## Appendix D

# List of Acronyms and Glossary

### Acronyms

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|---|---|
| AEC | –Atomic Energy Commission |
| ASDEX-U | –Axisymmetric Divertor Experiment Upgrade; Garching, Federal Republic of Germany |
| ATF | –Advanced Toroidal Facility; Oak Ridge National Laboratory, Oak Ridge, Tennessee |
| CERN | –European Laboratory for Nuclear Research (after its original French acronym) |
| CIT | –Compact Ignition Tokamak; proposed for the Princeton Plasma Physics Laboratory, Princeton, New Jersey |
| COCOM | –Coordinating Committee |
| CPMP | –Comprehensive Program Management Plan |
| CPRF | –Confinement Physics Research Facility; under construction at Los Alamos National Laboratory, Los Alamos, New Mexico |
| D III | –Doublet ill; GA Technologies Inc., San Diego, California |
| D II I-D | –Doublet III Upgrade; GA Technologies, San Diego, California |
| D-D Reaction | – Deuterium-deuterium fusion reaction (see Glossary) |
| D-T Reaction | —Deuterium-tritium fusion reaction (see Glossary) |
| DoD | –U.S. Department of Defense |
| DOE | –U.S. Department of Energy |
| dpa | –displacements per atom |
| EC | –European Community |
| ECRH | —electron cyclotron resonance heating (see Glossary) |
| EPRI | —Electric Power Research Institute; Palo Alto, California |
| ERAB | –Energy Research Advisory Board |
| ERDA | –Energy Research and Development Administration |
| ESECOM | –Senior Committee on Economic, Safety, and Environmental Aspects of Magnetic Fusion Energy |
| ETR | —engineering test reactor (see Glossary) |
| eV | —electron volt (see Glossary) |
| FED | –Fusion Engineering Device |
| FER | –Fusion Experimental Reactor (proposed Japanese engineering test reactor) |
| FPA | —Fusion Power Associates; Gaithersburg, Maryland |
| FRC | –field-reversed configuration (see Glossary) |
| GA | –GA Technologies Inc.; San Diego, California |
| GNP | –gross national product |
| IAEA | –International Atomic Energy Agency |
| ICRH | —ion cyclotron resonance heating (see Glossary) |
| IEA | –International Energy Agency |
| IFF | –Integrated Fusion Facility |
| INTOR | —International Tokamak Reactor |
| ITER | —International Thermonuclear Experimental Reactor |
| JAERI | –Japan Atomic Energy Research institute |
| JET | –Joint European Torus; Abingdon, UK |
| JIFT | –Joint Institute for Fusion Theory; University of Texas at Austin, Texas, and Nagoya University in Japan |
| JT-60 | –Japan Tokamak-60 |
| LANL | –Los Alamos National Laboratory; Los Alamos, New Mexico |
| LCT | –Large Coil Task; Oak Ridge National Laboratory, Oak Ridge, Tennessee |
| LLNL | —Lawrence Livermore National Laboratory; Livermore, California |
| LMFBR | –liquid metal fast breeder reactor (fission–see Glossary) |
| LWR | –light-water reactor (fission–see Glossary) |
| MFAC | —Magnetic Fusion Advisory Committee |
| MFECC | –Magnetic Fusion Energy Computing Center; Lawrence Livermore National Laboratory, Livermore, California |
| MFEE Act | –Magnetic Fusion Energy Engineering Act of 1980 (Public Law 96-386) |
| MFPP | –Magnetic Fusion Program Plan |
| MFTF-B | –Mirror Fusion Test Facility B at Lawrence Livermore National Laboratory, Livermore, California |
| MIT | –Massachusetts Institute of Technology; Cambridge, Massachusetts |
| NASA | –U.S. National Aeronautics and Space Administration |
| NET | —Next European Torus (proposed European engineering test reactor) |
| NIH | –U.S. National Institutes of Health |
| NRC | –U.S. Nuclear Regulatory Commission |
| NSF | –U.S. National Science Foundation |
| OER | –Office of Energy Research in the U.S. Department of Energy |

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| OFE | –Office of Fusion Energy in the Office of Energy Research, U.S. Department of Energy |
| OHTE | –Ohmically Heated Toroidal Experiment; GA Technologies Inc., San Diego, California |
| ORNL | –Oak Ridge National Laboratory; Oak Ridge, Tennessee |
| OTR | –Operational Test Reactor (proposed Soviet engineering test reactor) |
| PBX-M | –Princeton Beta Experiment Modification; Princeton Plasma Physics Laboratory, Princeton, New Jersey |
| PPPL | –Princeton Plasma Physics Laboratory; Princeton, New Jersey |
| Q | –Energy Gain (see Glossary) |
| RF | —radiofrequency |
| RFP | —reversed-field pinch (see Glossary) |
| TEXT | –Texas Experimental Tokamak; University of Texas Fusion Research Center in Austin, Texas |
| TEXTOR | –Tokamak Experiment for Technology Oriented Research; Julich, Federal Republic of Germany |
| TFTR | –Tokamak Fusion Test Reactor; Princeton Plasma Physics Laboratory, Princeton, New Jersey |
| TMX | —Tandem Mirror Experiment; Lawrence Livermore National Laboratory, Livermore, California |
| TMX-U | –Tandem Mirror Experiment Upgrade; Lawrence Livermore National Laboratory, Livermore, California |
| Tokamak | –Toroidal magnetic chamber, in Russian (see Glossary) |
| TPA | –Technical Planning Activity |
| TSTA | –Tritium Systems Test Assembly; Los Alamos National Laboratory, Los Alamos, New Mexico |
| UCLA | –University of California at Los Angeles |
| UFA | –University Fusion Associates |
| UK | –United Kingdom |

## Glossary

**Acid deposition:** A consequence of fossil fuel combustion in which combustion byproducts emitted as gases react in the atmosphere and are deposited on earth in the form of acidic substances. Also called "acid rain."

**Activation product:** Material made radioactive through exposure to neutrons in fission or fusion reactors.

**Active protection:** The condition in which the safety of a nuclear reactor can be assured only through the proper design and operation of active safety systems. See "Passive protection."

**Advanced tokamak:** A tokamak incorporating features such as steady-state current drive or shaping of the plasma in order to attain higher performance or more efficient operation than the conventional tokamak. See "Tokamak" or "conventional tokamak."

**Afterheat:** Heat produced by the continuing decay of radioactive atoms in a nuclear reactor after fission or fusion reactions have stopped. Afterheat in a fission reactor originates primarily in the fuel rods; in a fusion reactor it would result mainly from induced radioactivity in the reactor structure.

**Alpha particle:** A positively charged particle, identical to a helium-4 nucleus, composed of two protons and two neutrons. An alpha particle is emitted in the radioactive decay of many naturally occurring radioisotopes such as uranium and thorium; it is also one of the products of the D-T fusion reaction.

**Alternate confinement concept:** A fusion magnetic confinement concept other than the tokamak.

**Anomalous transport:** Loss of energy from tokamak plasmas due to escaping electrons that occurs at a rate several times higher than that predicted by present theory.

**Ash:** The end-product of a fusion reaction. For the D-T fusion reaction, the "ash" is helium gas.

**Atom:** A particle of matter indivisible by chemical means that is the fundamental building block of a chemical element. The dense inner core of the atom, called the nucleus, contains protons and neutrons and constitutes almost all the mass of the atom. The nucleus is surrounded by a cloud of orbiting electrons. Atoms contain equal numbers of positively charged protons and negatively charged electrons and as a whole are electrically neutral. An atom is a few billionths of an inch in diameter, and several sextillion (1 followed by 21 zeros) atoms are found in an ordinary drop of water.

**Atomic nucleus: See** "Nucleus."

Auxiliary heating: External systems that heat Plasmas to higher temperatures than can be reached from the heat generated by electric currents within the plasma. Neutral beam heating and radiofrequency heating are both examples of auxiliary heating systems.

**Axial:** The direction in a cylinder parallel to the central axis of the cylinder.

**Background radiation:** Naturally occurring sources of radiation. Primary sources are cosmic rays and naturally occurring radioactive isotopes that are found in the earth or are produced in the atmosphere by cosmic rays.

**Balance of plant:** Those systems in a fusion reactor not associated with producing or controlling the fusion reaction. Systems i n the balance of plant convert the heat produced by fusion reactions into electricity. See also "Fusion power core."

**Beta:** The ratio of the outward pressure exerted by the plasma to the inward pressure that the magnetic confining field is capable of exerting. Beta is equivalent to the ratio of the energy density of particles in the plasma to the energy density of the confining magnetic fields.

**Beta particle:** A high-energy electron emitted in the decay of certain radioactive isotopes.

**Bilateral agreement:** An agreement between two nations.

**Biologically active:** Substances that are absorbed by living organisms and are utilized in biological processes. Radioactive substances that are biologically active (e. g., radioactive iodine or strontium isotopes) become incorporated into living organisms.

**Blanket: Structure surrounding the plasma** in a fusion reactor within which the fusion-produced neutrons are slowed down, heat is transferred to a primary coolant, and tritium is bred from lithium.

**Breakeven:** The point at which the fusion power generated in a plasma equals the amount of heating power that must be added to the plasma to sustain its temperature.

**Breakeven-equivalent:** Attainment in a non-tritium-containing plasma of conditions (temperature, density, and confinement time) that would result in breakeven if the plasma contained tritium. Because plasmas not containing tritium are far less reactive than those containing tritium, the actual amount of fusion power generated by a breakeven-equivalent plasma will be far less than would be produced under actual breakeven conditions.

**Breeder reactor: A nuclear reactor that produces more fissionable fuel than it consumes. Breeders produce fissionable fuel by irradiating fertile materials with neutrons. See "Fertile material."**

**Breeding ratio:** The number of tritium atoms produced in the blanket of a fusion reactor for each tritium atom consumed in the fusion plasma.

**Burn control:** The mechanism by which the power level of a self-sustaining fusion reaction is regulated.

**Capital-intensive: An energy-generating technology** in which most of the cost of energy is due to the fixed cost of the capital investment in the generating station, as opposed to variable fuel or operations and maintenance expenditures.

**Carbon dioxide ($C0_2$):** An inherent product of the combustion of fossil fuels. Buildup of carbon dioxide i n the earth's atmosphere as a result of fossil fuel use may affect global climate. See "Greenhouse effect."

**Central cell:** In the tandem mirror confinement concept, the central cell is the region where most of the power-producing fusion reactions would occur. Plasma in the central cell is kept from escaping by electric fields generated by the end cells. See "End

**Centrifugal injector:** Device that uses centrifugal force to inject pellets of frozen fuel into fusion plasmas.

**Chlorofluorocarbons:** Manmade chemicals, used as refrigerants, industrial solvents, and for other purposes, which have heat-retaining properties similar to carbon dioxide when released into the atmosphere.

**Cladding:** In a fission reactor, the material that encloses nuclear fuel.

**Classical confinement:** The best possible plasma confinement, in which the only mechanism by which particles escape the plasma is through rare, but inevitable, collisions between plasma particles that cause them to migrate across the magnetic field towards the plasma edge. Classical confinement is also referred to as "classical diffusion. '

**Classification:** Restricting the dissemination of certain information for reasons of national security. Only people holding security clearances granted by the government are permitted access to classified information.

Closed **confinement concept:** Magnetic configuration in which the plasma is confined by magnetic lines of force that do not lead out of the device. Closed confinement concepts all have the basic shape of a doughnut or inner tube, which is called a torus.

**Collaboration:** An intensive type of international cooperation involving a substantial degree of program integration, funding commitment, and joint management.

**Commercial feasibility:** Fusion power's acceptance in the marketplace as a source of energy that is environmentally and socially acceptable and economically competitive when compared to alternate sources of energy.

**Compact toroids:** A class of magnetic confinement configurations in which the chamber containing the plasma need not have a central hole through which external magnet coils must pass. Examples are the spheromak and the field-reversed configuration.

**Compression heating:** Method of heating a plasma by compressing it into a smaller volume. The plasma is compressed by modifying the external magnetic fields.

**Conceptual design:** The basic or fundamental design of a fusion reactor or experiment that sketches out device characteristics, geometry, and operating features but is not at the level of detail that would permit construction.

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**Confinement:** Restraint of plasma within a designated volume. In magnetic confinement, this restraint is accomplished with magnetic fields.

Confinement concept: A particular configuration of magnetic fields used to confine a fusion plasma. Various confinement concepts differ in the shape of their magnetic fields and in the manner in which these fields are generated.

**Confinement parameter:** The product of plasma density and confinement time that, along with temperature, determines the ratio between power produced by the plasma and power input to the plasma. Also called "Lawson parameter."

**Confinement time:** A measure of how well the heat in a plasma is retained. The confinement time of a plasma is the length of time it would take the plasma to cool down to a certain fraction of its initial temperature if no heat were added.

**Confining magnets:** External magnets used to generate the confining magnetic fields in a fusion device.

**Containment building:** In a fission reactor, the containment building is a thick concrete structure surrounding the pressure vessel that encloses the reactor core and other components. It is designed to prevent radioactive material from being released to the atmosphere in the unlikely event that anything should escape from the pressure vessel. The need for containment buildings for fusion reactors has not vet been determined.

**Conventional tokamak:** A tokamak device not incorporating advanced steady-state current drive or plasma shaping technology. See "Tokamak," "Advanced tokamak."

**Coolant:** Fluid that is circulated through a component or system to remove heat. In a fusion reactor, the coolant would flow through the blanket to remove the heat generated by fusion reactions.

**Cooperation:** In the context of international activities, cooperation refers to all activities involving nations or individuals from different nations working together.

**Critical temperature:** The temperature below which a superconducting material loses all resistance to electricity. See "Superconductivity."

**Curie:** A unit of radioactivity. One curie of a radioactive substance is that amount that undergoes 3.7 x $10^{10}$ (37 billion) nuclear transformations per second,

**D-D reaction:** Fusion reaction in which one nucleus of deuterium fuses with another. Two different outcomes are possible: a proton plus a tritium nucleus, or a neutron plus a helium-3 nucleus.

**D-T reaction:** Fusion reaction in which a nucleus of deuterium fuses with a nucleus of tritium, forming an alpha particle and a neutron and releasing 17.6 million electron volts of energy. The D-T reaction is the most reactive fusion reaction.

**Decay heat: See** "Afterheat."

**Decommissioning:** The steps taken to render a plant, particularly a nuclear reactor, safe to the environment at the end of its operating lifetime.

**Dense z-pinch:** An open confinement concept in which a strong electrical current is suddenly passed through a fiber of frozen D-T fuel, turning it into a plasma and at the same time generating a powerful encircling magnetic field to confine the plasma. The dense z-pinch is in a very preliminary stage of development.

**Density:** Amount per unit volume. By itself, the term "density" often refers to particle density, or the number of particles per unit volume. However, other quantities such as energy density or power density (energy or power per unit volume, respectively) can also be defined.

**Detritiation systems:** Systems to remove tritium from air or water that are important to ensure the safety of tritium-handling facilities.

**Deuterium (D or $^2$H):** A naturally occurring isotope of hydrogen containing one proton and one neutron in its nucleus. Approximately one out of 6,700 atoms of hydrogen in nature is deuterium. Deuterium is one of the fuels (along with tritium) needed for the D-T fusion reaction, the most reactive fusion reaction.

**Diagnostics:** The procedure of determining (diagnosing) exactly what is happening inside an experimental device during an experiment. Also, the instruments used for diagnosing.

**Diffusivity:** The ability of a substance, especially a gas, to diffuse through another substance.

**Direct conversion techniques: Conversion** of the kinetic energy of plasma particles directly into electrical energy without first converting it into heat. Since conversion into heat and the subsequent reconversion to electricity impose inherent inefficiencies, direct conversion could improve the efficiency of a fusion generating station.

**Divertor:** A component of a toroidal fusion device used to shape the magnetic field near the plasma edge so that particles at the edge are diverted away from the rest of the plasma. These particles are swept into a separate chamber where they strike a barrier, become neutralized, and are pumped away. In this way, energetic particles near the plasma edge are captured before they can strike the walls of the main discharge chamber and generate secondary particles that would contaminate and cool the plasma. Diverters have also been

found to be responsible for establishing a mode of enhanced tokamak confinement called the "H-mode. " See "H-mode scaling."

**Driven fusion reactor:** A fusion reactor operating below breakeven that must be driven with more energy than it produces. Such a reactor might serve to generate neutrons for a fusion materials test facility.

**Electromagnetic radiation:** Radiation consisting of associated and interacting electric and magnetic fields that travel in a wave at the speed of light. Radio waves, microwaves, light, x-rays, and gamma rays are all forms of electromagnetic radiation; they differ from one another in wavelength and frequency.

**Electron:** An elementary particle with a unit negative electrical charge and a mass 1/1 837 that of a proton. In an atom, electrons surround the positively charged nucleus and determine the atom's chemical properties.

**Electron cyclotron frequency:** The frequency at which electrons in a plasma gyrate about magnetic field lines. The electron cyclotron frequency increases with increasing magnetic field strength and is typically hundreds of gigahertz, substantially higher than the ion cyclotron frequency. See also "ion cyclotron frequency. "

**Electron cyclotron resonance heating (ECRH):** A process in which only electrons gain energy from an applied radiofrequency field operating at the electron cyclotron frequency. The electrons then heat other plasma particles through collisions.

**Electron temperature:** The temperature of the electrons in a plasma. Electron temperature can differ from ion temperature. Some of the mechanisms by which energy is lost from the plasma, in particular radiation losses, depend on electron temperature.

**Electron volt (eV):** A unit of energy equal to the energy that can be acquired by singly charged particle (e.g., an electron) from a one-volt battery. Since the temperature of a system is proportional to the average energy of each particle in the system, temperature is also measured in electron volts; at a temperature of 1 eV, equal to 11,6050 K, the average energy of each particle is roughly 1 eV. As a unit of energy, one eV equals $1.602 \times 10^{-19}$ Joule, $3.827 \times 10^{-20}$ calorie, $1.519 \times 10^{-22}$ Btu, or $4.45 \times 10^{-26}$ kilowatt-hour.

End cell: In the tandem mirror confinement concept, the end cell is a magnetic mirror used to plug each end of the central cell. The function of the end cell is to generate an electric field that will keep the plasma in the central cell from leaking out. See also "Central cell."

**Energy gain (Q):** The ratio of the fusion power produced by a plasma to the amount of power that must be added to the plasma to sustain its temperature.

**Engineering feasibility:** The ability to design and construct all the components, systems, and subsystems required for a fusion reactor.

**Engineering test reactor:** A next-generation fusion experiment to study the physics of long-pulse ignited plasmas, provide opportunities to develop and test reactor blanket components under actual fusion conditions, and integrate the various systems of a fusion reactor.

**Equivalent Q:** For a plasma not containing tritium, a measure of what Q would have been i n a tritium-containing plasma that attained the same temperature and confinement parameter. See "Confinement parameter. "

**External heating: See** "Auxiliary heating. "

**External magnets:** Magnet coils outside the fusion plasma that generate those confining magnetic fields that are not generated by currents within the plasma itself.

**Fast breeder reactor:** A fission reactor in which fast neutrons are used both to induce fission reactions in the fuel, producing power, and to react with fertile materials, converting them to more fissile fuel. See "Fast neutron," "Fertile material, " and "Fissile material. "

**Fast neutron:** A neutron with energy greater than 100,000 electron volts.

**Fertile material:** Material that is not fissile but can be converted to fissile material through neutron irradiation. See "Fissile material. "

**Field-reversed configuration (FRC):** A magnetic confinement concept with no toroidal field, in which the plasma is essentially cylindrical in shape. The FRC is a form of compact toroid.

**Financial liability:** Costs, including those associated with death, injury, property damage, and loss of revenue, to which an electric utility would be exposed in the event of the worst credible accident attributable to a generating station.

**Fine-scale plasma instabilities:** Turbulence and other instabilities occurring over distances the size of the orbits of individual plasma particles (electrons and ions) about magnetic field lines. Also called "micro-in stabilities."

**First wall:** The first physical boundary that surrounds the plasma. The first wall can refer either to the surface of the blanket that faces the plasma, or to a separate component between the blanket and the plasma.

**Fissile material:** Material that can be used as fuel in fission reactors.

**Fission:** The process by which a neutron strikes a nucleus and splits it into fragments. During the process of nuclear fission, several neutrons are emitted at high speed, and heat and radiation are released.

**Fission/fusion hybrid:** A reactor using a fusion core to produce neutrons that in turn either induce fission reactions or breed fissile fuel in the reactor blanket. Fission/fusion hybrid reactors can produce energy, fissile fuel, or both.

**Flux:** The amount of a quantity (heat, neutrons, etc.) passing through a given area per unit time.

**Fossil plant:** A powerplant fueled by coal, oil, or gas.

**Fusion:** The process by which the nuclei of light elements combine, or fuse, to form heavier nuclei, releasing energy.

**Fusion power core:** That portion of a fusion reactor containing all the systems having to do specifically with the fusion process, such as the plasma chamber, the blanket, the magnets, and the heating, fueling, and impurity control systems.

**Fusion self-heating:** Heat produced within a plasma from fusion reactions. Since alpha particles produced in fusion reactions remain trapped within the plasma, they contribute to self-heating by transferring their energy to other plasma particles in collisions. Fusion-produced neutrons, on the other hand, escape from the plasma without reacting further and do not contribute to self-heating.

**Gauss:** A measure of magnetic field strength. The strength of the earth's magnetic field on the earth's surface is about one-half gauss; magnetic confinement fusion devices typically have maximum magnetic field strengths of tens of thousands of gauss.

**Gigahertz:** A measure of frequency equal to 1 billion hertz, or 1 billion cycles per second. See "Hertz."

**Gravitational confinement:** The fusion process that occurs in the sun and other stars in which fusion plasmas are confined by the gravitational fields generated by their own masses. Enormous masses (considerably more than that of the planet Jupiter) are required for gravitational confinement.

**Greenhouse effect:** Possible warming of the earth due to excess heat trapped in the atmosphere by increasing levels of carbon dioxide and other "greenhouse gases."

**Greenhouse gases:** Gases such as chlorofluorocarbons, methane, nitrous oxide, and carbon dioxide that, in the upper atmosphere, have the property of retaining heat that would otherwise escape from the earth to space. Accumulation of such gases may affect global climate. See "Greenhouse effect."

**"H-mode" scaling:** A mode of tokamak behavior in which confinement time does not degrade as increased amounts of auxiliary power are used to heat the plasma. This scaling has been observed in tokamaks that have diverters, and it is believed to be closely related to conditions at the edge of the plasma. See "L-mode scaling."

**Half-life:** The time required for one-half of the atoms of an unstable radioactive element to decay into atoms of other substances, Each radioisotope has a unique half-life, which can range from fractions of a second to billions of years.

**Heads-of-state agreement:** An agreement between nations signed by their respective heads-of-state, For the United States, the head-of-state is the President,

**Heat exchanger:** A device for transferring heat from one fluid to another without allowing them to mix. Heat exchangers are used in nuclear reactors to transfer heat out of the reactor core without circulating the coolant, which becomes radioactive, through the rest of the generating station,

**Heat load:** The amount of heat that a reactor component must withstand. Both the choice of materials for the component and the amount of cooling that must be provided to it depend on the component's anticipated heat load.

**Helium nucleus: See** "Alpha particle,"

**Hertz:** One cycle per second; a measure of frequency.

**High energy gain:** A fusion reaction producing many (1 O or so) times as much power as must be input to the reaction to maintain its temperature.

**High-level waste:** Radioactive waste that is extremely radioactive and would pose a serious health and environmental risk if released into the environment. Disposal of high-level waste must minimize the possibility of its release.

**Hydrogen (H):** The lightest element. All hydrogen atoms have nuclei containing a single proton and have a single electron orbiting that nucleus. Three isotopes of hydrogen exist, having O, 1, or 2 neutrons in their nuclei in addition to the proton. The term hydrogen is also used to refer to the most common isotope, technically called "protium," that has no neutrons in its nucleus.

**Ignition:** The point at which a fusion reaction becomes self-sustaining. At ignition, fusion self-heating is sufficient to compensate for all energy losses; external sources of heating power are no longer necessary to sustain the reaction.

**Impurities:** Atoms present in a plasma that are heavier than fusion fuel atoms. Impurities are undesirable because they dilute the fuel and because they

increase the rate at which the plasma's energy is radiated out of the plasma.

**Induced radioactivity:** Radioactivity created when non-radioactive materials are bombarded by neutrons and become radioactive. Radioactivity can be induced in essentially any material by exposure to neutrons, but the half-life and intensity of this radioactivity depends strongly on the material.

**Industrial base:** The industrial capability to design and manufacture the components of a fusion plant, to construct such plants, and to accomplish the preprocessing and reprocessing of fuels.

**Inertia:** Inertia is the property of an object to resist external forces that would change its motion. Unless acted upon by external forces, an object at rest will remain at rest, and an object moving in a straight line at constant speed will continue to do so. Under the influence of external forces, objects with differing inertias will respond at different rates. The inertia of an object depends solely on its mass.

**Inertial confinement:** An approach to fusion in which intense beams of light or particles are used to compress and heat tiny pellets of fusion fuel so rapidly that fusion reactions occur before the pellet has a chance to expand. The pellet's own inertia, or its initial resistance to expansion even when it is being blown apart, holds the pellet together long enough for fusion energy to be produced.

**Information exchange:** Sharing technical approaches and experimental data through any or all of several channels, including meetings, conferences, symposia, workshops, and publication in technical journals.

**Inherent safety:** In this report, inherent safety is the ability to assure, solely through reliance on passive systems and laws of physics, that no immediate offsite fatalities can result from any mechanical malfunction, operator error, or natural disaster. True inherent safety can be assured only by having so little hazardous material that even complete release could not cause an off-site prompt fatality, or by having so little stored energy that even if all the stored energy were released at once, the resultant explosion or fire would not be powerful enough to disperse a fatal dose of hazardous material, See "Active protection" and "Passive protection. "

**Instabilities:** Small disturbances that become amplified, or become more intense, once they begin. A cone balanced upside-down on its tip is subject to an instability, since once it begins to wobble, it will become more unbalanced until it falls over. A stable system, on the other hand, responds to disturbances by opposing them. Small disturbances in a stable system decrease in intensity until they die away. If a ball sitting in the bottom of a bowl is disturbed, for example, it will eventually come to rest again at the bottom of the bowl.

**Insulator:** Material that does not conduct electricity.

**Ion:** An atom (or molecularly bound group of atoms) that has become electrically charged as a result of gaining or losing one or more orbital electrons. A completely ionized atom is one stripped of all its electrons.

**Ion cyclotron frequency:** The frequency at which ions in a plasma gyrate about magnetic field lines. The ion cyclotron frequency increases with increasing magnetic field strength and is typically tens to hundreds of megahertz. See also "electron cyclotron frequency."

**Ion cyclotron resonance heating (ICRH):** A process in which only ions gain energy from an applied radiofrequency field operating at the ion cyclotron frequency. The ions then heat other plasma particles through collisions.

**Ion temperature:** The temperature of the ions in a plasma. Ion temperature can differ from electron temperature. Since it is the ions that fuse i n fusion reactions, it is the ion temperature that determines the fusion reaction rate. See also "Electron temperature."

**Ionization:** The process of removing or adding an electron to a neutral atom, thereby giving it an electric charge and creating an ion. The term is also used to denote removal of an electron from a partially ionized atom to make a more completely ionized one.

**Ionizing radiation:** Radiation energetic enough to ionize matter that it passes through. Depending on its intensity, ionizing radiation poses a health risk. Examples are alpha and beta particles, emitted by radioactive substances, and electromagnetic radiation having frequencies in the far ultraviolet, x-ray, and gamma ray regions.

**Isotope:** Different forms of the same chemical element whose atoms differ i n the number of neutrons i n the nucleus. (All isotopes of an element have the same number of protons in the nucleus and the same number of electrons orbiting the nucleus. ) Isotopes of the same element have very similar chemical properties and are difficult to separate by chemical means. However, they can have quite different nuclear properties.

**Joint construction and operation:** Pooling resources to construct and operate an experimental facility jointly.

**Joint planning:** Activities between nations that coordinate experimental and theoretical programs and identify areas of future cooperative research.

**Joint research:** Making major national facilities available to researchers from other nation's programs in exchange for financial or technical contributions.

**Kinetic energy:** Energy of motion. The energy released in a fusion reaction is originally in the form of kinetic energy of the reaction products. When these reaction products (alpha particles and neutrons) collide with atoms or nuclei in the plasma or in the reactor structure, they slow down and their kinetic energy is converted into heat.

**"L-mode" scaling:** Mode of tokamak behavior in which confinement time degrades as increasing amounts of auxiliary heating power are input into the plasma. See "H-mode" scaling.

Large-scale plasma instabilities: Deformations of both the overall confining magnetic field and the plasma that can lead to sudden escape of the entire plasma from confinement.

Laser fusion: A form of inertial confinement fusion in which a small pellet of fuel material is compressed and heated by a burst of laser light. See "Inertial confinement ."

Lawson parameter: See "Confinement parameter."

Light-water reactor (LWR): A fission reactor in which ordinary water is used as coolant and as a neutron moderator. See "Neutron moderator. "

**Limiter:** Device placed inside the plasma chamber to intercept particles at the edge of a plasma. By "scraping off" these particles from the plasma edge, the limiter defines the size of the plasma.

**Liquid-metal fast breeder reactor:** (LMFBR) A fission fast breeder reactor with a liquid metal coolant. See "Fast breeder reactor."

**Lithium (Li):** A light, chemically reactive metal that can be converted i n the blanket of a fusion reactor into the tritium fuel needed for fusion reactions.

**Load change, capability for:** The mechanical and thermal characteristics of an electric generating station that limit its rate of response to changes in load or that restrict the time required for startup or shutdown.

**Long-lived radioactivity:** Radioactive isotopes having long half-lives.

**Low-activitation materials:** Materials that, under neutron irradiation, do not generate intensely radioactive, long-lived radioactive isotopes. Examples include certain vanadium alloys and ceramics such as silicon carbide. Fusion reactors made of low-activation materials would accumulate far less radioactivity over their lifetimes than reactors made with more conventional materials such as steels. Low-activation materials also produce less afterheat following a reactor shutdown than more conventional materials. See "Afterheat."

**Low-level waste:** Waste containing sufficiently low levels of radioactivity that it does not pose a major health or environmental risk. Disposal of low-level waste does not require the stringent precautions necessary for high-level waste.

**Magnetic confinement:** Any means of containing and isolating a hot plasma from its surroundings by using magnetic fields.

**Magnetic field:** The property of the space near a magnet that results, for example, in the attraction of iron to the magnet. Magnetic fields are characterized by their direction and their strength. Electrically charged particles moving through a magnetic field at an angle with respect to the field are bent in a direction perpendicular to both their direction of motion and the direction of the field. Particles moving parallel to a magnetic field are not affected. Therefore, magnetic fields cannot prevent plasma particles from escaping along field lines.

**Magnetic field line:** A (possibly curved) line whose direction at every point is given by the direction of the magnetic field through that point. Electrically charged particles in a magnetic field tend to gyrate around magnetic field lines; they can travel along the field lines much more easily than they can cross field lines.

**Magnetic mirror:** A generally axial magnetic field that has regions of increased intensity at each end where the magnetic field lines converge. These regions of increased intensity "reflect" charged particles traveling along the field lines back into the central region of lower magnetic field strength.

**Magnetohydrodynamics (MHD):** The study of electrically conducting fluids under the influence of electric and magnetic fields. MHD theory can be used to provide a good approximation to plasma behavior in many instances.

**Megahertz:** One million hertz, or one million cycles per second. See "Hertz."

**Microinstabilities: See** "Fine-scale plasma instabilities."

**Minimum-B mirror:** An open magnetic confinement concept with a magnetic field that is low in strength in the central region but that gets stronger in all directions away from the center. Particles in a minimum-B mirror tend to be "reflected" by the higher field regions back towards the center. Nevertheless, losses from the minimum-B mirror are too great for it to be a viable fusion concept by itself.

**Minimum load:** The power output level below which a generating plant cannot operate continuously.

**Ministerial agreement:** An agreement signed by the secretaries or ministers of the involved departments

or ministries. In the United States, ministerial agreements in fusion are signed by the Secretary of Energy.

**Multilateral agreement:** An agreement between three or more nations.

**Neutral beam heating:** Heating a confined plasma by injecting beams of energetic (typically greater than 100 keV) neutral atoms into it. Neutral atoms can cross magnetic lines of force to enter the plasma, where they transfer their energy to plasma particles through collisions. In these collisions, the neutral beam particles become ionized, and, like the other electrically charged plasma particles, are then confined by the magnetic fields.

**Neutron:** A basic atomic particle, found in the nucleus of every atom except the lightest isotope of hydrogen, that has no electrical charge. When bound within the nucleus of an atom, the neutron is stable. However, a free neutron is unstable and decays with a half-life of about 13 minutes into an electron, a proton, and a third particle called an antineutrino. The mass of a free neutron is 1.7 *x* 10-24 grams.

**Neutron flux:** A measure of the intensity of neutron irradiation. It is the number of neutrons passing through 1 square centimeter of a given target in 1 second.

**Neutron irradiation:** Exposure to a source of neutrons. Both fission and fusion reactors can provide neutron irradiation.

**Neutron moderator:** A material that slows neutrons down without absorbing them.

**Neutron multiplier:** A substance that reacts with neutrons to produce additional neutrons.

**Neutron wall loading:** The energy per unit area per unit time (or energy flux) carried by neutrons into the first wall of a fusion reactor. The higher the neutron wall loading, the more rapidly the first wall will suffer radiation damage, the more radioactivity will be induced, and the more frequently first wall components will have to be replaced.

**Non-ohmically heated plasma:** Plasma heated with auxiliary or external heating.

**Nuclear fission: See** "Fission. "

**Nuclear fusion: See** "Fusion. "

**Nuclear grade:** Designation given to components used in important safety-related systems in nuclear reactors certifying that the components meet stringent quality control standards,

**Nuclear physics:** The study of atomic nuclei and nuclear reactions.

Nucleus (nuclei): The central core of an atom, consisting of protons and neutrons, that contains over 99.95 percent of the atom's mass.

**Ohmic heating:** Heating that occurs when an electric current is passed through a resistive medium. Although plasmas are excellent conductors of electricity, they are nevertheless resistive enough to be heated when they carry large electric currents. Ohmic heating becomes less efficient as the plasma gets hotter, and most confinement configurations therefore require auxiliary (or non-ohmic) heating to reach ignition.

**Open confinement concept:** Magnetic configuration in which the magnetic field lines leave the system. The magnetic mirror is one example.

**Order of magnitude:** A factor of 10.

**Outage rate:** The percentage of time that an electric generating station is unavailable due to component failures or other unforeseen conditions that require the unit to be removed from service.

**Overnight construction cost:** Total construction cost of a facility if it could be built instantaneously. Overnight construction cost does not include allowances for inflation, nor does it include finance charges such as the interest payments on funds borrowed to begin construction.

**Oxidation chemistry:** Study of chemical reactions of substances with oxygen.

**Part-load efficiency:** The ratio of the change in efficiency of an electric generating station to the change in load when the load is decreased from full load to half.

**Particle collisions:** A close approach of two or more particles during which quantities such as energy, momentum, or charge are exchanged.

**Passive protection:** Ability to ensure the safety of a reactor without the use of active safety systems. Various degrees of passive protection exist. At one level, the safety of a reactor design might be ensured provided that certain passive systems and components (e.g., coolant loops or tanks) remained intact. Before the safety of such a plant could be demonstrated, it would have to be proven that no credible accident could interfere with the operation of those passive systems or components. At a much more stringent level of passive protection, called "Inherent safety, " materials properties and the laws of physics alone would be sufficient to ensure the safety of the reactor. No assumptions concerning the integrity of any reactor systems or components would need to be made. Such an "inherently safe" reactor would remain safe even if it could somehow be crumpled up into a ball. See also "Active protection" and "Inherent safely. "

**Personnel exchange:** The transfer of personnel between different nation's programs through visits or assignments.

**Plant capital cost:** The total cost necessary to bring the plant to commercial operation. It includes the costs of items such as engineering and design work, materials, construction labor, construction management, interest during construction, escalation, sales tax, equipment, and land.

**Plant licensability:** How readily a generating technology such as fusion can be expected to receive regulatory approval.

**Plant life:** The total time a plant can be operated before decommissioning.

**Plasma:** An ionized gaseous system composed of approximately equal numbers of positively and negatively charged particles and variable numbers of neutral atoms. The charged particles interact among themselves, with the neutral particles, and with externally applied electric and magnetic fields. The plasma state is sometimes called "the fourth state of matter" due to the fundamental differences in behavior between plasmas and solids, liquids, or neutral gases.

**Plasma current:** Electrical current flowing within a plasma. In many confinement schemes, plasma currents generate part of the confining magnetic fields.

**Plasma exhaust:** Particles escaping from the plasma that are collected by limiters or diverters.

**Plasma physics:** The study of plasmas.

**Plant safety:** The capability of the plant to be built and operated with minimal injury to plant personnel or to the public and minimal damage to property internal or external to the plant.

**Plutonium (Pu):** An element that fissions easily and can be used as a nuclear fuel for fission reactors or fission weapons. Plutonium is not found in nature, but it can be produced by irradiating uranium with neutrons in a nuclear reactor.

**Pneumatic injector:** Device that injects fuel pellets into plasmas at high speed by accelerating them with compressed gas.

**Poloidal direction:** On a torus, the poloidal direction runs around the torus the short way, perpendicular to the toroidal direction. See "Toroidal direction."

**Poloidal divertor:** A type of divertor. See "Divertor."

**Post-shutdown systems:** Systems in a nuclear reactor that must operate after the reactor is shut down to ensure that the afterheat does not build up to a level high enough to damage the reactor or pose a safety hazard, Such systems would be unnecessary in reactors not generating much afterheat, or ones in which the afterheat could be removed by purely passive means.

**Power density:** The amount of energy generated per unit time per unit volume of a reactor core; the power per unit volume.

**Project Sherwood:** The code-name under which fusion research was secretly conducted in the United States from 1951 until 1958.

**Proliferation:** The development of nuclear weapons by countries not now possessing them. Proliferation refers primarily to fission-based nuclear weapons.

**Prompt fatalities:** Deaths due to the immediate effects of a reactor accident or malfunction. Since deaths from radiation overdoses are not instantaneous except at extremely high doses, prompt fatalities include those due to radiation overdoses acquired soon after an accident even if death does not occur immediately. Prompt fatalities do not, however, include deaths many years later from cancer that may have been induced by radiation exposure.

**Proof-of-concept experiment:** Experiment done at a relatively early stage of development of a confinement concept to determine the limits of plasma stability, explore how the confinement properties appear to scale, and develop heating, impurity control, and fueling methods. Successful completion of such an experiment verifies that the confinement concept appears capable of operating successfully on a scale much closer to that needed in a reactor.

**Proof-of-principle experiment:** Experiment one stage beyond the "proof-of-concept" stage to determine optimal operating conditions, to establish that the concept is capable of being scaled to near-reactor level, to extend methods of heating to high power levels, and to develop efficient mechanisms for fueling and impurity control.

**Protium (H or $^{1}$H):** The most common isotope of hydrogen, accounting for over 99 percent of all hydrogen found in nature. The nucleus of a protium atom is a single proton with no neutrons.

**Proton:** An elementary particle with a single positive electrical charge. Protons are constituents of all atomic nuclei. The atomic number of an atom is equal to the number of protons in its nucleus.

**Pulsed operation:** Non-continuous operation of a fusion reactor. This term refers to reactors that must periodically stop and restart. In pulsed operation, individual pulses may last as long as hours.

**Pumped limiter:** A limiter that collects particles at the plasma edge, allows them to recombine into neutral gas atoms, and pumps the gas out of the vacuum chamber. A pumped limiter can operate for a longer period of time than a simple limiter, which does not remove the collected particles and can therefore become saturated. See "Limiter."

**Pure fusion reactor:** Reactor that generates all its energy from fusion reactions in the plasma and tritium-breeding reactions in the blanket. A pure fusion reactor is distinguished from a fission/fusion hybrid reactor, which either generates energy or

produces fissionable fuel by including fertile or fissile material in the reactor blanket. See "Fission/fusion hybrid. "

**Quality of confinement: See** "Confinement parameter. "

**Radiation:** The emission of particles or energy from atomic or nuclear processes. Radiation is also sometimes used as a shorthand for "electromagnetic radiation, " which refers specifically to emitted energy and does not include particles.

**Radiation dose:** A general term denoting the quantity of radiation absorbed.

**Radiation exposure:** The amount of radiation passing through a particular target.

**Radiative cooling:** Loss of heat from a system through electromagnetic radiation. Since electromagnetic radiation carries energy away, a system that radiates will cool down.

**Radioactive inventory:** The total amount of radioactive material present.

**Radioactive material:** A material of which one or more constituents exhibits radioactivity.

**Radioactivity:** The inherent property of the nuclei of unstable isotopes to spontaneously emit particles or energy and transform to other nuclei. Such radioactive isotopes can be either natural (e.g., carbon-14, which is produced by cosmic rays interacting with the earth's atmosphere) or manmade (e.g., plutonium).

**Radiofrequency power:** Electromagentic radiation having frequencies in the radio or microwave portions of the electromagnetic spectrum and extending up to the infrared band.

**Radiofrequency (RF) heating:** Heating a plasma by depositing radiofrequency power in it. Only radiation at certain specific frequencies—e.g., the electron cyclotron frequency or the ion cyclotron frequency–will be absorbed by the plasma. See "Electron cyclotron resonance heating" or "Ion cyclotron resonance heating. "

**Radioisotope:** A radioactive isotope; in particular, a radioactive isotope of a substance whose naturally occurring isotopes are not radioactive.

**Reactive:** Able to participate easily in chemical or nuclear reactions.

**Reactor potential:** A qualitative description of a fusion confinement concept denoting how easy it would be to design, build, operate, and maintain a fusion reactor based on that concept, as well as how acceptable such a reactor's environmental, social, economic, and safety characteristics would be.

**Reactor-scale experiment:** Experiment to test a confinement concept by generating a plasma equivalent to that needed in a full-scale reactor. Such an experiment must achieve reactor-level values of beta and must demonstrate temperature, density, and confinement times sufficient for the production of net fusion power. Furthermore, its heating, fueling, and other technologies must also be able to support a reactor-level plasma.

**Rem:** A measure of the effect of radiation on biological systems (acronym for Roentgen equivalent man). Different types of radiation (e.g., alpha particles, beta particles, neutrons, and gamma rays) have different biological effects. Therefore, doses are corrected by a different factor for each type of radiation to convert them into reins. One rem of any type of ionizing radiation produces the same biological effect as one Roentgen of ordinary x-rays.

**Remote maintenance:** Conducting maintenance on reactor systems or components by remote control, rather than "hands-on. " Remote maintenance will be required in fusion reactors and in many future fusion experiments because the radioactivity levels near and inside the plasma chamber will be too high to permit human access.

**Resistance:** The difficulty with which an electric current passes through a material. For a given amount of electric current, the higher the resistance, the more electrical energy will be dissipated as heat.

**Reversed-field pinch:** A closed magnetic confinement concept having toroidal and poloidal magnetic fields that are approximately equal in strength, and in which the direction of the toroidal field at the outside of the plasma is opposite from the direction at the plasma center.

**Roentgen:** A measure of radiation intensity.

**Routine release:** Releases that occur as a result of normal, or routine, plant operation.

**Runaway reaction:** A reaction whose rate increases as the power level rises, In such a reaction, any rise in output power increases the reaction rate, boosting the output power still further, and so on. Such a reaction is unstable, growing larger and larger until some other mechanism—e.g., exhaustion of fuel–limits the reaction power.

**Scaling:** Extension of results or predictions measured or calculated under one set of experimental conditions to another situation having different conditions. One of the most important functions of a confinement experiment is to determine how confinement properties scale with parameters such as device size, magnetic field, plasma current, temperature, and density. It is important to understand the scaling properties of a confinement concept—either empirically or theoretically—to assure that future experiments have a reasonable probability of succeeding.

**Scaling relationship:** The trend in behavior of a parameter as other parameters are varied. See "Scaling."

**Scientific feasibility:** The successful completion of experiments that produce high-gain or ignited fusion reactions in the laboratory using a confinement configuration that lends itself to development into a net power producing system.

**Self-regulating:** A system which, when disturbed in some way, will respond in a manner that tends to compensate for the disturbance. A self-regulating reaction would be the opposite of a runaway one; if the reaction power level were to increase, the system would respond by lowering the reaction rate, permitting the power level to drop back down again. Such a system is also called "stable. See also "Runaway reaction" and "instabilities."

**Shield:** A structure interposed between reactor components, such as magnetic field coils, and the fusion plasma to protect the components from the flux of energetic particles produced in the plasma.

**Simple magnetic mirror:** A magnetic field consisting of a cylinder filled with an axial magnetic field of relatively constant strength, with regions of stronger magnetic field at each end. The stronger field regions tend to "reflect" plasma particles back into the cylinder. However, too many particles nevertheless escape out the ends of the cylinder for the simple mirror to be a viable fusion concept.

**Volubility:** Ease with which a substance dissolves in another substance.

**Spheromak:** A magnetic confinement concept in which a large fraction of the confining magnetic fields are generated by currents within the plasma. The spheromak is a form of compact toroid.

**Spin:** An inherent property possessed by subatomic particles analagous to the rotation of the earth. Just as the spin axis of the earth points towards the North star, the spin axis of a subatomic particle points in some direction. The spin axis of a subatomic particle can be oriented in a particular direction by use of a magnetic field.

**Spin polarization:** Preparation of many particles, such as deuterium and tritium nuclei, so that their spins point in the same direction. If the spins of deuterium and tritium are polarized, the D-T reaction rate is enhanced.

**Spin-offs:** The secondary, or auxiliary, benefits of high-technology research and development programs in applications other than those which are the primary motivation for research.

**Steady-state operation:** Continuous operation, without repeated starting and stopping.

**Steam generator and turbine:** In an electric generating station, the steam generator uses the heat produced by the power source to boil water into steam, which is passed through a turbine to turn an electrical generator.

**Stellarator:** A toroidal magnetic confinement device in which the confining magnetic fields are generated entirely by external magnets.

**Superconductivity:** The total absence of electrical resistance in certain materials under certain conditions. Until recently, superconductivity had only been found to occur in certain materials cooled to within a few degrees of absolute zero. Since late 1986, however, a new class of materials has been discovered that become superconducting at temperatures far higher than the materials previously known. An electrical current that is established in a superconducting material will persist as long as the material remains below its critical temperature. See "Critical temperature."

**System studies:** Studies presenting preconceptual designs for fusion reactors that serve to uncover potential problems and determine how changes in design choices affect reactor characteristics. System studies are particularly valuable in guiding the reseach program by identifying areas where further research and development can have the greatest impact.

**Tandem mirror:** Type of open magnetic confinement configuration in which both ends of a simple magnetic mirror, called the central cell, are plugged by end cells to improve confinement. Each end cell is itself a magnetic mirror that generates an electric field to prevent particles in the central cell from escaping, See "Central cell" and "End cell. "

**Technological feasibility:** In this report, acquisition of both sufficient scientific understanding and sufficient engineering and technological capability to design and build a fusion reactor; attainment of both scientific feasibility and engineering feasibility.

**Temperature:** A measure of the average energy of a system of particles. Given sufficient time and enough interaction among the different portions of any system, all portions will eventually come to the same temperature. In short-lived plasmas, however, the ion and electron temperatures usually differ because of insufficient interaction between the two. Plasma temperatures are measured in units of electron volts, with 1 electron volt equal to 11,6050 K.

**Thermal instability:** Potential instability in a burning plasma arising from the fact that the fusion reaction rate increases strongly with temperature. It is not yet known to what extent burning (ignited) plasmas will be subject to this instability, or whether other, self-regulating aspects of plasma behavior will predominate. See "Runaway reaction."

**Thermonuclear fusion: See** "Fusion. " "Thermonuclear" refers to the extreme temperatures required for the fusion process to take place.

**Thermonuclear weapons:** Nuclear weapons utilizing the fusion process, also called hydrogen bombs. Thermonuclear weapons are very large-scale examples of the inertial confinement approach to fusion.

**Theta pinch: A pulsed device** in which a fast-rising, strong (100 kilogauss) magnetic field compresses and heats a plasma column in a few microseconds. The magnetic field is parallel to the axis of a plasma column.

**Tokamak:** A magnetic confinement concept whose principal confining magnetic field, generated by external magnets, is in the toroidal direction but that also contains a poloidal magnetic field that is generated by electric currents running within the plasma. The tokamak is by far the most developed magnetic confinement concept. See also "Conventional tokamak" or "Advanced tokamak."

**Toroidal direction:** On a torus, the toroidal direction runs around the torus the long way, in the direction that the tread runs around a tire. More generally, "toroidal" refers to devices in the shape of a torus.

**Torus:** The shape of a doughnut, automobile tire, and inner tube.

**Transformer:** Device in which a changing electrical current in one electrical conductor generates a changing magnetic field, which in turn induces electrical current in a second conductor. The plasma current in a conventional tokamak is established by a transformer in which one of the conductors is a set of coils located in the hole in the center of the plasma torus and the second conductor is the plasma itself.

**Treaty:** The highest level of formality for an international agreement. Treaties involving the United States must be ratified by a two-thirds majority of the U.S. Senate.

**Tritium (T or $^3$H):** A radioisotope of hydrogen that has one proton and two neutrons in its nucleus. Tritium occurs only rarely in nature; it is radioactive and has a half-life of 12.3 years. In combination with deuterium, tritium is the most reactive fusion fuel.

**Tritium breeding:** Production of tritium in the blanket of a fusion reactor by irradiating lithium nuclei with fusion-produced neutrons. Lithium nuclei undergo nuclear reactions with neutrons that yield tritium nuclei and alpha particles.

**Turbulence:** Random or chaotic flow of a fluid, such as that of water in the rapids of a river.

**Umbrella agreement:** General agreement between nations establishing a willingness to cooperate in a specific subject area and outlining general procedures, but not specifying particular activities or terms.

**Unit rating:** The electrical capacity of a generating station.

**Uranium (U):** A very heavy, radioactive element found in nature that can be used as nuclear fuel. Two uranium isotopes are important in nuclear energy: uranium-235 can undergo nuclear fission, and uranium-238, the most plentiful isotope, can be used to produce plutonium.

**Waste handling and disposal:** The in-plant handling, on-site disposal (or transportation), and off-site disposal of waste materials formed as byproducts of the energy production processes.