Nuclear Energy

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Nuclear energy results from a reaction that takes place in the nucleus of an atom. Nuclear power plants harness this reaction to generate electricity. Although nuclear power has the potential to meet the world's energy needs, its use has provoked controversy in the United States and some other countries. Some people maintain that the risks of this technology may outweigh its benefits.

Background

Nuclear power has been a significant source of energy in many parts of the world since the 1950s. To use this energy, scientists had to learn how to start a nuclear reaction and how to control it.

How Nuclear Power Is Produced

Two main types of nuclear reactions release energy: fission and fusion. Nuclear fission occurs when the nucleus of an atom is split apart into two smaller nuclei. In the process, a small amount of the mass of the nucleus is converted into a great amount of energy. Nuclear power plants harness this process in a controlled chain reaction, releasing energy in continuous and manageable amounts. That energy in the form of heat is used to boil water and generate steam. The steam turns turbines, which drive generators that produce electricity. Commercial nuclear reactors use a type of uranium, called U-235, for fuel.

In nuclear fusion, the nuclei of hydrogen atoms fuse together to produce larger nuclei, releasing energy in the process. Fusion has not been used as a commercial source of energy because it requires extremely high temperatures. Moreover, the process is difficult to contain once it has begun. Scientists must overcome these problems before nuclear fusion can be used as an energy source.

The History of Nuclear Power

Modern atomic science emerged in the late 1890s. By the 1930s, researchers in several countries were studying nuclear reactions, and German scientists achieved the first controlled atomic fission in 1938. During World War II (1939–1945), both German and American scientists studied fission as a means of building atomic weapons. After the war, the United States began to develop nuclear energy for nonmilitary purposes. The first American nuclear power plants began operating in the early 1960s. Meanwhile, the Soviet Union, Great Britain, France, and a number of other nations were also building nuclear plants for commercial energy.

Nuclear power has developed unevenly around the globe. In 1999, 436 nuclear plants were located in 32 countries, including the United States, Canada, Russia, Japan, India, and France. By 2013, this number remained steady at 437 nuclear plants in 31 countries. However, some regions of the world—most of Africa and the Middle East and much of Latin America and Asia—have no plants. The degree

of reliance on nuclear power also varies greatly. Only about 20 percent of the electricity in the United States comes from nuclear power, while France generates about 75 percent of its electricity by nuclear power.

Advantages and Disadvantages of Nuclear Power

Nuclear power has many advantages. Compared to fossil fuels, the main energy source in the United States, it is cheap and clean. Many people, however, are concerned about the risks associated with nuclear power plants and the waste products they produce.

Advantages over Fossil Fuels

Nuclear power has a number of advantages over the burning of fossil fuels. For instance, nuclear plants cost less to operate than fossil-fuel plants because they can produce vast amounts of energy with very little fuel. A typical nuclear reactor uses about two hundred tons of uranium fuel annually. To generate the same amount of energy, a coal-fired power plant would require three million tons of coal.

Another major advantage is that nuclear power production releases no pollutants into the air. By contrast, a typical coal-burning power plant releases 5,000 tons of ash into the environment every year. It also produces 175,000 tons of sulfur dioxide and nitrogen oxides, chemicals that contribute to acid rain. In addition, coal-burning plants release a radioactive gas called radon, which has been linked to cancer. Finally, the burning of fossil fuels is a major source of carbon dioxide, which plays a significant role in global warming.

Problems with Nuclear Power

One disadvantage of nuclear power is that nuclear power plants cost more to build than fossil-fuel plants and have a limited lifespan. After thirty years of operation, they need to be shut down permanently. In addition, nuclear reactors generate dangerous radioactive waste, and some of it can remain radioactive for thousands of years. The safe, long-term storage of radioactive waste is a difficult and controversial topic.

For many people, the greatest concern is the possibility of a major accident at a nuclear plant. They fear that such an accident would release dangerous amounts of radiation into the atmosphere or cause the reactor to explode. In truth, a modern nuclear reactor cannot explode like a bomb because the uranium fuel that it uses is not concentrated enough to cause that type of reaction. An accident at a nuclear power plant, however, could release radiation, which could lead to cancer in the surrounding population.

Scientists have estimated that if all the accidents at nuclear reactors were averaged out, they might cause as many as forty-five deaths per year. Supporters of nuclear power point out that the air pollution from coal burning may be responsible for as many as ten thousand deaths each year. A truly catastrophic accident, which could release enough radiation to be deadly within a couple of months, is considered highly unlikely.

Nuclear Power Under Attack

In the 1960s and 1970s, a powerful movement against nuclear energy emerged in the United States and West Germany. In the United States, in particular, antinuclear forces slowed the progress of nuclear development, eventually bringing the construction of new nuclear power plants to a temporary halt. Other developments also placed nuclear power under attack, including two highly publicized accidents at nuclear plants in the United States and the former Soviet Union.

Antinuclear Sentiment

Opponents of nuclear energy in the United States initially focused on the effects of thermal pollution on aquatic life. Thermal pollution occurs when nuclear power plants pump warm water from their cooling systems into nearby rivers and lakes. Attention soon shifted, however, to the risks of radioactivity.

News of nuclear plant accidents in foreign countries during the 1960s helped to fuel the antinuclear sentiment. At the same time, new federal guidelines governing the construction of nuclear power plants halted various new reactor projects. Opposition to nuclear power increased in the 1970s. In 1976, California passed a law that halted all nuclear plant construction in the state until the federal government found a satisfactory way to dispose of radioactive wastes.

Meanwhile, nuclear power utility companies were having financial problems, resulting primarily from the high cost of constructing and maintaining nuclear power plants. Despite higher costs for oil in the 1970s, the cost of building nuclear plants made them more expensive than traditional power plants run on fossil fuels. Then, in the late 1970s, the nuclear power industry in the United States was dealt a terrible blow by an accident at a facility in Pennsylvania.

Three Mile Island and Chernobyl

In March 1979, an accident at the Three Mile Island nuclear power plant in Pennsylvania allowed a small amount of radiation to leak into the surrounding atmosphere. The leak had no demonstrable effect on the health of anyone at the plant or in the surrounding area. Nevertheless, in the eyes of many Americans, the accident highlighted one of the dangers of nuclear power. Partly because of the Three Mile Island accident, the building of nuclear reactors was halted in the United States in the late 1970s.

A far more serious nuclear accident occurred at Chernobyl in the former Soviet Union in April 1986. The accident, which involved an explosion of the nuclear reactor, sent radioactive gas and dust into the atmosphere and from there to other parts of Europe. Chernobyl, which was at the time the worst recorded nuclear accident in history, was caused by a combination of mismanagement and faulty plant design. It caused a number of deaths in the immediate area and increased the risk of cancer and other diseases for thousands in surrounding areas. Reports more than two decades later showed more than six thousand cases of thyroid cancer in the region affected by Chernobyl, but researchers could not positively connect these cases directly to the nuclear disaster. They could not connect other issues such as genetic mutations, other cancers, or long-term medical effects.

Many experts point out that, despite the accidents at Three Mile Island and Chernobyl, nuclear power is still very safe. Indeed, one scientist has noted that the estimated number of deaths that might have resulted from Chernobyl is no greater than the annual number of deaths in the United States caused by

air pollution from coal-burning power plants. It has also been observed that accidents at other types of energy facilities, such as dams and gas pipelines, have been responsible for many more deaths than those immediately caused by the Chernobyl disaster.

Even so, fear of nuclear power remains strong in the United States. As a result, nuclear power is unlikely to make a comeback as a widely accepted form of energy until major technological breakthroughs occur or a crisis in fossil fuel energy emerges. Meanwhile, reactor building continues in other parts of the world such as France and Japan.

Earthquake Causes Japan Nuclear Plant Disaster

In March 2011, an earthquake and tsunami hit Japan causing a nuclear accident at three Fukushima Daiichi reactors. The accident caused three nuclear meltdowns and the release of radioactive materials. More than one hundred thousand people were evacuated from their homes, and while some deaths were reported due to the earthquake and tsunami, no one died in conjunction with the nuclear incident. The area around the nuclear accident was highly contaminated and will be uninhabitable for many years. The magnitude of the accident was comparable to Chernobyl, and like Chernobyl, the effects of the nuclear accident won't be known for many years to come.

Dealing with Nuclear Waste

Every country that generates nuclear power also generates highly radioactive waste, some of which will remain radioactive for years to come. Each country faces the problem of what to do with the waste so that it does not pose a danger to human health or to the environment.

Forms of Waste

Not all radioactive waste is equally dangerous. Some substances produce more intense radiation than others do, and some decay more quickly than others do. A substance with a short half-life—the time it takes for the substance to lose half its radioactivity—presents less of a danger. In the United States, the federal government has responsibility for dealing with the most dangerous forms of radioactive nuclear waste.

Most of the world's radioactive waste is low-level waste, which produces low levels of radiation and usually has a short half-life. Low-level radioactive waste comes from hospitals, laboratories, and industries, as well as from nuclear plants. This type of waste can be buried in shallow landfills without posing a significant threat to public health.

A much bigger problem is high-level waste, which releases powerful radiation and poses an extreme hazard. Disposing of high-level waste safely is difficult. Moreover, these wastes are often extremely hot and must be cooled before disposal. Used fuel rods from nuclear reactors are a major source of high-level waste. A large nuclear reactor produces about twenty-five tons of spent fuel per year.

Reprocessing

One way to reduce the quantity of radioactive waste is to reprocess it chemically. This breaks the material down into various elements, reducing the total amount of radioactive waste. Reprocessing

converts about 97 percent of a spent fuel rod into a form that can be reused for generating power.

The remaining high-level waste can be mixed with sand and other materials and condensed into a solid block of glass. This process is called vitrification. Vitrified waste can be stored without the risk of leaking out into water or soil. Reprocessing could convert a year's supply of spent fuel from a large nuclear plant into a block of vitrified waste about three cubic meters in size.

Reprocessing is an expensive technique. Because it allows nuclear fuel to be recycled, however, it saves much of the cost of mining uranium and disposing of radioactive waste. Several countries, including France, Russia, and Great Britain, reprocess their fuel. The United States has decided against reprocessing, mainly because it produces the element plutonium, which can be used to create nuclear weapons. American policy is to limit the amount of plutonium in the world to help keep it out of the hands of terrorists.

Permanent Storage

Every country with nuclear waste has concluded that the safest method of disposal is to bury the waste deep within the earth. This method involves risks. Because some of the wastes will remain dangerous for thousands of years, burial sites should be geologically stable—that is, not subject to earthquakes, volcanic activity, or other geological process that might alter the site and allow radioactive materials to escape.

After years of study, the United States identified Yucca Mountain in Nevada as the possible disposal site for the nation's most highly radioactive nuclear waste. The plan was to create miles of tunnels deep within the mountain, where the wastes could be stored in special containers. Initial studies of the site seemed to indicate that it was geologically stable. However, concerns about Yucca Mountain emerged. One concern was that the site sits above an aquifer that supplies water to surrounding areas. Some experts and opponents of the site worry that changes in geology in future centuries might allow the nuclear waste to contaminate the aquifer. Some critics fear that the special containers holding the waste might eventually corrode, allowing the radioactive material to seep in the earth. People have also raised concerns about safely transporting the wastes to Yucca Mountain from the temporary storage sites around the country. Concerns over Yucca Mountain led to the eventual abandonment of the project in 2010. That year, US Congress passed a budget that eliminated funding for the Yucca Mountain project. No waste was ever disposed of there.

Nuclear wastes are kept in places that are not suitable for long-term storage. Countries with these waste materials must decide on ways to dispose of them safely and to transport them to the disposal sites safely. In the meantime, nuclear waste materials continue to accumulate, posing an even greater threat to human health and the environment.

A Nuclear Renaissance?

A bright moment for nuclear power came with the Nobel Peace Prize in 2005. The prize was shared between the International Atomic Energy Agency (IAEA) and its president, Mohamed El Baradei. The Nobel Committee awarded the prize to the IAEA and El Baradei "for their efforts to prevent nuclear energy from being used for military purposes and to ensure that nuclear energy for peaceful purposes is used in the safest possible way."

Despite some of the bad press and public concern over nuclear power, signs of a potential renaissance for nuclear power have emerged. Global climate change and depleting stores of fossil fuels have brought the need for new energy sources to the international stage. US president Barack Obama publicly supported the creation of new nuclear power plants in the United States as an alternative to fossil fuels. This became a reality in 2013 when work began on two new nuclear power plants in the United States in more than three decades. The plants in South Carolina and Georgia were planned to be finished by 2016 or 2017. Work also resumed at an unfinished reactor in Tennessee, which could be finished as early as 2015.

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