Chapter 16
Nonrenewable Energy

"It's A Small World After All"

Outline

Types of Energy Resources

A. About ninety-nine percent of the energy we use for heat comes from the sun and the other 1% comes mostly from burning fossil fuels.
   1. Without the sun's energy, life on earth wouldn't exist. The sun is a giant nuclear fusion reactor.
   2. The sun provides other indirect forms of renewable solar energy such as wind, falling/flowing water and biomass.
   3. Commercial energy sold in the marketplace makes up the remaining 1% of the energy we use, most from nonrenewable resources.

B. About 76% of the commercial energy we use comes from nonrenewable fossil fuels with the remainder coming from renewable sources.
   1. About 50% of people in developing countries burn wood and charcoal to heat dwellings and cook.
   2. Most biomass is collected by users and not sold in the marketplace.
   3. Many people in developing countries face a fuelwood shortage that is getting worse because of unsustainable harvesting of fuelwood.

C. Net energy is the amount of high-quality usable energy available from a resource after subtracting the energy needed to make it available for use.
   1. It takes energy to get energy.
   2. Net energy available for use is calculated by estimating the total energy available from the resource over its lifetime and the subtracting the amount of energy used (the first law of thermodynamics), automatically wasted (the second law of thermodynamics), and unnecessarily wasted in finding, processing, concentrating, and transporting the useful energy to users.
   3. Net energy is like your net spendable income-your wages minus taxes and job-related expenses.
   4. We can express net energy as the ratio of useful energy produced to the energy used to produce it, as shown in Figure 16-4.
   5. Currently, oil has a high net energy ratio, but as supplies are depleted the net energy ratio of oil will decline and prices increase sharply.
   6. Electricity produced at a nuclear power plant has a low net energy ratio because of the energy consumed in the nuclear fuel cycle.

Oil

A. Crude oil is a thick liquid containing hydrocarbons that we extract from underground deposits and separate into products such as gasoline, heating oil, and asphalt.
   1. Three geological events led to the presence of oil:
      a. Sediments buried organic material faster than it could decay.
      b. Sea floors with these sediments were subjected to the right pressure and heat to convert organic material to oil.
      c. Oil collected in porous limestone or sandstone and was capped by shale or silt to keep it from escaping.
   2. Oil and natural gas provide us with food grown with the help of hydrocarbon-based fertilizers and pesticides. This type of oil is known as conventional oil or light oil.
   3. The oil industry today is a marvel of high tech. events to extract, refine, market, distribute to the world's populations.
   4. Oil and natural gas are often found together under a dome. On average, only about 35-50% of the oil in the deposit is recovered.
   5. The remaining heavy crude oil is too difficult or expensive to extract.
   6. Improved extraction technologies could raise the oil recovery rte to 75%.
   7. Crude oil is transported to a refinery where it is broken down into components with different boiling points. This process accounts for about 8% of all U.S. energy consumption.
   8. Petrochemicals are oil distillation products that are sued as raw materials in manufacturing

pesticides, plastics, synthetic fibers, paints, medicines and other products.
9. Industrial biotechnology is a new field, the goal of which is to use carbohydrates extracted from plants as building block organic chemicals.

B. Eleven OPEC countries-most of them in the Middle East- have 78% of the world's proven oil reserves and most of the world's unproven reserves.
   1. The control of current and future oil reserves is the single greatest source of global economic and political power.
   2. Saudi Arabia has the largest supply of oil reserves with 25%.
   3. Oil is the most widely used resource in the world. The U.S. imports about 60% of its oil, followed by China and Japan as the top three oil importing countries.
   4. Based on different assumptions, geologists expect the world's oil production to peak within the next 5-38 years and then begin a long decline.

C. After global oil production peaks and begins a slow decline, oil prices will rise and could threaten the lifestyles and economies of oil-addicted countries that have not shifted to new energy alternatives.
   1. Oil's nickname could change from black gold to black platinum.
   2. Some analysts say there is no serious problem because we will be able to find enough oil.
   3. Other analysts are more concerned that rising oil prices will affect the price of food and food production, see more land being used to produce crops that can be converted into ethanol and biodiesel, and other impacts that could have wide reaching effects on society.

D. The United States-the world's largest oil user- has only 2.9% of the world's proven oil reserves and only a small percentage of its unproven reserves.
   1. The U.S. uses about 25% of crude oil extracted worldwide each year.
   2. About 29% of U.S. domestic oil production and 21% of domestic natural gas comes from offshore drilling mostly in the Gulf of Mexico. Another 17% comes from Alaska's North Slope.
   3. U.S. oil production peaked in 1974. Most of the oil extracted costs $7.50-$10/barrel compared to about $1-2/barrel from Saudi Arabia.
   4. In 2005, the U.S. imported about 60% of the oil it used. According to a 2005 report, about one-fourth of the world's oil is controlled by states that sponsor or condone terrorism.
   5. By 2020 the U.S. could be importing 70% of the oil it will use.
   6. Geologists disagree as to the amount of oil that remains to be discovered, and to the amount of oil reserves.
   7. Some analysts feel that importing oil is not all bad, that U.S. oil reserves should be held in reserve.

E. Conventional oil is a versatile fuel that can last for at least 50 years, but burning it produces air pollution and releases the greenhouse gas carbon dioxide into the atmosphere.
   1. CO_2 release into the atmosphere helps promote climate change through global warming.
   2. Figure 16-7 lists the advantages and disadvantages of using conventional crude oil as an energy source.
   3. Figure 16-8 compares the amounts of carbon dioxide emitted per unit of energy in using fossil fuels, nuclear power, and geothermal energy.

F. Heavy and tar like oils from oil sand and oil shale could supplement conventional oil, but there are environmental problems.
   1. Bitumen is thick and sticky heavy oil with a high sulfur content that is found in oil sand and oil tar.
   2. The extraction and processing of this material uses a great deal of energy, so reduces net energy yield for the oil.
   3. Northeastern Alberta, Canada has about $3/4^{ths}$ of the world's oil sand reserves.
   4. Use of these oil sands could reduce U.S. dependence on imports from the Middle East.
   5. This extraction process has severe environmental impacts on land and produces more water pollution, air pollution and more CO_2/ unit energy than conventional crude oil.
   6. Oil shale deposits may be another potential source of oil. The material in this shale is kerogen. It is estimated that there are 240 times more global supplies than for conventional oil. At present it cost more to produce than the fuel is worth.
   7. Figure 16-10 lists the advantages and disadvantages of using heavy oil from oil sand and oil

shales as energy sources.

Natural gas

A. Natural gas consists mostly of methane, is often found above reservoirs of crude oil. Natural gas also contains small amounts of heavier hydrocarbons and a small amount of hydrogen sulfide.
   1. Conventional natural gas lies above most reservoirs of crude oil.
   2. Natural gas is sometimes burned off as an unwanted by-product of oil drilling, a waste of an energy source.
   3. Propane and butane gases are liquefied from a natural gas field and removed as liquefied petroleum gas (LPG) that is stored in pressurized tanks.
   4. Natural gas provides about 23%of the U.S. energy needs, heating about 53% of U.S. homes and providing about 12% of the country's electricity.
   5. The U.S. imports about 20% of its natural gas, and this is expected to rise in the future. Imports come mostly from Canada.
   6. Natural gas is a versatile fuel that can be burned to heat space and water and to propel vehicles with fairly inexpensive engine modifications.
   7. Natural gas releases less CO_2/ unit energy than burning oil, oil sand, or coal.
   8. Increasingly, natural gas is used to run medium-sized turbines to produce electricity. They are more energy efficient, cheaper to build, require less time to install, and are easier and cheaper to maintain than coal and nuclear power plants. Rising natural gas prices are impacting the cost advantages of such turbines.

B. Coal beds and bubbles of methane trapped in ice crystals deep under the arctic permafrost and beneath deep-ocean sediments are unconventional sources of natural gas.
   1. Coal bed methane gas is found in coal beds across parts of the United States and Canada.
   2. Extracting the methane produces huge volumes of water contaminated with salt and other minerals, in addition to causing environmental problems and public backlash.
   3. Russia and the Middle East could supply more natural gas to the United States in the future.
   4. Methane hydrate deposits are another source of unconventional natural gas found in the arctic permafrost and deep beneath the ocean bottom.
   5. Extraction techniques are too expensive at present, but are rapidly being developed. Methane hydrates must be kept cold or they release methane into the atmosphere when they reach the surface.

C. Russia and Iran have almost half the world's reserves of conventional natural gas, and global reserves should last 62-125 years.
   1. The long-term outlook for natural gas supplies is better than for conventional oil.
   2. Natural gas use should increase because it is fairly abundant, has lower pollution and CO_2 rates/unit of energy compared to other fossil fuels.
   3. Projections suggest that natural gas should last the world at least 200 years at the present consumption rate and 80 years if usage rates increase 2% per year.
   4. Shipping of LNG is very expensive and reduces net energy yield.

D. Natural gas is a versatile and clean-burning fuel, but it releases the greenhouse gases carbon dioxide (when burned) and methane (from leaks) into the troposphere.

Coal

A. Coal is an abundant energy resource that is burned mostly to produce electricity and steel. Coal is solid fossil fuel formed from land plants that lived between 300-400 million years ago. It is mostly carbon with small amounts of sulfur and trace amounts of mercury. Burning coal releases SO_2, trace amounts of mercury and radioactive materials.
   1. Coal is burned in power plants to produce 62% of the world's electricity and three-quarters of the world's steel.
   2. In the U.S. coal produces 50% of the electricity, followed by nuclear power (20%), natural gas (17%), renewable energy (10%), and oil (3%).
   3. Anthracite is the most desirable type of coal because of its high heat content and low sulfur. It is less common than other types of coal.
   4. Coal is extracted underground in dangerous circumstances (accidents and black lung disease).
   5. Area strip mining is used to extract coal close to the surface. Scars from this mining are rarely

restored after mining is finished.

6. In some cases of mountaintop mining, entire mountains have been removed and dumped into the valleys below to expose seams of coal.

B. Coal reserves in the U.S., Russia, and China could last hundreds to thousands of years.
1. Coal is the world's most abundant fossil fuel.
2. The U.S. has 27% of the world's proven coal reserves. Russia has 17%, China has 13%, India has 10%, and Australia has 9%.
3. Coal reserves in the U.S. and in China should last for about 300 years at current consumption rates.
4. If coal consumption in the U.S. increases by 4% a year – as the industry projects – the reserves would last only 64 years.

C. Coal is the most abundant fossil fuel, but compared to oil and natural gas it is not as versatile, has a much higher environmental impact, and releases much more carbon dioxide into the troposphere.
1. The advantages and disadvantages of using coal as an energy source are shown in Figure 16-14.
2. Coal has a severe environmental impact on air, water, and land and over 1/3 of the world's annual CO_2 emissions come from coal.
3. Coal emissions cause thousands of premature deaths, many thousands of cases of respiratory disease, and several billion dollars of property damage a year.

D. Coal can be converted to gaseous and liquid fuels that burn cleaner than coal, but the costs are high and burning them adds more carbon dioxide to the troposphere than burning coal. Coal can be converted into synthetic natural gas (SNG or syngas) by coal gasification or in to liquid fuel by coal liquefaction.
1. Figure 16-15 lists the advantages and disadvantages of these synfuels.
2. These techniques are not possible without huge government subsidies.
3. These procedures require 50% more coal be mined and will add 50% more CO_2 emissions to the atmosphere. They also cost more to produce than coal.
4. Coal gasification plants can be designed to remove all carbon dioxide from their emissions.

Nuclear energy

A. When isotopes of uranium and plutonium undergo controlled nuclear fission, the resulting heat produces steam that spins turbines to generate electricity.
1. A controlled chain reaction occurs when nuclei of atoms are split. The heat from the reactions used to produce high-pressure steam that spins turbines that generate electricity.
2. Light-water reactors (LWRs) produce about 85% of the world's nuclear-generated electricity.
3. The core of a LWR consists of long, thin rods are packed with fuel pellets and each pellet contains energy equivalent to 1 ton of coal or 4 barrels of crude oil. The uranium oxide fuel in each pellet consists of about 97% nonfissionable uranium-238 and 3% fissionable uranium-235.
4. Control rods absorb neutron-absorbing materials move in and out of spaces between the fuel assemblies in the core. This regulates the rate of fission and amount of power the reactor produces.
5. A moderator (material that slows down neutrons) keeps the reaction going. It may be water, graphite or deuterium.
6. A coolant, usually water, circulates through the core to remove heat to keep the components from melting and to produce steam for generating electricity.
7. A containment vessel with thick, strong walls surrounds the reactor as a safety backup. These are usually made of 4-foot reinforced concrete with a steel liner.
8. Spent rods are stored on-site in water-filled pools or dry casks with thick steel walls.
9. All the safety features make nuclear power plants very expensive to build and maintain.
10. The nuclear fuel cycle is shown in Figure 16-18. The nuclear fuel cycle includes the mining of uranium, processing it to make a satisfactory fuel, use in the reactor, safe storage of highly radioactive wastes for 10,000-240,000 years, and dealing with the reactor after its useful life.
11. A nuclear power plant must be decommissioned after 15-60 years of operation. It contains large quantities of radioactivity that must be kept out of the environment.
12. A closed nuclear fuel cycle removes fissionable isotopes uranium-235 and plutonium-239 for

reuse as nuclear fuel. This is rarely done currently because of high costs and potential use of the materials in nuclear weapons.

13. In an open nuclear fuel cycle the isotopes are eventually buried in an underground disposal facility. These wastes must be stored for about 240,000 years.

B. After more than 50 years of development and enormous government subsidies, nuclear power has not lived up to its promise.
   1. Nuclear power plants began being developed in the late 1950s for three reasons:
      a. The Atomic Energy Commission promised utility executives that fuel would be produced at much lower costs than coal, etc.
      b. The government paid about ¼ the cost of building the first reactors with a guarantee of no cost overruns
      c. Congress passed the Price-Anderson Act to protect the U.S. nuclear industry and utilities from significant liability in case of accidents.
   1. The goals set forth in the fifties have not been met even with an investment of $2 trillion dollars worldwide.
   2. Electricity production from nuclear power plants is the slowest growing energy source.
   3. The U.S. has not ordered any new reactor since 1978, all 120 plants ordered since 1973 have been cancelled. In 2005, there were 103 licensed nuclear power plants operating in the U.S.
   4. Several major reasons for the failure of nuclear power to grow are multibillion-dollar cost overruns, higher operating costs, more malfunctions than expected, and poor management.
   5. Public concerns about safety and stricter government regulations are two major setbacks, especially after the 1979 accident at the Three Mile Island nuclear plant in the U.S., and the 1986 accident at the Chernobyl nuclear plant in the Ukraine.
   6. Investors are concerned about the economic feasibility of nuclear power.
   7. Vulnerability of these plants to terrorist attacks is another concern.
   8. Germany, Sweden, and Spain are planning to eliminate their nuclear power plants over the next 20-30 years; Japan gets 30% and France 80% of its electricity from nuclear plants. China and South Korea are planning on building more nuclear plants in the future.

C. The world's worst nuclear power plant accident occurred in 1986 in Ukraine.
   1. On April 26, 1986, a series of explosions at the Chernobyl nuclear plant blew the roof off a reactor building, the reactor partially melted down, and its graphite moderator caught fire and burned for 10 days.
   2. The disaster was caused by poor reactor design and human error.
   3. By 2005, 56 people had died from radiation released by the accident. Many more may still die from cancers such as thyroid cancer and leukemia.
   4. Some 350,000 people had to abandon their homes because of radiation fallout 400 times greater than that released from the atomic bomb dropped on Hiroshima.
   5. In many parts of the Ukraine, people still cannot drink the water or eat locally produced food.
   6. The cost of the accident could eventually run into several hundreds of billions of dollars.
   7. A major nuclear accident anywhere has effects that reverberate throughout the world.

D. The nuclear power fuel cycle has a fairly low environmental impact and a very low risk of accident. But costs are high, radioactive wastes must be stored for thousands of years, facilities are vulnerable to terrorist attack, and the spread of nuclear reactor technology gives more countries the knowledge to build nuclear weapons.
   1. In 1995, the World Bank said nuclear power is too costly and too risky.
   2. Currently, 60 countries have nuclear weapons or the knowledge to build them.
   3. Because of built-in safety features, the risk of exposure to radioactivity from nuclear power plants in the United States and other developing countries is extremely low.
   4. Potassium iodide pills have been given out to people living close to nuclear power plants in France and California.
   5. The U.S. Nuclear Regulatory Commission (NRC) estimates that there is a 15-45% chance of a complete core meltdown at a U.S. reactor during the next 20 years. Also, 39 U.S. reactors have an 80% chance of failure in the containment shell from a meltdown or explosion of gases inside containment structures.
   6. There have been several incidents at nuclear facilities that have given the public cause for concern about the safety of some U.S. nuclear power plants.

7. There is widespread distrust of the ability of the NRC to enforce nuclear safety in nuclear facilities.

E. Terrorists could attack nuclear power plants, especially poorly protected pools and casks that have spent nuclear fuel rods. There is great concern about the vulnerability of U.S. nuclear power plants to a terrorist attack similar to September 11, 2001.
   1. The 2002 study by the Nuclear Control Institute found that the plants were not designed to withstand the crash of a large jet.
   2. Insufficient security at nuclear plants is another concern. The same study also found that many security guards at nuclear power plants have low morale, are overworked, underpaid, under trained and not equipped to repel a serious ground attack by terrorists.
   3. Since September 2001, the United States has spent $20 billion to improve aviation security but only $1 billion on beefing up nuclear plant security.
   4. There is disagreement between the National Academy of Sciences and the NRC on the issue of nuclear plant security.
   5. Spent fuel rods stored outside of the containment shells at 68 nuclear plants in the U.S. are vulnerable to sabotage or terrorist attack.
   6. The storage pool generally holds 5-10 times more than the core inside a plant's reactor.
   7. If the radioactive material was released into the atmosphere, it would contaminate large areas for decades.
   8. Studies indicate that about 161 million people live within 75 miles of an aboveground spent-fuel site.
   9. Nuclear power officials feel that plants are save from attack while critics call for constructing much more secure structures to protect spent-fuel storage sites.

F. Scientists disagree about the best methods for long-term storage of high-level radioactive waste.
   1. Some of the proposed methods are:
      a. Bury it deep underground.
      b. Shoot it into space or into the sun. This strategy has been abandoned for now.
      c. Bury it under the Antarctic ice sheet or the Greenland ice cap. This strategy is prohibited by international law. There is the possibility of heat making the ice sheets unstable.
      d. Dump it into descending subduction zones in the deep ocean. Wastes might be spewed out by volcanic activity. This method is also prohibited by international law.
      e. Bury it in thick deposits of mud on the deep-ocean floor in areas that tests show has been geologically stable for 65 million years. Because of corrosion problems this method is also prohibited by international law.
      f. Change it into harmless, or less harmful, isotopes. There is no way to do this at present.

G. Terrorists could wrap conventional explosives around small amounts of various radioactive materials that are fairly easy to get, detonate such bombs, and contaminate large areas with radioactivity for decades.
   1. Dirty radioactive bombs are made of explosives and mixed with radioactive material.
   2. Small amounts of radioactive material may be bought on the international black market or stolen from hospitals, university laboratories, and some industries that use small amounts of radioisotopes.
   3. Spent fuel rods could be reprocessed to remove plutonium in a closed nuclear fuel cycle. The United States abandoned nuclear fuel processing in 1977, but it is getting looked at again despite disagreements on both sides of the issue.
   4. A dirty bomb would not explode like a nuclear bomb, but could cause 540 initial deaths in a densely populated city, and increase cancer risks and cause widespread panic and long-term economic chaos.

H. When a nuclear reactor reaches the end of its useful life, its highly radioactive materials must be kept from reaching the environment for thousands of years. The nuclear plant thus has to be decommissioned when it reaches the end of its useful life.
   1. Scientists have proposed three ways to decommission plants:
      a. Dismantle the plant and store its large volume of radioactive materials in a high-level waste storage facility.
      b. Put up a physical barrier around the plant and set up full-time security for 30-100 years before the plant is dismantled.

   c. Enclose the entire plant in a tomb that must last and be monitored for several thousand years.
2. Decommissioning adds to the total costs of nuclear power as an energy option.
3. At least 228 large commercial reactors worldwide (20 in the United States) are scheduled for retirement by 2012. In the U.S. operators of half of the current reactors have applied to the NRC to extend the soon-to-expire 40-year licenses to 60 years.

I. Building more nuclear power plants will not lessen dependence on imported oil and will not reduce carbon dioxide emissions as much as other quicker, safer, and cheaper alternatives.

J. Nuclear engineers have developed several smaller and presumably safer new types of nuclear reactors, but there are problems with these new designs and they are costly.
1. These smaller, advanced light-water reactors (ALWRs) have built-in passive safety features designed to make explosions/radioactive emissions almost impossible.
2. Nucleonics Week states that experts are unconvinced that the goals have been achieved, and it still does not eliminate the threats and hazards of long-term storage of wastes.
3. One proposed new design is called a pebble bed modular reactor (PBMR) and is shown in Figure 16-21. This type of new design has its proponent and its critics.

K. Because of very high costs and bad safety experiences with several nuclear breeder reactors, this technology has essentially been abandoned.
1. Breeder nuclear fission reactors generate more nuclear fuel than they consume by converting nonfissionable uranium-238 into fissionable plutonium-239. This means that the world's known uranium reserves would last at least 1,000 years.
2. The reactor uses liquid sodium coolant that ignites when exposed to air and is explosive if it contacts water.
3. The U.S. ended government-supported research for breeder technology in 1994.
4. The French built a commercial-size breeder reactor in 1986. It cost so much that it was shut down in 1998 permanently. Some countries are still planning on building small-scale breeder reactors.

L. Nuclear Fusion: After more than 50 years of research and billions of dollars in government subsidies, this technology remains at a laboratory stage.
1. Nuclear fusion is a nuclear change in which two isotopes of light elements, such as hydrogen, are forced together at extremely high temperatures until they fuse to form a heavier nucleus, releasing energy in the process.
2. This type of energy production has a number of advantages such as no emissions of conventional air pollutants or carbon dioxide.
3. There would be no risk of a meltdown or risk from terrorist attack.
4. Fusion power could be used to destroy toxic wastes, supply electricity for ordinary use, and decompose water to produce hydrogen gas to run a hydrogen economy by the end of this century.
5. Building a fusion reactor would be much more expensive than the cost of a conventional reactor. The U.S., after more than 50 years of research, has spent around $25 billion on nuclear fusion, but none of the approaches so far has produced more energy than it uses.

M. There is disagreement over whether to phase out nuclear power or keep this option open in case other alternatives do not pan out.
1. Some analysts feel that nuclear power should be phased out regarding all or most government subsidies and the money to subsidize and accelerate the development of other promising energy technologies.
2. According to investors and the World Bank analysts, conventional nuclear power simply can't compete in today's energy market.
3. Proponents of nuclear power feel that governments should continue funding research and development. They say that we need to keep nuclear options open if various renewable energy options fail to keep up with electricity demands and reduce CO_2 emissions to acceptable levels.
4. Opponents say it makes better sense to invest government funds in spurring more rapid development of energy conservation and renewable energy resources.

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Summary

1. Alternative energy sources are evaluated based on the availability of each source in the future, the source's energy yield, cost to develop and use this source, the extent of subsidies needed, effects on national and global economic and military security, and environmental effects.

2. The advantages of oil include supply for the next 90 years, low cost, high net energy yield, easy transportation, low land use, well-developed technology, and efficient system of distribution. Disadvantages include need for a substitute discovery; low price encourages waste, air pollution, and water pollution.

3. The advantages of natural gas include plentiful supplies, high net energy yield, low cost, less air pollution than oil, moderate environment impact, and easy transport. Disadvantages include the fact that it is a nonrenewable resource, release of carbon dioxide when burned, leaks, and requirement of pipelines.

4. The advantages of coal include plentiful supplies, high net energy yield, low cost, well-developed technology, and air pollution can be managed with appropriate technology. Disadvantages include very high environmental impact, land disturbance, air and water pollution, threat to human health, high carbon dioxide emissions, and release of radioactive particles and mercury.

5. The advantages of nuclear power include large fuel supply, low environmental impact, low carbon dioxide emissions, moderate land disruption and use, and low risk of accidents. Disadvantages include high cost, low net energy yield, high environmental impact in case of accident, catastrophic accidents, long-term storage of radioactive waste, and nuclear weapons.

Objectives

1. How much of the total energy used to heat the earth and earth's buildings comes from commercial energy? List five key questions to ask about each energy alternative to evaluate energy resources. Define *net energy* and state its significance in evaluating energy resources.

2. Distinguish among primary, secondary, and tertiary oil recovery. List the advantages and disadvantages of using conventional oil, oil from oil shale, and oil from tar sands to heat space and water, produce electricity, and propel vehicles.

3. Distinguish among natural gas, liquefied petroleum gas, liquefied natural gas, and synthetic natural gas. List the advantages and disadvantages of using natural gas as an energy source.

4. List and describe three types of coal. Indicate which is preferred for burning and which is most available. List and briefly describe three methods for extracting coal. List advantages and disadvantages of using coal as a fuel source.

5. Briefly describe the components of a conventional nuclear reactor. List advantages and disadvantages of using conventional nuclear fission to create electricity. Be sure to consider the whole nuclear fuel cycle, including disposal of radioactive wastes, safety and decommissioning of nuclear power plants, and the potential for proliferation of nuclear weapons.

6. Summarize current thinking about disposal of low-level and high-level radioactive wastes.

7. List and briefly describe three ways to decommission a nuclear power plant. List findings of a 1987 commission which bring the credibility of the Nuclear Regulatory Commission to safeguard the nuclear power industry into question.

8. Describe the potential use of breeder nuclear fission and nuclear fusion as energy sources.

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Key Terms **(Terms are listed in the same font style as they appear in the text.)**

advanced light-water reactors (*ALWRs*) (p. 380)	*contour strip mining* (p. 368)
Arctic National Wildlife Refuge (ANWR) (p. 355)	*control rods* (p. 371)
area strip mining (p. 368)	*conventional (light) oil* (p. 358)
automatically wasted (p. 356)	*conventional natural gas* (p. 366)
bitumen (p. 363)	*coolant* (p. 372)
breeder nuclear fission reactor (p. 381)	*core* (p. 371)
Chernobyl (p. 374)	**crude oil** (p. 355)
coal (p. 368)	*decommissioned* (p. 379)
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coal gasification (p. 370)	*fuel assembly* (p. 371)
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