How a Nuclear Reactor Works
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http://www.howstuffworks.com/nuclear-reactor.htm/

Introduction to How a Nuclear Reactor Works

Nuclear reactors have one job: to split atoms in a controlled reaction and use the released energy to generate electrical power. Over the years, reactors have been viewed as both a miracle and a menace. When the first U.S. commercial reactor went on line in Shippingport, Pa., in 1956, the technology was hailed as the energy source of the future, one that some believed eventually would make electricity too cheap to meter. Countries around the world built 442 nuclear reactors, and about a quarter of those reactors were built in the United. The world has come to depend upon nuclear reactors for 14 percent of its electricity. In fact, futurists fantasized about having nuclear-powered automobiles.

Then, 23 years later, when Unit 2 at the Three Mile Island power plant in Pennsylvania suffered a cooling malfunction and a partial meltdown of its radioactive fuel, feelings about reactors changed radically. Even though the stricken reactor's containment held and there was no major radiation release, many people began to see reactors as overly complicated and vulnerable to human and equipment failures, with potentially catastrophic consequences. They also worried about the radioactive waste from reactors. Worse yet, many wondered if government regulators and the nuclear power industry were leveling with the public. As a result, the construction of new nuclear plants stopped in the United States. When a more serious accident occurred at the Soviet Union's Chernobyl nuclear plant in 1986, nuclear power seemed doomed to obsolescence.

But in the early 2000s, nuclear reactors began making a comeback, thanks to rising energy demand, diminishing fossil fuel supplies, and the growing concern about climate change due to carbon dioxide emissions. Late in the decade, the U.S. Nuclear Regulatory Commission began to approve permits for new plants, and President Barack Obama included nuclear power as a key part of his energy plan.

But then, in March 2011, yet another crisis hit -- this time at the earthquake-stricken Fukushima Daiichi nuclear power plant in Japan -- raising worries again.

In this article, we'll explain how nuclear reactors work, what happens when they malfunction, and the risks they pose to our health and the environment compared to other energy sources. We'll also take a look at what technological advances could make the nuclear reactors of the future safer.

But first, let's look at how nuclear fission, the process that actually produces the energy, actually works.

Which countries depend upon nuclear power the most?

The United States gets about 20 percent of its electricity from nuclear reactors, but other countries rely more heavily upon them. Here's a list of countries and nuclear power percentages:

Lithuania -- 76.2 percent
France -- 75.2 percent
Slovakia -- 53.5 percent
Belgium -- 51.7 percent
Ukraine -- 48.6 percent
Armenia -- 45.0 percent

Hungary -- 43.0 percent
Switzerland -- 39.5 percent
Slovenia -- 37.8 percent
Sweden -- 37.4 percent
Bulgaria -- 35.9 percent
S. Korea -- 34.8 percent

Harnessing a Nuclear Reaction

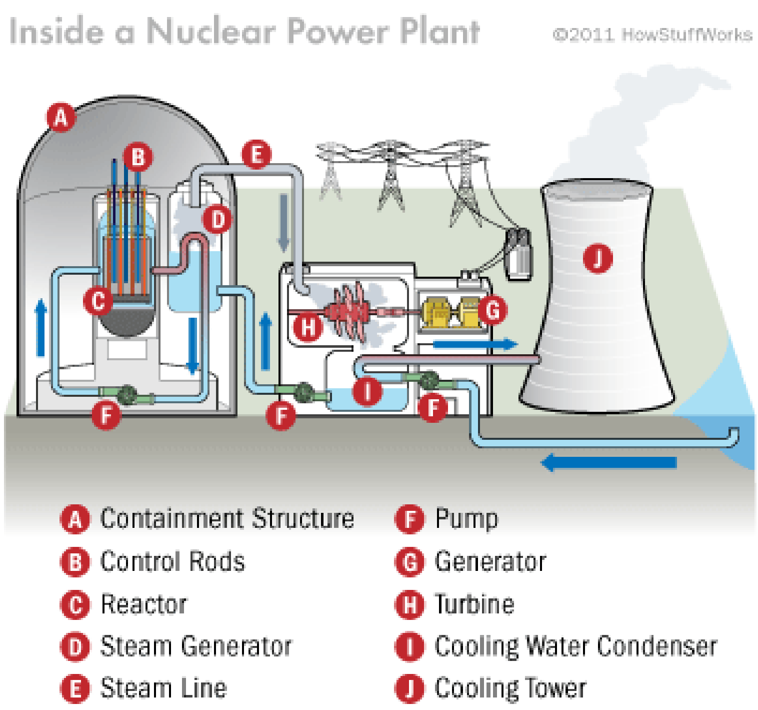
Put simply, a nuclear reactor splits atoms and releases the energy that holds their parts together.

If it's been a while since you took high school physics, we'll remind you how **nuclear fission** works: Atoms are like tiny solar systems, with the nucleus where the sun would be, and electrons orbiting around it. The nucleus is made up of particles called protons and neutrons, which are bound together by something called **strong force**. Perhaps it was named "strong force" because it's almost too powerful for us to imagine -- many, many billions of times stronger than gravity, in fact. Despite the strength of strong force, it's possible to split a nucleus -- by shooting neutrons at it. When that's done, a whole lot of energy is released. When atoms split, their particles smash into nearby atoms, splitting those as well in a chain reaction. (Think a multi-car crash on the freeway.)

Uranium, an element with really big atoms, is perfect for atom splitting because its strong force, though powerful, is relatively weak compared to other elements. Nuclear reactors use a particular isotope called **uranium-235**. Uranium-235 is rare in nature; the ore from uranium mines only contains about 0.7 percent uranium-235. That's why reactors use **enriched uranium**, which is created by separating out and concentrating the uranium-235 through a gas diffusion process.

This process is what gives an atomic bomb, like the ones that were dropped on Hiroshima and Nagasaki, Japan, during World War II, such terrible power. But in a nuclear reactor, the chain reaction is controlled by inserting control rods made of a material like cadmium, hafnium or boron, which absorb some of the neutrons. That still allows the fission process to give off enough energy to heat water to a temperature of about 520 degrees Fahrenheit (271 degrees Celsius) and turn it into steam, which is used to turn turbines and generate electricity. Basically, a nuke plant works like a coal-powered electrical plant, except that the energy to boil water comes from splitting atoms instead of burning carbon.

In the next section, we'll talk about the different types of reactors and how their key parts work.



This diagram shows all the parts of a nuclear reactor.

Nuclear Reactor Components

There are several different types of nuclear reactors, but they all have some common characteristics. All of them have a supply of radioactive fuel pellets -- usually uranium oxide, which are arranged in tubes to form fuel rods in the **reactor core**.

The reactor also has the previously mentioned **control rods** -- made of neutron-absorbing material such as cadmium, hafnium or boron -- which are inserted into the core to control or halt the reaction.

A reactor also has a **moderator**, a substance that slows the neutrons and helps control the fission process. Most reactors in the United States use ordinary water, but reactors in other countries sometimes use graphite, or **heavy water**, in which the hydrogen has been replaced with deuterium, an isotope of hydrogen with one proton and one neutron. Another important part of the system is a **coolant** -- again, usually ordinary water-- which absorbs and transmits heat from the reactor to create steam for turning the turbines and cools the reactor core so that it doesn't reach the temperature at which uranium melts (about 6,900 degrees Fahrenheit, or 3,815 degrees Celsius).

Finally, a reactor is encased in a **containment**, a big, heavy structure, typically several feet thick and made of steel and concrete, that keeps radioactive gases and liquids inside, where they can't hurt anyone.

There are a number of different reactor designs in use, but in the United States, about two-thirds of the reactors are **pressurized water reactors** (PWRs). In a pressurized water reactor, the water is pumped into contact with the core and then kept under pressure, so that it can't turn into steam. That pressurized water then is brought into contact with a second supply of unpressurized water, which is what turns to steam to turn the turbines. The remaining third of reactors in the United States are **boiling water reactors** (BWRs). With BWRs, the water that comes directly into contact with the reactor core is allowed to become steam for generating electricity.

In the next section, we'll look at the potential risks nuclear reactors pose, and how to evaluate them.

How is radiation measured?

The unit for quantifying radiation dose is a **Sievert** (Sv). It's the ratio of radiation energy (joules) to total body mass exposed (kilograms). A Sievert is a lot of radiation -- an instantaneous dose of 1 to 3 Sv could cause you severe nausea and cripple your immune system, and 10 Sv all at once could kill you. Normally, people are exposed to much smaller doses, which are measured in **millisieverts** (mSv) that amount to 0.001 of a Sievert. The average person is exposed to about 6.2 mSv annually from natural and manmade sources.

How Safe Is a Nuclear Reactor?

The answer to that question is pretty complicated, and it depends who you ask and how you define "safe." Are you concerned about radiation routinely leaking from plants or about the radioactive waste generated by reactors? Or, are you more worried about the possibility of a catastrophic accident? What degree of risk do you consider an acceptable trade-off for nuclear power's benefits? And to what extent do you trust the government and the nuclear power industry to keep things safe and provide accurate information to the public?

"Radiation" is a loaded word, mostly because we all know that big doses of radiation -- from a nuclear bomb blast, for example -- can kill scores of people or make them horribly ill.

Advocates of nuclear power, however, point out that we all routinely are exposed to radiation from a variety of sources, including cosmic rays and radiation naturally emitted by the Earth itself. The average annual exposure to radiation is about 6.2 millisieverts (mSv), half of it from natural sources and half from man-made sources, ranging from chest X-rays to smoke detectors and luminous watch dials. How much do we get from nuclear reactors? A tiny fraction of a percent of our typical annual exposure -- 0.0001 mSv.

While all nuclear plants inevitably leak small amounts of radiation, in the United States, regulators hold operators to a stringent standard. They can't expose people living around the plant to more than 1 mSv of radiation per year, and workers in the plant have a threshold of 50 mSv per year. That may sound like a lot, but according to the Nuclear Regulatory Commission, there's no medical evidence to show that annual radiation doses below 100 mSv pose any health risks.

But it's important to mention that not everybody agrees with that assessment of radiation risks. For example, Physicians for Social Responsibility, a longtime critic of the nuclear industry, cites a 2009 study of children living around German nuclear power plants. The study found that those living within 3.1 miles (5 kilometers) of the plants had twice the risk of contracting leukemia as those living farther away.

There's also the problem of radioactive waste generated by reactors.

Nuclear Reactor Waste

Nuclear power is touted by supporters as "clean" energy because it doesn't put large amounts of greenhouse gases into the atmosphere, the way coal-burning power plants do. But critics point to another environmental problem: disposing of nuclear waste. Some of the waste is spent fuel from reactors, which continues to give off radioactivity. Another waste material that must be stored is high-level radioactive waste (HLW), a liquid residue that's left over when spent fuel is reprocessed to remove and recycle whatever usable uranium remains in it. Right now, most of this waste is stored onsite at nuclear power plants, in pools of water that absorb some of the leftover heat generated by the spent fuel and help to shield workers from radiation exposure

One problem with spent nuclear fuel is that it's been changed by the fission process. When big uranium atoms are split, they create byproducts -- radioactive isotopes of several lighter elements, such as cesium-137 and strontium-90, called **fission products**. They're hot and very radioactive, but eventually, over a 30-year period, they decay into less dangerous forms. That period is called the **half-life**. Additionally, some uranium atoms also capture neurons and form heavier elements, such as plutonium. These transuranic elements don't generate as much heat or penetrating radiation as fission products, but they take a lot longer to decay. Plutonium-239, for example, has a half-life of 24,000.

This **high-level radioactive waste** from reactors is dangerous to humans and other life because it can give off a huge, fatal dose of radiation from even a short exposure. A decade after a fuel assembly is removed from a reactor, for example, it gives off 200 times as much radioactivity in an hour as it takes to kill a person. And if the waste gets into groundwater or rivers, it could enter the food chain and endanger large numbers of people.

Because the waste is so dangerous, many people are uneasy about having 60,000 tons of it sitting at nuclear plants close to major cities. But finding a safe place to store it hasn't been easy. For decades, the U.S. federal government, for example, has been studying the possibility of storing it inside Yucca Mountain in Nevada, 90 miles (144.8 kilometers) outside of Las Vegas. Despite strong local objections, Congress approved the project in 2004. But in 2009, Obama Administration Energy Secretary Steven Chu announced that the plan was being shelved, and that waste will be stored at local plants until the government finds another solution.

Radioactive waste is what concerns people most about nuclear reactors -- that is, beyond the obvious and more frightening possible scenario: a reactor breakdown that triggers potentially catastrophic consequences.

What Can Go Wrong With a Nuclear Reactor?

With government regulators looking over their shoulders, engineers have spent a lot of time over the years designing reactors for optimal safety -- not just so they work properly, but so there are backup safety measures in place when something breaks down. As a result, year in and year out, nuclear plants seem pretty safe compared to, say, air travel, which routinely kills anywhere from 500 to 1,100 people annually worldwide.

Nevertheless, nuclear reactors have suffered major breakdowns. On the International Nuclear Event Scale (INES), which rates accidents on an escalating scale of 1 to 7, there have been five accidents since 1957 that rated between 5 and 7.

The worst nightmare is a breakdown of the cooling system, which would allow the fuel to overheat and experience a meltdown. With a **meltdown**, the fuel turns to liquid and then burns through the containment vessel, spewing radiation far and wide. In 1979, Three Mile Island's Unit 2 came perilously close to this scenario, with the core partially melting down and flowing to the floor of the containment vessel. Fortunately, as scientists later discovered by lowering a camera into the unit, the well-designed containment was strong enough to stop the radiation from getting out.

The Soviets had worse luck. The worst nuclear accident in history was the April 1986 catastrophe at Unit 4 of the Chernobyl nuclear plant in the then-USSR, which was caused by a combination of system breakdowns, design flaws and badly trained personnel. During a routine test, the reactor suddenly surged, and the control rods jammed, preventing an emergency shutdown. The sudden buildup of steam caused two explosions, exposing the reactor's graphite moderator to air and setting it on fire. With nothing to cool them, the reactor's fuel rods then overheated and suffered a full meltdown, in which the fuel turned to liquid form. Thirty plant workers were killed. Unlike the plant at Three Mile Island, Chernobyl's stricken reactor apparently lacked a sturdy containment vessel, and large amounts of radiation spewed out over an area of 125,000 square miles (323,749 square kilometers). The number of deaths caused by radiation-related illnesses is still unclear, but a 2006 World Health Organization study estimated that it may have caused 9,000 cancer deaths.

In the next section, we'll look at how the crisis at the Fukushima Daiichi nuclear plant in Japan compares to past accidents, and how nuclear catastrophes are averted.

Fukushima Daiichi Nuclear Plant Crisis

Nuclear reactor designers build safeguards based on a **probabilistic assessment**, in which they try to balance the potential harm from an event with the likelihood of it actually occurring. But some critics say they should be preparing, instead, for the rarest, most unlikely but highest-impact events -- what philosopher Nassim Nicholas Taleb calls "black swan" events.

Case in point: The March 2011 crisis at the Fukushima Daiichi nuclear plant in Japan. The plant reportedly was designed to withstand a major earthquake, but not a disaster as big as the 9.0 quake that sent 46-feet-high (14-meter) tsunami waves crashing over seawalls designed to withstand 18-foot (5.4-meter) waves. The tsunami onslaught destroyed the diesel backup generators that were in place to power the cooling systems for the plant's six reactors, in the event electricity was cut off. Thus, even after the Fukushima reactors' control rods shut down the fission reactions, the still-hot fuel caused the temperature to rise dangerously inside the stricken reactors.

Japanese officials resorted to an extreme measure: flooding the reactors with massive amounts of seawater laced with boric acid, which might stave off meltdowns, but would destroy the reactor equipment in the process. Eventually, with the help of fire trucks and U.S. Navy barges, the Japanese were able to pump freshwater into the reactors. But by then, the reactor buildings and containments had suffered extensive damage, and monitoring already showed alarming levels of radiation in the surrounding land and water. In one village 25 miles (40.2 kilometers) from the plant, cesium-137, a radioactive element, was measured at levels much higher than the standard the Soviets used as a gauge in recommending abandoning land around Chernobyl, presenting the prospect that the area might become permanently uninhabitable.

While the Japanese disaster has triggered public qualms about U.S. nuclear power, William Levis, CEO of nuclear operator PSEG Power, told Congress in March 2011 that U.S. plants could withstand a similar event here. Levis said that U.S. utility companies spent $6.5 billion in 2009 alone to replace old equipment and improve precautions, and that plants are prepared for extreme events ranging from fires and explosions to loss of cooling pumps and multiple safety system failures. He also said nuclear plant operators were reassessing plants' vulnerability to massive earthquakes and might add more protective measures.

How a Nuclear Reactor Works

Answer the following questions on a separate piece of paper. Please, do not write on the article.

(1) What percentage of the world's electricity is from nuclear energy? What percentage of the United States' electricity comes from nuclear energy?

(2) What force holds protons and neutrons together in the nucleus? How is it possible to split a nucleus? What is released when this is done? What does this result in?

(3) What element is used as fuel in nuclear reactors? What makes this element a good choice? What isotope in particular is used? Why does this isotope need to be enriched?

(4) List three materials that can be used to make control rods. What is the function of a control rod?

(5) What is the heat from nuclear reactions used to form? Why?

(6) Give the main function of each component: moderator, coolant, and containment.

(7) What is the name and symbol of the unit used for describing a radiation dose? How much radiation is the average person exposed to annually from natural and manmade sources? What is a lethal dose of radiation?

(8) Give two examples of fission products that are created as byproducts from spent fuel. What is the primary problem with these isotopes? Give one example of a heavier isotope produced from neutron capture. How do these elements form? What is the primary problem with these isotopes?

(9) List three incidents of accidents at nuclear reactors. When and where did each of these accidents occur?

(10) What is meant by "meltdown"? At what temperature (in °C) does Uranium melt?

Advantages and Disadvantages of Nuclear Power
http://www.buzzle.com/articles/advantages-and-disadvantages-of-nuclear-power.html

Harvesting the energy residing in an atom was an unimaginable idea until the mid-20th century. It was Sir Ernest Rutherford, considered the 'father of nuclear physics', who first became aware of the energy trapped in an atom. While examining the result of an experiment conducted by John Cockcroft and Ernest Walton, the latter being his doctoral student, he realized the massive amount of energy produced in the 'splitting' of an atom. However, he also noted that looking for a stable source of energy in this process was pointless, since the energy required to split an atom of a light element was so much that the surplus output came up to a very small amount. While this notion holds true for lighter elements even to this day, the scientific world was yet to realize the capability of heavy, radioactive elements to produce a highly energy-efficient fission chain reaction.

Nuclear Fission
The process of nuclear fission was discovered by Otto Hahn in 1938. He discovered that neutron bombardment of uranium produced barium and krypton along with neutrons. Hahn was, at first, baffled by the results of his experiments, which did not fit the existing scientific paradigm as nuclear fission had not been invented yet. His colleague, Lise Meitner, confirmed that the result was due to nuclear fission. Meitner's cousin, Otto Frisch, also confirmed Hahn's results experimentally. Since then, nuclear power has risen in prominence, both as a useful boon and a destructive bane. While nuclear power remains the most effective power source available to mankind right now, the ever-present threats of the risky nuclear technology, ably demonstrated by the nuclear bombings of Hiroshima and Nagasaki and the Chernobyl and Fukushima-Daiichi reactor accidents, cannot just be ignored. Nuclear power is widely being harnessed across the world in an effort to reduce the global dependence on depleting stores of fossil fuels. But is nuclear energy really the "wonder fuel" it is made out to be? Let's find out.

Advantages
►► Extremely Efficient Power Source
Compared to fossil fuels, nuclear fission produces much more energy per unit of fuel - more than a million times more. Due to this, larger amounts of electricity can be produced more effectively via nuclear power. Fossil fuels release energy through chemical reactions, i.e., the transfer of electrons. Protons, on the other hand, contain much more energy - due to a force known as nuclear force - when clustered together in the nucleus, and thus produce correspondingly higher amounts of energy when separated.

►► 'Greener' Emissions
Nuclear reactors do not produce greenhouse, or otherwise harmful gases. Since, unlike fossil fuels, nuclear energy sources do not include hydrocarbons, gases such as carbon dioxide (CO_2), carbon monoxide (CO), and methane (CH_4), which are all compounds of carbon, are not produced. Carbon dioxide and methane are the primary contributors to the global greenhouse effect, while carbon monoxide is extremely poisonous. The only gaseous exhaust produced by nuclear reactors is water vapor.

►► Later Expiry Dates than Fossil Fuels
Although uranium stockpiles on the earth can hardly be termed 'inexhaustible', thorium, which is much more abundant, could provide electricity to the world for at least half a millennium. Fossil fuel reserves are, even by the most optimistic predictions, expected to have been exhausted by that time. The primary drawback with using thorium as nuclear fuel is that the naturally found form (isotope) of thorium is not fissile (not capable of sustaining a chain reaction of nuclear fission), unlike the naturally found form of uranium (which is fisile). The natural thorium isotope has to be converted into a fissile material before being used as a nuclear fuel. Although uranium is currently the first-choice nuclear fuel, many countries, primary among which is India, have set up extensive research facilities on the suitability of thorium as a substitute for uranium, and we could soon have thorium powering our nuclear reactors in place of uranium.

Disadvantages

►► Misuse of Nuclear Technology

The technology used for generating nuclear power can also be used to produce nuclear weapons. Left in the wrong hands, such as terrorist or extremist groups, nuclear technology could lay the foundations of a global disaster.

►► Radioactive Waste

Although gaseous exhausts from a nuclear reactor are environment-friendly, solid waste products generated in the same, which are radioactive, cause more long-term problems than the waste material generated by conventional fuels. The radioactive by-products can pollute the environment beyond repair and cause fatal diseases, such as cancer, in the human population if not properly disposed of.

►► Tragic Accidents

Accidents in nuclear reactors are much more devastating than those in conventional energy plants. Despite being a much rarer occurrence, individual nuclear disasters are much more deadly than, say, fossil fuel disasters. To be fair, the collective number of deaths from nuclear accidents are significantly less than those from conventional energy plants. However, apart from the immediate blast radius, a nuclear explosion (weapon detonation/reactor core meltdown) is also terrifyingly active in its thermal and ionizing radii. Radiation from the core can cause genetic abnormalities in the population, which can be carried on for generations. Long-term aftereffects of the Hiroshima-Nagasaki nuclear explosions continue to manifest in Japanese population even to this day.

►► High Costs

The construction cost of a nuclear reactor is high; according to various studies, the total cost of building and making a nuclear power plant operational ranges between $8-17 billion. The high cost, coupled with the inability of the plants to generate any income until fully operational, deters many sponsors.

►► Long Timeline

Building a nuclear power plant takes a number of years. Although extensive research is undertaken before initiating such a project, there's no guarantee that the conditions required for the power plant's maximum usage would prevail through the period of its construction. With increasing research in various other energy sources, the changing energy demographics could alter conditions so as to make the under-construction nuclear power plant redundant.

►► Contamination Perils

Uranium mining operations can turn out to be hazardous for the health of miners as well as the surrounding population. If necessary safety precautions are not observed, radioactive contamination can spread, even to the next generation.

Nuclear energy has its distinct set of pros and cons, and each has its own community of fierce proponents. While other renewable power sources such as solar energy and wind power are catching on, there is no doubt that at this point of technological advancement, nuclear energy remains the most efficient energy source. If its flip side could be negated, nuclear energy could propel the world into a clean, environment-friendly atomic age, an era fantasized by many for decades. However, supporters of an atomic age would do well to remember that atomic energy is, after all, completely dependent on limited and nonrenewable stocks of radioactive elements, which, like fossil fuels, will run out at some point in the future. Even if someone comes up with a solution to extend the application of nuclear fuels, it would and could only be a temporary one. Many countries, including the likes of Germany have prioritized the risks - rather than benefits - of nuclear power, and have decided against new nuclear power plants, and to decommission the existing ones. Some, like Italy, have banned nuclear power altogether. It is clear that although nuclear energy remains one of the most important technologies of the present, the future belongs to the renewable resources.

Name: ___________________________
Period: _______

Title of Text(s): ____

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Evidence: Chose three appropriate pieces of evidence from the article. Explain what information is given by each piece of evidence and how this evidence supports your claim.

Evidence Words, phrases, sentences copied from the text including author, quotation marks, and page/paragraph number.	**Explanation** In your OWN WORDS, what does the evidence state?	**Analysis** How and why this piece of evidence supports your claim.