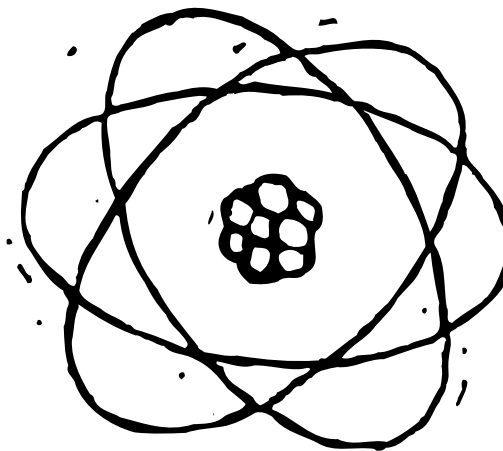


# Facts about Nuclear Energy

## Introduction

A recent revival on the energy scene, nuclear energy is associated with the promise of vast quantities of energy. It is also associated with health issues and environmental problems due to radiation and nuclear waste disposal. Despite the controversy surrounding it, nuclear energy supplies a significant amount of electricity for Wisconsin, the United States, and the world.



## Uranium

Mineral ores contain uranium in the form of uranium oxide. Two types of uranium atoms, called isotopes, are found in these ores: uranium-235 ( $U^{235}$ ) and uranium-238 ( $U^{238}$ ). Of these two, only  $U^{235}$  can undergo nuclear fission. However, 99.3 percent of naturally occurring uranium is  $U^{238}$  while only 0.7 percent is  $U^{235}$ .

Generally, foreign ores have a higher uranium content than those found in the United States. Ores found in the United States contain from 0.05 to 0.3 percent pure uranium. The uranium content of foreign ores ranges from 0.035 percent in southern Africa to 2.5 percent in northern Saskatchewan, Canada.

## Nuclear Fission

Nuclear energy can be obtained by a process called nuclear fission (or simply “fission”). Fission occurs when a neutron splits the nucleus of a  $U^{235}$  atom into two smaller nuclei, releasing energy and additional neutrons. The extra neutrons then split other  $U^{235}$  nuclei, releasing still more neutrons that split more  $U^{235}$  nuclei, and so on. This process is called a nuclear chain reaction.

A nuclear chain reaction cannot take place using naturally-occurring uranium. Nuclear power plants use fuels with a mixture of 3 percent  $U^{235}$ ; this fuel is produced from natural ores by an enrichment process. Nuclear fuel can produce immense amounts of energy. One kilogram of  $U^{235}$  can produce two to three million times the energy of one kilogram of coal.

## Nuclear Power Plants

In a nuclear power plant, energy from nuclear fission is produced in the reactor. A nuclear reactor is made up of the fuel assemblies, control rods, a moderator, a cooling tower, and the pressure vessel.

The fuel assemblies, control rods, and cooling system make up the reactor’s core.  $U^{235}$  in the fuel assemblies undergoes fission, releasing neutrons and large amounts of heat. Control rods are moved up and down between the fuel assemblies to absorb some of the neutrons, thereby regulating the rate of fission. A moderator, such as graphite, slows down the neutrons so that the fission reaction is more efficient. A coolant circulates through the reactor’s core to remove the heat so that it can be used to make steam in another part of the plant. The steam spins a turbine connected to a generator that produces electricity.

The core is surrounded by the pressure vessel, which is located inside the containment building, a structure made of thick concrete reinforced with steel bars.

A special type of nuclear reactor called a fast breeder reactor converts  $U^{238}$  into plutonium ( $Pu^{239}$ ) while also

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producing electricity. Because plutonium is fissionable, breeder reactors could greatly increase the amount of usable nuclear fuel. Breeder reactor projects were once considered in Germany, the United Kingdom, Japan, and the United States but research has since been discontinued due to the extreme risk in extracting plutonium and the cost of developing the reactors.

## Electricity Production

There were 61 nuclear power plants with 99 reactors located in 30 states in 2016. Combined they produced 805.3 kWh of electricity in the United States in 2016, close to 20 percent of the nation's electricity. Nuclear power plant construction ceased in the late 1990's, but has rebounded and several new power plants are ordered and at the same time many existing plants have been extended to continue operations.

The United States has more nuclear capacity than any other country in the world. France has the second, Russia the third, and South Korea the fourth. In 2016, 63 reactors are under construction in 15 countries throughout the world, mostly in the Asian region. Nuclear power capacity worldwide has been increasing steadily.

Wisconsin utilities currently have two nuclear power units, both at Point Beach in Two Rivers, Wisconsin. These units produce about one-sixth of all electric power in Wisconsin. There are now 444 operable civil nuclear power reactors around the world.

## Uranium Reserves

Uranium reserves are described in terms of how much it costs per pound to mine the ore. Ores with a high concentration of uranium cost less to mine than those with low concentrations. The U.S. Department of Energy estimates that there were about 66 million pounds of \$30 per pound uranium reserves and 362 million pounds at up to \$100 per pound uranium reserves in the United States in 2015. (Plutonium from decommissioned weapons can also be used as a nuclear fuel).

U.S. uranium deposits in 2014 were over 207,400 tons of uranium, which is 4 percent of the world reserves. Wisconsin, however, has no known reserves. Other countries with major reserves include Australia, Kazakhstan, Canada, Russia, and South Africa.

## Mining and Processing Uranium

Most uranium ore is mined using surface mining, also called "open mining." At a mill near the mine the ore is crushed and ground and the uranium oxide is chemically extracted. This yields uranium concentrate, also referred to as yellowcake. The ore, rocks, and soil left over after mining and milling are called tailings. The tailings contain radioactive materials and must be buried.

Other types of mining include underground mining, in situ leach (ISL) mining (where fortified groundwater is pumped into the aquifer, dissolving the uranium from the host sand), and heap leaching.

Trucks or trains then ship the uranium concentrate to a chemical plant where it is converted into a gas. This gas is then enriched, which increases the amount of  $U^{235}$  in the uranium mixture from 0.7 percent to 3.5-5 percent.

After enrichment, the gaseous uranium compound is converted into ceramic fuel pellets. The pellets, which are the size of a fingertip, are sealed inside metal tubes called fuel rods. Each 12- to 14-foot fuel rod contains about 200 pellets. Fuel rods are bound together in assemblies, each containing about 240 rods. Trucks or trains transport finished fuel assemblies to a nuclear power plant.

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## Other Uses

Nuclear energy is widely used in the military to power submarines and aircraft carriers. Nuclear power plants aboard naval vessels offer great reliability and allow ships and submarines to sail for long periods of time without refueling. Nuclear weapons use  $U^{235}$  or plutonium to produce nuclear explosions. Nuclear energy also has important uses in medical diagnosis and treatment.

## Effects

Nuclear energy has some important benefits. Because large amounts of energy can be obtained from a small amount of  $U^{235}$ , some of the environmental effects of mining uranium for energy are not as great as they are for coal. Also, nuclear power plants do not produce air pollutants or release carbon dioxide (a cause of global climate change) into the atmosphere. Some experts believe that nuclear energy is better able to meet the world's growing demand for energy than fossil fuels or renewable energy resources.

The main disadvantage of nuclear energy is that uranium and the waste materials produced from nuclear fission are radioactive. Radioactive materials emit alpha and beta particles and gamma rays, which can harm living cells. Radioactive materials are present in the mining, production, and transportation of nuclear fuel; in the operation of nuclear power plants; and in nuclear waste. Transportation is one of the most serious concerns related to nuclear energy use. After the fuel is mined, it needs to be transported to the plant and after the fuel is spent, it is transferred to the storage site. Transporting the fuel many miles to a permanent storage site adds even more risk and complications. On a global scale, there is fear associated with countries exporting and importing fuel by sea and by air. All these operations must be designed and managed to protect the environment from the release of radioactive materials. This often requires expensive and complex technology.

Although nuclear power plants are designed with many safety protocols to prevent releases of radiation, accidents at the Three Mile Island power plant in the United States in 1979 and the Chernobyl plant in the Ukraine in 1986, as well as the Fukushima plant in Japan in 2011, increased public concern about their safety. Safer nuclear reactors have been designed and tested, and are being put into use today.

Radioactive waste is classified as one of the following: Exempt waste; very low-level waste, low-level waste, intermediate-level waste, or high level waste. Low-level waste, for example, contains a small amount of radioactivity within a relatively large amount of material. These wastes include tools, equipment, and protective clothing exposed to radioactive materials. They must be stored in steel drums and buried for several decades until their radioactivity decreases to a safe level. The U.S. government has burial sites for low-level wastes in Barnwell, South Carolina; Richland, Washington; Clive, Utah; and Andrews, Texas.

Nuclear fuel from power plants is an example of a high-level waste. These wastes are extremely hazardous and must be safely stored for thousands of years until their radioactivity decreases to a safe level.

New research in reusing radioactive wastes is being conducted. It may be feasible at some point in time to remove the uranium, plutonium, and minor actinides for recycling in a fast breeder reactor. Currently, however, this recycling of radioactive wastes is not available on a commercial scale.

In the U.S., no permanent storage site for high-level waste exists. Currently, all nuclear power plants in the U.S. store their spent nuclear fuel in steel-lined concrete pools. These are temporary facilities near the plant; some of which are nearly full. Storing wastes deep underground is the option most likely to be used in the near future. The wastes would be sealed in metal canisters and buried about half a mile underground in a

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location where earthquakes do not occur and contact with groundwater is avoided. (However, it is difficult to predict whether an underground site will be geologically stable for thousands of years). Yucca Mountain in southern Nevada has been the leading candidate for a permanent disposal site since the 1980s. Studies of the area have been conducted to ensure the repository would be safe and environmentally sound for a one-million-year period of waste isolation. No final decision has been made about use of the site as of 2017.

## Outlook

Nuclear energy has some important benefits. Because large amounts of energy can be obtained from a small amount of  $U^{235}$ , some of the Reserves of uranium will last for the projected lifetimes of the world's current nuclear power plants. Because only a small fraction of uranium is  $U^{235}$  (0.7 percent), uranium reserves are only thought to be enough to last about 90 years. However, new technologies could potentially extend this outlook past 200 years supply.

The expense and complexity of nuclear power plants and concerns about radiation exposure, disposal, and long-term safe containment of nuclear wastes have led many people to oppose nuclear energy. On the other hand, nuclear energy does not add pollutants or carbon dioxide to the atmosphere. It can also meet the world's growing demand for energy. Nuclear energy will continue to be used to produce electricity in the near future, but its long-term fate is somewhat uncertain.

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# Nuclear Power Plant Diagram

