Uranium (Nuclear)

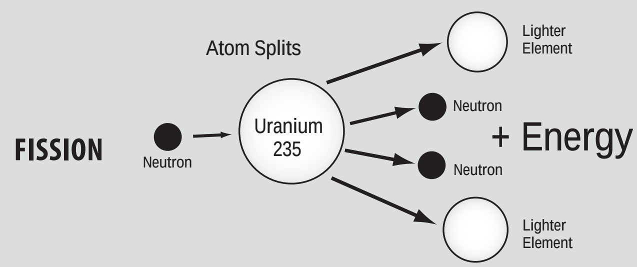
Uranium at a Glance 2008

Classification:
- Nonrenewable

Major Uses:
- electricity

U.S. Energy Consumption:
- 8.46 Q
- 8.5 %

U.S. Energy Production:
- 8.46 Q
- 11.5%



What is Uranium?

Uranium is the heaviest of the 92 naturally occurring elements and is classified as a metal. It is the fuel used by nuclear power plants for fissioning.

It is also one of the few elements that is easily fissioned. Uranium was formed when the earth was created and is found in rocks all over the world. Rocks that contain a lot of uranium are called uranium ore, or pitch-blende. Uranium, although abundant, is a **nonrenewable** energy source.

Two forms (isotopes) of uranium are found in nature, uranium-235 and uranium-238. These numbers refer to the number of neutrons and protons in each atom. Uranium-235 is the form commonly used for energy production because, unlike uranium-238, the nucleus splits easily when bombarded by a neutron. During fission, the uranium-235 atom absorbs a bombarding neutron, causing its nucleus to split apart into two atoms of lighter weight.

At the same time, the fission reaction releases energy as heat and radiation, as well as releasing more neutrons. The newly released neutrons go on to bombard other uranium atoms, and the process repeats itself over and over. This is called a chain reaction.

What Is Nuclear Energy?

Nuclear energy is energy that comes from the nucleus (core) of an atom. Atoms are the particles that make up all objects in the universe. Atoms consist of neutrons, protons, and electrons.

Nuclear energy is released from an atom through one of two processes: **nuclear fusion** or **nuclear fission**. In nuclear fusion, energy is released when the nuclei of atoms are combined or fused together. This is how the sun produces energy.

In nuclear fission, energy is released when the nuclei of atoms are split apart. Nuclear fission is the only method currently used by nuclear plants to generate electricity.

History of Nuclear Energy

Compared to other energy sources, nuclear energy is a very new way to produce energy. It wasn't until the early 1930s that scientists discovered that the nucleus of an atom is made up of protons and neutrons. Then in 1938, two German scientists split the nucleus of the atom apart by bombarding it with a neutron—a process called fission. Soon after, a Hungarian scientist discovered the chain reaction and its ability to produce enormous amounts of energy.

During World War II, nuclear fission was first used to make a bomb. After the war, nuclear fission was developed for generating electricity.

The first nuclear power plant came online in Shippingport, Pennsylvania in 1957. Since then, the industry has experienced dramatic shifts in fortune. Through the mid 1960s, government and industry experimented with demonstration and small commercial plants. A period of rapid expansion followed between 1965 and 1975.

No new plants, however, were ordered after the 1970s until recently, as a result of public opposition, as well as building costs, problems with siting a waste repository, and lower demand for power. Today, there is renewed interest in nuclear power to meet future demand for electricity and plans for new plants are underway.

Uranium Fuel Cycle

The steps—from mining the uranium ore, through its use in a nuclear reactor, to its disposal—are called the nuclear fuel cycle.

▪ Mining

The first step in the cycle is mining the uranium ore. Workers mine the ore much like miners mine coal—in underground mines or surface mines. A ton of uranium ore in the U.S. typically contains three to ten pounds of uranium.

▪ Milling

After it has been mined, uranium ore is crushed. The crushed ore is usually mixed with an acid, which dissolves the uranium, but not the rest of the crushed rock. The acid solution is drained off and dried, leaving a yellow powder called **yellowcake**, consisting mostly of uranium. This process of removing uranium from the ore is called **uranium milling**.

▪ Conversion

The next step in the cycle is the conversion of the yellowcake into a gas called **uranium hexafluoride**, or UF6. The uranium hexafluoride is then shipped to a **gaseous diffusion plant** for enrichment.

Enrichment

Because less than one percent of uranium ore contains uranium-235, the form used for energy production, uranium must be processed to increase the concentration of uranium-235. This process—called enrichment—increases the percentage of uranium-235 from one to five percent. It typically takes place at a gaseous diffusion plant where the uranium hexafluoride is pumped through filters that contain very tiny holes. Because uranium-235 has three fewer neutrons and is one percent lighter than uranium-238, it moves through the holes more easily than uranium-238. This method increases the percentage of uranium-235 as the gas passes through thousands of filters.

Fuel Fabrication

The enriched uranium is taken to a fuel **fabrication plant** where it is prepared for the nuclear reactor. Here, the uranium is made into a solid ceramic material and formed into small barrel-shaped pellets. These **ceramic fuel pellets** can withstand very high temperatures, just like the ceramic tiles on the space shuttle. Fuel pellets are about the size of your fingertip, yet each one can produce as much energy as 150 gallons of oil. The pellets are sealed in 12-foot metal tubes called **fuel rods**. Finally, the fuel rods are bundled into groups called **fuel assemblies**.

Nuclear Reactor

The uranium fuel is now ready for use in a nuclear reactor. Fissioning takes place in the reactor core. Surrounding the core of the reactor is a shell called the **reactor pressure vessel**. To prevent heat or radiation leaks, the reactor core and the vessel are housed in an airtight containment building made of steel and concrete several feet thick.

The reactor core houses about 200 fuel assemblies. Spaced between the fuel assemblies are movable **control rods.** Control rods absorb neutrons and slow down the nuclear reaction. Water also flows through the fuel assemblies and control rods to remove some of the heat from the **chain reaction**.

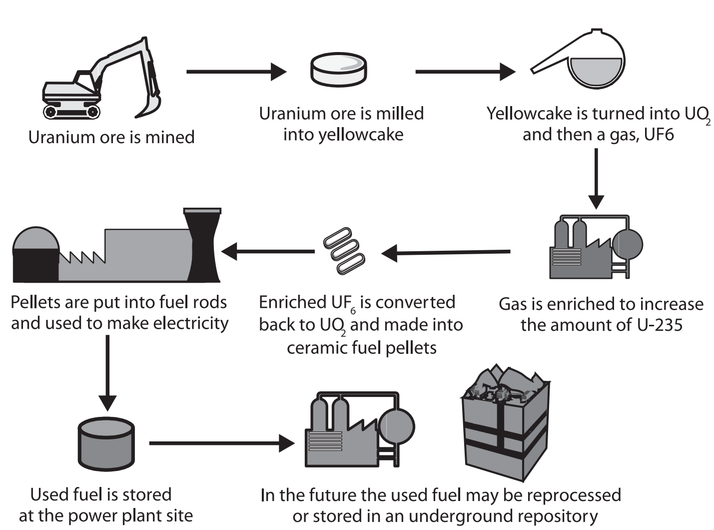
The nuclear reaction generates heat energy just as burning coal or oil generates heat energy. Likewise, the heat is used to boil water into steam that turns a **turbine generator** to produce electricity. Afterward, the steam is condensed back into water and cooled. Some plants use a local body of water for cooling; others use a structure at the power plant called a **cooling tower**.

Used Fuel Storage

Like most industries, nuclear power plants produce waste. One of the main concerns about nuclear power plants is not the amount of waste created, which is quite small compared to other industries, but the radioactivity of some of that waste. The fission process creates radioactive waste products. After about three cycles, these waste products build up in the fuel rods, making the chain reaction more difficult. Utility companies generally replace one-third of the fuel rods every 12 to 18 months to keep power plants in continuous operation.

The fuel that is taken out of the reactor is called **used fuel**. The used fuel contains both radioactive waste products and unused fuel. The used fuel is usually stored near the reactor in a deep pool of water called the used fuel pool. The used fuel cools and loses most of its radioactivity through radioactive decay. In three months, the used fuel will lose 50 percent of its radiation; in one year, 80 percent; in 10 years, 90 percent. The used fuel pool was intended as a temporary method for storing used nuclear fuel. However, there is no permanent storage solution yet for used nuclear fuel, and fuel pools space is running out. The nuclear industry has designed dry cask storage as another temporary solution. Now, the used fuel stays in the pool for five to seven years. Then, it is moved elsewhere on the nuclear power plant site to be stored in vaults or dry casks. Each of these methods for managing used nuclear fuel puts the fuel into airtight, steel and concrete structures. The U.S. Nuclear Regulatory Commission has stated that it is safe to store used fuel on site for at least 120 years. Eventually, the used fuel will be reprocessed and/or transported to a permanent federal disposal site.

URANIUM FUEL CYCLE



Reprocessing

Used fuel contains both radioactive waste products and unused nuclear fuel. In fact, about one-third of the nuclear fuel remains unused when the fuel rod must be replaced. Reprocessing separates the unused nuclear fuel from the waste products so that it can be used in a reactor again.

Currently, American nuclear power plants store the used fuel in used fuel pools—without reprocessing. Reprocessing is more expensive than making new fuel from uranium ore. If uranium prices rise significantly or storage becomes a bigger problem, reprocessing may gain favor.

Used Fuel Repository

Most scientists believe the safest way to store nuclear waste is in rock formations deep underground—called geological repositories. In 1982, Congress passed the **Nuclear Waste Policy Act**. This law directed the Department of Energy to site, design, construct, and operate America's first repository by 1998. This didn't happen.

The same law also established the Nuclear Waste Fund to pay for a permanent repository. People who use electricity from nuclear power plants pay 1/10 of a cent for each kilowatt-hour of electricity they use. An average household, which uses about 7,500 kilowatt-hours a year, contributes $7.50 a year to the fund.

In 2002, the U.S. Congress voted to designate Yucca Mountain in Nevada as the proposed national repository for used fuel.

What is RADIATION?

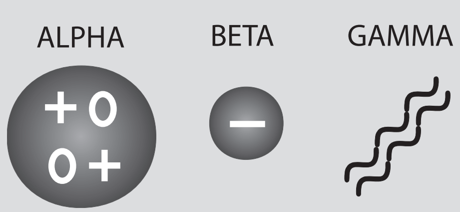
Radiation is energy released by atoms. It is very powerful and moves very fast. Not all atoms are radioactive. Some atoms—the radioactive ones—have more neutrons than protons, making them unstable. In a natural process called radioactive decay, these atoms give up their extra neutrons and become stable.

Radiation cannot be touched, seen, or heard, but it is around us all the time. Natural sources of radiation include cosmic rays from outer space, minerals in the ground, and radon in the air. Man-made sources of radiation include the x-ray equipment used by doctors, smoke detectors, color television sets, and luminous dial clocks. Nuclear waste is another kind of man-made radiation that usually contains higher than natural concentrations of radioactive atoms.

Atoms emit radiation in the form of tiny particles, called alpha and beta radiation, and in the form of rays, called gamma radiation. **Alpha radiation** is the slowest moving type of radiation and can be blocked by a sheet of paper or the outer layer of skin on your body. **Beta radiation** is faster and lighter than alpha radiation and can pass through about an inch of water or skin. **Gamma radiation** is different from alpha and beta radiation because it is an electromagnetic wave, just like radio waves, light, and x-rays. Gamma radiation has no weight and moves much faster than alpha and beta radiation. It takes several inches of lead, several feet of concrete, or a large amount of water to stop gamma rays. It can easily pass through the human body as medical x-rays do.

Alpha, beta, and gamma radiation are called ionizing radiation because they can produce electrically charged particles, called **ions**, in the things that they strike. (Visible light and radio waves are non-ionizing forms of radiation.) Ionizing radiation can be harmful to living things because it can damage or destroy cells. The used fuel from nuclear power plants is called high-level nuclear waste because of its dangerous levels of radiation.

The unit used to measure radiation is the **rem** and **millirem** (1/1000 of one rem). The average American is exposed to about 360 millirem a year from natural and man-made sources, a harmless amount. About 260 millirem of this total comes from natural (background) sources of radiation such as soil, rocks, food, and water. Another 55 millirem comes from medical x-rays and about 10 millirem from a variety of sources including mineral mining, burning fossil fuels, and such consumer products as color television sets and luminous dial clocks. Radiation emitted from nuclear power plants accounts for only a tiny amount of exposure, only about .01 millirem of exposure per year.



The Department of Energy (DOE) originally looked at Yucca Mountain, Nevada to be the site of a national used nuclear fuel repository. In 2002, after many tests and studies Congress and President George W. Bush approved **Yucca Mountain** as the repository site. In 2008 an application was submitted to the Nuclear Regulatory Commission to move forward with building the repository. Some people supported the site at Yucca Mountain as a safe site for used nuclear fuel. However, some people living in Nevada were worried about possible safety hazards and did not want the repository in their state.

In 2010, the DOE withdrew its Yucca Mountain application with the intention of pursuing new long-term storage solutions. A Blue Ribbon Commission was formed in January 2010. The commission's job is to provide recommendations for managing used nuclear fuel in the United States. Until a final storage solution is found, nuclear power plants will continue storing used fuel at their sites in used fuel pools or dry cask storage.

Nuclear Energy Use

Nuclear energy is an important source of electricity—third after coal and natural gas—providing 19.6 percent of the electricity in the U.S. today. There are 104 nuclear reactors in operation at 65 power plants. No new plants are under construction in the U.S. at this time, though several are in planning stages.

Worldwide, however, nuclear energy is a growing source of electrical power. New plants are going on-line each year with many more were under construction. Nuclear energy now provides about 18 percent of the world's electricity. The U.S., France, Japan and Germany are world leaders. France generates 75 percent of its electricity with nuclear power.

Licensing Nuclear Power Plants

Nuclear power plants must obtain permits to start construction and licenses to begin operation. Researchers conduct many studies to find the best site for a nuclear power plant. Detailed plans and reports are submitted to the Nuclear Regulatory Commission, the federal government agency responsible for licensing nuclear power plants and overseeing their construction and operation.

When the builders of a nuclear power plant apply for a license, local hearings are held so people can testify and air their concerns and opinions. After a plant is built, the **Nuclear Regulatory Commission** places inspectors at the site to assure the plant is operating properly.

Economics of Nuclear Energy

The cost of electricity from nuclear energy is somewhat higher than the cost of electricity from coal. Much of the cost of producing electricity at a nuclear plant comes not from the fuel source—uranium is a very small part of the operating cost—but from the cost of building and monitoring the plant. Nuclear plants have very high up-front costs because of the licensing, construction, and inspection requirements.

If you consider only the fuel costs and operating costs, nuclear electricity is about two cents per kilowatt-hour (kWh). In comparison, the cost of producing electric power from new coal plants is approximately four cents per kWh.

Uranium is an abundant natural resource that is found all over the world. Because uranium is an extremely concentrated fuel source, it requires far less mining and transportation than other fuel sources for the energy it furnishes. At current rates of use, uranium resources could last more than 500 years. A process called **breeding**, which converts uranium into plutonium—an even better fuel—could extend uranium reserves for millions of years. Breeder reactors were tested in France, but they are not planned for use in this country.

Nuclear Energy and the Environment

Nuclear power plants have very little impact on the environment. Generating electricity from nuclear power produces no air pollution because no fuel is burned. Most of the water used in the cooling processes is recycled.

In the future, using nuclear energy may become an important way to reduce the amount of carbon dioxide produced by burning fossil fuels and biomass. Carbon dioxide is considered the major greenhouse gas.

People are using more and more electricity. Some experts predict that we will have to use nuclear energy to produce the amount of electricity people need at a cost they can afford.

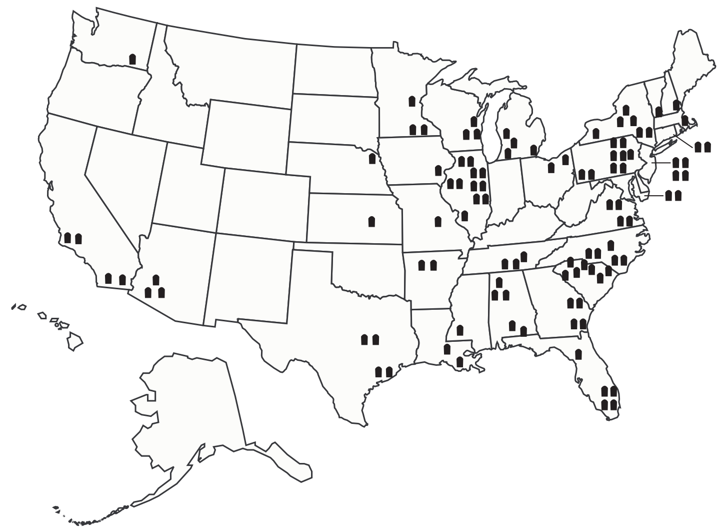
Whether or not we should use nuclear energy to produce electricity has become a controversial and sometimes highly emotional issue.

URANIUM Prices

The United States has an abundant supply of domestic uranium. Today, however, about 80 percent of the uranium used in the U.S. is imported. This high level of import is the result of low uranium prices in other countries. Prices are expected to rise sharply in the future, but energy experts do not expect rising uranium prices to have a significant effect on the cost of electricity from nuclear power plants, because the cost of uranium fuel is such a small percentage of the total cost of operating the power plants.

U.S. NUCLEAR POWER PLANTS

Location of Nuclear Power Reactors in the United States



NUCLEAR Safety

The greatest potential risk from nuclear power plants is the release of high-level radiation. In the United States, plants are carefully designed to contain radiation, and emergency plans are in place to alert and advise nearby residents if there is an accident.

Two serious accidents have occurred since the industry began over 30 years ago—Three Mile Island in the U. S. (1979) and Chernobyl in the Ukraine (1986). At Three Mile Island, about half the uranium fuel melted when water to the reactor core was inadvertently cut off. A small amount of radioactive material escaped into the surrounding area before the mistake was discovered. But due to the safety design features of the plant—multiple barriers contained most of the radiation—no one was injured or died as a result of this accident.

The accident at Chernobyl was far more serious. It happened when two explosions blew the top off the reactor building. A lack of containment structures and other design flaws caused the release of a large amount of radioactive material into the surrounding area. More than 100,000 people were evacuated from their homes and about 200 workers were treated for radiation sickness and burns; 31 of them died.

Could a Chernobyl–type accident occur at an American nuclear power plant? Many experts say no. Old nuclear plants like the one in Chernobyl do not have the safety systems and containment chambers that are standard on all American plants. Ukraine officials closed the last reactors still in operation at Chernobyl in December 2000. The U. S. has pledged funding to help clean up the remaining contamination.