mind•full: a brainsnack for future leaders with ethical appetites

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nuclear energy

Nuclear power plants convert uranium, a naturally occurring radioactive element, into energy by causing a chain reaction through fission. Praised by some as a solution to the world's energy needs, nuclear energy also has been stigmatized as dangerous and expensive. Others promote it as a possible solution to the problem of global warming, which experts claim is caused by the gasses released by burning fossil fuels such as coal and oil. Unlike fossil fuels, nuclear energy does not release these gasses into the atmosphere and provides an opportunity for many countries to lower their emissions—a key concern after the recent Kyoto conference on global warming.

Nuclear reactors, however, produce large amounts of radioactive waste which lasts tens of thousands of years and can have devastating effects on health and the environment. Although supporters of nuclear energy feel that this waste can be dealt with responsibly, others feel there are too many dangers associated with its long-term storage. Others point to Three Mile Island and Chernobyl as warnings that an accident at a nuclear reactor is too plausible a scenario to justify its use. But supporters maintain that better reactor construction has improved the safety of new plants.

There is also concern that plutonium could be diverted from power plants and used in clandestine nuclear weapons programs. Large quantities of nuclear materials remain unsafeguarded throughout the world and, some believe, at risk of being stolen. Others believe that international agreements, a strengthened International Atomic Energy Agency, and increased safeguards could address these concerns.

As Earth's population increases and the demand for energy grows there will continue to be a need for reliable energy sources. How much nuclear energy is used will depend largely on our willingness to accept and manage the risks that accompany it.

The mission of Student Pugwash USA is to promote the socially responsible application of science and technology in the 21st century. As a student organization, Student Pugwash USA encourages young people to examine the ethical, social, and global implications of science and technology, and to make these concerns a guiding focus of their academic and professional endeavors.

The **mind•full** series encourages readers to explore crucial ethical dilemmas associated with the application of science and technology.

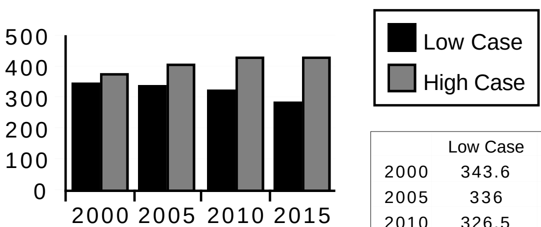
STUDENT PUGWASH USA

go figure!

Nuclear power plants provide a significant percentage of our energy. According to the Energy Information Administration of the US Department of Energy, nuclear power accounted for 17 percent of total electricity generated worldwide in 1996. This energy came from 442 commercial plants operating in 32 countries. However, these plants also created roughly 10.4 thousand metric tons of nuclear waste in 1997. In the United States, 110 nuclear reactors provided 100.7 gigawatts-electric, or 21.9 percent, of the total utility generated electricity in 1996. United States plants created roughly 2.1 metric tons of nuclear waste in 1996. This total is expected to drop in the future since more than one-third of the United States's current nuclear capacity is scheduled for retirement by 2015.

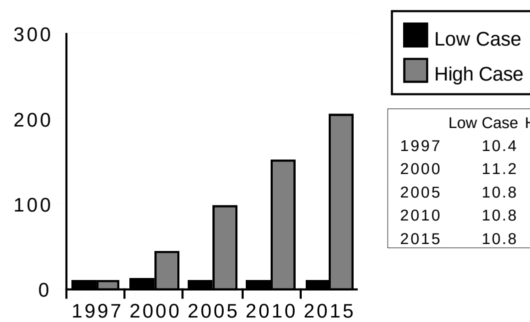
The US Department of Energy provides estimates on how much nuclear energy will be used in the future. These estimates, which predict both high case and low case scenarios, help policy makers have a clearer idea of nuclear energy's future.

high and low case nuclear capacity projections, net gigawatts-electric



	Low Case	High Case
2000	343.6	373.2
2005	336	404.7
2010	326.5	432.9
2015	286.7	431.9

projected world cumulative discharges of spent fuel, in thousand metric tons



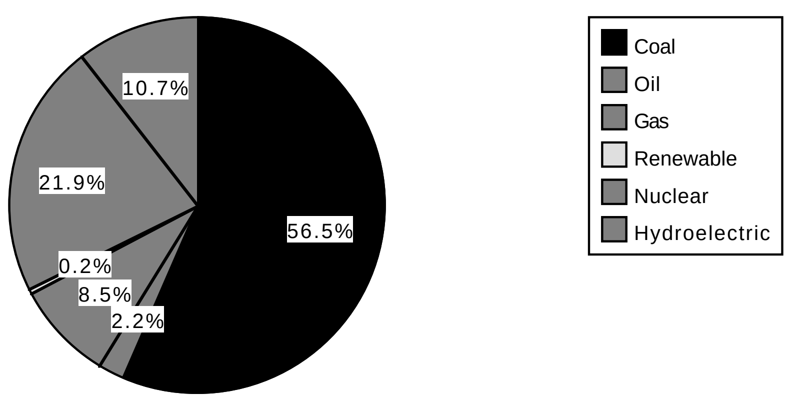
	Low Case	High Case
1997	10.4	10.4
2000	11.2	43.8
2005	10.8	97.6
2010	10.8	151.2
2015	10.8	205.8

Source: *Nuclear Power Generation and Fuel Cycle Report, 1997*, Energy Information Administration. Washington, DC: US Department of Energy, 1997.

power surge!

net generation by energy source, 1997, in gigawatthours

Coal	1,737,453
Oil	67,346
Gas	262,730
Renewable	7,214
Nuclear	674,729
Hydroelectric	327,970



Source: "Monthly Power Plant Report," *Energy Information Administration, Form EIA-759*, Energy Information Administration. Washington, DC: US Department of Energy, 1997.

in control or out of it ?

US policy makers are deciding what role nuclear energy will play in the future. They are debating how to clean up nuclear waste, which nuclear technologies should be developed, and who should have access to these technologies. In addition, there are questions about how current trends to deregulate the electric utilities will affect the nuclear industry. The United States continues to see nuclear power as a viable option for its future energy needs. The US Department of Energy's strategic plan for 1997 calls for increased research in nuclear waste disposal issues and development of advanced nuclear technologies with the goal to have an order for a new nuclear power plant by the year 2010.

Nuclear power plants generate large quantities of waste that remains radioactive for tens of thousands of years. How to dispose of this waste and manage it for such a long period of time remains an important policy concern and technological challenge. The Nuclear Waste Policy Act of 1982, as amended, gives the Department of Energy the responsibility for developing a waste disposal system for spent nuclear fuel and high-level radioactive waste. Most waste from nuclear reactors resides under water in storage pools. These on-site storage facilities are reaching capacity. As a result, utilities are having to find ways to deal with the additional waste, including moving it to dry storage units outside the pools and rearranging the storage pools to hold more spent fuel. Currently US government officials plan to move this waste to a repository in Yucca Mountain in southern Nevada. Critics of the Yucca Mountain plan feel that decisions are being made too hastily, that the mountain is not geologically safe, and that transporting the nuclear waste to the site poses serious safety risks.

Currently there is a debate concerning the reprocessing of spent fuel. Some advocate extracting the plutonium found in spent fuel and combining it with uranium to create a mixed-oxide fuel (MOX). The MOX fuel would then be re-fed through a reactor—in effect, recycling the unused fissionable material that remains in spent fuel. Critics of this plan believe that such large quantities of separated plutonium would be difficult to fully monitor and instead of being re-fed into a reactor, could conceivably be stolen or diverted into an illicit nuclear weapons program. Because of the proliferation

nerds' words

fission—the splitting of a fissionable nucleus into two smaller, nearly equal, radioactive nuclei, accompanied by the emission of two or more neutrons and a significant amount of energy. Fission in a nuclear reactor is initiated by the fissionable nucleus absorbing a neutron.

fission products—the radioactive atoms produced by the splitting of uranium-235 in a nuclear reactor.

nuclear chain reaction—in a nuclear chain reaction, a fissionable nucleus absorbs a neutron and splits into two smaller, nearly equal nuclei, releasing additional neutrons. These in turn can be absorbed by other fissionable nuclei, releasing still more neutrons. This gives rise to a self-sustaining reaction.

nuclear reactor—a device in which a fission chain reaction can be initiated, maintained, and controlled.

nuclear waste—radioactive byproducts from any activity including energy and weapons production, as well as medical treatment and research.

radioactivity—the property possessed by some elements, such as uranium, of spontaneously emitting alpha or beta particles or gamma rays.

reprocessing—extraction of uranium and plutonium from spent fuel for reuse.

spent fuel—fuel that has been used in a nuclear reactor and then withdrawn. Spent fuel is thermally hot and highly radioactive.

uranium—a naturally occurring radioactive element with the atomic number 92 and an atomic weight of approximately 238.

Source: *Science, Society, and America's Nuclear Waste*, Washington, DC: US Department of Energy, 1995.

concerns, as well as the economics and high costs associated with it, the process was banned in the United States in 1977, with the hopes that other countries would do likewise. The issue of MOX fuel has resurfaced in the United States due to a recent report by the National Academy of Sciences (NAS) about how to get rid of plutonium that is removed from retired nuclear weapons. The NAS recommends that the United States allows some of the plutonium from nuclear weapons to be converted into MOX fuel and re-fed through a reactor, thus eliminating the possibility that it would be reassembled into a nuclear warhead. The NAS, however, warns that this process be used only for plutonium from nuclear weapons and not from commercial reactors. Currently the United States does not have the facilities to produce MOX fuel.

Although the United States has made no new orders for nuclear reactors since 1979, other countries continue to develop their nuclear energy programs. This is especially true in East Asia where, according to the US Department of Energy, at least 30 percent of the world's new nuclear capacity will be located. The US nuclear industry and the United States government are working to export US reactor technology and services to a number of Asian-Pacific countries. Proposed sales to China have elicited concern because of questionable transfers of nuclear technologies China has made to Iran and Pakistan.

fuel cycle 101

The nuclear fuel cycle is the process which converts uranium (U) in nuclear reactors into energy through nuclear fission. Uranium, as found in nature, consists of 99.3 percent of the isotope U-238 and .7 percent U-235. When U-235 is hit by a neutron, it fissions into two smaller atoms and releases two or more additional neutrons, plus an amount of energy. The additional neutrons released from the fission then collide with more uranium atoms which, in turn, release more neutrons and energy. Thus, a self-sustaining nuclear chain reaction capable of generating large quantities of energy can be created under controlled conditions. The nucleus of a U-238 atom when hit by a free neutron absorbs the neutron and changes into the isotope U-239, which quickly decays into plutonium (Pu-239), which, like U-235, is also fissionable.

In nuclear power reactors, fuel rods filled with uranium are used to create a controlled chain reaction and thus create energy. As the reactor operates, the concentration of fissionable material decreases. When the amount of fissionable uranium and plutonium decreases to a certain level the fuel rod is replaced. The old, or "spent," fuel rod is highly radioactive nuclear waste containing non-fissioned plutonium and U-235 atoms, as well as U-238 and other radioactive materials.

another chernobyl?

On April 26, 1986 the worst nuclear disaster in history took place when an explosion at the Chernobyl nuclear power plant in Ukraine, spread radioactive contamination throughout Europe. According to a report by the United Nations secretary-general, an area of 160,000 square kilometers (the size of England, Wales, and Northern Ireland combined) was contaminated, and an estimated 9 million people were affected. In addition, serious health consequences continue to plague the region, as cases of thyroid cancers in children continue to rise. But can a similar disaster happen again? According to a report by the Natural Resources Defense Council, there are 26 more reactors with similar design flaws operating in the Soviet Union and Eastern Europe. These reactors are known to have serious safety risks that cannot be repaired through technical upgrades. These plants continue to operate because the countries say they cannot afford to replace them with safer energy sources, whether nuclear or from another source.

(anything but a) conclusion

Countries likely will use nuclear power well into the future. Many countries will continue to look to it as an option, especially considering recent efforts to lower emissions of greenhouse gasses. Questions about management and storage of nuclear waste, the safety of nuclear reactors, and ensuring that nuclear energy programs are not used for clandestine weapons programs will all have to be addressed. Ultimately society will have to decide if the benefits of nuclear energy outweigh the risks. In the meantime, we must continue to explore other energy options, such as alternative energy sources and increased energy efficiency measures.

How do **you** answer the **tough questions**

Do you think nuclear energy is a viable energy option for the future? Do the benefits of a zero-emission energy source outweigh the risks associated with nuclear waste and possible accidents? Why?

Should governments continue to fund research in advanced nuclear technologies or should they be spending that money to study other energy options? Why? What are the benefits of either course of action?

The nuclear industry has many strong supporters as well as opponents that publish a lot of information on either the benefits or dangers of nuclear power. Are you more likely to believe a report on nuclear safety by the nuclear industry, a watchdog group, or a government agency? Why?

The post-World-War-II era has often been called the nuclear age. In what ways has nuclear energy affected us culturally? In what ways do we see nuclear energy reflected in our entertainment, thinking, and way of life?

Many experts agree that nuclear power programs in “rogue” countries could help advance clandestine nuclear weapons programs. What measures should the international community take in order to prevent such an occurrence? What types of control, if any, should the international community impose?

Do you think the community should be involved more directly in determining what types of energy sources it uses or do you think the public's opinions are already adequately represented through our democratic system? How could citizens participate more fully in the process—through citizens' committees, individual action, advocacy groups, or some other means? What role should the scientific community play in focusing research on alternative energy sources that rely on abundant resources?

What responsibility does society have to adopt better energy efficiency measures before it invests in more power plants? What incentives do you think would encourage energy efficiency?

If a nuclear accident occurs in one country, should that country be held responsible for the health and environmental damage that is caused across its borders? If so, how? If not, why?

Many nuclear power plants across the United States are closing because they are economically inefficient. Who should pay for the costs of closing the plants? The nuclear industry? The taxpayers? The consumers? Why?

Linguists have been hired by the government to try to figure out how to convey "danger" on signs near planned disposal sites that could be understood tens of thousands of years into the future. Do you think our society has a right to produce nuclear waste that will have such long-lasting effects. Why or why not?

highly enriched reading

• *Beyond Engineering: How Society Shapes Technology*, Robert Pool—uses the history of nuclear energy as a case study to demonstrate the interplay between machines and society. Oxford University Press, 1997.
• *Chernobyl*, Frederik Pohl—a "drama-documentary" novel about the disaster. Bantam Books, 1987.
• *Chernobyl: The Forbidden Truth*, Alla Yaroshinska—tells of the author's struggle to publish the truth about the Chernobyl disaster. Inbook, 1994.
• *Citizen Scientists*, Frank von Hippel—this Pugwashite's book includes a section on nuclear reactor accidents. New York: Touchstone, 1991.
• *The Curve of Binding Energy*, John McPhee—documents views of Pugwashite Ted Taylor on the risks involved with nuclear energy and nuclear weapons. Farrar Straus & Giroux, 1974.
• *Genius in the Shadows*, William Lanouette—documents the life of Leo Szilard, a Pugwashite and one of the designers of the first nuclear reactor. Chicago: University of Chicago Press, 1992.
• *Management and Disposition of Excess Weapons Plutonium*, National Academy of Sciences—addresses the issue of reducing the world's stockpiles of excess plutonium. Washington, DC: National Academy Press, 1994.
• *Midas World*, Frederik Pohl—science fiction about a world that has discovered a dirt-cheap energy source and the consequences. London: New English Library, 1983.
• *Nuclear Power Generation and Fuel Cycle Report*, 1997, Energy Information Administration—excellent resource for information on nuclear energy around the globe. Washington, DC: US Department of Energy, 1997.
• *Orion Shall Rise*, Poul Anderson—science fiction about a young noble and his band who conspire to use the power of the atom, outlawed for centuries, to regain the lost heritage of space flight. Baen Books, 1991.
• *Plutonium and Highly Enriched Uranium 1996: World Inventories, Capabilities and Policies*, David Albright et al—an excellent overview of how much weapons grade plutonium and uranium is in the world. SIPRI and Oxford University Press, 1997.
• "Renewable Energy," *mind•full: a brainsnack for future leaders with ethical appetites*, Vol. I, No. 8, Student Pugwash USA, April 1997, David Blecker—you can download this at www.spusa.org/pugwash/
• *US Department of Energy Strategic Plan*, US Department of Energy—learn how the federal government plans to use nuclear energy in the future. Washington, DC: Department of Energy, 1997.

check it out !

nuclear projections

• *The China Syndrome*—Jane Fonda and Michael Douglas star in this classic about a cover up of an accident at a nuclear power plant.
• *Silkwood*—based on a true story, whistleblowers try to expose unsafe practices at an Oklahoma nuclear power plant after a worker is contaminated.
• *Class of Nuke 'Em High*—a nuclear waste spill near a high school in New Jersey spawns a monster and mutates a few straight-A students.
• *The Simpsons*—a new fun-filled nuclear disaster in just about every episode.

cyberspace

top picks

• International Atomic Energy Agency (loaded with information, including the work they do to safeguard nuclear materials)—www.iaea.org

• The Virtual Nuclear Tourist! Nuclear Power Plants Around the World (a well-organized site that provides tons of understandable technical information on all aspects of nuclear energy)—www.cannon.net/~gonyeau/nuclear/index.htm

best of the rest

• Chernobyl No More (a good site on the Chernobyl disaster, with suggestions on how to prevent another disaster)—www.ecn.cz/c10/index.html
• Frontline: Nuclear Reaction (site based on a PBS documentary)—www.pbs.org/wgbh/pages/frontline/shows/reaction
• The Institute for Energy and Environmental Research (lots of good fact sheets on nuclear issues)—www.ieer.org/ieer/index.html
• Nuclear Control Institute (this site is mainly concerned with the proliferation risks associated with nuclear energy)—www.nci.org/nci/
• Nuclear Energy Institute (the NEI is the nuclear industry's policy organization)—www.nei.org
• Nuclear Information and Resource Service (anti-nuclear group that looks at nuclear power, radioactive waste, radiation, and sustainable energy issues)—www.nirs.org
• Nuclear Waste Citizens Coalition (brings together sixteen different anti-nuclear groups to educate and protest waste disposal and reprocessing)—www.essential.org/orgs/nwcc/nwcc.html
• Office of Nuclear Energy, Science and Technology (the Department of Energy has put a lot of reports and information on the Web)—www.ne.doe.gov
• Union of Concerned Scientists (information on energy policy, arms control, and plutonium)—www.ucsusa.org
• The United States Nuclear Regulatory Commission (agency whose mission is to provide adequate protection of the public health and safety, the common defense and security, and the environment in the use of nuclear materials in the United States)—www.nrc.gov
• The Uranium Institute: Uranium and Nuclear Energy (good information about the fuel cycle and nuclear waste. Check out the carbon emissions calculator!)—Www.uilondon.org

This **mind•full** was written by David Andersen, Student Pugwash USA's national chapter coordinator. Special thanks to Alan Krass of the US Arms Control and Disarmament Agency, and David Blecker, an analyst with MSB Energy Associates, Inc., for their comments. Any errors are the responsibility of Student Pugwash USA.

but wait, there's more!

• **mind•full: a brainsnack for future leaders with ethical appetites**. Volume one available, includes: international weapons trade; emerging infectious diseases; access and the Internet; public's role in science; future of nuclear weapons; water quality and availability; war and disease; renewable energy. Volume two issues available: pugwash conferences; exploring human genetics; science, technology, & culture; communications technologies; and beyond nuclear weapons.
• **Jobs You Can Live With: Working at the Crossroads of Science, Technology, and Society**. The fifth edition of the Student Pugwash USA internship directory. It highlights approximately 200 organizations that work to promote the ethical use of science and technology and provides suggestions on how to go about the internship and job search.
• **Science, Technology, and Ethical Priorities: Proceedings of Student Pugwash USA's Ninth International Conference**.
• **Pugwatch.** The chapter newsletter.
• **Chapter Organizing Guide.** Newly updated, provides chapter members with an A to Z guide to getting a campus-based chapter up and running.

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