Nuclear Energy

Definition of Nuclear Energy

Nuclear energy is energy released from an atom's nucleus when a small amount of mass is converted to energy during atomic fission or fusion according to the famous Einstein equation $E=mc^2$ or energy equals mass times the speed of light squared.

All matter is composed of atoms. Inside the atom, the protons and neutrons of the nucleus are bound together by the nuclear force, a strong energy bond. Very large atoms like uranium are bound less tightly than smaller atoms like iron or krypton, so when uranium is split up in a reactor, the difference in energy is released and can make steam to drive a turbine. Once water is heated to steam the energy production process is the same as a coal, gas, or wood fired electricity generator.

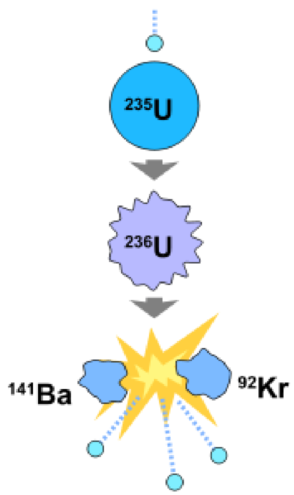
How is nuclear energy obtained?
Nuclear energy can be released from the nucleus of an atom through fission, or splitting the atom's nucleus. Nuclear energy can also be released through fusion, or combining atoms. However, the world's scientists have not yet perfected a method for harnessing nuclear fusion or power generation. It is an area of current research.

What is nuclear energy used for?
In the U.S., nuclear energy is solely used for electricity generation. As of 2006, 19% of the electricity consumed by the U.S. came from nuclear energy. In France and Japan the majority of the electricity produced is from nuclear power plants.

Brief History of Nuclear Energy

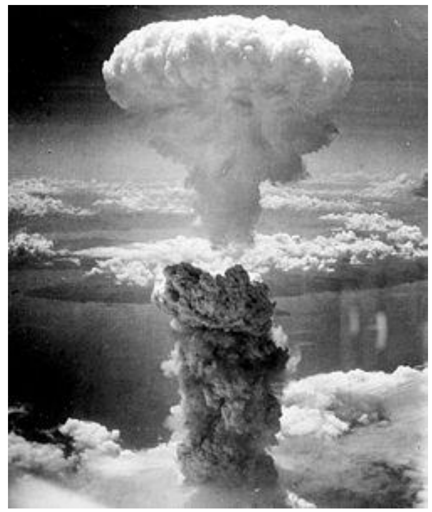
Compared to other energy sources which have been used for centuries, nuclear energy is much newer.

Scientific Discoveries



In 1938, two German scientists bombarded an atom's nucleus with a neutron and split the atom. Shortly thereafter, a Hungarian scientist discovered that the process of splitting the atom, or fission, could generate lots of energy via a chain reaction in which the extra neutrons given off by each fission reaction strike other uranium atoms to cause them to split and continue to react.

Nuclear for Weaponry



During World War II, the United States, Britain and Canada used fission to develop nuclear weapons for the war. The codename for this work was the Manhattan Project. It yielded the world's first nuclear bombs which were used at Hiroshima and Nagasaki. After the war ended, scientists began investigating peaceful uses of nuclear energy.

Nuclear for Electricity

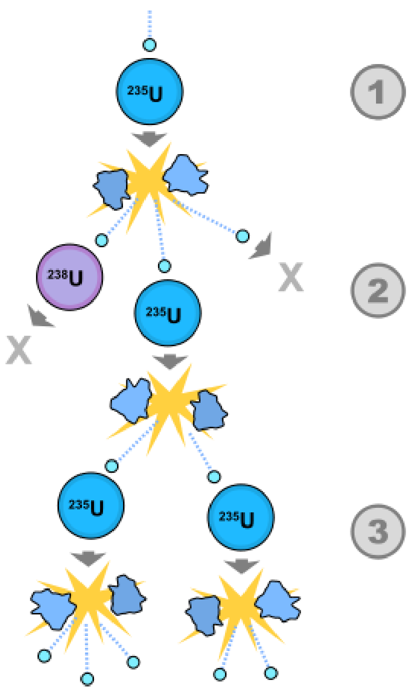
In 1954, the Obninsk Nuclear Power Plant opened in the USSR. It was the world's first nuclear power plant. It could produce about 5 megawatts of electricity which is supplies to the utility grid. In 1957, the Shippingport Atomic Power Station (pictured above) opened in the USA. It was the first US commercial reactor.

During the last third of the 20th century, a general movement against nuclear power has risen based on the fear of a possible nuclear accident as well as the history of accidents at Three-Mile Island in Pennsylvania and at Chernobyl in the Soviet Union (now Ukraine). However, with the Obama administration, there is now renewed interest in nuclear energy.

Nuclear Fusion vs. Nuclear Fission

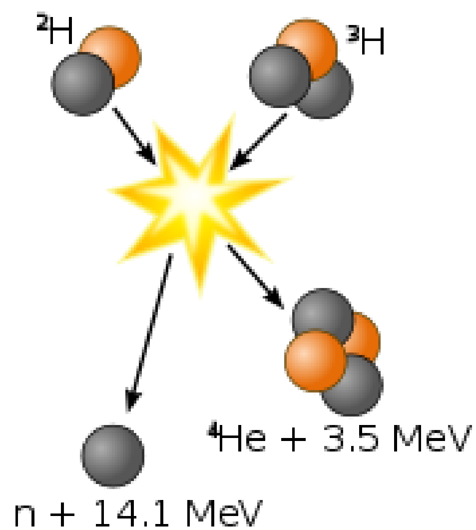
Nuclear energy is released by an atom's nucleus. During nuclear fission, the nucleus of an atom is split and energy is released. During nuclear fusion, nuclei combine and energy can also be released.

Fission



When large fissile atoms, usually uranium 235 or plutonium 239, absorbs a neutron, a fission of the atom often results. Fission splits the atom into two or more smaller nuclei and also releases gamma radiation and free neutrons. Some of the neutrons produced can be absorbed by other fissile atoms, which split and release more neutrons sustaining a chain reaction. The self-sustaining chain reaction can be controlled and used to heat water to steam and drive a turbine to produce electricity.

Fusion



Nuclear fusion occurs in stars like our sun. The sun's energy is produced from the fusion of two hydrogen nuclei to create a helium atom and energy. Nuclear fusion is the name for the general process where two or more atomic nuclei fuse together to make a heavier nucleus, a new element. When light nuclei fuse, energy is released until a nucleus reaches the size of iron. Beyond that, it requires energy to create larger atoms, which is why fission releases energy from the spliting of very large atoms. Controlled nuclear fusion has yet to be achieved by scientists for electricity production.

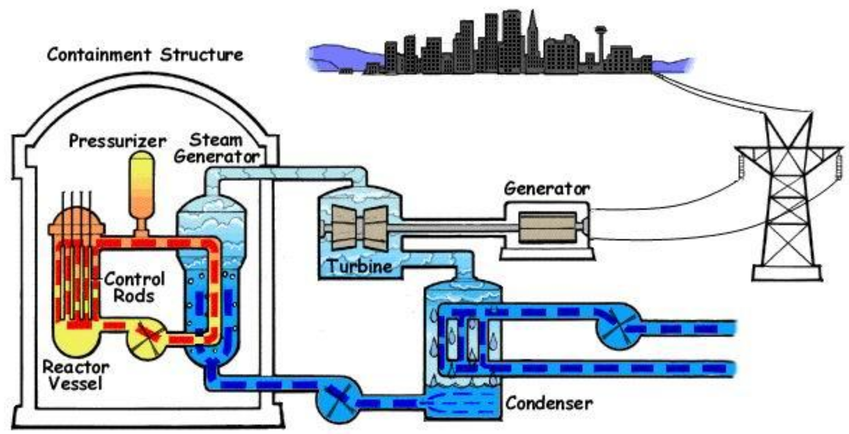
Nuclear Power Plants

Nuclear power plants convert the thermal energy released from the fission of the nucleus of an atom into electricity.

The self-sustaining *chain reaction of nuclear fission* can be controlled using control rods and a water bath as a modulator that slows and absorbs some neutrons; this controls the rate of more fissions.	A *cooling system* removes heat from the reactor core and transports it to another area of the plant, where the hot coolant can be used to produce electricity.	The *emitted water* is either sent into cooling towers where it released as condensed water droplets (like a cloud) or is discharged into, lakes, rivers, or oceans.

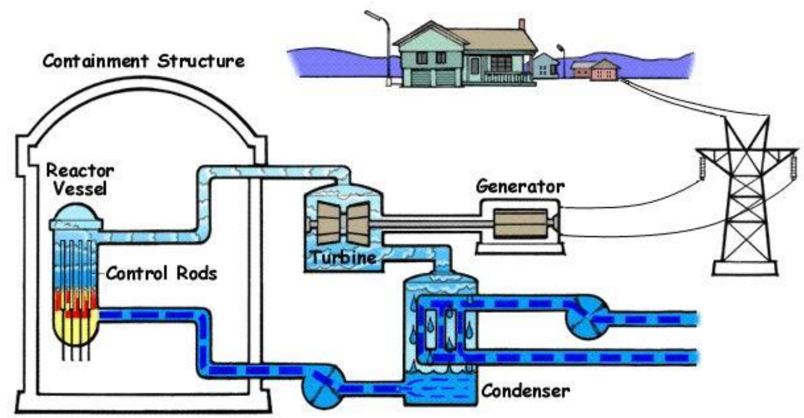
Nuclear power plants that use heat from nuclear fission reactions rely on one of two reactor types.

Pressurized Water Reactor (PWR)



The more common reactor type is a pressurized water reactor. Pressurize water is pumped to the reactor vessel where it becomes heated. The superheated water passes through the coolant system where steam is generated to drive the turbine.

Boiling Water Reactor (BWR)



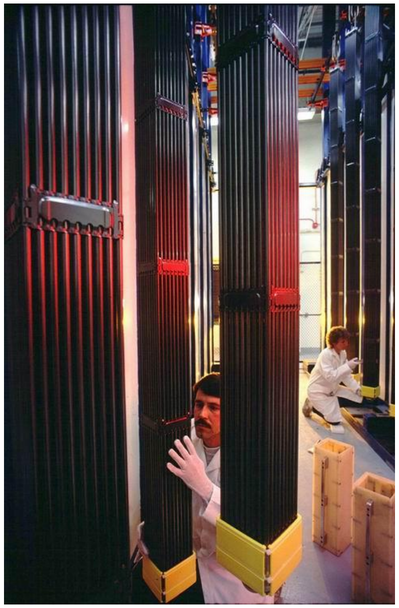
The less common reactor type is a boiling water reactor. There is no separate coolant system. Rather, the heat from the fission reactions directly heats the cooling waters. Eventually, the water boils producing steam to turn the turbine.

Nuclear Fuel

Naturally occurring uranium is processed into nuclear fuel rods. The current amount of uranium is abundant, however, reprocessing of spent fuel rods can greatly extend the Earth's uranium fuel supply.

Uranium is an element found in the Earth's crust. Uranium is approximately as common as tin and is about 35 times more common than silver. Uranium is a trace constituent of most rocks, dirt, and of the oceans but can only be mined economically where there is a large concentration ore. At today's prices, there is enough mineable uranium to supply reactor fuel for another century.

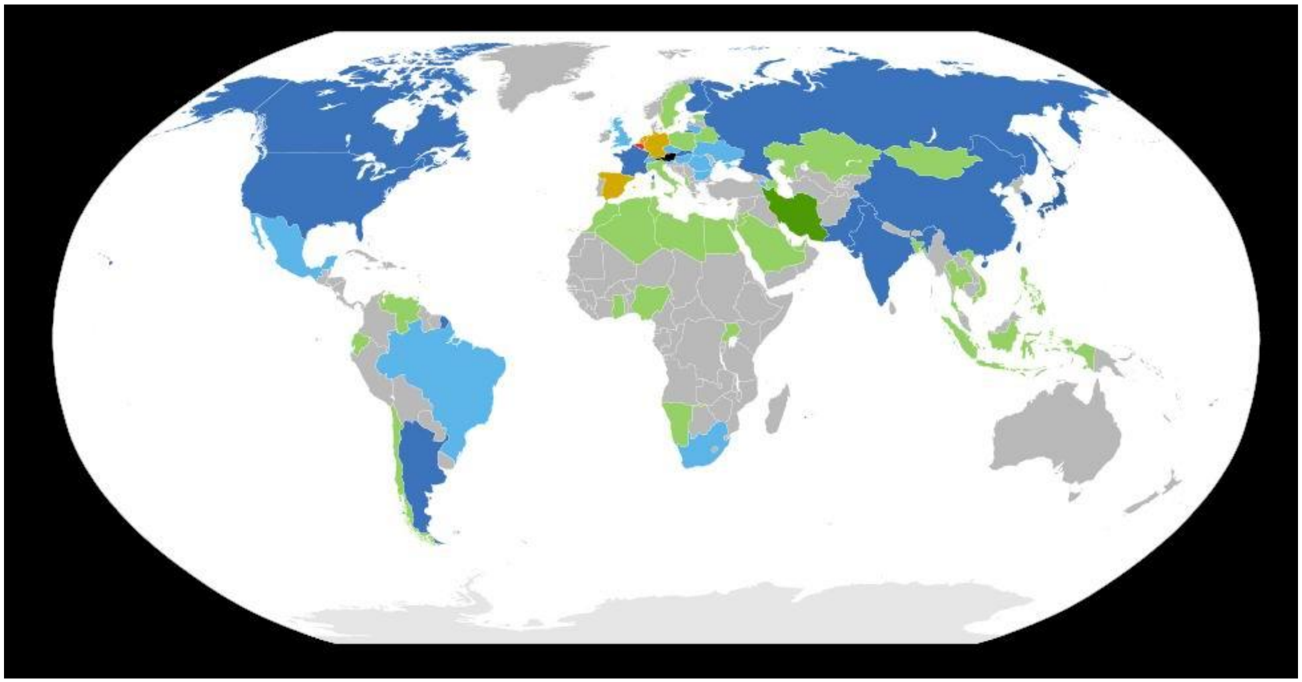
Uranium ore is processed into yellowcake and converted to uranium hexafluoride, which is then enriched using various techniques. At this point, the enriched uranium, containing more than 0.7% U-235, is used to make rods of the proper composition and geometry for the particular reactor that the fuel is destined for.



The fuel rods typically spend 5-6 years inside the reactor until about 3% of their uranium has been fissioned. The spent rods are then moved to a spent fuel pool where the short-lived isotopes can decay away. After about 5 years in a cooling pond, the spent fuel is radioactively and thermally cool enough to handle, and it can be moved to dry storage casks or reprocessed.

Global Use of Nuclear Energy

Different countries have different attitudes about using nuclear energy. Many countries use—or are planning to use—nuclear reactors. Yet, some countries are ready to shut down their reactors.



The status of nuclear power globally:

- Operating reactors, building new reactors
- Operating reactors, planning new build
- No reactors, building new reactors
- No reactors, planning new build
- Operating reactors, stable
- Operating reactors, considering phase-out
- Civil nuclear power is illegal
- No reactors

As of 2005, 15% of the world's electricity was provided by nuclear power. The majority of nuclear generated electricity comes from the U.S., France, and Japan.

As of 2006, the most nuclear energy was produced by the United States. However, France uses nuclear reactors for a higher percentage of its total electrical production.

As of 2007, reports showed that 439 nuclear power reactors were operating around the world. These reactors were spread over 31 countries.

Environmental Problems of Nuclear Power Plants

The safe storage and disposal of nuclear waste remains a significant challenge and yet unresolved problem.

A large nuclear reactor produces 25–30 tons of spent fuel each year. It is primarily composed of unconverted uranium and about 3% of it is made of fission products. The unfissioned uranium, plutonium, and curium are responsible for the bulk of the long-term radioactivity, whereas the fission products are responsible for the bulk of the short term radioactivity.

As of 2007, the U.S. had accumulated more than 50,000 metric tons of spent nuclear fuel from nuclear reactors. After 10,000 years of radioactive decay, according to U.S. Environmental Protection Agency standards, the spent nuclear fuel will no longer pose a threat to public health and safety. Underground storage at Yucca Mountain was proposed as permanent storage and extensive geologic assessment of the site was conducted. Because of controversy over spending several decades and billions of dollars to build the Yucca Mountain facility, the Obama administration went on record to state that Yucca Mountain will not open as a high level radioactive waste repository.

In the United States, the nuclear power industry generates approximately 2,000 tons of solid waste annually. In comparison, coal fueled power plants produce 100,000,000 tons of ash and sludge annually and this waste is laced with dangerous substances also such as mercury and nitric oxide.

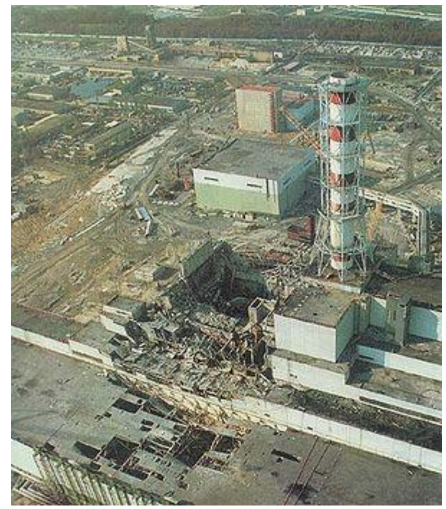
Nuclear Accidents

The term *meltdown* refers to the melting of the fuel in the reactor. There have only been two cases of significant fuel melting: Three Mile Island in Pennsylvania and at Chernobyl in the Ukraine. Only in the case of Chernobyl were there significant offsite radiation releases.

Three Mile Island: On March 28, 1979, a minor malfunction led to a series of errors at the Three Mile Island nuclear power station just outside Harrisburg, Pennsylvania. The malfunction shut down the main and emergency cooling systems for a while.

The residual heat of the nuclear wastes melted part of the core. The billion-dollar reactor was a total loss, but the worst damage was probably to the public's trust in the safety of nuclear power. Still, the reactor vessel was not breached and the second line of defense—the heavy concrete "containment building"—also remained intact.

Chernobyl: On April 26, 1986, an unwise engineering experiment at low power got out of control at the Chernobyl power reactor near Kiev, the capital of the Ukraine. The power level surged, the reactor vessel burst, hot steam exploded, and generated hydrogen mixed with oxygen of the atmosphere to produce an intense fire.



This was a big reactor and it was not encased in a containment building. The plume of the intense fire rose to high altitudes and spread radioactive debris over a wide area. Towns and villages near Chernobyl had to be evacuated and agricultural produce over much of Europe was contaminated. The remains of the reactor were later encased in a thick cover of concrete to entomb the radioactive waste left inside. In the last 24 years, the natural ecosystem has returned to the area and thrives more actively than it had for over a century prior to the meltdown. This is because people were evacuated from the area and no longer disturb the plants and animals. If the people return, they may again be a threat to the ecosystem.

Benefits and Challenges of Nuclear Energy

BENEFITS

Nuclear energy offers significant benefits, which include:

- Nuclear energy is clean; it does not pollute the water or air. It does not emit greenhouse gases like coal and oil power plants.
- Nuclear power technology exists and does not have to be developed.
- It is possible to generate lots of electricity from a single nuclear power plant.

CHALLENGES

There are challenges to using nuclear energy, which include:

- The waste from nuclear energy is extremely dangerous. It has to be carefully stored for thousands of years.
- Though the probability is small, if an accident happens at a nuclear power plant, the results can be catastrophic.
- During the operation of nuclear power plants, radioactive waste is produced which, in turn, can be used for the production of nuclear weapons.