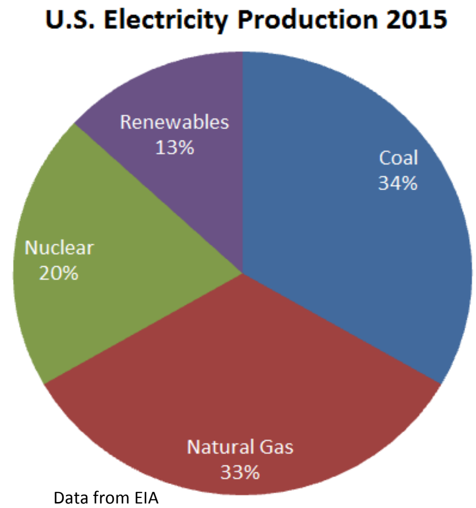
# Youth Education & Interpretation It's in Our Nature

## Energy Producing Systems: Nuclear Power

Nuclear energy involves harnessing the power of the atom. Atoms are the fundamental building blocks of matter and are composed of protons, neutrons and electrons. The forces that hold the central part (nucleus) of the atom together are immense. Two processes are possible that can release this energy. A **nuclear fusion reaction** involves combining the nuclei of two or more atoms. A **nuclear fission reaction** involves breaking the nucleus apart. In either case very large quantities of energy can be released.

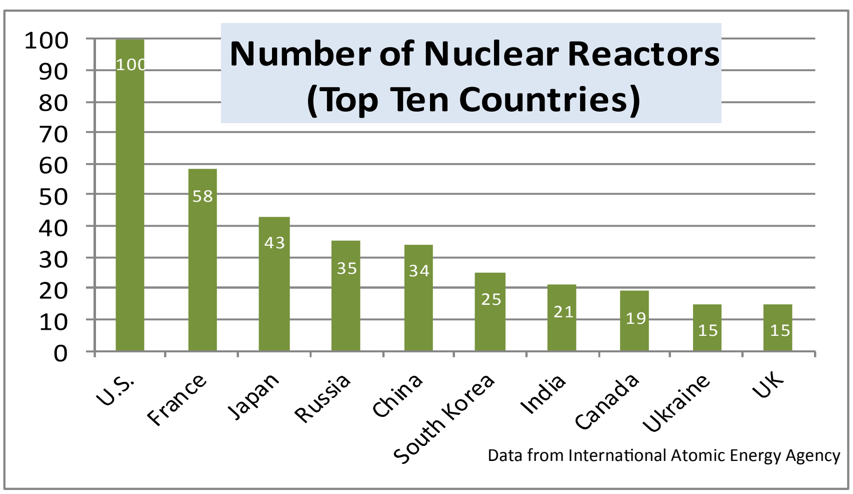



All nuclear power plants currently operate using fission reactions (*splitting the atom*). Part of the energy released by fission reactions is in the form of **thermal energy**. It is this thermal energy that is used to heat water to steam and drive **turbine** systems designed to produce **electrical power**. During this process the fission reactions also produce a form of energy called **radiation** along with solid **radioactive waste** products. Radiation is a very powerful form of energy that can cause cell damage and impair cell function of living organisms. Care must be taken in designing and operating nuclear power plants in order to appropriately contain the resulting radioactive by-products.

More than 30 countries have developed nuclear power programs and there are 446 nuclear reactors worldwide with 15 countries developing 63 new plants. Of extant facilities, more than 20 percent are located in the U.S. Currently, nuclear power is third behind coal and natural gas in the generation of electrical power in the U.S. and provides about 20 percent of our electrical needs.

## Nuclear Power Systems

### Fission Reactors



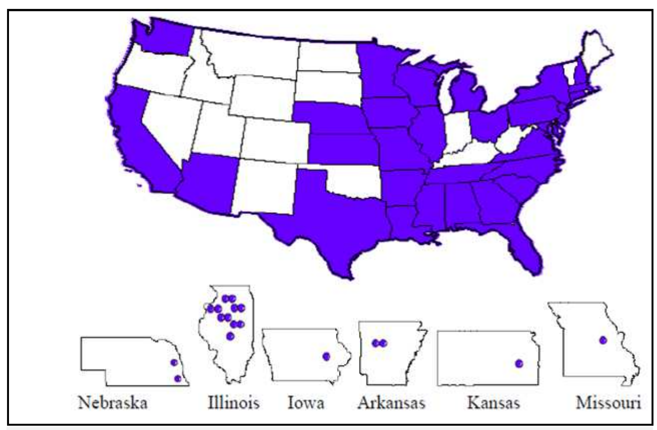

The only form of nuclear power generation in use today involves fission reactor plants. In addition to generating electrical power for general use, such power systems are used by the military to power submarines and other large navel vessels. Fission reactors essentially involve splitting atoms apart under controlled conditions. Uranium (U-235) is the fuel used by most nuclear power systems. First, the uranium is processed (concentrated) from mineral deposits and then formed into fuel pellets. These fuel pellets are stacked in stainless steel tubes called fuel rods. When an atom of uranium splits it ejects a stream of neutrons. These neutrons collide with nearby uranium atoms causing more atoms to split and thus releasing even more neutrons. The whole process gains momentum in what is called a *chain reaction*. By controlling the number of fuel rods and their proximity to each other, the nuclear plant operators control the rate of these nuclear chain reactions. The fission reactions also release energy in the form of radioactivity and thermal energy (heat). Typically the entire assembly of fuel rods is submerged in a sealed tank of water and the resulting heat from the fission reactions is used to generate steam. The steam is then used to drive turbines to generate electricity or operate large motors as in the case of a nuclear navel vessel. The overall approach is similar to that used by coal-fired or natural gas power plants, except the heat is provided by the nuclear reactions. The rate of the chain reactions must be carefully controlled and the radioactive by-products that result from the nuclear reactions must be carefully handled and properly disposed of.

## Fusion Reactions


The heat of our Sun is basically the result of a massive set of on-going nuclear fusion reactions. The process is so intense that you can step outside on a sunny day and feel the heat from these nuclear reactions even though the Sun is more than 80 million miles away. The Sun's gravitational forces and immense heat are so intense that the nuclei (center) of millions of hydrogen atoms are continuously being combined.

Currently, scientific teams are working on ways to create fusion-type reactions for our own power needs. This would be an attractive source of power because many of the radioactive byproducts and disposal problems associated with *fission* reactions would be eliminated. Scientists have been able to create and briefly sustain fusion reactions, but the amount of energy required to create even a small reaction in the laboratory is greater than the energy gained from the event. Estimates put the achievement of commercially-viable reactors at sometime in the 2040s with commercial use of fusion following soon after. If scientists can determine a practical way to maintain and harness fusion this may be a very attractive energy source indeed.

## **Nuclear Power Locations**



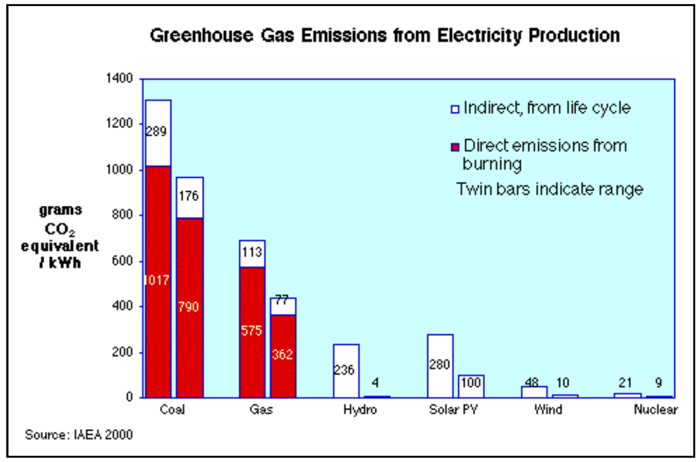

States Utilizing Nuclear Power and Reactor Sites in Missouri and Surrounding States. (Source: Nuclear Energy Institute)

Nuclear power plants can be located in a number of areas. For safety reasons the site selected should be geologically stable. It is inappropriate to locate these facilities in high population zones such as highly urbanized areas. Often a lake or other body of water such as river is incorporated into the plant site selection. The source of water is required to cool and control the nuclear reactions and to generate steam. Most nuclear power utilities are engineered so that the nuclear reactions take place in a contained system designed to transfer the heat generated into an external water supply.

Nuclear power plants often have very large cooling towers used to cool and condense the steam after is has expanded through the systems of electrical turbines. The "smoke" that is released from the top of these cooling towers is actually water vapor and does not contain any radioactivity. A nuclear plant that is properly designed does not release radiation during normal operation. However, radioactive waste is generated each time the fuel rods are changed and short or long-term storage of such waste is a factor in site selection. In the United States all such waste is currently stored on-site at each facility.

# Specific Characteristics of Nuclear Power

Nuclear energy cannot be classified as a **renewable energy source**. The raw material used to generate nuclear power (Uranium-235, and related radioisotopes) are primarily mined from mineral deposits in the Earth's crust. However, the supply of these radioisotopes is surprisingly abundant (about as common as tin and zinc). At current consumption levels and known supply, the OECD Nuclear Energy Agency projects there is enough uranium for at least 120 years. However, increased exploration is expected to reveal more sources in the coming years and other technological advances and secondary sources of uranium (such as disassembling nuclear weapon stockpiles) will make even more uranium available. If the price of uranium becomes high enough, it will even be viable to extract it from seawater. One Dept. of Energy laboratory estimates seawater uranium could fuel global power plants for 6,500 years! While being potentially very abundant, nuclear power also has the advantage of producing very low air emissions when compared to other forms of energy production.




There are safety issues unique to nuclear power. Even when operated correctly a nuclear power plant produces high-level radioactive waste whenever fuel rods are replaced roughly every few years. High-level radioactive waste must be handled and stored carefully. Exposure to such radioactivity has been linked to increased risks of cancer, other diseases, and even death. Nuclear waste loses its radioactivity through a process called radioactive decay. However, this process takes thousands of years. As a result, storage and transportation of this waste is a major safety concern.

In 1979 an accident at the Three Mile Island nuclear plant in Pennsylvania became the most serious in the history of U.S. commercial nuclear power. A sequence of events related to equipment malfunctions, design problems and worker error led to significant damage of the reactor core and the release of a large amount of radiation which was mostly contained. The amount of radioactivity released off-site (averaging one chest x-ray per person exposed) is generally believed, though not by all researchers, to have not caused any deaths or significant health consequences.

Another far more serious accident occurred in the former Soviet Union in 1986. The accident at the Russian nuclear plant located in Chernobyl, Ukraine caused the evacuation of 135,000 people and seriously contaminated an 18-square mile zone around the plant. Chernobyl caused radioactive contamination as far away as Western Europe and was even detectable in the United States. Thirty-one people died within 10 days of the accident, mostly those fighting fires at the accident site. Long term health effects have been difficult to determine with estimates ranging from negligible to a few thousand to tens of thousands.

A more recent disaster at the Fukushima Daiichi Nuclear Power Plant in Japan occurred when an earthquake and subsequent tsunami caused meltdowns in three nuclear reactors in March of 2011. The radiation release resulted in the evacuation of over 450,000 people and radiation is still leaking from the plant as of 2016. While it is still too soon to determine the health consequences of the radiation fallout, some estimates place total eventual deaths near 10,000. Fukushima is considered the worst nuclear disaster since Chernobyl.

The result of accidents like Three Mile Island, Chernobyl, and Fukushima tend to mobilize public outcry against nuclear power even though proponents of nuclear resources view this resistance to be unfounded as U.S. plants have very high safety standards (compare the results of Fukushima and Chernobyl to Three Mile Island). Nevertheless, the potential for disastrous public health crises from nuclear accidents emphasizes the need for careful planning, management, and safety protocols for nuclear power resources.

**Several factors contribute to the increased cost of nuclear power as compared to producing electricity from coal or natural gas:**

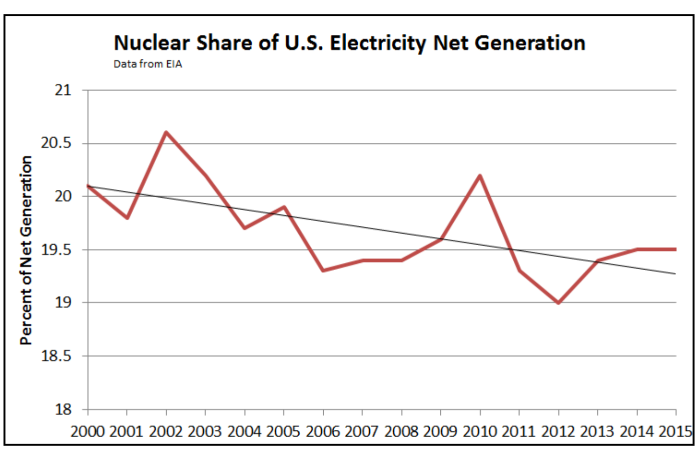
- The expense involved in mining and processing the uranium.
- Much of the cost of constructing and operating a reactor in the United States is associated with safety systems and structures.
- The radioactive waste that is generated by nuclear reactors must be handled and stored correctly.
- No permanent storage facility has been approved in the United States forcing nuclear plants to store radioactive waste on-site at significant expense.
- A nuclear plant cannot just be shut down and simply closed. The plants core reactor needs to be dismantled and removed very carefully and handled as a radioactive waste. This process is very expensive and factors heavily into the price of energy from nuclear power.

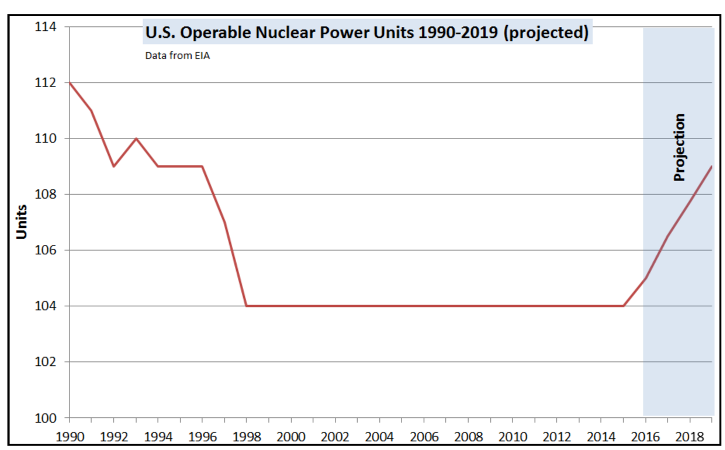
*NOTE: Utilities are required to charge customers a fee to help cover the eventual costs associated with the above activities.*

## The Future of Nuclear Power in Missouri

Missouri has a nuclear power plant located in Callaway County, 80 miles west of St. Louis. The reactor is operated by Ameren Missouri and was built in 1984. The plant was originally licensed until 2024, but was recently granted an extension to 2044. Callaway provides approximately 10.5% of the electricity consumed in Missouri.

Nuclear energy as a whole is on a slight decline as a result of safety concerns, waste disposal issues, and economics. The United States currently generates about 20 percent of its electricity from nuclear energy, but when measured more precisely, annual averages have been decreasing slightly since 2000 (see chart below left, note modified scale). However, the first new nuclear power plant since 1996 is scheduled to go online beginning in the summer of 2016 with four more by 2019 (see chart below right). This would likely increase or at least maintain nuclear electricity generation shares. For North America, the average annual growth rate of nuclear power production through 2030 is expected to range from a .4 percent decrease to a 1.5 percent increase. Internationally, 63 nuclear plants are under construction in 15 countries. The world average growth rate is expected between 2.1 and 5 percent.



## Glossary

**Electrical Power:** Electrical energy used to conduct work; the measure of the rate of electrical energy used by a circuit. This is usually measured using a unit called a Watt (W)

**Nuclear fission reactions**: The process of breaking apart the nuclei of atoms through chain reactions to release potential energy

**Nuclear fusion reactions:** The process of combining the nuclei of atoms to release immense amounts of energy

**Radiant energy/Radiation:** Transmission or emission of kinetic energy as waves through space. Light is one type of radiant energy. Electromagnetic radiation can be classified by the electromagnetic spectrum

**Radioactive Waste:** The spent fuel and byproducts from the nuclear fission reactions used to produce nuclear power which continue to emit harmful radiant energy for thousands of years after their use

**Renewable energy source/fuel:** Primary energy source that can be replenished at an equal or greater rate to its consumption; sustainable energy source

**Thermal energy:** Kinetic energy associated with the movement of molecules; commonly produced from combustion. Heat is the transfer of thermal energy from bodies of higher kinetic energy to lower kinetic energy

**Turbine:** A device which harnesses the kinetic energy of an incoming force (often steam, water, or air) to spin rotors and create mechanical power. In electrical power generation the spinning motion of turbine rotors is used to turn generators which use rotating magnets inside copper wire to create an electrical current

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