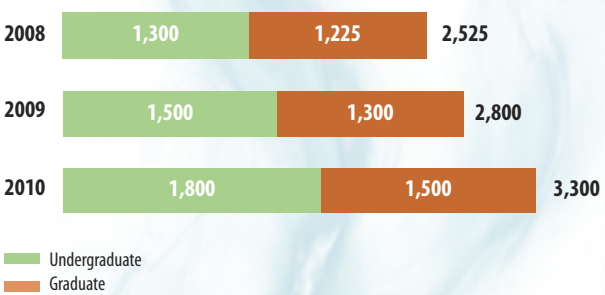
Nuclear Energy Key Statistics

FACT The nuclear industry expects to hire about 25,000 more workers in the next four years.

Industry efforts to increase the workforce are showing results.

The number of students enrolled in four-year nuclear engineering programs increased to 1,800 in 2010—the highest number since 1982. 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 energy facilities.

Nuclear Engineering Enrollment



Source: Oak Ridge Institute for Science and Education

Nuclear energy's expansion in the United States will require thousands of new skilled workers like these assembling a new steam generator.

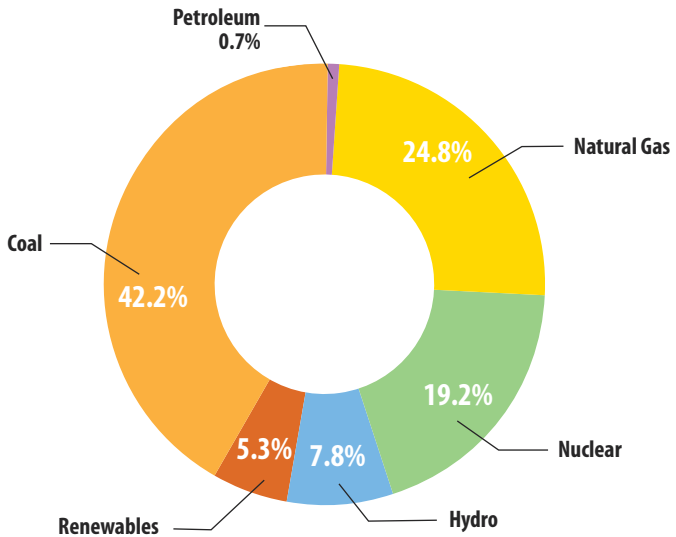
FACT In seven states, nuclear energy makes up the largest percentage of electricity production: Vermont (72%), New Jersey (52%), South Carolina (51%), Illinois (48%), Connecticut (47%), New Hampshire (41%) and Virginia (38%).

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

Each year, America's 104 nuclear energy facilities **alone** produce more electricity than does any single country from **all generating sources** except China, Japan and Russia. Efficiency gains alone have enabled nuclear energy facilities to increase output by 40 percent since 1990. Because nuclear facilities do not produce greenhouse gases, the amount of carbon dioxide emissions they prevent is more significant than all other electricity sources combined. America is the global nuclear energy industry leader in safety, regulation and technology. As a result of these factors, public opinion surveys show **strong 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



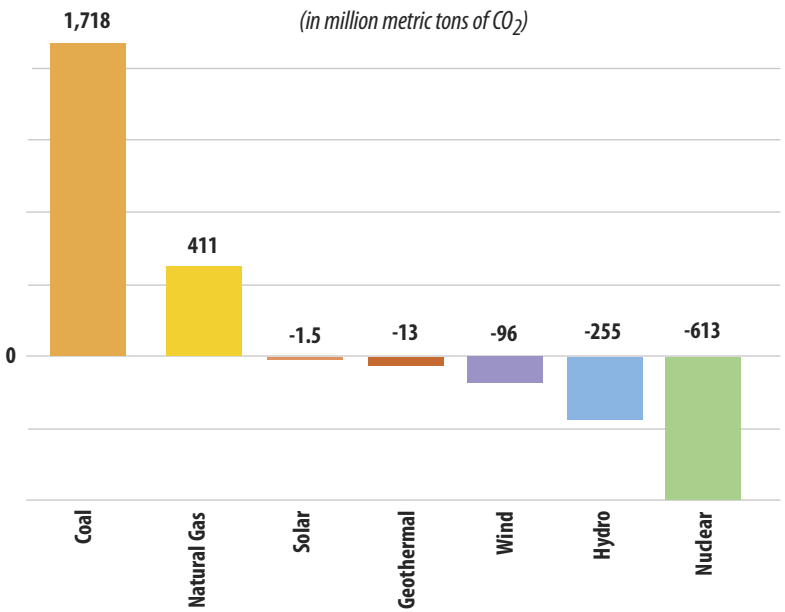
Source: Energy Information Administration, 2011

Nuclear Energy Key Statistics

FACT By more than a two-to-one margin, Americans favor the use of nuclear energy as one way to produce electricity. They see nuclear energy as important to the future.

Carbon Dioxide Emissions by U.S. Electric Power Industry (2011)

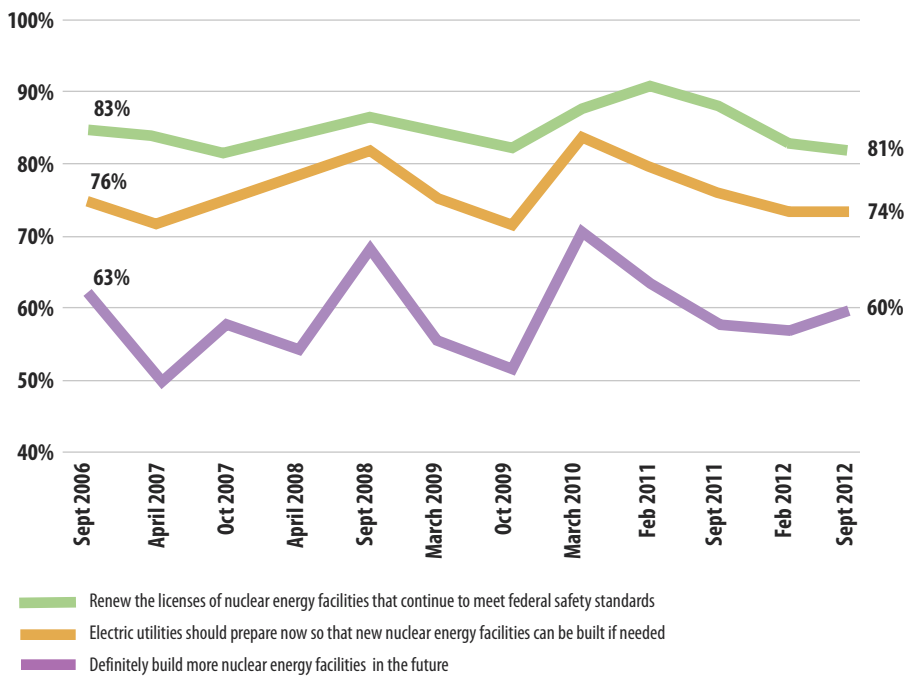
(in million metric tons of CO_2)



Source: Environmental Protection Agency/Energy Information Administration, 2011

Support for Nuclear Energy License Renewal and Building New Nuclear Energy Facilities

(Percent Who Agree)



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NEI improves the environment by reducing its carbon footprint.

The Nuclear Energy Institute is an industry policy organization that fosters the beneficial uses of nuclear technologies worldwide.

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

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