American Nuclear Society

Questions & Answers

Nuclear Energy Facts:

Nuclear Energy & Electricity

ANS order No. 750020
Q&A Nuclear Energy Facts:
Nuclear Energy & Electricity
ISBN-0-89948-505-9
First Edition - 1977
Second Edition - 1980
Third Edition - 1985
Fourth Edition - 1988
Fifth Edition - 2000
Revised 2013

555 N. Kensington Ave.
La Grange Park, IL 60526 USA
www.ans.org

American Nuclear Society

What is the American Nuclear Society?

The American Nuclear Society is a professional organization devoted to advancing science and engineering related to the atomic nucleus. The Society's membership of more than 11,000 professionals represents all sectors of the global economy, including individuals in government, academia, research laboratories, and private industry.

A not-for-profit scientific and educational organization, ANS integrates many disciplines as its members explore nuclear applications in agriculture, aerospace, energy, industry, and medicine.

The American Nuclear Society, founded in 1954, upholds its mission to "serve its members in their efforts to develop and safely apply nuclear science and technology for public benefit through knowledge exchange, professional development, and enhanced public understanding."

Nuclear Energy and Electricity

Table of Contents

Introduction

With the goal of increasing public understanding of nuclear science and technology, professionally qualified members of the American Nuclear Society (ANS) have created the "*Q&A Nuclear Energy Facts"* series. The series is published by ANS as a public service. Each booklet answers some of the most-asked questions about nuclear energy and its beneficial uses. Topics are addressed briefly but as factually as possible in a short format.

The purpose of the *Nuclear Energy and Electricity* booklet is to provide factual information to the general public about nuclear energy. The American Nuclear Society originally published this booklet in 1973 and it has undergone several revisions to keep up with events such as the accident at Three Mile Island. Some of these revisions became very technical due to the perceived need to fully and accurately explain the technology. However, it became apparent that explanations became very complicated and that there was a need to return to the original purpose which was to explain the technology to the general public.

The 2013 version has been updated to include more recent events such as the accidents at Chernobyl and Fukushima. These are complicated events and an effort has been made to keep the explanations short and focused.

There is a lot of information about nuclear energy now available on the internet. This technology did not exist when the booklet was first published links and resources are in the back to provide additional information on specific topics that are of interest to the reader. These links are a good starting point for further information about the specific subject.

Will we have enough energy?

The Department of Energy projects that U.S. electricity demand will increase 25% by 2030. Progressively, energy supply issues must address economic, environmental, and political aspects of electricity generation. Nuclear power is a vital part of the energy supply for more and more people around the world. It is receiving increased public attention as an option because energy consumption continues to grow, and future generations will need new energy solutions.

How important is it to have more energy and more electricity?

Access to adequate supplies of energy is very important. Human labor is one substitute for energy, but it is a very inefficient one. Our ancestors learned to use the energy of animals to ease their burdens. They became skilled at using the energy of wind, water, and fire before developing the sources we have today to produce electricity: wood, fossil and nuclear fuels, falling water, wind, and the sun.

We already enjoy the benefits of a society that needs and uses a great deal of energy. However, many countries in the world still use human and animal labor to do work. To raise their standards of living they need high quality energy sources, like electricity, which can be powered by uranium, fossil fuels, hydropower, or other sources.

One of the challenges which the world faces today is that as more nations strive to increase their standard of living, there is increased demand for fossil fuels. Fossil fuels have been the primary source of energy during the industrial revolution. Fortunately, for the production of electricity, another fuel (uranium) has been developed which can help meet the increased demand. Many nations such as China and India are pursuing crash programs to develop civilian nuclear power, as they realized that this is the only path available for them for significantly improving their standard of living.

Do we need nuclear power to generate electricity?

Yes, we need nuclear power to generate electricity for many reasons.

Clean energy: Of all the large-scale ways to generate electricity, nuclear is the cleanest. The operation of nuclear power plants does not involve combustion and causes near-zero air and water pollution. From the mining of the uranium ore to final waste disposal, nuclear power has little environmental impact[1], with insignificant greenhouse gas (carbon dioxide/CO_2) emissions.[2]

Concentrated: One uranium fuel pellet—the size of the tip of your little finger—is the equivalent of 17,000 cubic feet of natural gas, approximately 1 ton (1,780 pounds) of coal, or 126 gallons of oil.[3] Since the energy released from splitting the uranium atom is much greater than the energy released from combustion, the amounts of land, materials, fuel used, and wastes produced, are smaller than the amounts for fossil fuels.

Sustainable: Using nuclear power gives us a greater diversity of fuel sources and reduces our dependence on foreign sources of energy. Our dependence on coal, oil, and gas to make electricity limits their use for other purposes. Uranium, though, has few uses other than as a fuel source, and its supply is plentiful.

Affordable: Nuclear power is one of the most affordable forms of electricity generation. The nuclear plants are expensive to build, but once they are built, they provide electricity at low cost. The cost of the electricity is not sensitive to daily fuel price fluctuations which occur for fossil fuels.

Which energy sources should we rely on?

We need all types of energy sources. The amount of electricity provided by each source for our "energy mix" depends on the availability, cost, and convenience of each energy source. Currently, nuclear power provides 20 percent of the electricity in the United States.

Hydroelectric (or water) power: Many of the best hydropower sites in the United States are operating at full capacity on our rivers. Most hydroelectric power sites have already been utilized and thus the potential for developing more is limited. Hydropower provided 7 percent of the electricity in the United States in 2009.

Solar and wind power: These renewable resources present diffuse energy sources. Although the sunshine and wind are free, there is significant cost associated with gathering enough energy to produce electricity. Another significant disadvantage is that they are intermittent sources, and may not be available to meet the peak electricity demand. Wind and Solar Photovoltaic respectively provided 1.8% and 0.02% of the U.S. electricity in 2009.

Alternatives: Geothermal technology uses the natural warmth of the earth to produce electricity. Biomass energy production involves capturing and burning methane gas from farms and landfills, or burning organic materials. Geothermal and Biomass provided 0.4% and 1.4% of the U. S. electricity in 2009.

Base Load Generation: The low cost generators which operate continuously to meet the base load (the level below which electricity demand seldom drops) are mostly nuclear and coal. Nuclear and Coal provided 20% and 44% of the U.S. electricity in 2009.

Peak Load Generation: The more expensive generators which are placed on line to meet the peak load of the grid are currently use mostly natural gas. Natural Gas provided about 23% of the electricity generation in 2009.

(Note that Hydro is sometimes used as a Peak Load as well as a Base Load generator if it is available)

Will conserving electricity reduce or postpone the need for new power plants?

Energy conservation is important, but it will not eliminate the need for new plants. The world population is growing and the rapid increase in demand for electricity will require the construction of more power plants.

There has been much of discussion about “smart grids” to reduce electricity demand. These smart grids would allow centralized control of electricity loads that are not time sensitive. This is an important improvement and would have the tendency to reduce the daily load variations thus, reducing the need for peaking generators. But this would result in only a temporary relief in the need for more power plant construction.

There is a need for long-term planning for the electricity generation. Nuclear provides the only emission free generation which can meet the increased long term need.

How does the cost of nuclear power compare with that of other sources?

Today, the electricity cost from nuclear power plants is among the lowest of any other energy source. In 2009, the Nuclear Energy Institute reported that the average electricity production cost for nuclear plants was 2.03 cents per kWh; for coal-fired power plants, 2.97 cents per kWh; for natural gas, 5.00 cents; and for oil, 12.37 cents.

Nuclear power plants also have the added cost benefit that their low generation cost helps to lower the cost associated with fossil fuels, by reducing their demand.

Notice that the cost of oil generated electricity is about six times more expensive than nuclear. This high cost has virtually eliminated oil as a source of electricity generation in the United States. In 2009 oil generated only about 1% of the electricity in the United States. Much of this oil generation occurred in Hawaii where there is not much other choice. Hawaii consequently has the highest electrical rates in the United States. (29.2 cents/kWh versus as U.S. average of 11.3 cents/kWh in 2008)

How do the environmental costs of nuclear power compare to other energy sources?

The environmental costs of nuclear power are considerably less than those of other energy sources because nuclear is the only energy source used today that collects and safely disposes of the byproducts generated from energy production.

Nuclear power plants are required by a law to completely isolate all their byproducts from the environment and they set aside money to do this. These nuclear byproducts are often referred to as "waste", but since they still contain usable energy many refer to these byproducts as a future "energy resource".

One of the chief advantage of nuclear generated electricity is that there are no emission, such as CO_2 during normal operation. By comparison, the CO_2 emissions from fossil power are not easily removed from the environment. One proposed method, known as CO_2 sequestration would pump the emissions underground. This method has not yet, been developed commercially, and may not be economical.

What happens to the price of electricity when any power plant is built?

The price of electricity depends on the type of power plant built and the fuel used, as well as the costs of construction, operation, and interest rates. This is true for any new large-scale generating plant such as coal, natural gas, hydro, or nuclear.

The costs, including interest and carrying charges the utility has paid on the funds for construction, sometimes only go into the rate base after the plant is operational. Delays in completion for any reason drive up the costs, especially in times of high inflation.

The question of how a utility should be allowed to recover its construction costs is controversial. Different states and their regulatory agencies take different approaches. Utilities and rate commissions try to ease the price changes to consumers by slowly increasing rates after the plant is completed.

Once a nuclear generating plant is operational and included in the rate base, the cost of power is stable for many decades since the price of uranium ore is a minor portion (approximately 2-3 percent) of total plant costs.

How are locations for nuclear plants selected?

As with any power plant, nuclear plants are located as close as practical to people who use the power they produce, while ensuring against any risks to large populations. This is an economic choice to keep down transmission, distribution, and delivery equipment costs.

Choosing a power plant site involves consideration of technical, economic, legal, environmental, and public opinion factors. Studies are made of the ecology, water quality, geology, meteorology, archaeology, and, if near an ocean, oceanography. Topography, aesthetics, zoning, water supply, and transportation also are considered.

Site selection is a lengthy process. It involves many organizations including the Nuclear Regulatory Commission, the Environmental Protection Agency, state agencies, local government, and others. The public also participates in the process through public hearings.

Most all of the sites proposed for the construction of new nuclear plants in the United States are at sites that already have operating plants, or were already approved for new construction.

What is “license renewal”?

To help utility companies plan for future electrical generation, some existing nuclear power plants, after extensive review, have been granted extended operating licenses. License renewal is the process nuclear plant operators and regulators use to ensure the continued safe operation of plants.

In recent years, utility companies with reactors began submitting special applications to extend the operating life of the plant by 20 years (from 40 to 60 years). The applications go through rigorous review and analysis by the Nuclear Regulatory Commission to make sure that the power plant components are maintained and inspected for safe, reliable future operation.

When nuclear plants were originally licensed the 40 year life time was selected to be consistent with other large power plant projects such as hydroelectric plants. This does not mean that designers thought that they would only last 40 years. At the time there was no experience to judge one way or another. However, after about 50 years of nuclear power experience, it is clear the nuclear plants, with proper upgrades, can last much longer. The extension to 60 years has been granted for many plants (more than half) and extensions to 80 years have been proposed. These extensions are being granted by the NRC only after a thorough review of all the design features of the reactors. Components are replaced as necessary to maintain full safety and operability. Extending the life of power reactors significantly reduces the long-term cost of electricity to the consumer.

How is the public protected from personal injury or property loss that might result from a nuclear accident?

The public is protected by insurance carried and paid for by the owners of nuclear power plants as required by the Price-Anderson Act, passed by the U.S. Congress. This Act makes it unnecessary for a member of the public to provide his or her own coverage.

This no-fault insurance covers any nuclear accident that happens at a nuclear generating plant, or because of the transportation or storage of the plant's nuclear fuel or waste. With no-fault insurance, claimants do not have to go through courts, and lawsuits trying to prove who is at fault before getting a claim settled.

This coverage is in two layers. The first is liability insurance provided by private insurers. The second is a financial pool funded by required contributions assigned to each reactor. If accident damages exceed a specified amount, the Act requires Congress to consider necessary and appropriate action to provide additional compensation as needed. Contractors and vendors in the nuclear industry must adhere to strict standards and safety requirements specified in the Price Anderson Act Amendment (PAAA).[4]

How does spent fuel disposal and nuclear plant decommissioning affect the price of electricity?

As required by law, the price of electricity generated from nuclear power includes a small charge to cover all costs associated with disposing of spent fuel and decommissioning (taking plants out of service). Regulatory agencies audit and monitor the utilities to ensure that enough money is being set aside to cover all these present and future costs.

The amounts of spent fuel are small. About 50 spent fuel assemblies are removed from the average reactor each year. All of the used nuclear fuel generated in every nuclear plant in the past 50 years would fill a football field to a depth of less than 10 yards, and 96 % of this "waste" can be recycled [*]. Used fuel is currently being safely stored. The U.S. National Academy of Sciences and the equivalent scientific advisory panels in every major country support geological disposal of such wastes as the preferred safe method for their ultimate disposal. Industry analysts estimate that decommissioning costs will be about 5 percent of the total generation costs of a given nuclear plant.[5]

What is radiation?

Radiation and radioactivity are natural processes as old as the earth. Materials that are radioactive are made up of atoms that contain excess energy. These radioactive atoms give off their excess energy as radiation in the form of waves or sub-atomic particles.

"Ionizing" radiation is high-frequency radiation that gives off enough energy that it can cause observable chemical changes in the surrounding atoms.

The three basic kinds of radiation that come from radioactive materials are alpha, beta, and gamma radiation. All three types are present in nature. Naturally occurring radiation from soil, water, the atmosphere, and cosmic radiation (from space) is called "background radiation."

Alpha particles are clusters of two protons and two neutrons, equivalent to the nuclei (centers) of helium atoms. They can be blocked by a sheet of paper.

Beta particles are high-speed electrons. A thin sheet of aluminum can block them.

Gamma radiation, like medical X-rays, consists of photons (electromagnetic radiation), except that gamma radiation comes from the atomic nucleus. Gamma rays can be blocked by several inches of lead, several feet of concrete, or a large amount of water.

.

How are we exposed to radiation?

Unstable isotopes that give off ionizing radiation (radiation capable of knocking electrons off of atoms) are found everywhere. Much of the earth's natural background radiation is in the form of gamma radiation, which comes from outer space. We are also exposed to radiation that comes from such elements as potassium, thorium, uranium, and radium. We are constantly surrounded by small amounts of radiation.

Deposits of rocks and minerals vary in concentration and location. In places where certain elements are concentrated, there are also higher amounts of radiation. For example, living near a granite rock formation can increase an individual's background radiation by as much as 100 millirems per year.[6] Living in Denver, Colorado, or flying in an airplane also increases a person's exposure to radiation.

Living things are made of radioactive elements such as carbon and potassium; therefore, they are made of naturally radioactive materials. About half of the radioactivity in our bodies comes from potassium-40. Most of the rest of our bodies' radioactivity is from carbon-14 and tritium, a radioactive form of hydrogen.

Americans get about 25 millirems of radiation from the food and water they eat and drink each year. For example, bananas and Brazil nuts have high concentrations of potassium.

We receive man-made radiation from medical sources, building materials, coal-fired plants, and historic nuclear weapons testing from the 1950s.

How is radiation measured?

The units used to measure radiation are the rem and the millirem (1/1,000th of a rem). The international unit for measuring radiation exposure is the sievert (Sv), and 1 Sv = 100 rems.

Individuals received an average exposure from all sources of about 360 millirems per year in the 1980s. This includes natural sources (such as rocks and cosmic radiation) and man-made sources (such as X-rays). However, the average dose received today is about 620 millirems per year. The difference is due almost entirely to the increased use of radiation in advanced medical diagnostic procedures. This has been an important tool to limit such procedures as exploratory surgery to determine the extent of a medical problem.

What are the health effects of radiation?

Conclusive scientific evidence regarding the health effects of radiation doses less than 1,000 millirems (or 1 rem) is not available. Radiation doses above 5 rems but less than 25,000 millirems (or 25 rems) cause minor blood changes detectable only by laboratory examination. No other clinically observable effects are seen until a dose of more than 50,000 millirems (50 rems) is received.[7]

The health effects of very high doses of radiation are serious, while effects of normal background radiation can only be estimated.

Some studies investigating a theory called "hormesis" show that low doses of radiation may be beneficial to health as it may stimulate the immune system (much like a vaccine).

Radiation at high levels may have two kinds of health effects: somatic and genetic. Somatic effects of radiation include a slightly increased chance of disease in the person exposed. Genetic effects are those that might be passed on to the exposed person's offspring by changes in the genes.

Radiation treatments are widely used in medicine to help cure patients with some kinds of cancer. Doses of 5,000 rems to specific organs or parts of the human body are common. Much smaller doses of radioactive materials are used as diagnostic tools. The use of radioactive materials in medicine for both diagnostic and therapeutic purposes helps millions of people every year.[8]

How much radiation do I get from nuclear power plants?

From all sources, a person in the United States receives an average exposure to radiation of 620 millirems per year. Some of this exposure comes from natural radiation in the soil, water, atmosphere, rocks, building materials, and food. For example, potassium is a common, naturally occurring radioactive element found in certain foods.

Radiation exposure to the public from all commercial nuclear power plants has averaged 0.01 millirem per person annually. Those who live near and many who work at a nuclear power plant typically receive less than 5 millirems per year. The federal limit for people who work in nuclear power plants is a maximum limit of 5,000 millirems per year. Utilities normally set their exposure limits even lower than federal requirements.

How are nuclear plants licensed and regulated?

Before any nuclear plant can be built and go into service, the utility must obtain many different licenses and operating permits from federal, state and local agencies. The Nuclear Regulatory Commission (NRC) requires that strict design and environmental conditions be met, and provides public hearings before the NRC issues a construction permit.

After construction is completed, additional Commission requirements must be met before the NRC issues an operating license, again after a public hearing. During and after construction, the NRC stations full-time inspectors at the plant. Other visiting inspectors are sent to do specific on-site inspections. This assures that the plant is built and operated according to its license.

Each utility checks its plants for radioactive releases. The records are sent to and examined by the NRC and the Environmental Protection Agency. Abnormal conditions or operations are reported to these agencies which then scrutinize utility management problem resolution at the plants or levy fines if there is inadequate utility management action.

What guidelines are followed for the release of radioactivity from nuclear plants?

The guiding principle for releases from nuclear power plants is known as ALARA (As Low As Reasonably Achievable). Plant operators pay continuous, careful attention to assure themselves and the public that any radiation releases are well below the levels that have any observable environmental or human health effects. These levels are set by law and are based on data collected for more than 65 years. The current exposure limit to the public is 25 millirems per year at the plant boundary.

Interestingly, nuclear plants release less radioactivity into the environment than coal-fired plants do, due to small amounts of naturally occurring radioactive materials found in coal deposits.[9]

What do U.S. nuclear plants do to be certain they have minimal effects on the environment?

Utility companies set up an environmental monitoring program several years before bringing nuclear fuel onto any site. The utilities continue monitoring and sampling the environment around the power plant, comparing any effects before and during plant operations. This may include monitoring of a nearby lake, milk from cows, broad leafy vegetables, and fish. In this way they know exactly what effect operation of the plant is having on the environment.

Independent laboratories analyze the samples around these power plantsm and report their results to the utility and public regulatory agencies. All of these records are publicly available. The operation of commercial U.S. nuclear plants has had little, if any, measurable negative impact on the environment. In fact, areas around nuclear power plants have provided excellent habitats for wildlife to thrive, including endangered species such as osprey, peregrine falcons, bald eagles, and the beach tiger beetle.[10]

Extensive environmental monitoring demonstrates that no members of the public receive more than one percent of their total background radiation exposure from nuclear plants. If nuclear plants were completely eliminated as sources of radioactive releases, that elimination would cause no detectable change in the average person's radiation exposure.

How do we know how much radioactivity is released from a nuclear plant if an accident happens?

The amount of radioactivity released by a nuclear power plant is monitored continuously to be sure it does not exceed allowed levels. Sophisticated monitoring equipment provides exact information about any release. The plant operators as well as the Nuclear Regulatory Commission monitor these statistics and reports. Additional monitoring equipment and personnel are on hand for emergency use. Teams practice environmental and radiation monitoring several times a year in emergency drills with independent governmental agency personnel, who also participate.

Have there been serious accidents at nuclear power plants?

Nuclear power involves use of hazardous materials. When an atom of uranium is split to release energy, the pieces left over, the “fission products”, are radioactive. While radioactive materials and radiation are part of the natural environment, too much of them can be hazardous. These materials must be kept sequestered within the power plant to protect the workers and the public. Since these materials also release heat, cooling must be provided, even when the power plant is shut down, to protect the structures that contain the radioactive materials.

Despite an excellent safety record world wide, there have been three serious accidents.

In 1979 at the Three Mile Island nuclear power plant in Pennsylvania, a valve failure followed by operator error resulted in meltdown of the reactor core. The reactor was a total loss, and a small amount of radiation was released, but no one was injured.

In 1986, poor reactor design and operator error at the Chernobyl nuclear power plant in Ukraine (then part of the Soviet Union) resulted in destruction of the reactor and the death of 47 plant workers and fire fighters, as well as 9 members of the public. A significant amount of radioactive material was released and may cause as many as 4,000 additional cancer deaths in addition to the ~200,000 “natural” cancer deaths expected among the 600,000 person population of that area.

In **March 2011**, a severe, Richter 9.0, earthquake and resulting giant 15 meter (50 foot) high tsunami hit the Fukushima Daiichi nuclear power plant in Japan. The tsunami knocked out the shut-down cooling system diesel generators and without cooling, 3 of the 6 reactors melted down with subsequent release of large amounts of radioactive materials. While 19,000 people were killed by the earthquake and tsunami, no one was injured by the nuclear plant failures and no additional deaths are expected due to radiation effects[11].

What is the safety record of U.S. nuclear plants?

In the years since the first U.S. commercial power reactor in Shippingport, Pennsylvania, went into service in 1957, no property damage or injury to the public has ever been caused by radiation from a U.S. commercial nuclear power plant. At present there are more than 100 operable U.S. nuclear plants. From its beginnings, the nuclear power industry's primary concern has been to protect the health and safety of the public.

In 1979, an accident at the Three Mile Island plant brought attention to the safety of nuclear power. The event was a serious financial loss to the utility, but no lives were lost. The maximum estimated individual radiation exposure was 46 millirems—about as much as the extra cosmic radiation a person from sea-level Florida would get by going camping in the mountains of Yellowstone National Park. No one was physically harmed or is likely to suffer future ill effects.

Nuclear professionals carefully apply the lessons learned from plant operations around the globe to maintain the industry's strong safety record.

What happened at Three Mile Island?

The Three Mile Island accident which occurred in 1979 was caused by valve which failed to close thus releasing water from the reactor into the containment. This failure was not recognized for several hours after the reactor was shut down.

The heat production from the fission chain reaction stopped, however, the decaying byproducts still produce some heat and therefore needed to be cooled.

Due to inadequate instrumentation, the operators acted on the wrong information and made the accident worse by shutting off some of the emergency protective systems.

Eventually the water level in the reactor decreased to a level low enough to uncover a portion of the fuel assemblies. When the valve was finally closed, it was too late to prevent a portion of the reactor core to collapse and become virtually uncoolable. Some of the fuel material eventually melted and dropped to the bottom of the reactor pressure vessel.

This accident was the worst accident that the nuclear industry experienced in the U.S. and it resulted in many lessons for improvement, such as improved instrumentation, which make a repeat of this type of accident unlikely.

However, it is also important to note what did <u>not</u> happen.

1. No one was killed or injured
2. No significant amount of radiation was released
3. The pressure vessel remained intact
4. The evacuation that occurred was unnecessary and based on false interpretation of radiation measurements.

What happened at Chernobyl?

In April 1986 a nuclear power plant at Chernobyl, Ukraine (then part of the Soviet Union) suffered a severe accident. The reactor design did not meet the safety standards required in the US and Europe (see the next Q&A).

Operator error resulted in a large, rapid rise in reactor power. The control rods were inserted, which shut down the reactor, but the large pulse of power caused the reactor cooling water, running through high pressure metal tubes in the reactor core, to flash into steam. This burst the cooling tubes and blew the top off the reactor. With no cooling, the reactor core melted. With no top on the reactor, radioactive materials and radiation escaped. With no containment building over the reactor, the radioactivity spread to the surrounding area.

Forty-seven plant workers and fire fighters and 9 members of the public were killed by the fire and by the high radiation doses they received during the accident. No one off the reactor site was exposed to high levels of radiation, but a significant amount of radioactive material was released from the reactor to the surrounding countryside. The population of that area was evacuated, but because the Soviet government initially tried to hide the fact that an accident had occurred, many people in the area received more radiation than is safe. This may cause as many as 4,000 additional cancer deaths in addition to the ~200,000 "natural" cancer deaths expected among the 600,000 person population of that area[12].

This is clearly the worst reactor accident that has ever occurred. Many lessons were learned for the experience. The Soviet RBMK reactor design was phased out and is being replaced by designs that do meet the new, stricter, safety requirements. The existing RBMK reactors are being shut down, including the other 3 reactors at the Chernobyl site.

Why is a Chernobyl type of accident unlikely to occur at US reactors?

The Chernobyl reactor was designed by the former Soviet Union and did not have the safety features required for all U.S. reactors. These features include:

1. The requirement of a containment structure of sufficient strength to contain radioactive products that might be released in the worst possible accident scenario.
2. All U. S. reactors are designed to be stable. That is, power increases must result in natural feedbacks which tend to offset the power increase.
3. Safety features cannot be bypassed by reactor operators
4. Testing in a power reactor is not allowed in U.S. reactors without significant oversight by the NRC.

The U.S. has an organization (INPO) which monitors the industry for adherence to best practices, and distributes information to all reactor licensees about any event at any reactor which may have any safety significance. This is one of lessons learned from the TMI accident. Such an organization was not in place in the Soviet Union at the time of the Chernobyl accident, but is now (WANO- World Association of Nuclear Operators)

What happened at Fukushima?

On March 11, 2011, a major earthquake of Richter magnitude 9.0, one of the largest earthquakes in recorded history, struck off the coast of Japan. This resulted in massive damage to the buildings and infrastructure of the area. There were 11 nuclear power plants operating at four power stations operating in the area at the time. These reactors suffered no significant damage from the earthquake and shut down automatically. Shutdown cooling was started, using electric power from the grid. When off-site power was not available due to the earthquake, emergency diesel generators provided the needed electricity to maintain reactor cooling.

Then, about an hour after the earthquake, massive tsunamis, created by the earthquake, hit the coast of Japan. At Fukushima, seven reactors were operating at two nuclear plants, Fukushima Daiichi (One) and Fukushima Daini (Two). All shut down safely and were being cooled by pumps operated by diesel generators. When the tsunami reached the coast at Fukushima, it was 15 meters (50 feet) high, much higher than imagined possible. The water submerged the pumps and diesel generators of the three reactors at Fukushima Daiichi, putting them out of operation. With no power, the cooling water could not be circulated. With no cooling, the temperature and pressure inside the reactor began to rise. Steam had to be vented to keep the pressure within limits. Efforts to get outside sources of electricity for the pumps were futile because of the devastation of the entire area by the earthquake and tsunami. Eventually, the fuel melted and some of the volatile fission products were vented and released along with the steam. Reaction of the zirconium metal cladding on the fuel rods with steam created hydrogen, which exploded, further added to the venting, carrying volatile radioactive fission products outside the reactor.

Shortly after the accident began, the population living near the plant was evacuated. This zone was eventually extended to 20 km (12.5 miles) and included ~100,000 people[13]. While this was unnecessarily conservative, no member of the public was exposed to any significant level of radiation. Similarly, the plant staff, while receiving higher levels of radiation, was not exposed to hazardous levels. No immediate radiation-related injuries were experienced, and no long-term effects are expected.

As in previous accidents, many lessons were learned at Fukushima. Reactors around the world are being reinforced to withstand higher levels of impact from “natural” events such as earthquakes and tsunamis. Newer reactor designs, called “Generation Three (Gen-III)” designs, now include a higher level of passive safety, where cooling is provided by natural circulation and needs no external source of power to maintain safe temperature levels. There is much interest in smaller modular reactors that could go without external cooling for weeks and in Generation Four designs like the Modular Helium Reactor, that have inherent passive safety and need no source of external cooling to protect the plant and the public.

How are employees and the public protected from potential hazards at operating nuclear power plants?

Safety systems with multiple redundancies are in place to shut the reactor down safely at the first sign of abnormal operation. Plant workers have constant, rigorous training. In the United States, plant operators must be licensed by the Nuclear Regulatory Commission. The electric utilities also created the Institute of Nuclear Power Operations (INPO) to promote the highest levels of safety and reliability among their workers.

The greatest potential hazard from an operating nuclear power plant is from the radioactive products created in the fuel. These come from the fission process that generates the heat to make electricity. Plants are designed to keep these fission products inside the plant. The physical barriers designed to do this include: the building which consists of concrete and steel walls that are 3 ½ -feet thick, the solid fuel itself, and water and metal around the fuel.

Every operating plant has plans in place to alert and advise residents of an emergency. Local civil authorities practice these plans each year. A few communities have demonstrated the value of these plans as they have implemented their nuclear emergency plans to deal with non-nuclear, and potentially, deadly threats.

How do nuclear plant emergency plans protect surrounding communities?

The extensive emergency preparedness exercise programs developed to support nuclear power plants have proven effective even though no radiation-related emergency has ever put them into action.

For example, 10,000 people in Iowa were evacuated following a fire at a sewage treatment plant that spread a plume of toxic gases over the city. City officials credited the nuclear power plant emergency planning program— specifically the plans, the drills, and the exercises—for the knowledge and public awareness that was shown during a large-scale emergency.

Seventeen thousand residents were evacuated from St. Charles, Louisiana, following a leak at a chemical plant. A nuclear power plant emergency plan was used to enable this evacuation.

In Pennsylvania, a fire at a metal plant necessitated the evacuation of 13,000 people. The Susquehanna Nuclear Power Plant evacuation plan was used to organize this effort.

The city of San Luis Obispo, California, evacuated approximately 3,000 people due to an out of control wildfire.

In each of these instances, the plans were immediately and successfully implemented.[14]

How would an earthquake or other natural disaster affect a nuclear power plant?

Nuclear plants are designed to withstand whatever natural forces are likely to happen in specific locations, such as tornadoes, hurricanes, floods, tsunamis, and earthquakes.

Nuclear plants continue to operate during a moderate tremor to provide the electricity needed to maintain communications and public services. However, the plant would be shut down at the first sign of abnormal operations and if seismic (earthquake) activity was greater than a certain amount. Plants have equipment that continuously monitors any potential seismic activity.

Nuclear plants located in areas with a history of earthquakes are built to withstand the maximum motion that could be expected and to be able to shut down safely. Also, all vital devices, equipment, and machines are tested and approved to work during earthquakes, even for plants located away from likely earthquake areas. Nuclear plants are generally built away from earthquake-prone areas, and are designed to withstand a tremor should one occur.

What do plant operators do to prevent sabotage or other man-made disasters?

Utilities follow stringent security precautions to protect nuclear power plants and equipment from malicious damage. People working in the plants are carefully screened for their integrity and emotional stability. Random visitors cannot enter. Authorized employee escorts always accompany business-related visitors and must keep them in sight at all times.

Since September 11, 2001, the industry has dedicated additional resources to respond to security concerns. Since nuclear power plants were already designed for both natural disasters and other risks, nuclear reactors have always had a very high degree of safety from such threats.

The robust physical protection already present at nuclear power plants also provides a high degree of protection from external forces, such as attacks with explosives or aircraft. Studies done by the Nuclear Regulatory Commission and the Electric Power Research Institute have shown that aircraft attacks against nuclear power plants, spent fuel pools, and dry storage casks have a very low chance of resulting in any significant release of radioactivity.

What is nuclear waste and how much is there?

Nuclear waste consists of the radioactive byproducts of nuclear reactors, fuel processing plants, and institutions such as hospitals and research facilities.

The Office of Civilian Radioactive Waste Management reports that as of 2003, the United States accumulated about 49,000 metric tons of spent nuclear fuel. Nuclear wastes are, for the same power output, almost a million times *smaller* in volume than the wastes from coal plants.

It is important to note that only about 5 percent of the total recoverable energy in nuclear fuel is used for power production at this time. Reprocessing of the used fuel and the use of advanced power reactors, such as fast breeders and the integrated fast reactor, will provide future generations with a nearly sustainable source of nuclear energy.

Reprocessing to recover uranium and plutonium avoids the waste of a valuable resource because most of the spent fuel (uranium at less than 1 percent U-235 and a little plutonium) can be recycled as fresh fuel, saving some 30 percent of the natural uranium otherwise required to make new fuel[15]

What are the kinds of radioactive waste?

The Nuclear Regulatory Commission separates wastes into two broad classifications—high-level or low-level waste—based on levels of radioactivity, chemical elements, and biological materials.

Low-level wastes contain very low amounts of radioactivity. They usually require little or no shielding, and no cooling. Low-level radioactive waste results from reactor operations and other uses in hospitals, research laboratories, and manufacturing. They consist of used disposable protective clothing from medical facilities and nuclear power plants, water-treatment resins and filters, compacted trash, contaminated lab equipment, plastics, metals, and liquids. They are the result of good housekeeping practice in which non-radioactive waste is separated from slightly contaminated waste.

High-level radioactive waste comes from the fuel used by nuclear power plants that generate electricity. It has been removed from the reactor along with the assemblies that house the fuel. It is highly radioactive material and requires special shielding during handling and transport.

How do we dispose of low-level waste?

Most low-level wastes are put into drums, and buried at a commercial disposal site. There they are placed at the bottom of trenches (about 20 feet deep). At the Barnwell, South Carolina, site, trenches are back filled with sand and covered with clay each day to keep moisture from getting in. When full, trenches are mounded and capped with clay, and finished off with a foot of topsoil. Grass is planted to help prevent erosion.

The collection, transportation, and burial of low-level radioactive wastes are all closely monitored and controlled by the Department of Transportation, the Environmental Protection Agency, and state agencies.

When properly managed, these low-level wastes do not pose a hazard. The industry now has many decades of experience in handling and shipping these materials. There never has been an accident with these wastes that resulted in the release of radioactivity causing health effects.

What are the issues regarding high-level waste disposal?

The federal government is responsible for disposing of high-level radioactive waste as outlined in the Nuclear Waste Policy Act of 1982.[16] The Department of Energy (DOE) and its Office of Civilian Radioactive Waste Management must ship and store the waste. The Department of Transportation and the Nuclear Regulatory Commission establish and enforce regulations the DOE follows.

These multiple government bodies must coordinate with citizens, private companies, American Indian tribes, and local governments to define policies for the nuclear industry. With diverse interests competing for solutions, frequently debated issues emerge, including:

Storage:
Where and how should the waste be stored?

Transportation:
How should waste be moved?
To which locations should it be moved?

Regulation:
Who has the authority and jurisdiction to make which decisions?

Safe waste processing and handling techniques are established; it is a question of resolving the institutional issues, and then implementing proven radioactive waste management techniques to safely transport and dispose of radioactive wastes.

What happens to used nuclear fuel that comes out of a reactor?

During refueling, fuel rods are removed from the reactor and stored underwater at the plant site. Water cools the used or "spent" fuel and also provides shielding from the radiation as the radiation starts to decay. Much of the high-level radiation decays away within a year of being removed from the core. U.S. utilities also use above-ground, air-cooled storage casks, which are also used safely in Canada and Europe. In the future, the fuel will be shipped to a private or federal storage facility.

It is possible to reprocess and recycle the used fuel, rather than to bury it as waste. More than 90 percent of spent fuel can be recycled and used again as new fuel. But with the large amounts of uranium still available, it is less expensive to mine new fuel than to reprocess the spent fuel. Reprocessing is being done in other countries, such as France and Japan.

What is the Nuclear Waste Fund?

Since their first day of operation, all U.S. nuclear plants have been paying one tenth of a cent per kilowatt-hour generated into the Nuclear Waste Fund to pay for permanent storage of all used fuel. Nuclear plants have so far paid more than $15 billion and, because of those payments, are the only industry in America that has paid the cost of disposing of its waste.

The Department of Energy (DOE), after 20 years of study, has chosen Yucca Mountain, Nevada, as the permanent disposal site for all nuclear waste. The DOE has prepared and submitted an application to the Nuclear Regulatory Commission (NRC) for a license to construct the repository. Before the facility is allowed to receive used nuclear fuel, the NRC must grant a license to receive and possess used nuclear fuel. However, the Obama administration has decided not to pursue Yucca Mountain as the ultimate disposal solution. This has now become a political issue and the remains to be resolved between the Executive branch and the Legislative branch of our government.

Some other nations do not have the same issues with used fuel disposal because they reprocess their used fuel, reclaiming the approximately 97 percent which is unburned for new fuel rods.

Why transport nuclear wastes?

As noted earlier, most *low-level* wastes are packaged in drums and transported to licensed burial sites for storage, monitoring, and control.

High-level waste from commercial nuclear power plants consists of used fuel rods. As mentioned earlier, these fuel rods are stored at the nuclear plant sites. The onsite fuel storage pools at plants were sized initially with the intention of reprocessing the spent fuel for reuse at the plant.

Since reprocessing has been discontinued in the United States, the storage pools at some plant sites are filling up. Fuel rods from these pools are placed in a specially designed and certified cask, and moved to a protected dry cask storage area on-site until they can be moved to a permanent federal repository.

In 1982, Congress enacted the Nuclear Waste Policy Act that calls for high-level waste to be moved to a temporary storage facility or to a permanent Department of Energy (DOE) repository. The DOE's Final Environmental Impact Statement for the Yucca Mountain Project anticipates about 11,000 rail or 53,000 truck shipments during the expected operation of a permanent repository in Nevada.

Are there risks associated with transporting radioactive waste?

The Department of Transportation (DOT) Office of Hazardous Materials Safety estimates that an average of 800,000 shipments of hazardous materials (HAZMAT) are made each day in the United States.[17] It is less hazardous to ship solid nuclear fuel than to ship many other materials (such as gasoline or liquefied natural gas) that are routinely transported all over the country.

Specially designed and tested shipping containers prevent the release of radioactive materials, even in the most severe accident. Sample containers have undergone severe crash and fire tests to prove they can withstand the most severe accidents.

High-level waste is transported in shipping containers by truck, barge, or railway. All shipments are subject to strict federal regulation by the DOT and the Nuclear Regulatory Commission.

According to the National Safety Council, as of mid-1998, four accidents had occurred during spent fuel shipments. None of them released radioactive material.

From 1971 to 1999, 62 accidents occurred during the transport of low-level radioactive waste in the United States. Of these, only four resulted in the release of radioactive materials and those releases caused no measurable radiation exposures.[18]

How are nuclear material shipments regulated?

Regulations and procedures for shipping nuclear materials are governed by two objectives: (1) the transportation procedure should minimize the chance for an accident to occur; and (2) the materials should be packaged so no radioactive material is released if an accident does occur.

The main safety factor is the shipping container. Containers for spent fuel are rigorously designed and tested according to requirements set by the Nuclear Regulatory Commission (NRC) and the Department of Transportation (DOT). The containers are tested at national laboratories by severe tests involving crashes, fire, water, and falls. These tests are much worse than conditions that would occur during a highway accident. These tests assure the container's ability to remain tightly sealed under any conceivable transportation condition.

The DOT has general authority to regulate the transportation of hazardous materials, including radioactive materials. The NRC is responsible for licensing and certifying the casks for high-level radioactive shipments.

Will radioactive waste be left as a "legacy" for future generations?

Radioactive waste need not be an unhealthy legacy for future generations. Some researchers consider a repository to be an asset to future generations who will have the technology to utilize the spent fuel to its fullest potential.

High-level radioactive waste will be stored in solid form in stable geologic formations deep under the earth's surface.

Studies of long-term effects from nuclear power's waste stream demonstrate similar risks to those from solid waste (garbage) or from the waste streams of other industries. These wastes also last for long time periods, and are generated in vastly larger volumes than is nuclear waste, which results in less precaution being taken in their burial.[19]

How much land is used?

Nuclear power is a concentrated energy source and the site land required is typically measured in 1 or 2 square miles. A typical wind farm of equal capacity would require 100s of square miles. However, wind farms do not have the same capacity as nuclear plants (20-33% for wind and 90-95% for nuclear)[20], so relying on wind for a source of electricity has a much greater impact on land use.

What are the emissions from a nuclear plant?

Nuclear power plants do not have greenhouse gas emissions, such as CO_2, during normal operation. However, there are some emissions associated with the construction, such as the use of concrete. The latter is about the same emission as the emission associate with the construction of industrial windmills.

There are controlled releases of some radioactive gases which have been allowed to decay to harmless levels.

The only other emission which might be considered is a slight warming of water if the reactor is cooled using river or ocean water. This type of warming also occurs for fossil power plants which use river or ocean water for cooling, and is generally harmless to fish and is some cases has been beneficial.

Does the development of nuclear power lead to proliferation of nuclear weapons?

Nations which use commercial nuclear power do not use the fuel for weapons production. The enrichment is too low for this purpose. There is plutonium in the spent fuel, but it is not very well suited for producing nuclear weapons, even if the fuel is reprocessed.

If a nation wants to produce nuclear weapons it will do so by producing nuclear material in specially designed reactors. It is much cheaper for them to follow this path than use the materials created in a commercial nuclear reactor. No nation which has developed nuclear weapons has yet obtained the material from a commercial reactor.

How can the spread of nuclear weapons be prevented?

The only way to prevent the spread of nuclear weapons is through diplomatic means.

It is even counter-productive to withhold the development of commercial nuclear power from nations in order to prevent the spread of nuclear weapons. Those nations which have a desire for nuclear weapons may use the acquisition of the technology, such as enrichment, as an excuse for developing nuclear power, which has been denied them, for secretly using the same technology to develop nuclear weapons.

Which new type of reactors are being considered in the U.S.?

As of January 2011, a number of companies have announced their intent to order new reactors. All the announced reactor types are based on existing LWR technology. That is, they use ordinary water for cooling the fuel rods. A total to 23 reactor type have been selected. Most of them are based on the PWR (Pressurized Water Reactor) technology. These reactors have 3 isolated coolant loops and generate steam in a separate vessel called a Steam Generator.

There 3 PWR types currently on order:

- 14 are based on the 1,150 MWe Westinghouse AP1000 design. It is a simplified reactor design with passive safety systems.
- 4 are based on the 1,600 MWe EPR (Evolutionary Power Reactor) design by Areva.
- 1 is based on the 1,700 MWe Mitsubishi APWR (Advanced Pressurized Water Reactor) design

The other LWR design is based on BWR (Boiling Water Reactor) technology. In this design the steam is generated inside the reactor vessel. These reactors have 2 separate isolated coolant loops and there is no Steam Generator.

There 2 BWR types currently on order:

- 1 is based on the 1,600 MWe ESBWR design by GE Hitachi
- 1 is based on the 2,350 MWe ABWR design by Toshiba

There are also 7 companies who have made the decision to build new reactors, but have not yet decided on a design.

Two companies have started construction in the U. S. for 4 reactors (as of 2011). All these reactors under construction are based on the AP1000 design.

How does public opinion influence nuclear power?

Most Americans believe the benefits of harnessing nuclear energy are worth the potential risks. A variety of polls in the United States have found that Americans think that nuclear energy is a good or realistic choice as an energy source for large-scale use.

Supporters of nuclear power were significantly more likely than they were two years ago not to mind a nuclear plant close to their homes. A poll conducted for the Associated Press by International Communications Research indicated that Americans have become more comfortable with nuclear power, with over half saying they support using nuclear plants to produce electricity.

In our democratic society, decisions are made by majority agreement through the political process and our elected representatives. Such majority agreement depends on balancing concerns regarding health and safety, quality of life, and the laws of nature. Tolerances for risk are often calculated in terms of the perceived benefits or probable consequences of a course of action.

What other uses are there for nuclear energy?

Radiation and radioactive elements make our lives easier and more productive in many ways. From industrial applications to medical uses, nuclear science has provided the foundation for many time-and life-saving applications.

For example, the transparent plastic wrap used to package fruits and other foods depends on a radiation process for its strength and clinging ability. Radioactive elements are also used to protect the environment by detecting pathways for pollutants to get into water supplies.

In the medical field, the radioactive isotope Cobalt-60 helps to stop the body's immune reaction to transplanted human organs. Also, tests using nuclear materials in hospital laboratories can detect thyroid under-activity in newborn babies. This makes prompt treatment possible, saving many children from mental retardation.

Small nuclear power generators are used as sources for heat and electricity in remote and extreme climates, including outer space. There are uses for small reactors to produce hydrogen, power remote mining operations, and desalinate seawater.

Nuclear technology also is used to:

- Investigate crime
- Inspect welds
- Explore for gas and oil
- Measure the amount of liquid in a can.

What is our responsibility concerning nuclear energy?

It is *our* responsibility to become informed and make decisions based on reliable information. The scientific community takes responsibility for collecting knowledge about energy technologies, evaluating technologies, and inventing new applications.

Working together, researchers, community members, and policy makers can make decisions based on scientific facts. We also have a responsibility to future generations to ensure they have an adequate supply of energy and a healthy ecosystem.

As technology evolves with advanced power plants, future generations around the world will be able to sustain a good standard of living that will also protect the environment.

FURTHER READING

American Nuclear Society (2012, March). *Fukushima Daiichi*. Retrieved from http://fukushima.ans.org/report/

Carbon, M. W., (1997). *Nuclear Power: Villain or Victim?,* Madison, WI: Pebble Beach Publishers.

Cohen, B., (1983). *Before It's Too Late: A Scientist's Case FOR Nuclear Energy.* New York, NY: Plenum Publishing Corp.

Deuthsch, R. W., (1987). *Nuclear Power: A Rational Approach*, (4th edition). Columbia, MD: GP Courseware.

Henderickx, H. V., (1999). *Plutonium, Blessing or Curse*. Denver, CO: Copper Beach.

Hurley, P. M. (1982). *Living with Nuclear Radiation*. Ann Arbor, MI: University of Michigan Press.

Lapp, R. E., (1979). *The Radiation Controversy.* Connecticut: Reddy Communications Press.

Murray, R. L. (2003). *Understanding Radioactive Waste*, (5nd edition). Columbus, OH: Battelle Press.

Tokyo Electric Power Company, Inc. (2012, June). *TEPCO: Press Release / Release of the Fukushima Nuclear Accidents Investigation Report.* Retrieved from http://www.tepco.co.jp/en/press/corp-com/release/2012/1205638_1870.html

REFERENCES

[1] European Research News Centre (2002, July). *Research – News Centre: Revealing the hidden costs of energy*. Retrieved from http://ec.europa.eu/research/news-centre/en/env/02-10-env02.html

[2] International Atomic Energy Agency (2000, November). *Climate Change and Nuclear Power.* IAEA/PI/A72E 00-01799.

[3] American Nuclear Society (2013). *Source Energy Equivalents*.

[4] Public Law 100-408. (August 20, 1988). *Price-Anderson Amendments Act of 1988.*

[5] U.S. Department of Energy Office of Nuclear Energy, Science and Technology. (2004). *Nuclear Energy*. DOE/NE-0068.

[6] American Nuclear Society (2003, May). *Detecting Radiation in our Radioactive World*. La Grange Park, IL.

[7] American Nuclear Society (2013). *Radiation Dose Chart*.

[8] Rockwell, T. (2004). *Getting Real: The Importance of Basing Analysis and Regulation on Physical Reality*. La Grange Park, IL: American Nuclear Society.

[9] U.S. Geological Survey (USGS). (1997, October). Radioactive Elements in Coal and Fly Ash, Fact Sheet FS-163-97. Retrieved from http://pubs.usgs.gov/fs/1997/fs163-97/FS-163-97.html

[10] Nuclear Energy Institute. (2003). *Powering the Future with Environmentally Sound Nuclear Energy: Ecological Stewardship of the Nuclear Energy Industry.* Washington, DC.

[11] World Nuclear Association (2013, June) *Chernobyl /Chernobyl Accident / Chernobyl Disaster.* Retrieved from http://www.world-nuclear.org/info/chernobyl/inf07.html

[12] World Nuclear Association (2013, June) *Chernobyl /Chernobyl Accident / Chernobyl Disaster.* Retrieved from http://www.world-nuclear.org/info/chernobyl/inf07.html

[13] World Nuclear Association (2013, June) *Fukushima Accident 2011.* Retrieved from http://www.world-nuclear.org/info/fukushima_accident_inf129.html

[14] Nuclear Regulatory Commission. (2003, September). Public

Meeting: *Briefing on Emergency Preparedness Program Status*, Rockville, Maryland.

[15] World Nuclear Association. (2012, April). *Radioactive Waste Management / Nuclear Waste Disposal.* Retrieved from http://www.world-nuclear.org/info/Nuclear-Fuel-Cycle/Nuclear-Wastes/Radioactive-Waste-Management
[16] Public Law No. 97-425. *Nuclear Waste Policy Act of 1982*. (January 7, 1983).
[17] U.S. DOE Office of Civilian Radioactive Waste Management. (2003, November). *Strategic Plan for the Safe Transportation of Spent Nuclear Fuel and High-Level Radioactive Waste to Yucca Mountain: A Guide to Stakeholder Interactions*. Retrieved from http://pbadupws.nrc.gov/docs/ML0334/ML033450106.pdf
[18] National Safety Council. (2005, July). *Understanding Radiation in Our World.* Retrieved from http://www.nsc.org/safety_home/Documents/UnderstandingRadiation.pdf
[19] Saunders, L. D., Chen, W. and Hurdey. S. E. (1997). *Studies of hazardous waste sites and human health: evaluation of internal validity*. *Environmental Reviews,* 5 ,167-180.
[20]Entergy. Backgrounder: *A Comparison: Land Use by Energy Source - Nuclear, Wind and Solar.* Retrieved from http://www.entergy-arkansas.com/content/news/docs/AR_Nuclear_One_Land_Use.pdf

750020.2013

American Nuclear Society

555 N. Kensington Ave.
La Grange Park, IL 60526
(708) 352-6611 telephone
outreach@ans.org email
www.NuclearConnect.org