Career currents

Exploring Today's Energy Careers with the NEED Project Vol. 1, No. 3 Feb. 2006

A World of Opportunities as a Nuclear Engineer

Nuclear Engineers search for efficient ways to capture and use the tiny bursts of energy from naturally disintegrating atoms. As a nuclear engineer, you may solve challenges in the areas of consumer and industrial power, space exploration, world food and water supply, environmental protection, medicine and transportation. For example, you might...

- develop designs for nuclear plants that generate electric power on ships.
- apply radiation in the diagnosis and treatment of disease.
- develop ways to use radiation to produce and preserve food supplies.
- operate and support nuclear energy systems to reduce environmental air pollution.
- develop power plants that run satellites and deep space probes.
- develop and apply regulations to ensure safety in handling radiation sources and operating nuclear systems.

Employment and Earnings

In 2002, there were 16,000 nuclear engineers working in many areas of the nuclear industry. Almost half were employed in utilities, one-quarter in professional, scientific, and technical services firms, and 14 percent in the Federal Government.

Median annual earnings of nuclear engineers were $81,350 in 2002. According to a 2003 salary survey by the National Association of Colleges and Employers, bachelor's degree candidates in nuclear engineering received starting offers averaging $50,104 a year.

Job Outlook

Although no commercial nuclear power plants have been built in the U.S. for many years, nuclear engineers are needed to operate existing plants. Currently, there is a substantial shortage of all types of engineers at nuclear power plants. This shortage is expected to increase as a large number of people leave the work force for retirement within this decade. In addition, nuclear engineers will be needed to research and develop future nuclear power sources, to work in defense-related areas, to develop nuclear medical technology, and to improve and enforce waste management and safety standards.

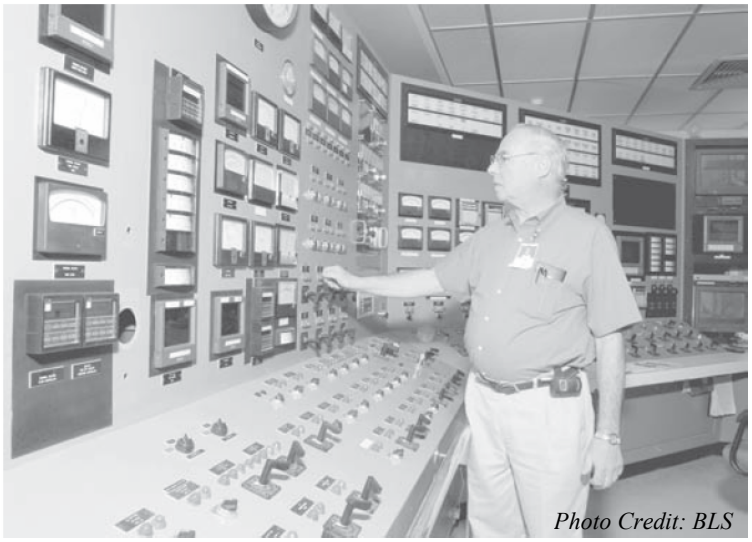

Photo Credit: BLS

The U.S. nuclear industry will need 90,000 new professional and craft workers in the next decade to replace workers leaving the labor force.

Information from the Bureau of Labor Statistics' Occupational Outlook Handbook, www.bls.gov, and the American Nuclear Society, www.ans.org/pi/edu/students/careers.

In This Issue

The goal of this newsletter is to provide educators and students with resources that introduce energy careers. Each issue of *Career Currents* will focus on a different segment of the energy industry. No single issue is meant to be all-inclusive to either the industry segment profiled or all careers in energy. This issue focuses on careers in nuclear science and technology.

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Putting Energy into Education

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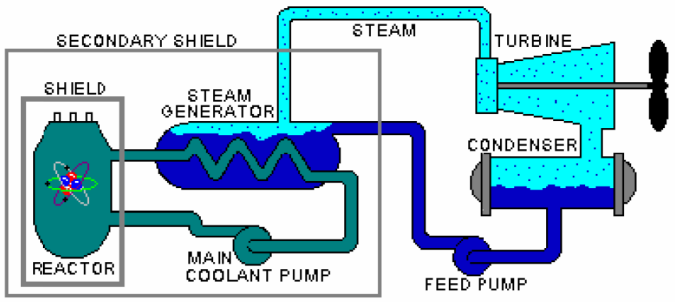
Nuclear Propulsion

The U.S. Navy operates half of the nuclear power reactors in the U.S. aboard surface ships and submarines. Nuclear power allows ships to travel at high speeds for years without refueling. For example, the first nuclear-powered submarine, USS Nautilus, operated on nuclear power for more than two years and covered 62,562 miles before refueling. In contrast, a diesel-powered ship would use two million gallons of fuel to cover the same number of miles!

On the USS Wyoming, fissioning of uranium atoms in the reactor core produces heat. Since this process also produces radiation, 100 tons of lead shielding are placed around the reactor to protect the crew. During a typical submerged patrol, a crew member receives less radiation exposure than he would onshore working in an office building.

Propulsion plants use a **pressurized water reactor** design, which has two basic systems: a primary and a secondary system. The primary system circulates ordinary water through a closed loop consisting of the reactor vessel, piping, pumps, and steam generator. The heat produced in the reactor is transferred to the water under high pressure to prevent boiling. The heated water passes through the steam generator where it transfers its energy to the secondary system. The primary water is pumped back to the reactor for reheating.

Inside the steam generator, the heat from the primary system is transferred across a water-tight boundary to the water in the secondary system. The water boils and creates steam to drive the turbine generator, which supplies the ship with electricity, then flows to the main propulsion turbine to drive the propeller. After passing through the turbine, the steam is condensed into water and fed back to the steam generator by a feed pump. All water is re-circulated, transforming energy produced by the nuclear reaction into useful work.



PRESSURIZED WATER REACTOR

Since there is no step during power generation that requires the presence of air or oxygen, the ship operates completely independent of the earth's atmosphere for extended periods of time. In fact, the length of a submerged submarine patrol is limited primarily by the amount of food the ship can carry for the crew.

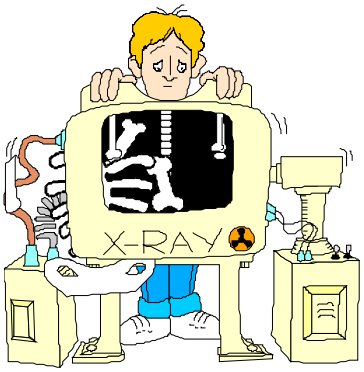
For more information on nuclear propulsion, visit the U.S. Naval Academy's website www.usna.edu, or the Federation of American Scientists at www.fas.org.

The Diverse Field of Nuclear Science and Technology

These are exciting times for professionals in the nuclear science and technology field. New discoveries allow researchers and technicians to save lives, improve the environment, and venture into space. You can be a part of the future by choosing a career in this unique field. Salaries are excellent, and there are unlimited opportunities to advance. Set your sights on a career that will be both professionally and personally rewarding.

Nuclear Medicine

Discoveries based on nuclear science have dramatically improved both longevity and quality of life. Nuclear medicine benefits over 35,000 patients daily in U.S. hospitals and medical clinics. Physicians rely on x-rays to diagnose tumors without invasive surgery. Radiation is used to treat leukemia and other types of cancer. More than half of all medical equipment in hospitals is sterilized with radiation. ***Radioisotopes*** are used in the development of more than 80 percent of all new drugs.



Some career choices:

- **Health Physicists** assure safe application of radiation.
- **Physicians** use nuclear medicine to diagnose and treat diseases.
- **X-ray Technicians** work with patients in hospitals.

Environmental Research

As the world's population grows, the need for food and other perishable resources is increasing rapidly. Radiation is used to develop plants that produce higher yields, to raise healthier animals, to eliminate pests without chemicals and to enhance food safety. In recent years, more than 1,500 new crop varieties have been developed in 40 countries. Scientists used radiation technology to develop 90 percent of those new varieties. In Italy, over half the pasta is made from a wheat variety developed using radiation techniques.

In Africa, Sterile Insect Technique (SIT) is used to control the Tsetse fly population, which can transmit disease in cattle and sleeping sickness in humans. The SIT is the first insect pest control method that uses genetics, by breeding huge quantities of target insects in a "factory" and sterilizing the males by exposing them to low doses of radiation. Sterile male Tsetse flies are released over infested areas, where they mate with wild females. If the sterile males vastly outnumber the fertile wild males, the wild fly population quickly dies out.

Radionuclides and Radioisotopes

A ***radionuclide*** is an atom with an unstable nucleus. The radionuclide undergoes radioactive decay by emitting gamma rays and/or subatomic particles. Radionuclides may occur naturally, but can also be artificially produced.

Radionuclides are often referred to by chemists and biologists as radioactive isotopes or ***radioisotopes***, and play an important part in the technologies that provide us with food, water and good health.

Radionuclides are used in two major ways: for their chemical properties and as sources of radiation.

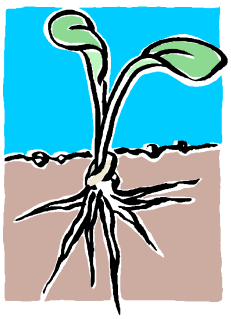
Uses

- Medicine: radioisotopes are used for diagnosis, treatment, and research; to sterilize syringes and other medical equipment.
- Biochemistry and genetics: radionuclides are used to label molecules, in DNA replication and amino acid transport.
- Food preservation: radiation is used to stop the sprouting of root crops after harvesting, to kill parasites and pests, and to control the ripening of stored fruit and vegetables.
- Agriculture and farming: radionuclides are used to yield higher crops, disease and weather resistant varieties of crops, to study how fertilizers and insecticides work, and to improve the production and health of domestic animals.
- Industry and mining: radionuclides are used to examine welds, to detect leaks, to study the rate of wear of metals, and to analyze minerals and fuels.
- Residential: household smoke detectors contain the radionuclide americium formed in nuclear reactors, saving many lives.
- Environmental: radionuclides are used to trace and analyze pollutants, to study the movement of surface water, to measure water runoff from rain and snow, as well as the flow rates of streams and rivers.
- Archaeology and paleontology: radionuclides are used to measure the ages of objects.

Source: http://en.wikipedia.org/wiki/Radioisotope.

Some career choices:

- **Gamma Facilities Operators** use radiation to destroy microorganisms like salmonella and E. coli.
- **Biologists** conduct experiments to develop new varieties of crops.
- **Research Assistants** help scientists and **Food Engineers** collect and analyze data.



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Nuclear Power Plants Offer Careers in Design, Operations and Maintenance

Repairs and plant improvements are seldom made in a nuclear power plant without modernizing a system or piece of equipment. Design, operations and maintenance engineers work together closely to solve problems and keep a power plant running smoothly.

Dominion's North Anna Power Station, in Mineral, VA, offers many career opportunities in nuclear science and technology.

Careers in Design

Fuel Engineers make sure the reactor core is correctly configured and assembled. They specify the fuel to be ordered, conduct reload analyses of new fuel, and supervise its receipt and inspection. They also design the reactor shielding, conduct periodic surveillance tests to ensure fuel limits are not exceeded and monitor tests on potential new fuel.

Chemical Engineers/Chemists are responsible for the chemical properties of the water flowing through the reactor and other cooling and heat removal systems. They minimize pipe corrosion and equipment degradation by monitoring the environmental conditions of the reactor's temperature, pressure, and radiation and by regulating the use of protective chemical additives.

Civil/Structural Engineers ensure the physical integrity of plant structures, including the containment building and radiation shielding for the nuclear reactor. They make certain the structures will safely handle loads produced by ordinary plant operations, that the reactor core will remain intact and safely cooled in the event of an accident, and that the structures will safely withstand extreme-magnitude natural events, such as earthquakes. Civil/structural engineers make sure plant equipment is properly installed so that the plant generates electricity under normal conditions.

Careers in Operations and Maintenance

Reactor Operators (licensed and unlicensed) conduct start-up and shutdown procedures and perform all monitoring functions in nuclear power plants. Operators are stationed at the plant around the clock to perform these responsibilities. While a plant operator position does not require a college degree, an operator does receive many years of training.

Senior Reactor Operators are individually licensed to operate the nuclear power plant in accordance with all regulations. The senior reactor operator with overall responsibility for the plant is usually called the Shift Manager or Shift Supervisor. Several senior reactor operators work on each operating shift. Qualifying for this position typically requires five or more years of experience as a reactor operator, one year of additional training, and passing a Nuclear Regulatory Commission (NRC) exam.

Reactor Operators are licensed operators reporting to the senior reactor operator. Reactor operators move control rods, start and stop equipment, implement operations procedures, conduct surveillance tests and record data in logs. This position requires five years of experience as a non-licensed operator, one year of training, and passing an NRC exam.

Non-Licensed Operators are operators who work in the plant in support of reactor operators and senior reactor operators, assisting according to their direction. Non-licensed operators open and close valves, electrical breakers and other devices as well as directly monitor plant equipment performance. They also prepare systems for maintenance work by applying identification tags and, when the work is complete, removing the tags and realigning the systems for operation. Qualifying as a non-licensed operator generally requires some previous experience and one year of training.

Operations Engineers analyze plant performance and prepare procedures for the plant's components, systems and reactor to generate energy, using their knowledge of the plant as a whole. They require a diverse level of knowledge and expertise, including such areas as mechanical engineering, electrical engineering, reactor physics and chemistry.

Energy Ant in the control room simulator during his training as a Reactor Operator at Dominion's North Anna Power Station.

Reactor Engineers verify the equipment functions within the reactor and take receipt of the fuel. They are responsible for the control rod drive system, reactor instrumentation, and control rod sequence changes.

Systems Engineers are responsible for the performance of specific plant systems, optimizing plant capacity by ensuring that their respective systems are enhancing rather than constraining output. They oversee plant performance and cost data; analyze preventive and predictive maintenance tasks, surveillance tests, equipment hours and availability of repair parts; and recommend and implement design changes.

Maintenance Engineers keep plant machinery in optimal condition to ensure reliable plant operation, so that the plant produces electricity as long as possible and avoids unscheduled shutdowns. They oversee and advise on routine maintenance, including scheduled replacement of worn parts. They also conduct equipment failure analyses and recommend corrective actions to improve reliability.

Health Physicists protect plant workers and the general public from radiation. Health physicists write radiation protection procedures, safety standards and emergency plans to ensure that plant radiation practices conform to federal regulations. They select and maintain radiation and contamination detection equipment. In case of a radiation accident, they assess its environmental impact and prepare protective action recommendations.

Nuclear plants have an outstanding industrial safety record.

Chemists analyze water, oil and particulate samples in support of plant operations. They routinely adjust the pace of the nuclear reaction and can shut down the reactor in an emergency by controlling the boron level added to the cooling water.

Instrumentation and Control Engineers have responsibility for switches, wiring, relaying, terminal boards, control systems and sensing devices. They are involved with circuit design and function, including engineering documentation.

Process or **Project Managers** use operations research, industrial engineering and business management to improve the efficiency of the business and operational functions of the plant. In particular, these engineers devise schedules for all work to be performed during routine refueling/maintenance outages, keeping shutdowns as short as possible.

Information from the Nuclear Energy Institute, www.nei.org.

During his visit to Dominion's North Anna Nuclear Power Station in Mineral, Virginia, Energy Ant learned about career opportunities available to people interested in nuclear energy. Above, Energy Ant explores just how thick the safety barrier is on a nuclear reactor – four feet six inches thick!

A nuclear power plant is a complex technological marvel that needs many different kinds of employees:

- Engineers – **Nuclear**, **Electrical**, **Chemical**, **Mechanical**, **Materials**, **Civil/Structural**
- Professionals – **Health Physicists**, **Radiation Protection Technicians**, **Chemists**, **Non-Destructive Examination (NDE) Analysts**, **Accountants**, and experts in **Instrumentation and Control (I&C)**, **Maintenance**, **Information Technology**, **Business Management**, **Document Control**, **Fire Protection**, **Industrial Safety**, **Security**, **Training**
- Skilled Workers – **Electricians**, **Welders**, **Pipe Fitters**, **Machinists**, **Carpenters**, **Millwrights**, **Heavy Equipment Operators**

Nuclear Medicine Technologist

Nature of the Work

In nuclear medicine, radionuclides (unstable atoms that emit radiation spontaneously) are used to diagnose and treat disease. Radionuclides are purified and compounded to form radiopharmaceuticals. **Nuclear Medicine Technologists** administer radiopharmaceuticals to patients and then monitor the characteristics and functions of tissues or organs in which the drugs localize. Abnormal areas show higher or lower than expected concentrations of radioactivity.

Nuclear medicine technologists operate cameras that detect and map radioactive drugs in patients' bodies to create diagnostic images. After explaining test procedures to patients, technologists prepare dosages of the radiopharmaceuticals and administer them typically by mouth or injection. They position patients and start gamma scintillation cameras, or "scanners," which create images of the distribution of the radiopharmaceuticals as they localize and emit signals from the patients' bodies. The images are produced on computer screens or on film for physicians to interpret.

When preparing radiopharmaceuticals, technologists adhere to safety standards that keep the radiation dose to workers and patients as low as possible. Technologists keep patient records and record the amount and types of radionuclides received, used and safely discarded.

Working Conditions

Nuclear medicine technologists generally work a 40-hour week, perhaps including evening or weekend hours. Opportunities for part-time and shift work are available. In addition, technologists in hospitals may have on-call duty on a rotational basis.

Although the potential for radiation exposure exists in this field, it is kept to a minimum by the use of shielded syringes, gloves and other protective devices, as well as adherence to strict radiation safety guidelines. Technologists also wear badges that measure radiation levels.

Employment and Earnings

Nuclear medicine technologists held about 17,000 jobs in 2002. About two-thirds of all jobs were in hospitals. Most of the rest were in offices of physicians or in medical and diagnostic laboratories, including diagnostic imaging centers.

Median annual earnings of nuclear medicine technologists were $48,750 in 2002. The middle 50 percent earned between $41,460 and $57,200.

Training, Other Qualifications, and Advancement

Many employers require certification from the American Registry of Radiologic Technologists or the Nuclear Medicine Technology Certification Board. Nuclear medicine technologists must meet the minimum federal standards on the administration of radioactive drugs and the operation of radiation detection equipment.

Photo Credit: BLS

Nuclear medicine technologists operate sophisticated equipment to help physicians and other health practitioners diagnose and treat patients.

Nuclear medicine technology programs range in length from one to four years and lead to a certificate, associate degree or bachelor's degree. Courses cover the physical sciences, biological effects of radiation exposure, radiation protection and procedures, the use of radiopharmaceuticals, imaging techniques and computer applications.

Technologists may advance to **Supervisor**, **Chief Technologist**, or **Department Administrator**. Some technologists specialize in clinical areas such as nuclear cardiology or computer analysis, or they take positions in research laboratories. Some become instructors in nuclear medicine technology programs, a step that usually requires a bachelor's or master's degree in nuclear medicine technology. Others leave the occupation to work as sales or training representatives for medical equipment and radiopharmaceutical manufacturing firms or as radiation safety officers in regulatory agencies or hospitals.

The Future of Nuclear Medicine

Technological innovations may increase the diagnostic uses of nuclear medicine. One example is the use of radiopharmaceuticals in combination with antibodies to detect cancer at far earlier stages than is possible today without resorting to surgery. Another is the use of radionuclides to examine the heart's ability to pump blood. Wider use of nuclear medical imaging to observe metabolic and biochemical changes for neurology, cardiology, and oncology procedures will spur demand for nuclear medicine technologists.

Information from the Bureau of Labor Statistics' Occupational Outlook Handbook, www.bls.gov.

Nuclear Energy Information & Career Resources

- American Nuclear Society - www.ans.org/pi/edu and www.aboutnuclear.org for additional useful information for the classroom including back issues of "ReActions", the newsletter for teachers.
- Bureau of Labor Statistics - www.bls.gov
- At the Canadian website www.centreforenergy.com, click on "Careers in Energy" for descriptions of occupations in the energy industry, including management, professional, technical, sales and service, trades and laborers.
- Dominion's North Anna Nuclear Power Station Information Center - www.dom.com
- The Energy Information Administration provides nuclear statistics at www.eia.doe.gov/fuelnuclear.
- The JETS' website, www.jets.org, includes resources, articles, and activities about engineering and technology careers. Their May 2005 Newsletter highlights nuclear engineering.
- Lawrence Berkeley National Lab's ABC's of Nuclear Science - www.lbl.gov/abc
- Nuclear Energy Institute - www.nei.org
- U.S. Department of Energy's Office of Nuclear Energy, Science and Technology - www.ne.doe.gov
- U.S. Nuclear Regulatory Commission, www.nrc.gov

Nuclear Resource for K-4 Teachers

"Dear Sandy," from NEED's Primary Stories and More, includes information about nuclear energy, and a hands-on activity for understanding a chain reaction. For a copy of Primary Stories and More, contact NEED at info@need.org, or call 1-800-875-5029.

Hey Bookworms…

Have you read an interesting biography or book about a person in a cool energy career? Share it with us! Write a book review, including the title and author, a few paragraphs about the book, what you learned, and your recommendations. If we select your book review to publish in a future issue of *Career Currents*, you'll receive a free NEED t-shirt! E-mail your book review to info@need.org, or mail to:

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Other nuclear-related career choices include archaeology and paleontology, crime investigation, science education, policy making, and art appraisal and authentication.

A Career in Nuclear Science and Technology

Take steps to prepare yourself during your high school and college years. Strong backgrounds in science and math are required for engineers and scientists. To enter the field as a scientist or engineer, you will need at least a four-year bachelor's degree, and some positions require a master's degree or doctorate.

Technologists and technicians also need math and science education. Entry level positions generally require at least two years of college. In addition, professionals in all these jobs benefit from communication and business skills. It is important to be able to explain your ideas, research, and projects to managers or to those in other fields.

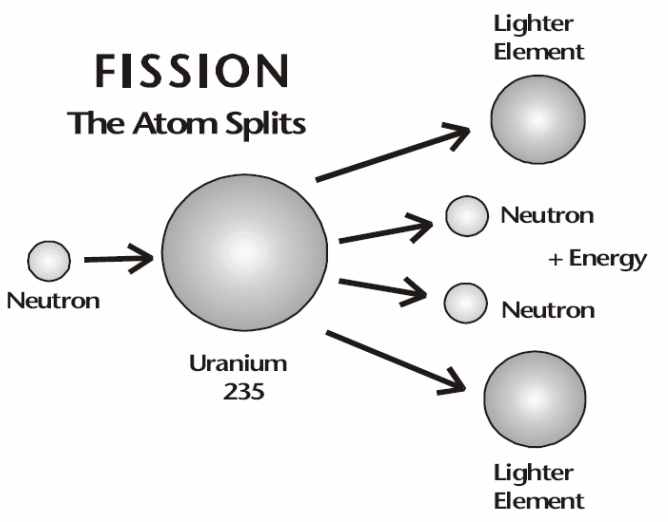
If Art is More Your Style…

Last summer, conservators at the London National Gallery found a sketch by Leonardo Da Vinci hidden behind a painting hanging in the museum! The sketch, layered under paint and invisible to the naked eye, was found while studying the painting "The Virgin on the Rocks" with infrared techniques.

Conservators care for, preserve and treat works of art, work that requires substantial historical, scientific and archaeological research. They use x-rays, chemical testing and special lights to examine objects and determine their condition, need for restoration and the appropriate preservation method. Conservators treat items to minimize their deterioration or restore them to their original state. They usually specialize in a particular area, such as documents and books, or paintings. Conservators need a master's degree in conservation and a background in chemistry, archaeology, studio art, art history and foreign languages.

Information from the American Nuclear Society, www.ans.org, Bureau of Labor Statistics, www.bls.gov, Food and Agriculture Organization of the United Nations, www.fao.org, and The National Gallery, www.nationalgallery.org.uk.

Fission



In nuclear fission, atoms are split apart to form smaller atoms, releasing energy. Nuclear power plants use nuclear fission to produce electricity.

The fuel most widely used by nuclear plants for nuclear fission is uranium. Uranium is nonrenewable, although it is a common metal found in rocks all over the world. Nuclear plants use a certain kind of uranium, U-235, as fuel because its atoms are easily split apart. Though uranium is quite common, U-235 is relatively rare. Most U.S. uranium is mined in the Western United States. Once uranium is mined, the U-235 must be extracted and processed before it can be used as a fuel.

During nuclear fission, a small particle called a neutron hits the uranium atom and it splits, releasing a large amount of energy as heat and radiation. More neutrons are also released. These neutrons go on to bombard other uranium atoms, and the process repeats itself over and over again. This is called a chain reaction.

For more information about nuclear energy, how a nuclear plant works and nuclear waste, visit the Energy Information Administration's website, www.eia.doe.gov/fuelnuclear.

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