UNIT V: ENERGY RESOURCES AND CONSUMPTION (10–15%)

Areas on Which You Will Be Tested

A. **Energy Concepts**—energy forms, power units, conversions, and laws of thermodynamics.

B. **Energy Consumption**

   1. History—Industrial Revolution, exponential growth, and energy crisis.
   2. Present global energy use.
   3. Future energy needs.

C. **Fossil Fuel Resources and Use**—formation of coal, oil, and natural gas, extraction/purification methods, world reserves and global demand, synfuels, and environmental advantages/disadvantages of sources.

D. **Nuclear Energy**—nuclear fission process, nuclear fuel, electricity production, nuclear reactor types, environmental advantages/disadvantages, safety issues, radiation and human health, radioactive wastes, and nuclear fusion.

E. **Hydroelectric Power**—dams, flood control, salmon, silting, and other impacts.

F. **Energy Conservation**—energy efficiency, CAFE standards, hybrid electric vehicles, and mass transit.

G. **Renewable Energy**—solar energy, solar electricity, hydrogen fuel cells, biomass, wind energy, small-scale hydroelectric, ocean waves and tidal energy, geothermal, and environmental advantages/disadvantages.

Energy

CHAPTER 8

Climb the mountains and get their good tidings. Nature's peace will flow into you as sunshine flows into trees. The winds will blow their own freshness into you and the storms their energy, while cares will drop away from you like the leaves of autumn.

—John Muir

ENERGY CONCEPTS

The following table describes the different energy forms.

Forms of Energy

Form	Description
Mechanical	There are two types of mechanical energy: potential energy (a book sitting on a table) and kinetic energy (a baseball flying through the air).
Thermal	Heat is the internal energy in substances—the vibration and movement of the atoms and molecules within substances.
Chemical	Chemical energy is stored in bonds between atoms in a molecule.
Electrical	Electrical energy results from the motion of electrons.
Nuclear	Nuclear energy is stored in the nuclei of atoms. It is released by either splitting or joining of atoms.
Electromagnetic	Electromagnetic energy travels by waves.

Power and Units

Power is the amount of work done per time. The most common unit of power is the kilowatt-hour (kWh).

Units of Energy/Power

Unit or Prefix	Description
Btu (British Thermal Unit)	Btu is a unit of energy used in the United States. In most countries it has been replaced with the joule. A Btu is the amount of heat required to raise the temperature of 1 pound of water by 1°F. 1 watt is approximately 3.4 Btu/hr. 1 horsepower is approximately 2,540 Btu/hr. 12,000 Btu/hr. is referred to as a "ton" in many air-conditioning applications.
Horsepower	Primarily used in the automobile industry. 1 horsepower (HP) is equivalent to 746 watts.
Kilo-	Means 1,000 or 10^3. 1 kW = 10^3 watts.
Mega- (M)	Means 1,000,000 or 10^6. 1 MW = 10^6 watts.
Watt (electrical)	A kilowatt-hour (kWh) is the amount of energy expended by a 1 kilowatt (1000 watts) device over the course of one hour. Often measured in the context of power plants and home energy bills.
Watt (thermal)	Nuclear power plants produce heat measured in thermal watts.

Conversions

Let's do a sample conversion problem that you might experience on the APES exam. We will break it down into steps and show you how it might be graded.

EXAMPLE PROBLEM #1

Thorpeville is a rural community with a population of 8,000 homes. It gets its electricity from a small, municipal coal-burning power plant just outside of town. The power plant's capacity is rated at 20 megawatts with the average home consuming 10,000 kilowatt hours (kWh) of electricity per year. Residents of Thorpeville pay the utility $0.12 per kWh. A group of entrepreneurs is suggesting that the residents support a measure to install 10 wind turbines on existing farmland. Each wind turbine is capable of producing 1.5 MW of electricity. The cost per wind turbine is $2.5 million dollars to purchase and operate for 20 years.

(a) The existing power plant runs 8,000 hours per year. How many kWh of electricity is the current plan capable of producing?

2 points. 1 point for correct setup. 1 point for correctly calculating the amount of electricity generated. You must correctly convert MW to kW. Points may be earned if you write the answer as a word problem. No points will be awarded without showing your work. Alternative setups are acceptable.

TIP

Be sure to practice these types of conversion problems. They appear very frequently in the Free-Response Question on the APES test. Also, be sure you are comfortable with scientific notation and the factor-label method.

$$\frac{20\,\cancel{\text{MW}}}{1} \times \frac{(1\times10^{6}\,\cancel{\text{watts}})}{1\,\cancel{\text{MW}}} \times \frac{1\,\text{kW}}{10^{3}\,\cancel{\text{watts}}} = 2 \times 10^{4}\text{ kW}$$

$$\frac{(2\times10^{4}\,\text{kW})}{1} \times \frac{8{,}000\text{ hours}}{1\text{ yr.}} = 16{,}000 \times 10^{4}\text{ kWh/yr}$$

$$= 1.6 \times 10^{8}\text{ kWh/yr.}$$

(b) How many kWh of electricity do the residents of Thorpeville consume in one year?

2 points. 1 point for correct setup. 1 point for correctly calculating the amount of electricity generated. You must correctly convert MW *to* kW. *No points will be awarded without showing your work. Alternative setups are acceptable.*

$$\frac{8\times10^{3}\,\cancel{\text{homes}}}{1} \times \frac{1\times10^{4}\,\text{kWh}/\cancel{\text{home}}}{1\text{ yr.}} = 8 \times 10^{7}\text{ kWh/yr.}$$

(c) Compare answers (a) and (b). What conclusions can you make?

2 points, plus 1 possible elaboration point. 1 point for comparing answers (a) with (b) with an explanation of why the numbers in parts (a) and (b) would be the same or different (must be a viable reason).

OR

1 point for a solid or accurate explanation of why (a) and (b) are different even if the calculations were not attempted.

1 possible elaboration point for explanations that go into great detail about why the numbers differ.

Note: If you say that (a) and (b) are the same, you must state that this can only occur if the households have backup systems that will produce energy for them if they exceed the power generated by the plant.

The power plant produces 1.6×10^{8} kWh per year. The residents, however, only use 8×10^{7} kWh per year. This leaves a surplus of $1.6 \times 10^{8} - 8 \times 10^{7} = 8 \times 10^{7}$ kWh in one year which can be sold to other towns. At a rate of \$0.12 per kWh, this provides a surplus of 8×10^{7} kWh × \$0.12/kWh = $\$0.96 \times 10^{7}$ = \$9,600,000.

Additional revenues could be generated by running the power plant 24 hours a day, 365 days a week

Differences between Thorpeville's consumption and the power plant's output could be attributed to the following:

- The power plant needs to produce higher amounts of power to compensate for line loss.
- The power plant needs to produce higher amounts of power to supply energy to the town during peak hours, not just the average usage.
- The power plant needs to plan for possible future growth of the town.
- The power plant was built over capacity to provide a source of income to the town.

(d) Assuming that the population of Thorpeville remains the same for the next 20 years, and that electricity consumption remains stable per household, what would be the cost (expressed in $ per kWh) of electricity to the residents over the next 20 years if they decided to go with wind turbines?

2 points. 1 point for correct setup. 1 point for correct answer with calculations. Alternative setups are acceptable. If your answer in part (b) is incorrect but you appropriately use it as the basis for the calculations for answering the question in part (d), you will receive full credit for answering part (d) if the setup and calculations are correct, even if the answer is not correct.

Based on current community consumption of 8×10^7 kWh/yr. from part (b).

$$\text{kWh for 20 years} = \frac{8\times10^{7}\,\text{kWh}}{\cancel{\text{year}}} \times 20\ \cancel{\text{years}} = 1.6\times10^{9}\ \text{kWh}$$

$$\text{Direct cost for 20 years} = 10\ \cancel{\text{turbines}} \times \frac{\$2.5\times10^{6}}{\cancel{\text{turbine}}} = \$2.5\times10^{7}$$

$$\text{cost/kWh} = \frac{\$2.5\times10^{7}}{1.6\times10^{9}\,\text{kWh}} = \$1.6\times10^{-2}/\text{kWh} = \$0.016/\text{kWh}$$

(e) What are the pros and cons of the existing coal-burning plant compared with the proposed wind farm?

Pros	**Cons**
WIND: The electricity produced from the wind turbines costs $0.016 per kWh, but each homeowner would also have to pay $25,000,000/8,000 homes = $3,125.00 over 20 years ($156.25/yr.) to pay for the wind turbines. 10,000 kWh at $0.016 per kWh for electricity produced from wind turbines = $160 plus $156.25 per year to pay for the wind turbines = $316.25 per year.	COAL: Electricity costs $0.12 per kWh produced from the coal-burning plant. 10,000 kWh of electricity per year from the coal-burning plant at $0.12 per kWh = $1,200 per year. Clearly, electricity produced from wind turbines is much cheaper.
WIND: Zero emissions. Acid rain would be reduced as well as photochemical smog.	COAL: Produces air pollution, specifically SO_2 and NO_x.
WIND: The wind is free.	COAL: As labor prices increase, the price of coal would be expected to increase over the next 20 years.
WIND: No heavy-metal or radioactive emissions.	COAL: Coal-burning plants produce heavy metals such as mercury, lead, and cadmium pollution along with radioactive contaminants.
WIND: No thermal pollution.	COAL: Can produce thermal pollution to local streams. However, cooling towers can be installed to reduce this form of pollution.
WIND: Multiple use of the land.	COAL: Cannot utilize the concept of multiple use of land.

EXAMPLE PROBLEM #2

(a) An electric water heater requires 0.30 kWh to heat a gallon of water. The thermostat is set to 150°F. The cost of electricity is $0.20 per kWh. A washing machine with a flow rate of 6.0 gallons per minute runs four times each Saturday. Each time it runs it takes in water for a total of 15 minutes. How much total water does the washing machine use in one year?

$$\frac{4\ \cancel{\text{cycles}}}{\cancel{\text{Saturday}}} \times \frac{15\ \cancel{\text{minutes}}}{1\ \cancel{\text{cycle}}} \times \frac{6.0\text{ gallons}}{1\ \cancel{\text{minute}}} \times \frac{52\ \cancel{\text{Saturdays}}}{1\text{ year}} = 18{,}720\text{ gallons / year}$$

2 points. 1 point for correct setup. 1 point for correct answer with calculations. Alternative setups are acceptable.

(b) Calculate the annual cost of the electricity for the washing machine, assuming that 3.0 gallons per minute of the water used by the machine comes from the hot-water heater.

$$18{,}720\text{ gallons / }2 = 9{,}360\text{ gallons of hot water per year}$$

$$\frac{9{,}360\ \cancel{\text{gallons}}}{1\text{ year}} \times \frac{0.30\ \cancel{\text{kWh}}}{1\ \cancel{\text{gallon}}} \times \frac{\$0.20}{\cancel{\text{kWh}}} = \$561.60\text{ / year}$$

2 points. 1 point for correct setup. 1 point for correct answer with calculations. Alternative setups are acceptable. If your answer in part (b) is incorrect but you appropriately used information from part (a) as the basis for answering the question, you will receive full credit, even if the numerical answer is wrong.

Laws of Thermodynamics

FIRST LAW

Energy cannot be created or destroyed.

SECOND LAW

When energy is converted from one form to another, a less useful form results (energy quality). Energy cannot be recycled to a higher quality. Only 20% of the energy in gasoline is converted to mechanical energy. The rest is lost as heat and is known as low-quality energy.

ENERGY CONSUMPTION

Wood (a renewable energy source) served as the predominant form of energy up until the Industrial Revolution. During the Industrial Revolution, coal (a nonrenewable energy source) surpassed wood's usage. Coal was overtaken by petroleum during the middle of the 20th century, with petroleum continuing to be the primary source of energy worldwide. Natural gas and coal experienced rapid development in the second half of the 20th century.

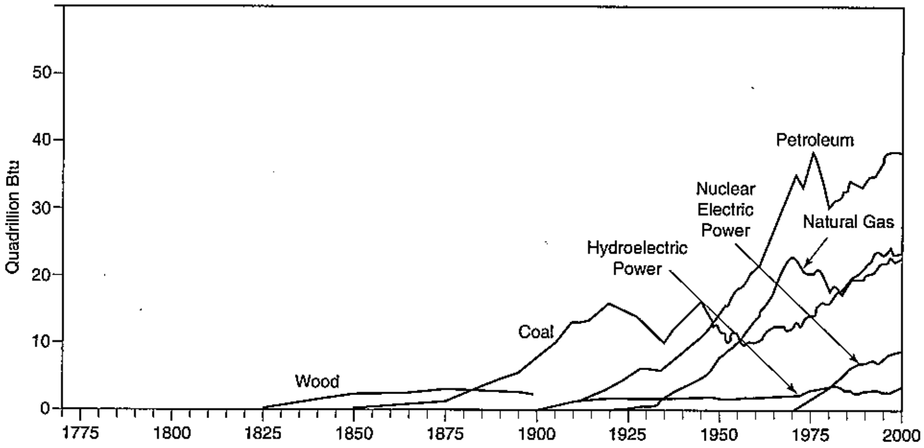

Figure 8.1 Energy consumption by source

Source: Energy Information Administration

The United States was self-sufficient in energy until the late 1950s. At that time, energy consumption began to outpace domestic production, which then led to oil imports.

The industrial sector in the United States has traditionally used the largest share of energy, followed by transportation and then residential and commercial uses. While coal was once the predominant form of energy in the industrial sector, it gave way to natural gas and petroleum in the late 1950s, with rapid increases occurring through the 1970s.

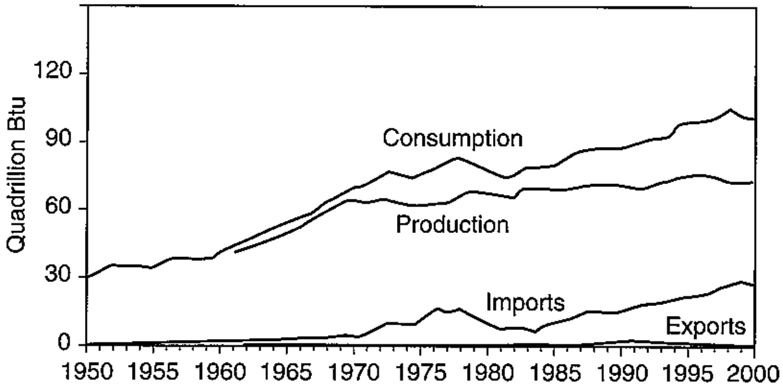

Figure 8.2 U.S. energy overview

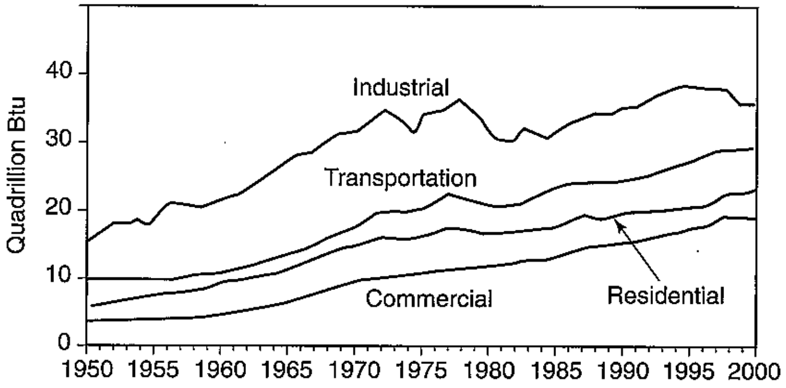

Figure 8.3 Energy consumption in the United States by end use

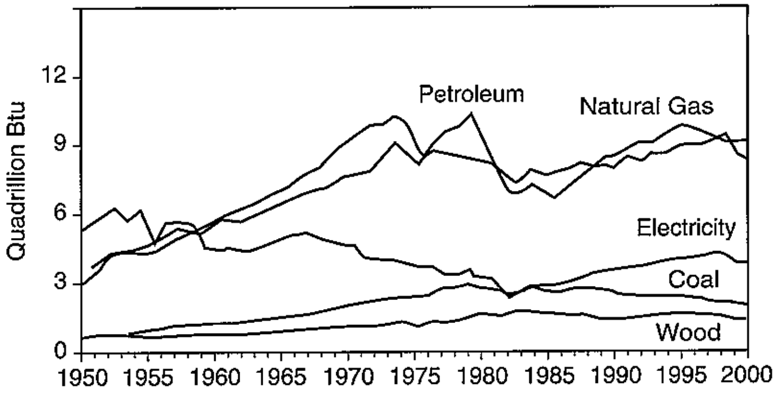

Figure 8.4 Industrial energy consumption

Beginning in 1998, net imports of oil surpassed the domestic oil supply in the United States. The United States accounts for 25% of the world consumption of petroleum.

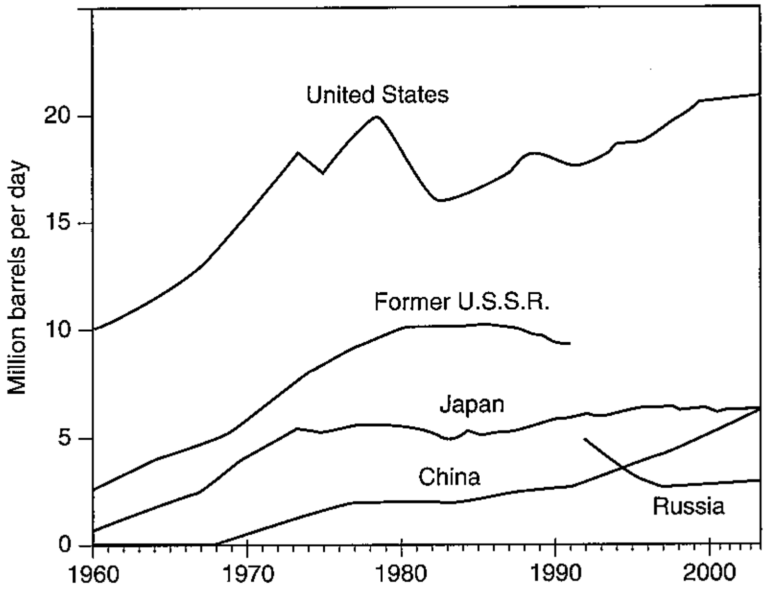

Figure 8.5 Leading petroleum consumers

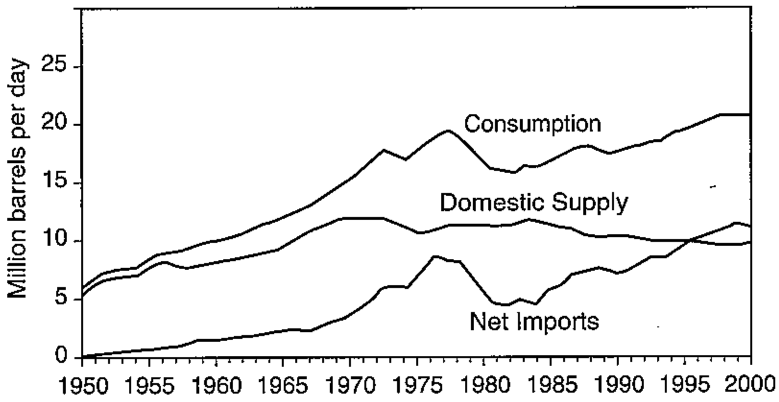

Figure 8.6 U.S. petroleum overview

Present Global Energy Use

In the United States, most of the energy comes from nonrenewable energy sources such as coal, petroleum, natural gas, propane, and uranium. These energy sources are called nonrenewable because their supplies are limited. Renewable energy sources include biomass, geothermal energy, hydropower, solar energy, and wind energy. They are called renewable energy sources because they are replenished in a relatively short time.

U.S. Energy Production vs. Consumption

Commodity	U.S. Production	U.S. Consumption
Oil	18%	39%
Natural gas	27%	23%
Coal	33%	23%
Nuclear	10%	7%
Renewable (geothermal, biomass, solar, wind)	9%	3.6%
Hydroelectric	5%	4%

U.S. Energy Production by Sector

Sector	%
Transportation	27%
Industrial	38%
Residential and commercial	36%

*Source: U.S. Geological Survey

Commodity Consumption by the United States

Commodity	%
(% of Total World Usage)	
Oil	40%
Natural gas	23%
Coal	23%

Future Energy Needs

Although the United States's energy history is one of large-scale change as new forms of energy were developed, the outlook for the next few decades is for continued growth and reliance on the three major fossil fuels: petroleum, natural gas, and coal. The most realistic, economical, and viable resources of future energy needs for the immediate future are clean coal, methane hydrates, oil shale, and tar sands.

CLEAN COAL

The world's supply of coal is substantial and can be expected to meet the world's energy needs for many years to come. Clean-coal technology refers to processes that reduce the negative environmental effects of burning coal. The processes include washing the coal to remove minerals and impurities and capturing the sulfur dioxide and carbon dioxide from the flue gases. Other clean-coal technology is focusing on natural gas or microbial fuel cells charged from biomass or sewage.

In the following diagram, oxygen is introduced to burn coal completely at Step 1. At Step 2, coal is pulverized in order to burn more completely. Coal is also washed at this point to remove contaminants. At Step 3, ash is removed using electrostatic precipitators. At Step 4, steam is condensed and returned to the boiler. And at Step 5, CO_2 is recovered using lime and then sequestered.

Cleaner Coal Combustion

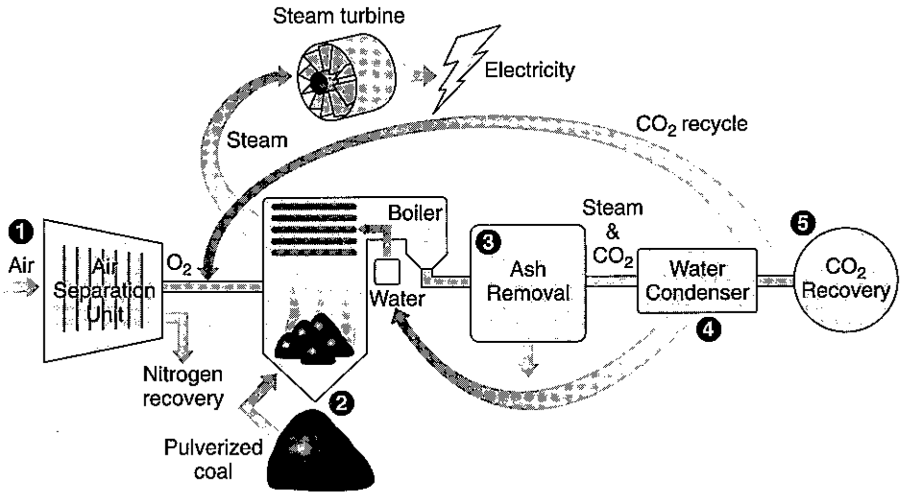

Figure 8.7 Steps used in producing clean coal

METHANE HYDRATES

Methane hydrates (methane locked in ice) are a recently discovered source of methane that form at low temperature and high pressure. They are found in two types of geologic settings: on land in permafrost regions where cold temperatures persist in shallow sediments and beneath the ocean floor at water depths greater than 1,640 feet (500 m) where high pressures dominate and where the hydrate deposits themselves may be several hundred meters thick. Some believe there is enough methane in the form of hydrates to supply energy for hundreds or thousands of years.

Natural gas is expected to take on a greater role in power generation. This is largely because of increasing pressure for clean fuels and the relatively low capital costs of building new natural gas–fired power equipment. The United States will consume increasing volumes of natural gas well into the 21st century. U.S. natural gas consumption is expected to increase 40%. Also, natural gas demand is expected to grow because of its expanded use as a transportation fuel and potentially, in the long-term, as a source of alternative liquid fuels and a source of hydrogen for fuel cells. The primary waste product of burning natural gas is carbon dioxide—a greenhouse gas that contributes to global warming.

OIL SHALE

Oil shales contain an organic material called kerogen. If the oil shale is heated in the absence of air, the kerogen converts to oil. There are approximately 3 trillion barrels of recoverable oil from oil shale in the world, with 750 billion of it being located in the United States. Oil shale can be extracted through either surface mining or *in situ* methods that consist of heating the oil shale underneath the ground and extracting the oil and gases through pumping. Most of the oil shale in the United States is found in Wyoming, Utah, and Colorado. The largest world reserves are found in Estonia, Australia, Germany, Israel, and Jordan.

Surface mining of oil shale negatively impacts the environment. The net energy yield of producing oil through oil shale is moderate since energy is required for blasting, drilling, crushing, heating the material, disposing of waste material, and environmental restoration. *In situ* methods have the potential of affecting aquifers. Even though the world has large oil shale reserves, the problem remains that once the oil is obtained from shale, traditional issues of environmental pollution, acid rain, and global warming will continue.

TAR SANDS

Tar sands contain bitumen—a semisolid form of oil that does not flow. Specialized refineries are capable of converting bitumen to oil. Tar sand deposits are mined using strip-mining techniques. *In situ* methods using steam can also be used to extract bitumen from tar sands. The sulfur content of oil obtained from tar sands is high, about 5%. Most of the tar sand deposits are located in Canada and Venezuela, with those in Canada being the most concentrated and therefore the most economical to mine. The oil in tar sands represents about two-thirds of the world's total oil reserves. The net-energy yield of producing oil through tar sands is moderate since energy is required for blasting, drilling, crushing, heating the material, disposing of waste material, and environmental restoration. As with oil shale, once the oil has been extracted from tar sands, the problems of environmental pollution, acid rain, and global warming continue.

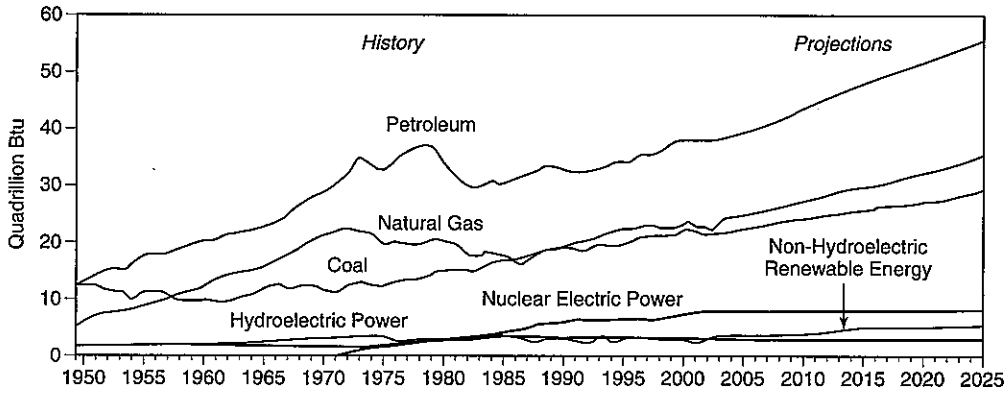

Figure 8.8 Energy consumption history and outlook, 1949–2025

Energy Crisis

In a free-market economy, the price of energy is driven by the principle of supply and demand. Sudden changes in the price of energy can occur if either supply or demand changes. In some cases, an energy crisis is brought on by a failure of world markets to adjust prices in response to shortages. Oil supply is largely controlled by nations with significant reserves of easily extractable oil, such as Saudi Arabia and Venezuela, who belong to an association of oil-producing countries known as OPEC (Organization of Petroleum Exporting Countries). When OPEC reduces the output quotas of its member countries, the price of oil increases as the supply diminishes. Similarly, OPEC can boost oil production in order to increase supplies, which drives down the price. When OPEC raises the price of oil too high, demand decreases and the production of oil from alternative sources becomes profitable. Historically, there have been several energy crises.

Most of the world's energy is supplied by burning oil. At current rates of consumption, world oil reserves are predicted to last 50 years, with oil reserves in the United States predicted to last 25 years. The industrialization of China will significantly decrease this predicted number of years. As supply decreases, prices will increase. Higher prices for oil may make other sources (shale oil and tar sands) more economical.

U.S. Commodity Consumption

Year	Description
1973	Oil crisis. Export embargo by OPEC in response to western support of Israel.
1979	Oil crisis caused by the Iranian Revolution.
1990	First Gulf War.
2000–2001	California electricity crisis. Deregulation of the industry and corporate corruption.
2006	Oil price increases due to increased demand by India and China, political instability in Iran, Iraq, and Venezuela.

FOSSIL FUEL RESOURCES AND USE

Coal is produced by decomposition of ancient (286 million-year-old) organic matter under high temperature and pressure. Sulfur from the decomposition of hydrogen sulfide (H_2S) by anaerobic bacteria became trapped in coal. There are three types of coal: lignite, bituminous, and anthracite. Lignite or brown is the softest and has the lowest heat content. Bituminous is soft, has a high sulfur content, and constitutes 50% of the U.S. reserve. Anthracite is hard, has a high heat content and low sulfur content, and makes up 2% of the U.S. reserve. Peat is precoal and is used in some countries for heat but it has low heat content. Coal supplies 25% of the world's energy, with China and the United States consuming the most. In the United States, 87% of the coal is used for power plants to produce electricity. The Clean Air Act requires up to a 90% reduction in the release of sulfur-containing gases.

Oil is a fossil fuel produced by the decomposition of deeply buried organic material (plants) under high temperatures and pressures for millions of years. Compounds derived from oil are known as petrochemicals. They are used in the manufacture of paints, drugs, plastics, and so on.

Natural gas (known as methane or CH_4) is produced by the decomposition of ancient organic matter under high temperatures and pressure. Conventional sources of methane are found associated with oil deposits. Unconventional sources include coal beds, shale, gas hydrates, and tight sands. Methane can be liquefied (LNG), which allows for worldwide distribution.

Extraction-Purification Methods

COAL

There are two primary methods of mining coal: surface mining and underground mining. Coal that is going to be burned in solid form may go through a variety of preparation processes. These include removing foreign material, screening for size, crushing, and washing to remove contaminants. It is also possible to turn solid coal into a gas or liquid fuel through clean-coal technologies.

OIL

Oil occurs in certain geologic formations at varying depths in Earth's crust. In many cases, elaborate, expensive equipment is required to extract it. Oil is usually found trapped in a layer of porous sandstone, which lies just beneath a dome-shaped or folded layer of some nonporous rock such as limestone. In other formations, the oil is trapped at a fault, or break in the layers of the crust. Natural gas is usually present just below the nonporous layer and immediately above the oil. Below the oil layer, the sandstone is usually saturated with salt water. The oil is released from this formation by drilling a well and puncturing the limestone layer. The oil is usually under such great pressure that it flows naturally, and sometimes with great force, from the well. However, in some cases, this pressure later diminishes so that the oil must be pumped. Once the oil has been collected, it is sent to a refinery, where it is cracked. Cracking involves separating the components of oil by their boiling points. Refining crude oil produces gasoline, heating oil, diesel oil, asphalt, etc.

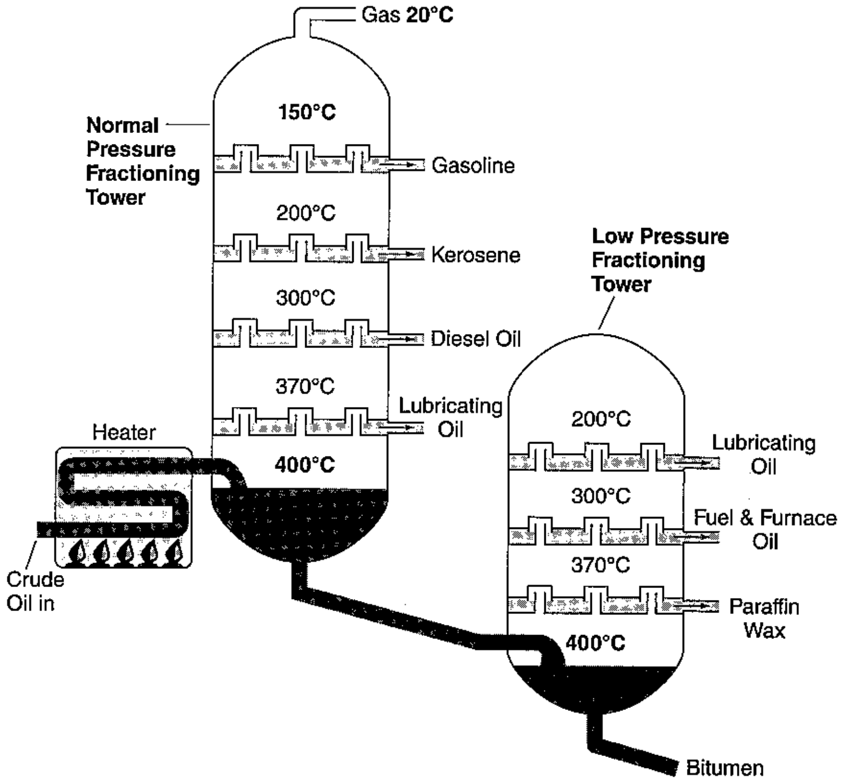

Figure 8.9 Oil refinery

CASE STUDY

Arctic National Wildlife Refuge (ANWR): The largest national wildlife refuge in the United States, the ANWR is located in northeastern Alaska and consists of 19 million acres (78,000 km^2). The question of whether to drill for oil in the ANWR has been an ongoing political controversy in the United States since 1977. Much of the debate over whether to drill in ANWR rests on the amount of economically recoverable oil, as it relates to world oil markets, weighed against the potential harm oil exploration might have on the wildlife.

NATURAL GAS

Natural gas typically flows from wells under its own pressure. It is collected by small pipelines that feed into the large gas transmission pipelines. In the United States, about 20 trillion cubic feet (560 billion m^3) of gas is produced each year.

World Reserves and Global Demand

Coal, oil, and natural gas are nonrenewable energy resources. Following is a brief description of the known world reserves of these energy sources and their expected demands in the future.

COAL

Best estimates show that coal reserves are expected to last for about 300 years at current rates of consumption. The largest reserve of coal is in China.

OIL

Of all known oil reserves, 65% is found in 1% of all fields—primarily in the Middle East.

NATURAL GAS

Russia and Kazakhstan have approximately 40% of the world reserves, the Middle East has about 25%, and the United States has about 3%.

Synfuels

A synfuel is a liquid fuel synthesized from a nonpetroleum source such as coal, natural gas, oil shale, or waste plastics. Shale oil is an example of a synfuel as it is derived from shale oil that is heated and the vapor condensed. Synthetic natural gas (SNG) is produced from coal liquefaction.

SOLID COAL TO SYNTHETIC NATURAL GAS (SNG), METHANOL, OR SYNTHETIC GASOLINE

Pros

- Easily transported through pipelines.
- Produces less air pollution.

- Large supply of raw materials available worldwide to meet current demands for hundreds of years.
- Can produce gasoline, diesel, or kerosene directly without reforming or cracking.

Cons

- Low net energy yield and requires energy to produce SNG.
- Plants are expensive to build.
- Would increase depletion of coal due to inherent inefficiencies.
- Product is more expensive than petroleum products.

Environmental Advantages/Disadvantages of Sources

COAL

Pros

- Abundant, known world reserves will last approximately 300 years at current rate of consumption.
- Unidentified world reserves are estimated to last 1,000 years at current rate of consumption.
- United States reserves are estimated to last about 300 years at current rate of consumption.
- Relatively high net-energy yield.
- U.S. government subsidies keep prices low.
- Stable; nonexplosive; not harmful if spilled.

Cons

- Most extraction in the United States is done through either strip mining or underground mining. These methods cause disruption to the land through erosion, runoff, and decrease in biodiversity.
- Up to 20% of coal ends up as fly ash, boiler slag, or sludge. Burning coal releases mercury, sulfur, and radioactive particles into the air. Thirty-five percent of all CO_2 releases are due to the burning of coal, with 30% of all pollution due to NO_x.
- Underground mining is dangerous and unhealthy.
- Expensive to process and transport. Cannot be used effectively for transportation needs.
- Pollution causes global warming. Scrubbers and other antipollution control devices are expensive.

OIL

Pros

- Inexpensive; however, prices are increasing, making alternatives more attractive.
- Easily transported through established pipelines and distribution networks.
- High net-energy yield.
- Ample supply for immediate future.
- Large U.S. government subsidies in place.
- Versatile—used to manufacture many products (paints, medicines, plastics, etc.).

Cons

- World oil reserves are limited and declining.
- Produces pollution (SO_2, NO_x, and CO_2). Production releases contaminated wastewater and brine.
- Causes land disturbances in drilling process, which accelerates erosion.
- Oil spills both on land and in ocean from platforms and tankers.
- Disruption to wildlife habitats (e.g., Arctic Wildlife Refuge).
- Supplies are politically volatile.

NATURAL GAS

Pros

- Pipelines and distribution networks are in place. Easily processed and transported as LNG over rail or ship.
- Relatively inexpensive, but prices are increasing. Viewed by many as a transitionary fossil fuel as the world switches to alternative sources.
- World reserves are estimated to be 125 years at current rate of consumption.
- High net energy yield.
- Produces less pollution than any other fossil fuel.
- Extraction is not as damaging to the environment as either coal or oil.

Cons

- H_2S and SO_2 are released during processing.
- LNG processing is expensive and dangerous, and it results in lower net energy.
- Leakage of CH_4 has a greater impact on global warming than does CO_2.
- Disruption to areas where it is collected.
- Extraction releases contaminated wastewater and brine.
- Land subsidence.

Fuel Type	Btu Value per Unit	Units Req'd to Produce 1,000,000 Btus	Fuel Price per Unit	Cost to Produce 1,000,000 Btus	Appliance Efficiency[3]	Effective Cost per 1,000,000 Btus
Electricity	3,413 per kWh	293 kWh	$0.14	$41.84	100%	$41.84[1]
Natural Gas	1,000 per ft^3 1 therm = 100 ft^3	10 therms	$1.35 per therm	$13.50	80%	$16.88[1]
Fuel Oil	139,000 per gallon	7.1 gallons	$2.86 per gallon	$20.30	80%	$25.38
LP Gas	91,690 per gallon	11 gallons	$2.95 per gallon	$32.45	80%	$40.56
Wood	22,000,000 per cord	0.0607 cords	$225 per cord	$13.66	60%	$22.77[2]
Wood Pellets	8,000 per pound	125 pounds	$0.12 per pound	$14.69	80%	$18.36
Kerosene	135,000 per gallon	7.41 gallons	$3.30 per gallon	$24.45	95%	$25.68

[1] Does not include a fixed monthly charge.

[2] Includes delivery.

[3] Electricity is set at 100% for comparative purposes.

Figure 8.10 Comparisons of U.S. Fuel Prices (as of March 2010)

NUCLEAR ENERGY

During nuclear fission, an atom splits into two or more smaller nuclei along with by-product particles (neutrons, photons, gamma rays, and beta and alpha particles). The reaction is exothermic. If controlled, the heat that is produced is used to produce steam that turns generators that then produce electricity. If the reaction is not controlled, a nuclear explosion can result.

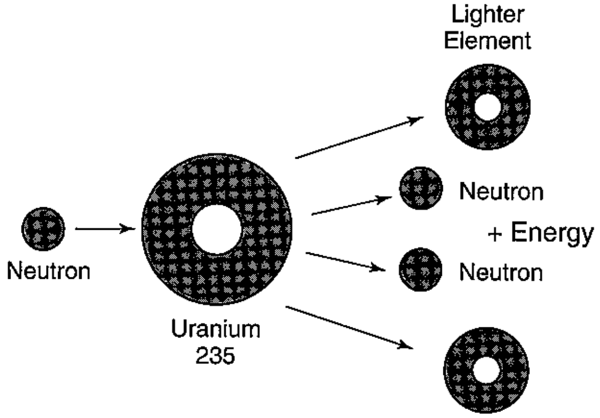

Figure 8.11 Nuclear fission

The amount of potential energy contained in nuclear fuel is 10 million times more than that of more traditional fuel sources such as coal and petroleum. The downside is that nuclear wastes remain highly radioactive for thousands of years and are difficult to dispose. The most common nuclear fuels are U-235, U-238, and Pu-239.

Nuclear Fuel

U-235

U-235 differs from U-238 in its ability to produce a fission chain reaction. The minimum amount of U-235 required for a chain reaction is called the critical mass. Low concentrations of U-235 can be used if the speed of the neutrons is slowed down through the use of a moderator. Less than 1% of all natural uranium on Earth is U-235. Uranium that has been processed to separate out U-235 is known as enriched uranium and is a subject of current controversy with Iran and North Korea. Nuclear weapons contain 85% or more U-235; nuclear power plants contain about 3% U-235. The half-life of U-235 is 700 million years.

U-238

U-238 is the most common (99.3%) isotope of uranium and has a half-life of 4.5 billion years. When hit by a neutron, it eventually decays into Pu-239, which is used as a fuel in fission reactors. Most depleted uranium is U-238.

PU-239

Pu-239 has a life-life of 24,000 years. It is produced in breeder reactors from U-238. Plutonium fission provides about one-third of the total energy produced in a typical commercial nuclear power plant. Control rods in nuclear power plants need to be changed frequently due to the buildup of Pu-239 that can be used for nuclear weapons and due to the buildup of Pu-240, a contaminant. International inspections of nuclear power plants regulate the amount of Pu-239 produced by power plants.

Electricity Production

The use of nuclear energy as a source for producing electricity in the United States started during the 1960s and increased rapidly until the late 1980s. Reasons for its decline included cost overruns, higher-than-expected operating costs, safety issues, disposal of nuclear wastes, and the perception of it being a risky investment. However, due to electricity shortages, fossil fuel price increases, and global warming, there is a renewed interest and demand for nuclear power plants. As of 2005, nuclear power provided 6% of the world's energy and 15% of the world's electricity, with the U.S., France, and Japan together accounting for 57% of nuclear generated electricity. As of 2007, there were 439 nuclear power reactors in operation in the world, operating in 31 countries. Globally, during the 1980s, one new nuclear reactor started up every 17 days on average; by the year 2015 this rate could increase to one every 5 days.

The United States produces the most nuclear energy, with nuclear power providing 19% of the electricity it consumes, while France produces the highest percentage of its electrical energy from nuclear reactors—78% as of 2006. In the European Union as a whole, nuclear energy provides 30% of the electricity.

Proponents of nuclear energy assert that nuclear power is a sustainable energy source that reduces carbon emissions and increases energy security by decreasing dependence on foreign oil. Proponents also claim that the risks of storing waste are small and can be further reduced by the technology in the new reactors. Furthermore, the operational safety record is already good when compared to the other major kinds of power plants. Critics believe that nuclear power is a potentially dangerous and declining energy source, with decreasing proportions of nuclear energy in power production, and dispute whether the risks can be reduced through new technology. Critics also point out the problem of storing radioactive waste, the potential for possibly severe radioactive contamination by accident or sabotage, the possibility of nuclear proliferation, and the disadvantages of centralized electrical production.

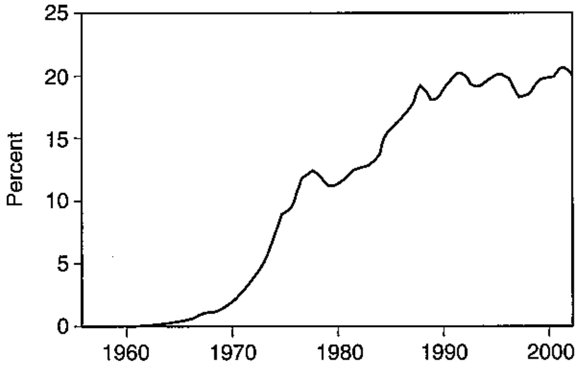

Figure 8.12 Nuclear share of electricity in the United States

Nuclear Reactor Types

Several different nuclear reactor types are in use: light-water reactors, heavy-water reactors, graphite-moderated reactors, and exotic reactors. However, they all have several features in common (see Figure 8.13).

- **A.** The *core* contains up to 50,000 fuel rods. Each fuel rod is stacked with many fuel pellets, each pellet having the energy equivalent of 1 ton (0.9 m.t.) of coal, 17,000 cubic feet (481 m^3) of natural gas, or 149 gallons (564 L) of oil.
- **B.** Uranium oxide is the *fuel*: 97% use U-283 and 3% use U-235.
- **C.** *Control rods* (usually made of boron) move in and out of the core to absorb neutrons and slow down the reaction.
- **D.** A neutron *moderator* is a medium that reduces the velocity of fast neutrons, thereby turning them into thermal neutrons capable of sustaining a nuclear chain reaction. Moderators can be water, graphite (can produce plutonium for weapons), or deuterium oxide (heavy water).
- **E.** *Coolant* removes heat and produces steam to generate electricity.

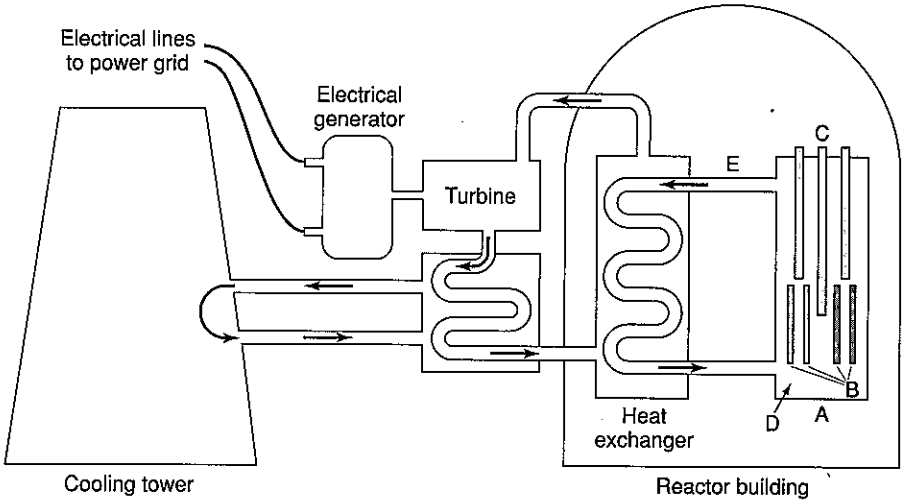

Figure 8.13 Diagram of nuclear power plant

LIGHT-WATER REACTORS

Both the moderator and coolant are light water (H_2O). To this category belong the pressurized-water reactors (PWR) and boiling-water reactors (BWR).

In PWR, the water coolant operates at a high pressure and is then pumped through the reactor core, where it is heated to about 620°F (325°C). The superheated water is pumped through a steam generator. Through heat exchangers, a secondary loop of water is heated and converted to steam. This steam drives one or more turbine generators, is condensed, and is pumped back to the steam generator. The secondary loop is isolated from the water in the reactor core and is not radioactive. A third stream of water from a lake, river, or cooling tower is used to condense the steam.

In BWR, the water coolant is permitted to boil within the core by operating at a lower pressure. The steam produced in the reactor pressure vessel is piped directly to the turbine generator, is condensed, and is then pumped back to the reactor. Although the steam is radioactive, there is no intermediate heat exchanger between the reactor and turbine to decrease efficiency. As in the PWR, the condenser cooling water has a separate source such as a lake or river.

HEAVY-WATER REACTORS

Heavy water, also known as deuterium oxide (D_2O), is a form of water in which each hydrogen in the water molecule contains one proton, one electron, and one neutron. Heavy water is used in certain types of nuclear reactors where it acts as a neutron moderator to slow down neutrons so that they can react with the uranium in the reactor. The use of heavy water essentially increases the efficiency of the nuclear reaction.

GRAPHITE-MODERATED REACTORS

This category uses light water for cooling, graphite for moderation, and uranium for fuel. These reactors require no separated isotopes such as enriched uranium or heavy water. This type of reactor, built by the Russians, was very unstable and is no longer being produced (see the Chernobyl case study).

EXOTIC REACTORS

Fast-breeder reactors and other experimental installations are in this group. Breeder reactors produce more fissionable material than they consume.

Environmental Advantages/Disadvantages of Nuclear Power

PROS

- No air pollutants if operating correctly.
- Releases about 1/6 the CO_2 as fossil fuel plants, thus reducing global warming.
- Water pollution is low.
- Disruption of land is low to moderate.

CONS

- Nuclear wastes take millions of years to degrade. Problem of where to store them and keeping them out of hands of terrorists.
- Nuclear power plants are licensed in the United States by the Nuclear Regulatory Commission (NRC) for 40 years. After that, they can ask to renew their license, or they can shut down the plant and decommission it. Decommissioning means shutting down the plant and taking steps to reduce the level of radiation so that the land can be used for other things. Since it may cost $300 million or more to shut down and decommission a plant, the NRC requires plant owners to set aside money when the plant is still operating to pay for future shutdown costs.
- Low net-energy yield—energy required for mining uranium, processing ore, building and operating plant, dismantling plant, and storing wastes.
- Safety and malfunction issues.

RELEVANT LAW

Price-Anderson Nuclear Indemnity Act (1957): Covers all nonmilitary nuclear facilities constructed before 2026. It indemnifies the nuclear industry against all liability claims arising from nuclear accidents while ensuring compensation coverage for the general public through no-fault insurance—the first $10 billion coming from the nuclear industry and anything above $10 billion coming from the U.S. government.

Safety Issues (Radiation and Human Health)

The U.S. Department of Energy (DOE) estimates that up to 50,000 radioactive contaminated sites within the United States require cleanup with a projected cost of $1 trillion dollars. The situation is many times worse in the former Soviet Union.

Estimated Health Risks per Year in the United States

	Nuclear	Coal
Premature death	6,000	65,000
Genetic defects/damage	4,000	200,000

CASE STUDY

Chernobyl, Ukraine (1986): Explosion in a nuclear power plant sent highly radioactive debris throughout northern Europe. Estimates run as high as 32,000 deaths, and 62,000 square miles (161,000 sq km) remain contaminated. About 500,000 people were exposed to dangerous levels of radiation. According to the World Health Organization, the Chernobyl nuclear disaster will cause 50,000 new cases of thyroid cancer among young people living in the areas most affected by the nuclear disaster, and the incidence of thyroid cancer in children rose tenfold in the Ukraine region. In certain parts of Belarus, 36% percent of children who were under four when the accident occurred can expect to develop thyroid cancer. Cost estimates run as high as $400 billion. The cause was determined to be both design and human error.

Nuclear Fusion

Nuclear fusion can occur when extremely high temperatures are used to force nuclei of isotopes of lightweight atoms to fuse together, which causes large amounts of energy to be released. A coal-fed electrical generating plant producing 1,000 megawatts of electricity in one day produces 30,000 tons of CO_2 gases, 600 tons of SO_2 gas, and 80 tons of NO_2 gas. In contrast, a fusion plant producing the same amount of electricity would produce 4 pounds of harmless helium as a waste product.

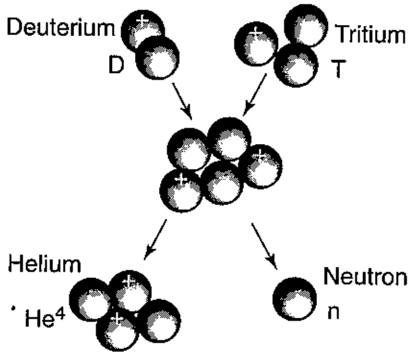

Figure 8.14 Deuterium-tritium fusion reaction

HYDROELECTRIC POWER

Dams are built to trap water, which in turn is then released and channeled through turbines that generate electricity. Hydroelectric power supplies about 10% of the electricity in the United States and approximately 3% worldwide.

Pros

- Dams control flooding.
- Low operating and maintenance costs.
- No polluting waste products.
- Long life spans.
- Moderate to high net-useful energy.
- Areas of water recreation.

Cons

- Dams create large flooded areas behind the dam from which people are displaced. Water is slow moving and can breed pathogens.
- Dams destroy wildlife habits and keep fish from migrating.
- Sedimentation requires dredging. Prevents sedimentation from reaching downstream and enriching farmland.
- Expensive to build.
- Destroys wild rivers.
- Large-scale projects are subject to earthquakes.
- Water loss due to increased water surface areas.

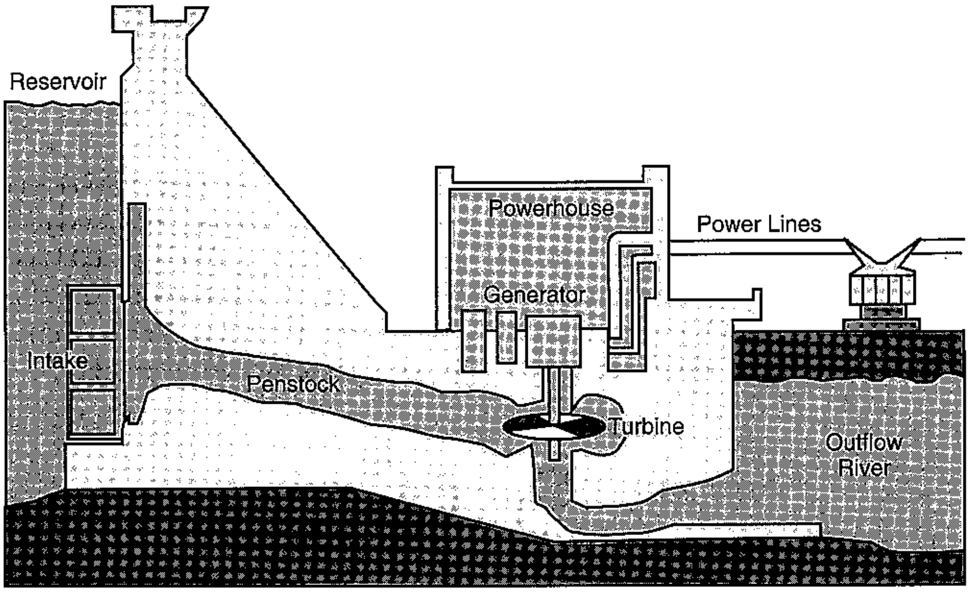

Figure 8.15 Typical hydroelectric dam

RELEVANT LAW

Water Resources Development Act (1986): Established dam safety programs and standards.

Flood Control

Methods to control floods include:

CHANNELIZATION

Straighten and deepen streams. Cons: removes bank vegetation and increases stream velocity, which causes erosion; may increase downstream flooding and sedimentation, which negatively impacts aquatic habitats.

DAMS

Dams store water in reservoirs. During periods of excessive rainfall, dams can be overwhelmed and excess water needs to be released.

IDENTIFY AND MANAGE FLOOD-PRONE AREAS

By identifying flood-prone areas, precautionary building practices such as floodways, building elevation, and pumping stations can be adopted.

LEVEES OR FLOODWALLS

Levees are raised embankments to prevent a river from overflowing. Levees contain river and stream flows but increase water velocity. Levees can break as they did in New Orleans during Hurricane Katrina in 2005.

PRESERVE WETLANDS

This technique preserves natural flood plains and maintains biodiversity.

Salmon

There are an estimated 74,993 dams in America, blocking 600,000 miles (965,000 km) of what had once been free-flowing rivers. Salmon are migratory fish that hatch in streams and rivers and then swim downstream to the ocean to live most of their lives. They return to the rivers and streams from which they hatched to spawn. Dams now block almost every major river system in the West. Many of those dams have destroyed important spawning and rearing habitats for salmon. In the Sacramento Valley in California, less than 5% of the salmon's original habitat is still available. In the Columbia River Basin, once the most productive salmon river system in the world, less than 70 miles (110 km) still remains free-flowing. As a result of habitat destruction, at least 106 major U.S. west coast salmon runs are extinct, and 25 more are now endangered. Dams also change the character of rivers, creating slow-moving, warm-water pools that are ideal for predators of salmon. Low water velocities in large reservoirs can also delay salmon migration and expose fish to higher water temperatures and disease. Cutting trees in forests near the streams and rivers clouds the water with silt and reduces water quality.

Things that have been done to reduce the impacts of dams on fish include fish passage facilities and fish ladders that help juvenile and adult fish migrate over or around many dams. Spilling water at dams over the spillway can help pass juvenile fish downstream because it avoids sending the fish through turbines. Water releases from upstream storage reservoirs have been used to increase water velocities and to reduce water temperatures in order to improve migration conditions through reservoirs. Juvenile fish also are collected and transported downstream in barges and trucks.

Silting and Other Impacts

DISEASE

Dam reservoirs in tropical areas, due to their slow movement, are literally breeding grounds for mosquitoes, snails and flies—the vectors that carry malaria, schistosomiasis, and river blindness.

DISPLACEMENT

Flooded areas behind dams destroy rich croplands and displace people.

EFFECTS ON WATERSHED

Downstream areas are deprived of the nutrient-rich silt that would revitalize depleted soil profiles.

IMPACT ON WILDLIFE

Migration and spawning cycles are disrupted.

SILTING

Silting occurs when silt (very fine particles intermediate in size between sand and clay) that is dissolved in river water settles out behind dams. Over time, the silt builds up and must be removed (dredged).

WATER LOSS

Large losses of freshwater occur through evaporation and seepage through porous rock beds.

ENERGY CONSERVATION

Energy Star is a joint program of the U.S. Environmental Protection Agency and the U.S. Department of Energy. It is designed to protect the environment through energy-efficient products and practices. Programs coordinated through Energy Star saved enough energy in 2005 to avoid greenhouse gas emissions equivalent to 23 million cars and $12 billion in utility bills. The symbol shown below appears on products that meet Energy Star standards.

CAFE Standards

Transportation needs consume two-thirds of the petroleum consumption in the United States. This sector of energy consumption is increasing faster than any other sector (1.8% growth per year). Imports of crude oil and other petroleum products are expected to increase 66% by 2020. CAFE (Corporate Average Fuel Economy) standards are the average fuel economies of a manufacturer's fleet of passenger cars or light trucks. The testing follows the guidelines established by the Environmental Protection Agency. It is estimated that CAFE standards result in savings of over 55 billion gallons (210 billion L) of fuel annually with a substantial reduction in carbon dioxide emissions of approximately 10%. CAFE standards are achieved through better engine design, efficiency, and weight reduction. The average CAFE standard of 27.5 miles per gallon (11.7 km/L) for automobiles has not increased in the United States since 1996 with SUV standards less than those for light trucks. Significant improvements in fuel mileage could be achieved by expanding CAFE standards to include:

1. Streamlining
2. Reduced tire-rolling resistance
3. Engine improvements, especially transitioning to a hybrid technology
4. Optimized transmission improvements
5. Transition to higher voltage automotive electrical systems
6. Performance-based tax credits

Hybrid Electric Vehicles

Cars should be able to drive at least 300 miles (482 km) between refuelings, be refueled quickly and easily, and keep up with the other traffic on the road. A gasoline-powered car meets these requirements but produces a relatively large amount of pollution and generally gets poor gas mileage. For example, 1 gallon (4 L) of gasoline weighs 6 pounds (2.7 kg). When burned, the carbon in it combines with oxygen from the air to produce nearly 20 pounds (9 kg) of carbon dioxide. An electric car, however, produces almost no pollution but has limited range between charges. A hybrid vehicle attempts to increase the mileage and reduce the emissions of a gas-powered car significantly while overcoming the shortcomings of an electric car.

Gasoline-electric hybrid cars contain five important parts. First, it has an engine. The gasoline engine on a hybrid is smaller than on a gas-only car and uses advanced technologies to reduce emissions and increase efficiency. Second, the fuel tank in a hybrid is the energy storage device for the gasoline engine. Gasoline has a much higher energy density than batteries do. For example, about 1,000 pounds (455 kg) of batteries are needed to store as much energy as 1 gallon (3.7 L) or 6 pounds (2.7 kg) of gasoline. Third, advanced electronics allow the electric motor to act as a generator. For example, when it needs to, the motor can draw energy from the batteries to accelerate the car. When acting as a generator, it can slow down the car and return energy to the batteries. Fourth, the generator is similar to an electric motor, but it acts only to produce electrical power. It is used mostly on series hybrids. Fifth, the batteries in a hybrid car are the energy storage device for the electric motor. Unlike the gasoline in the fuel tank, which can power only the gasoline engine, the electric motor on a hybrid car can put energy into the batteries as well as draw energy from them.

A parallel hybrid has a fuel tank that supplies gasoline to the engine and a set of batteries that supplies power to the electric motor. Both the engine and the electric motor power the car at the same time. In a series hybrid, the gasoline engine turns a generator, which charges the batteries and/or powers an electric motor. The gasoline engine never directly powers the vehicle.

Plug-in hybrid electric vehicles are hybrid cars with an added battery. Plug-in hybrids can be plugged in to a 120-volt outlet and charged. Plug-ins run on the stored energy for much of a typical day's driving—up to 60 miles per charge. When the charge is used up, plug-in hybrids automatically keep running on the fuel in the fuel tank. A plug-in does not entail any sacrifice of vehicle performance or driver amenities. A midsize plug-in can accelerate from 0 to 60 miles per hour (0–96 kph) in less than 9 seconds and sustain a top speed of 97 miles per hour (156 kph). Higher initial costs are partly offset by lower operating costs.

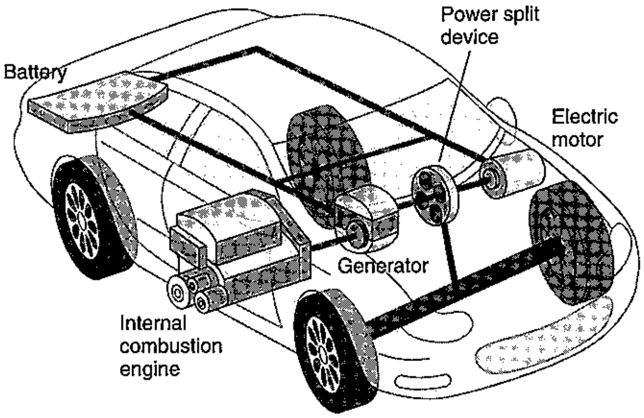

Figure 8.16 Hybrid electric vehicle

Mass Transit

Mass transit includes rail, bus services, subways, airlines, ferries, and so on. Mass transit often determines where people live, where they work, and how much air pollution they are subjected to. In the United States, private cars are the primary mode of transportation. In the rest of the world, mass transport is the primary form. For example, in the United States, only 3% of the population utilizes mass transit on a regular basis. In Japan, that figure expands to 47%. Land availability and whether cities expand vertically (land is not available) or expand horizontally (land is available) often determines the preferred mode of transportation. Use of mass transit use rises sharply with population density. Mass transit can be faster than private cars when either a separate infrastructure is reserved for mass transit or special lanes on shared highways are designated for mass transit vehicles, which results in higher speeds and less delay. In some areas, public transport systems are poorly developed and take significantly longer than an equivalent trip in a private vehicle. Perhaps the most efficient method to promote mass transit is to adopt a user-pay approach, where all external costs of operating a private vehicle are factored into license fees and/or vehicle taxes. However, this approach would be met with fierce private and political opposition.

LIGHT RAIL

Consists of trains that share space with road traffic and trains that have their own right-of-way and are separated from road traffic.

GROUP OR PERSONAL RAPID TRANSIT

Private vehicles similar to automobiles or buses able to travel under a driver's control but then be able to enter an automated guideway or track for extended distances. Could be powered by fuels when out of system and electricity when entering the automated guideway.

AUTOMATED HIGHWAY SYSTEMS

Sensors in the roadbed monitor and control traffic flow by adjusting vehicle speed and spacing to reduce congestion.

BUS RAPID TRANSIT

Includes bus-dedicated and grade-separated right-of-ways, bus lanes, bus signal preference and preemption, bus turnouts, bus-boarding islands, curb realignment, off-bus fare collection, and level boarding.

MAGLEV

Magnetically levitated trains that "float" above the rails to reduce friction.

TUBULAR RAIL

Trains that do not sit on tracks but rather travel through distantly spaced support structures.

RENEWABLE ENERGY

Several different forms of renewable energy can be used.

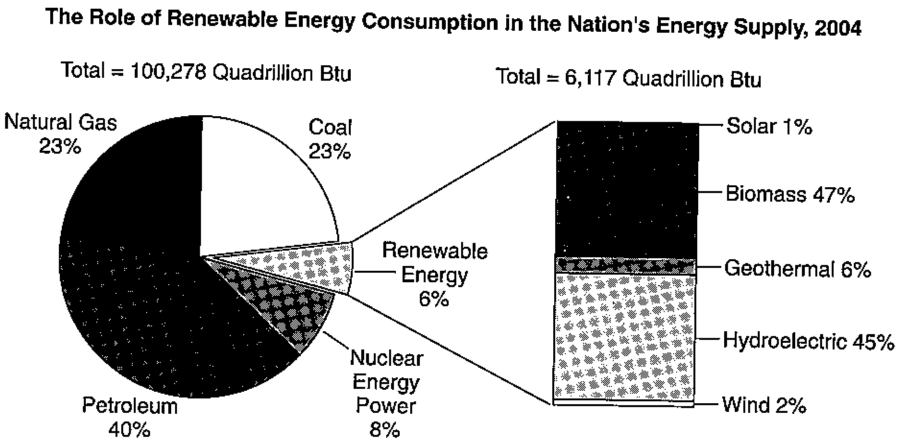

Figure 8.17 Renewable energy sources

Solar Energy

Solar energy consists of collecting and harnessing radiant energy from the sun to provide heat and/or electricity. Electrical power and/or heat can be generated at home and industrial sites through photovoltaic cells, solar collectors or at a central solar-thermal plant.

Active solar collectors use the sun's energy to heat water or air inside a home or business. It requires an electrical input for pumps and fans. Passive solar requires no moving parts. The structure is built to maximize solar capture, such as large, south-facing windows. Photovoltaic cells are used to generate electricity.

Pros

- Supply of solar energy is limitless.
- Reduces reliance on foreign imports.
- Only pollution is in manufacture of collectors. Little environmental impact.
- Can store energy during the day and release it at night—good for remote locations.

Cons

- Inefficient where sunlight is limited or seasonal.
- Maintenance costs are high.
- Systems deteriorate and must be periodically replaced.
- Current efficiency is between 10%–25% and not expected to increase soon.

Hydrogen Fuel Cells

Nine million tons of hydrogen is produced in the United States each day—enough to power 20 to 30 million cars or 5 to 8 million homes. Most of this hydrogen is used by industry in refining, treating metals, and processing foods.

The hydrogen fuel cell operates similar to a battery. It has two electrodes, an anode and a cathode, that are separated by a membrane. Oxygen passes over one electrode and hydrogen over the other. The hydrogen reacts with a catalyst on the anode that converts the hydrogen gas into negatively charged electrons and positively charged hydrogen ions. The electrons flow out of the cell to be used as electrical energy. The hydrogen ions move through the electrolyte membrane to the cathode, where they combine with oxygen and the electrons to produce water. Unlike batteries, fuel cells never run out.

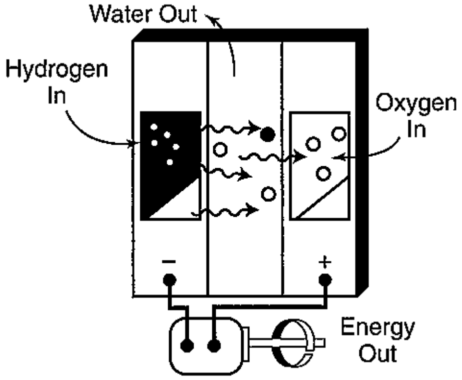

Figure 8.18 Hydrogen fuel cell

Pros

- Waste product is pure water.
- Ordinary water (either ocean or freshwater) can be used to obtain hydrogen.
- Does not destroy wildlife habitats and has minimal environmental impact.
- Energy to produce hydrogen could come from fusion reactor, solar, or other less-polluting source.

- Hydrogen is easily transported through pipelines.
- Hydrogen can be stored in compounds to make it safe to handle. Hydrogen is explosive, but so are methane, propane, butane, and gasoline.

Cons

- Takes energy to produce the hydrogen from either water or methane.
- Changing from a current fossil fuel system to a hydrogen-based system would be very expensive.
- Hydrogen gas is explosive.
- At the current time, it is difficult to store hydrogen gas for personal cars.

Biomass

Biomass is any carbon-based, biologically derived fuel source such as wood, manure, charcoal, or bagasse grown for use as a biofuel. Examples include biodiesel, methanol, and ethanol. Plants that are suitable for biofuel include switch grass, hemp, corn, and sugarcane. Biomass can also be used for building materials and biodegradable plastics and paper. Approximately 15% of the world's energy supply is derived from biomass and is most commonly used in developing nations.

Pros

- Renewable energy source as long as used sustainably.
- Can be sustainable if issue of deforestation and soil erosion are controlled.
- Could supply half of the world's demand for electricity.
- Biomass plantations (cottonwoods, poplars, sycamores, switch grass, and corn) can be located in less desirable locations and can reduce soil erosion and restore degraded land. In the U.S. alone, 200 million acres (80 million ha) are suitable for biomass plantations.

Cons

- Requires adequate water and fertilizer, of which sources are declining.
- Use of inorganic fertilizers, herbicides, and pesticides would harm environment.
- Corn being diverted to produce ethanol raises food prices.
- Would cause massive deforestation and loss of habitat, resulting in a decrease in biodiversity.
- Inefficient methods of burning biomass would lead to large levels of air pollution, especially particulate matter.
- Expensive to transport because it is heavy.
- Not efficient. About 70% of the energy derived from burning biomass is lost as heat.

Biomass can also be burned in large incinerators as an energy source.

Pros

- Crop residues are available (e.g., sugarcane in Hawaii).
- Ash can be collected and recycled.
- Reduces impact on landfills.

Cons

- Net-energy yield is low to moderate. Energy required for drying and transporting material to a centralized facility is prohibitive.

- Severe air pollution if not burned in a centralized facility.
- CO_2 production would have a major impact on global warming.

CASE STUDY

About 90% of the cars in Brazil run on either alcohol or gasohol (a mixture of gasoline and ethanol). Flex fuel engines can run on either. The alcohol is produced from sugarcane, which grows in abundance in Brazil. The use of alcohol and gasohol has had a negative impact on rainforests.

Wind Energy

Wind turns giant turbine blades that then power generators. Turbines can be grouped in clusters called wind farms.

Pros

- All electrical needs of the United States could be met by wind in North Dakota, South Dakota, and Texas.
- Wind farms can be quickly built and can also be built out on sea platforms.
- Maintenance is low and the farms are automated.
- Moderate-to-high net-energy yield.
- No pollution. Wind farms are in remote areas so noise pollution is minimal to humans.
- Land underneath wind turbines can be used for agriculture (multiple-use).

Cons

- Steady wind is required to make investment in wind farms economical. Few places are suitable.
- Backup systems need to be in place when the wind is not blowing.
- Visual pollution.
- May interfere with flight patterns of birds.
- May interfere with communication, such as microwaves, TV, and cell phones.
- Noise pollution.

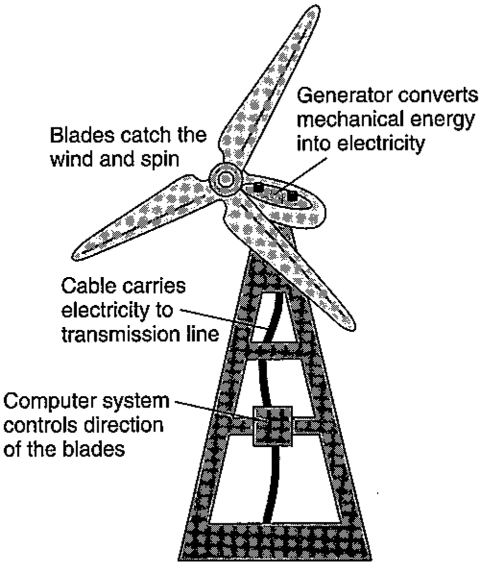

Figure 8.19 Wind turbine

Small-Scale Hydroelectric

Small-scale hydropower utilizes small turbines connected to generators submerged in streams to generate power. Generally, the capacity of small-scale hydropower is 100 kW or less. This technology does not impede stream navigation or fish movement. This technology is especially attractive in remote areas where power lines are not available. Several factors should be considered when installing small-scale hydropower:

- The amount of water flow available on a consistent basis
- The amount of drop (head) the water has between the intake and output of the system
- Regulatory issues such as water rights and easements.

In many cases, there are economic incentives for installing small-scale hydropower systems through grants, loans, and tax incentives.

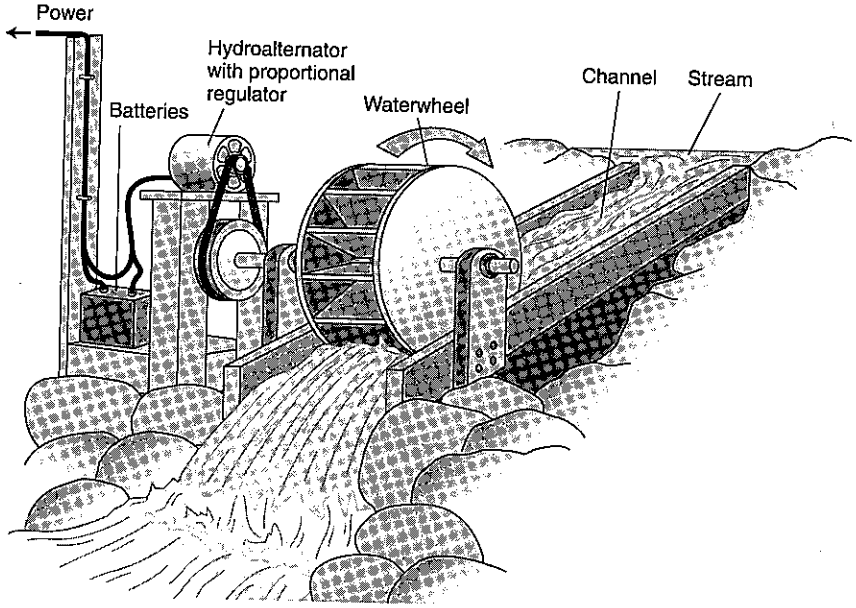

Figure 8.20 Small-scale hydroelectric generator

Ocean Waves and Tidal Energy

The natural movement of tides and waves spin turbines that generate electricity. Only a few plants are currently operating worldwide. They are on the north coast of France and in the Bay of Fundy between the United States and Canada.

Pros

- No pollution.
- Minimal environmental impact.
- Net-energy yield is moderate.

Cons

- Construction is expensive.
- Few suitable sites.
- Equipment can be damaged by storms and corrosion.

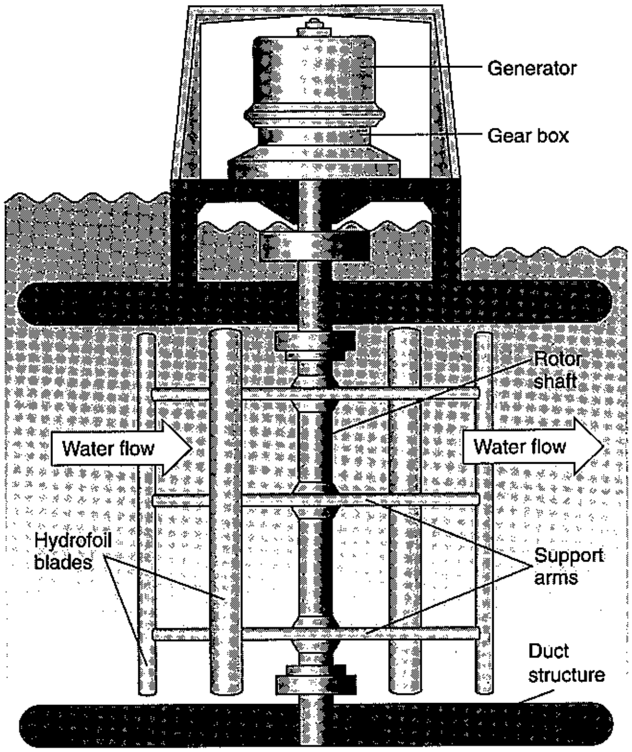

Figure 8.21 Tide turbine used to generate electricity

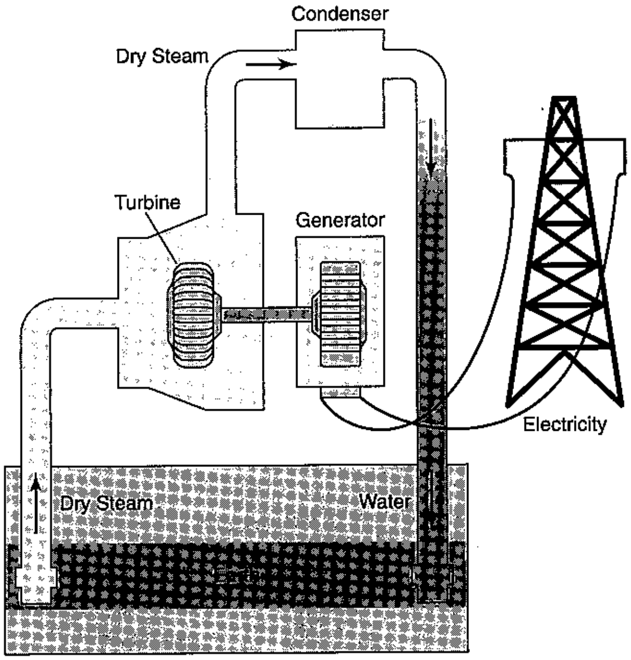

Figure 8.22 Geothermal generator

Geothermal

Heat contained in underground rocks and fluids from molten rock (magma); hot dry-rock zones, and warm-rock reservoirs produce pockets of underground dry steam, wet steam, and hot water. This steam can be used to drive turbines, which can then generate electricity. Geothermal energy supplies less than 1% of the energy needs in the United States. Geothermal energy is currently being used in Hawaii, Iceland, Japan, Mexico, New Zealand, Russia, and California. Areas of known geothermal resources tend to follow tectonic plate boundaries.

Pros

- Moderate net-energy yield.
- Limitless and reliable source if managed properly.
- Little air pollution.
- Competitive cost.

Cons

- Reservoir sites are scarce.
- Source can be depleted if not managed properly.
- Noise, odor, and land subsidence.
- Can degrade ecosystem due to corrosive, thermal, or saline wastes.