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Energy

For the AP Environmental Science Exam, you'll be expected to know the basics of the concept of energy; in fact according to the AP outline, 10–15 percent of the questions you'll see on the exam relate to energy.

Unlike the essential elements we discussed in earlier chapters, energy flows on a one-way path through the atmosphere, hydrosphere, and biosphere, and is essential for living organisms in many of its forms. At the most fundamental level, **energy** is defined as the capacity to do work. There are two types of energy: **Potential energy** is energy at rest—it's stored energy—while **kinetic energy** is energy in motion. You might recall from your physics class that potential energy can be converted to kinetic energy. A third type of energy is in the form of **radiant energy,** or sunlight. Two other terms that describe the movement of energy around Earth are **convection,** which is the transfer of heat by the movement of the heated matter, and **conduction,** which is the transfer of energy through matter from particle to particle. Keep in mind that different energy sources are capable of storing types of energy that differ in quality. For example, both wood and coal will burn to produce heat, but coal produces more heat because it contains higher **energy quality**.

As you saw in our chapter about weather, convection and conduction are very important processes that drive the movement of water in the hydrosphere of Earth. This is just one way in which the flow of energy around the earth affects every process—geological or biological—that takes place.

In this chapter, we'll begin with a discussion of the basic units of energy, and go through the two laws of thermodynamics that you'll need to know for the test. After that, we'll begin our discussion of Earth's energy resources—the earth provides humans with resources of energy, just as it does the physical, natural resources that we learned about in the last chapter. Let's begin!

UNITS OF ENERGY

For this exam, you'll be expected to recognize the following units of energy and power:

- **Energy Units:** Joule (J), Calorie (cal), British thermal unit (Btu), and kilowatt hour (kWh), which is a measure of watt/time
- **Power Units:** Watt (W) and Horsepower (hp)

Remember, a watt is equal to volts × amperage. You should also be intimately familiar with the First and Second Laws of Thermodynamics, so let's review those before we move on—and make sure you memorize these before test day!

LAWS OF THERMODYNAMICS

1. The **First Law of Thermodynamics** says that energy can neither be created nor destroyed; it can only be transferred and transformed. One example of such a transformation occurs in photosynthesis. In photosynthesis, radiant energy from the sun is converted to chemical energy in the form of the bonds that hold together atoms in carbohydrates.
2. The **Second Law of Thermodynamics** says that the entropy (disorder) of the universe is increasing. One corollary of this Second Law of Thermodynamics is the concept that, in most energy transformations, a significant fraction of energy is lost to the universe as heat; for example, as we reviewed in Chapter 3, in food chains, only about 10 percent of the energy from one trophic level is available for the next energy upon consumption.

Okay, those are the basics about energy that you'll need to know for the test. Now let's begin our review of the energy resources that exist on Earth.

NONRENEWABLE ENERGY

Perhaps surprisingly, one of our biggest uses of energy is in the production of electricity. In other words, we use tons of energy each year to produce electricity—another form of energy!

In general, electricity is produced in the following way: An energy source provides the power that heats up water, transforming it into steam, which then turns a turbine. Hence, the turbine converts kinetic energy (from the steam) into mechanical energy (the spinning of the turbine). Now here's where the generator comes in. The generator consists of copper wire coils and magnets, one of which is stationary (stator) and the other of which rotates (rotor). As the turbine spins, it causes the magnets in the generator to pass over the wire coils (or vice versa), generating a flow of electrons through the copper wire and thus producing an alternating current that passes into electrical transmission lines. In lieu of steam, flowing water or wind can also provide the power needed to turn the turbine and produce electricity.

So, where do we get the energy that we use to heat up that water in the first step of the creation of electricity? Well, the three main sources for the global production of electricity are

- fossil fuels (provide 64 percent of the world's electricity)
- nuclear energy (provides 17 percent of the world's electricity)
- renewable energy sources (provide 19 percent of the world's electricity)

Let's go through each of the types of energy above and see where they came from, what effect their use has on the Earth, and how sustainable they are.

Fossil Fuels

During the Industrial Revolution (in the early eighteenth century), steam was produced almost exclusively through the burning of firewood and coal—and this, in turn, provided the energy for most mechanical processes. Today, oil is our primary power source. About 35 percent of total global energy production comes from oil products; the runner-up to oil is coal, and the runner-up to coal is natural gas. Together these three fossil fuels provide 80 percent of the world's energy.

Fossil fuels, as the name indicates, are formed from the fossilized remains of once-living organisms. Over vast tracts of time, this organic matter was exposed to intense heat and pressure. Eventually, theses factors broke down the organic molecules into oil, coal, and natural gas.

Oil is made of long chains of hydrocarbons; and coal contains a mixture of carbon, hydrogen, oxygen, and other atoms. Natural gas is made mostly of methane gas (CH_4) with a mixture of other gases.

Generally, oil and natural gas are formed in the same areas. These materials are found deep in the earth under both land and ocean floor, where they are stored in the pores (spaces) between rocks. Coal is found in long continuous deposits, called **seams,** at various depths underground. The seams represent areas where large amounts of plant remains were buried and eventually transformed into coal. We will cover the process of coal mining on the next page.

Certain types of geologists locate fossil fuel reserves. They plan and supervise the extraction of these fuels from the Earth. Using knowledge of the geology and rock formations, these scientists make predictions about which sites are most likely to have fossil fuel deposits. They use **exploratory wells** to drill and sample a particular area. If an exploratory well hits a fossil fuel reserve, it can provide an estimate of the amount of fuel that can be obtained from that area; this is called the **proven reserve.** It is important to know that although exploratory wells can provide a fairly precise estimate of the size of a reserve, these numbers are just educated guesses (not so proven after all!). The amount of a resource that can be extracted from a reserve is dependent on the technologies available and the cost of extraction. If extraction costs are too high, it is not economically feasible to extract the resource. If a coal seam is buried very deeply, for instance, it may cost more money and fuel to extract it than the value of the seam.

What About Oil?

When oil is pumped up fresh from a reserve, it is called **crude oil.** Crude oil varies greatly from reserve to reserve. It can range from thin to viscous (thick); from high sulfur to low sulfur; it can even vary in color and odor.

There are three different methods of extracting oil. In primary extraction, the oil can be easily pumped to the surface. When some oil wells are tapped for the first time, there is a large release of oil and gas, a *gusher,* due to the pressure in the reserve. When the oil is harder to extract, people rely on pressure extraction, which uses mud, saltwater, and even CO_2 to push out the oil from the reserve. The final method utilizes steam, hot water, or hot gases to partially melt very thick crude oil and make it easier to extract. Oil reserves can also be found in rock (shale oil) and surface sands (tar sands).

Drilling for oil is only moderately damaging to the environment because little land is needed to drill. However, since oil is transported thousands of miles by tankers, pipelines, and trucks, a lot of environmental damage can occur during transportation.

What About Coal?

Let's spend some time reviewing coal. The qualities of different types of coal are ranked by the number of BTUs that they produce upon burning. The purest coal is called **anthracite;** this coal is almost pure carbon. The second-purest coal is **bituminous,** followed by **subbitumimous,** and finally **lignite**—the least pure coal. Coal mining occurs through one of two processes—strip mining or underground mining—both of which can be hazardous and have serious environmental impacts. **Underground mining** involves the sinking of shafts to reach underground deposits. In this type of mining, networks of tunnels are dug or blasted and humans enter these tunnels to manually retrieve the coal. After production stops at these mines, cave-ins can occur, causing massive slumping or **subsidence. Strip mining** involves the removal of the Earth's surface, all the way down to the level of the coal seam. The coal is then removed and then the **overburden** (the Earth that was removed) is replaced, topped with soil, and the area is contoured and re-vegetated. Most states require strip mine owners and operators to completely reclaim areas that are mined by taking all of the steps outlined above. However, the process of mining and removing the coal from the Earth leaves hazardous slag heaps containing sulfur that can be leached out and enter the water table.

At this time, coal is the most abundant fossil fuel, and it is used to generate electricity in over 50 percent of the power plants in the United States. The use of coal to produce electricity has several disadvantages; for one, when it is burned in the production of electricity, carbon dioxide, nitrogen oxides, mercury, and sulfur dioxide—all of which contribute to air pollution—are released as by-products. However, some of these by-products can be removed through the actions of **scrubbers,** which contain alkaline substances that precipitate out much of the sulfur dioxide. The neutral compound formed in the scrubber (calcium sulfate) is eliminated in waste sludge. Two other waste products produced by the burning of coal are **fly ash** and **boiler residue**—you should be familiar with both of these terms for the exam.

Another problem with coal is that it often contains a significant amount of the element sulfur, both in the form of iron sulfide (pyrite) and as organic sulfur. Sulfur is another contributor to air pollution. While iron sulfide can be removed by grinding the coal into small lumps and washing it, organic sulfur is only released during the combustion (burning) of coal. However, scrubbers can remove organic sulfur from the flue gases after the coal is burned. Another solution to this problem is to burn the coal with limestone—the liberated sulfur combines with the calcium in limestone to form calcium sulfate; and this prevents it from being released through the flue.

You've probably seen lots of news reports lately about the harmful effects—particularly to babies and very young children—of ingesting seafood that's contaminated with mercury. An EPA study found that one in six women of childbearing age in the U.S. may have blood mercury levels that could be harmful to a developing fetus. Coal-fired power plants are the major source of mercury pollution in the environment. Airborne mercury pollution can deposit in the ground as a result of rainfall, and into lakes, streams, or other bodies of water both directly from rainfall, and as a result of runoff—and the mercury can travel hundreds of miles from its source through the air before being deposited. Mercury in water can accumulate in fish, which are then eaten by people. (You see where we're going with this, right?) Abandoned metal and coal mines frequently produce **acid mine drainage**, highly acidic water which flows to surrounding areas.

What About Natural Gas?

The third fossil fuel you need to know about is natural gas. Natural gas is made mostly of methane (CH_4) as well as pentane, butane, and several other gases in small quantities. As you learned earlier, natural gas is produced by the actions of heat and pressure over long periods of time. In today's environment, it is also produced by living organisms (mostly by anaerobic bacteria). Methane-producing bacteria can be found in landfills, swamps, and the intestines of various animals. Here's an interesting fact: While the largest source of methane is wetlands, the second largest source is our flatulent livestock.

Currently, natural gas is used for home-heating and cooking. It can also be burned to generate electricity. Some power plants are designed to switch between oil and natural gas fuels depending on the cost. The engines of cars and trucks can be modified to burn natural gas instead of gasoline. There is a landfill operator in the state of New Jersey who tested a process of trapping methane from a landfill, liquefying it and then using the liquid methane to power the trucks that bring garbage to the landfill.

Because of its simple molecular structure, natural gas produces only carbon dioxide and water when it burns. It does not produce the oxides of nitrogen and sulfur associated with burning coal or oil. Before you get really excited about natural gas, you should be aware of its dangers. In an uncontrolled release (like a leak), it can cause violent explosions. It is also more difficult to transport than coal or oil. Because a tank can hold a small amount of gas, producers liquefy it by putting the gas under high pressure (Liquefied Natural Gas). This process requires energy. Natural gas can also be transported by pipes; pipes carry the risk of leaks and explosions, and some habitats are damaged during the building of the pipe system.

How Much Fossil Fuel Is Left?

In order to understand how long our accessible fossil fuel supplies will last, you should know how quickly we are using up those fuels. Let's take oil, the most widely used fuel, as an example. The table on the following page represents the amount of petroleum (thousands of barrels) that selected countries use each day. These data are from 2004, the last year for which we have this information.

COUNTRY	2004 PETROLEUM CONSUMPTION (THOUSANDS OF BARRELS PER DAY)
United States	20,731.2
China	6,400.0
Japan	5,353.2
India	2,450.0
United Kingdom	1,826.7

As you can see, the United States is by far the largest consumer of petroleum. A quick bit of addition shows that these five countries alone consume almost 84,940,000 barrels of oil each day! As you can imagine, that leads some scientists to ask questions about how long our supplies of oil (and the other fossil fuels) will last. One well-known authority on the future of oil production, the late M. King Hubbert, stated that the end of oil as a cheap and easily available form of energy is in the near future and that we must begin to develop alternative fuel sources.

Vampire appliances, appliances that consume electricty even when they are turned off, not only cost consumers, but increase the demand for electricity. The amount of available oil and natural gas, as estimated by the Society of Petroleum Engineers in 2004, is a bit more than 1.2 trillion barrels of oil and 6,000 trillion cubic feet of natural gas. If we consume those resources as quickly as we did in 2004, the oil will last about 44 years and the natural gas about 66 years. The World Coal Institute estimates that the there are over 998 billion tons of coal reserves, which at current use rates will last about 147 years. As of 2004, 67 percent of the world's coal reserves were concentrated in just four countries: the United States, Russia, China, and India.

NUCLEAR ENERGY

Nuclear energy is the world's primary non-fossil fuel nonrenewable energy source. In the United States, 20 percent of electrical energy is provided by nuclear power plants. Worldwide, more than 400 nuclear power plants produce approximately 16 percent of the world's electrical energy. China and India lead the world in the creation of new nuclear facilities.

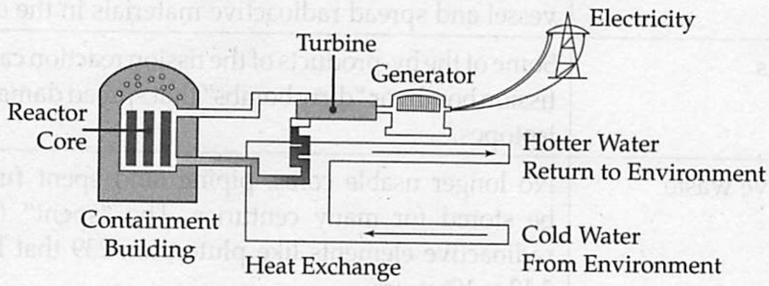
Let's talk a little bit about what exactly these nuclear power plants do. The current nuclear plant technology involves the use of uranium-238 which is enriched with 3 percent uranium 235. The uranium 235 isotope is split in a process called **fission;** this is the key reaction in the production of nuclear energy. **Breeder reactors** generate new fissionable material faster than they consume such material. Furthermore, they can use a more abundant form of uraniumm, uranium-238, or an alternative called thorium.

However, the future of nuclear power will probably involve **nuclear fusion,** which is the process of fusing two nuclei (most likely two isotopes of hydrogen—tritium-2 neutrons and deuterium-1 neutron). One other important thing you should know for the exam is that radioactive materials all have **half-lives,** which is the time it takes for half of the radioactive sample to degrade.

In the Unites States, there are two types of nuclear reactors. They are known as boiling water reactors and pressurized water reactors.

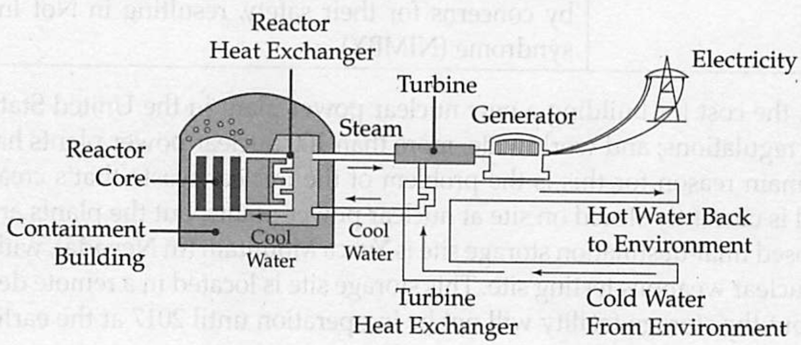
- **Boiling Water Reactors**—These reactors use the heat of the reactor core to boil water into steam. This steam is piped directly to the turbines. The steam spins the turbines that generate the electricity. The water is cooled back to a liquid (by a heat exchanger), then pumped back to the core to be turned into steam again. This reactor uses two water circulations systems; one system makes steam and carries it to the turbine and the other cools the water from the core so it can be turned back into steam.

Boiling Water Reactor



- **Pressurized Water Reactors**—These reactors use the heat from the core to heat a second water supply via a heat exchanger. This second water system provides the steam to spin the turbines. A third water circulation system cools the steam from the turbines (by using a second heat exchanger) so it can be used to make steam again. These reactors use three water circulation systems; the first cools the core, the second makes the steam, and the third cools the steam back into water so it can be made into steam again.

Pressurized Water Reactor



Some arguments in favor of the use of nuclear power include the fact that the production of nuclear energy produces no sulfur dioxide or nitrogen oxide and less carbon dioxide than does the production of fossil fuels.

Since the first testing of atomic weapons, people have been concerned about safety issues surrounding nuclear energy. The nuclear reactor accident that occurred at the Three Mile Island facility in Pennsylvania in 1979 and the devastating explosion that occurred at the Chernobyl facility in the Ukraine in 1986 brought some major safety concerns to the public's attention.

Review the chart below that shows a few of these issues.

Safety Issue	Description
Meltdown	Reactor loses coolant water and thus the very hot core melts through the containment building. The radioactive materials could then get into the groundwater.
Explosion	Gases generated by a uncontrolled core burst the containment vessel and spread radioactive materials in the environment.
Nuclear weapons	Some of the by-products of the fission reaction can be remade into fission bombs or "dirty bombs" that spread damaging radioactive isotopes.
Highly radioactive waste	No longer usable cores, piping, and spent **fuel rods** need to be stored for many centuries. The "spent" fuel can contain radioactive elements like plutonium-239 that has a half-life of 2.13×10^6 years.
Thermal pollution	The water used to cool turbines is returned to local bodies of water at a much higher temperature than when it was removed unless first cooled.
Radioactive elements	Gamma rays produced by radioactive decay can damage cells and DNA, which can cause breast, thyroid, stomach, and leukemia cancer. Damage to the immune system can also result.
Concern for one's safety	People suffer from mental stress, anxiety, and depression caused by concerns for their safety, resulting in Not In My Backyard syndrome (NIMBY).

At this point, the cost for building a new nuclear power plant in the United States is prohibitive due to changing regulations; and worldwide, more than 100 nuclear power plants have been decommissioned. The main reason for this is the problem of the nuclear waste that's created. The United States' spent fuel is currently stored on site at nuclear power plants, but the plants are running out of space. The proposed final-destination storage site is Yucca Mountain (in Nevada), within the boundaries of a former nuclear weapons testing site. This storage site is located in a remote desert on federally protected land, but the storage facility will not be in operation until 2017 at the earliest.

RENEWABLE ENERGY

Obviously, the advantage to discovering or developing renewable energy sources lies in the fact that these types of energy sources are bottomless. However, globally only about 14 percent of our energy needs are currently met using renewable resources.

Biomass is one of the most consistently and widely used renewable energy sources today. Biomass includes wood, charcoal (wood that has been baked to remove water and impurities), and animal waste products. Although biomass is renewable, as we discussed in Chapter 6, it is only renewable when it is used at a pace that allows it to replace itself.

One interesting fuel that's recently been developed is called gasohol. **Gasohol** is a gasoline extender made from a mixture of 90 percent gasoline and 10 percent ethanol, which is often obtained by fermenting agricultural crops or crop wastes. So, as you can see, it is partly derived from organic substrate. Gasohol has higher octane than gasoline and burns more slowly, coolly, and completely, thus resulting in reduced emissions of some pollutants. Despite those advantages, it also vaporizes more readily than gasoline, and has the potential to aggravate ozone pollution in warm weather. Additionally, because ethanol is carbon-based, carbon dioxide is released during its combustion. Ethanol-based gasohol is also expensive and energy-intensive to produce—one bushel of corn produces only two and a half gallons of ethanol.

This is clearly an inefficient way to use biomass. However, researchers are developing new and better ways to use biomass as a fuel; for example, a new product called **biodiesel** is made largely from waste vegetable oils.

Hydroelectric Energy

As its name suggests, **hydroelectric power** is generated by the force of water. Specifically, the electricity is generated as moving water turns a turbine. One advantage of hydroelectric power is that its production releases no pollutants. However, hydroelectric power does produce thermal pollution; in addition, it requires that rivers are dammed, and this can change the rates at which rivers flow and also lead to the destruction of habitats. On the other hand, as water is held behind dams, new habitats, in the form of wetlands, are created.

There are other problems associated with dams that you need to know about. One of them is silting. As water sits behind the dam, the normal sediments it carries have time to sink to the bottom. This puts additional weight on the structure and means that dams have to be built strong enough to hold back the many tons of sediment. This also means that the sediment is not passed farther down the river. The sediment that used to fertilize the flood plains of the river is now trapped behind the dam. In addition, the reservoir usually has a greater surface area than the preceding lake or river; this increased surface area can actually result in a higher rate of evaporation and water loss than before.

Another problem is that fish that spawn in the normally silty river no longer have a place to do so. Salmon and other anadromous fish breed in the streams where they hatched from eggs. Dams prevent the salmon from returning to their hatching streams. While "fish ladders" do let some fish return upriver, the number of fish that get through is so limited that the populations will still decline.

One more important note about hydroelectric power: The development of this as an alternative, renewable energy source is limited—simply because there is a limited number of rivers of sufficient power in the world that can be used for these purposes.

Solar Energy

While it is important to remember that we already obtain through the sun the energy we need to live—producers capture the sun's energy and convert it into chemical energy—solar energy also has the potential to supply many of our external energy needs as well.

The use of solar energy actually dates back to Roman times; the Romans developed window glass, which allowed sunlight to come in, and trapped solar heat indoors. Another interesting historical note is that the Swiss scientist Horace De Saussure built a solar reflector in 1767 that could heat water and cook food.

Passive solar energy collection is the use of building materials, building placement, and design to passively collect solar energy (such as through windows) that can be used to keep a building warm or cool. On the other hand, **active collection** is the use of devices, such as solar panels, that collect, focus, transport, or store solar energy. Solar panels absorb solar energy and pass the energy on to tubes in which water is circulating; this heated water can be stored for later use. Direct collection of solar energy via **photovoltaic cells** (PV cells) produces electricity, which is then stored in batteries. After this, one of two things can happen. If the home or building is connected to a regional electric grid, the energy produced is fed into the grid; this results in the electricity meter on the building actually spinning backward! Homeowners who have installed solar panels actually receive checks from their electricity providers when the energy that they've fed into the grid exceeds the amount of energy the household uses. If the home or building is not connected to the local electric grid, the energy stored can be stored in batteries to be utilized later.

While the use of solar energy produces no air pollutants, the production of photovoltaic cells does require the use of fossil fuels. The advantages to solar panels are that photovoltaic cells use no moving parts, require little maintenance, and are silent. However, not every location receives enough sunlight to make solar panels worthwhile. Also, the initial financial outlay for solar power is significant, although money is saved when the home is disconnected to the regional grid. Additionally, some states (such as New Jersey) give homeowners financial assistance for the installation of solar systems in their homes. Eventually, new technology should significantly lower the cost of solar systems.

WIND ENERGY

People have been using wind to produce energy for centuries; as early as the seventeenth century windmills were so abundant in Schermerhorn (which is northwest of Amsterdam) that their turning paddles could be heard as far as 20 miles away! Windmills work in this way: Wind turns the blades, or paddles, of the windmill and this drives a shaft that's connected to several cogs. The cogs then turn wheels that can perform mechanical work, such as grinding grain or pumping water. Although the Dutch windmill is a picturesque symbol of wind power, the modern wind **turbine** looks more like an airplane propeller. The wind that blows into the wind turbine spins the blades, and this, in turn, causes the machinery inside the base of the windmill to rotate. The base of the windmill is called the **nacelle,** and it houses a gearbox and generator as well as machinery that controls the turbine. Wind turbines can be designed to utilize the energy from wind at all speeds, or to function only when the wind is at a certain velocity.

Wind energy is the fastest growing alternative energy source, and modern wind turbines are usually placed in groups called **wind farms** or parks. In the United States, the largest of these wind farms is located in Altamont Pass, California; this farm has several thousand wind turbines. Wind-generated power has been increasing at a rate of more than 30 percent per year and is projected to supply 3 percent of the world's energy needs by 2010 and perhaps up to 10 percent in Europe. Although in the United States wind farms are predominately in California and Texas at this time, many locations have enough prevailing winds to make production of electricity from wind power feasible. Wind farms can also be located offshore, in the ocean; and although they're currently only located near to shore, in the future they may be placed on floating docks in deep water.

At this time, wind power is more costly than using fossil fuels because of the initial outlay of capital that must be invested in order to build the windmills; windmills are also considered by many to be annoyingly loud and unattractive. However, perhaps the biggest problem with this type of renewable energy source is that alternate energy sources must be in place for times when there is no wind. In the 1990s one other public concern about the use of wind turbines was that birds would be cut up and killed by the blades, but now we know that as long as wind farms are not located in the middle of migration routes, only one or two birds per turbine per year are killed—and this is far fewer than the number of birds killed by other types of towers. Finally, one tremendous advantage of using wind energy is that it produces no harmful emissions. Let's move on and talk about another type of renewable energy source—geothermal energy.

Geothermal Energy

Geothermal energy is a form of energy that's obtained from within the earth; it's energy that's produced by harnessing the earth's internal heat. The greatly elevated temperatures within the earth result in a buildup of pressure; some of this heat escapes through fissures and cracks to the surface. Some common examples of these fissures and cracks that you may have heard of are geysers, hydrothermal vents, and hot springs.

More specifically, in the process of geothermal energy production, the naturally heated water and steam from the earth's interior turn turbines, and this creates electricity. Although surface water from geysers could be used, wells are typically drilled down into the earth as far as thousands of meters to water that is 300–700 degrees Fahrenheit and then brought to the surface and converted to steam, which powers a turbine. Geothermal energy can also be used directly; in this process, the heated water is piped directly though buildings to heat them—this is a common method for heating homes in Iceland. In a sense, geothermal energy is renewable; however, if the groundwater is used at a faster rate than it is replaced, then this energy source is limited.

The use of geothermal energy is also limited because only a few areas have geothermal sources to tap. Another problem with this renewable energy source is that the salts that are dissolved in the water corrode machinery parts; additionally, some gases (such as methane, carbon dioxide, hydrogen sulfide, and ammonia) that are trapped in the water may be released as the water is utilized.

Still Other Sources of Energy

There are two other less widespread renewable energy sources: energy that can be harnessed from tidal movement in the ocean, and hydrogen cells. You should be somewhat familiar with both of these energy sources for the exam.

Ocean Tides

The tidal movements of ocean water can be tapped and used as a source of energy. To harvest tidal energy, dams are erected across outlets of tidal basins. Incoming tides are sluiced through the dam, and the outgoing tides pass through the dam, turning turbines and generating electricity. Recently, ocean dams have been developed that allow energy to be harnessed from both the outgoing and incoming tides.

At this time, there are no commercial power plants using the energy from ocean, but several different designs have been proposed. One of these involves having the wave push into a chamber of air; the compressed air is then forced through a small hole at the turbine, and turns the turbine as it is released. An experimental prototype of this design has been installed off the coast of Scotland and is nicknamed the LIMPET (Land-Installed-Marine-Powered Energy Transformer).

Hydrogen Cells

Hydrogen fuel cells are considered by many to be the best, cleanest, and safest fuel source. Free hydrogen is not found on Earth, but it can be released through the process of electrolysis, in which hydrogen atoms are stripped from water, leaving the oxygen atom. Hydrogen can also be obtained from organic molecules, but the use of organic sources can release pollutants—as can the process of electrolysis if a fossil fuel, such as natural gas or coal, is used to drive the process. However, once the free hydrogen is released, it can be stored and then used to generate electricity through the reverse reaction of electrolysis.

One of the major benefits of the use of hydrogen fuel cells is that the only waste from the fuel cell is steam—water vapor. This technology has been used for decades in spacecrafts, but the high cost of the fuel cell and lack of hydrogen fuel stations has limited the technology to just a few test programs. The United States Department of Energy estimates that hydrogen fuel cells large enough to power light trucks and cars in the United States will require the production of 150 megatons of hydrogen per year (in 2004, only nine megatons of hydrogen were produced).

In order for hydrogen to become a truly viable option as a renewable energy source, an inexpensive and efficient way to produce hydrogen from nonfossil fuel sources must be developed. One of the most promising techniques for this involves the use of photovoltaic cells to harvest sunlight and then power the splitting of the water molecule.

ENERGY CONSERVATION, A FINAL NOTE

When we discuss energy conservation, we are basically referring to the practice of reducing our use of fossil fuels and reducing the impact we have on the environment as we produce and use energy.

One important form of energy conservation is the use of alternative fuel cars. They are gaining in popularity and acceptance. Hybrid vehicles are built with two motors: one electric and one gasoline-powered. The electric motor powers the car from 0 to about 35 miles per hour. Above 35 mph, the gasoline engine starts and powers the car. At highway speeds, both the electric and gas motors operate. The cars are designed so that when the brakes are applied, some of the energy is transferred from the brakes to recharge the electric motor's battery. Not only do these cars have good gas mileage, but they also produce far less CO_2 pollution. Although not as common as hybrids, several carmakers make models that use propane or natural gas as fuels. These generate only CO_2 and water as emissions and they get good gas mileage. A problem is the lack of refueling stations, although devices are available that allow refueling from home. Cars can also be retrofitted with natural gas fuel tanks, so the driver can choose between gasoline or methane fuel.

Another type of alternative fuel is used cooking oils. The oils used in deep-fat fryers can be filtered and then burned in diesel-fueled cars, trucks, and buses. After starting the engine on pure diesel fuel, the driver switches to the **biofuel** to drive. At the end of the trip, the driver runs on pure diesel fuel again for a few minutes before shutting off the engine.

It has been argued that finding new fossil fuel sources would serve the same purpose as would reducing our current use of fossil fuels. However, this is not true—this statement does not take into consideration the fact that our use of fossil fuels has numerous negative effects on the environment. Additionally, in the long term it will not help us much to conserve fossil fuel resources—simply because these are not renewable energy sources—so they will eventually be depleted. Therefore, if we are to have dependable long-term renewable sources of energy, we must continue to develop, implement, and improve upon current technology and methods.

On the legislative front, the United States has adapted the CAFE, or Corporate Average Fuel Economy, standards. These standards set mile per gallon standards for a fleet of cars. The goal of these standards is to reduce energy consumption by increasing the fuel economy of cars and light trucks. Review the CAFE standards described on pages 155–156.

Finally, do not forget the role of mass transit in reducing pollution. Buses and trains can move many more people than cars. When the amount of pollution made by the vehicle is divided by all the passengers it is carrying, the bus or train generates far less pollution per person than a car.

In the next chapter, we will further discuss pollution—the effects it has on Earth and its inhabitants, and the types of wastes that currently exist, and how we can manage them.

Before you move on, study the terms and try the questions in the drill on the next page. Good luck!

KEY TERMS

Use some of your renewable brain energy to study these terms.

Energy
- potential energy
- kinetic energy
- radiant energy
- conduction
- convection
- energy quality
- first and second laws of thermodynamics

Fossil Fuels
- seam
- exploratory well
- proven reserve
- crude oil
- shale oil
- tar sand
- petroleum
- anthracite
- bituminous coal
- subbituminous coal
- lignite
- underground mining
- strip mining
- overburden
- subsidence
- fly ash
- vampire appliance
- acid mine drainage

Nuclear Energy
- fission
- nuclear fusion
- breeder reactor
- half-life
- fuel rod
- NIMBY

Renewable Energy
- gasohol
- biodiesel
- hydroelectric power
- fish ladder
- passive collection
- active collection
- photovoltaic cells
- nacelle
- turbine
- wind farm
- geothermal energy
- hydrogen cell
- CAFE standards

CHAPTER 7 QUIZ

Directions: Each of the questions or incomplete statements below is followed by five suggested answers or completions. Select the one that is best in each case.

1. A fuel's net energy yield is correctly defined as

   (A) how much of this fuel is left in the world
   (B) how much time it takes to extract and transport
   (C) a comparison between the amount of pollution the fuel generates and the amount of useful energy produced
   (D) a comparison between the costs of mining, processing, and transporting a fuel and the amount of useful energy the fuel generates
   (E) a comparison between the amount of fuel in reserve and the speed at which the fuel is being removed

2. A regular light bulb has an efficiency rating of 3 percent. For every 1.00 joule of energy that bulb uses, the amount of useful energy produced is

   (A) 1.03 joules of light
   (B) 1.03 joules of heat
   (C) 0.97 joules of light
   (D) 0.03 joules of light
   (E) 0.03 joules of heat

3. Methane gas and ethanol are two examples of biogases that are produced in which of the following processes?

   (A) The distillation of oil
   (B) The pressurization of natural gas
   (C) The anaerobic digestion of biomass
   (D) The catalytic reaction of coal and limestone
   (E) The breakdown of water by electricity

4. Hybrid car engines have which of the following types of motors?

   (A) Gasoline powered only
   (B) Natural gas powered only
   (C) Electric powered only
   (D) Gasoline and natural gas powered engines
   (E) Gasoline and electric powered engines

5. All of the following are ways to increase energy efficiency EXCEPT

   (A) using low volume shower spray heads
   (B) insulating your home thoroughly
   (C) switching incandescent light bulbs to fluorescent bulbs
   (D) leaving room lights on
   (E) increasing fuel efficiency of vehicles

6. A typical coal-burning power plant uses 4,500 tons of coal per day. Each pound of coal produces 5,000 BTUs of electrical energy. How many BTUs are produced each day from this plant?

(A) 4.5×10^{10}
(B) 0.45×10^{10}
(C) 11.5×10^{3}
(D) 4.5×10^{8}
(E) 0.25×10^{6}

7. Which of the following produces the least amount of carbon dioxide while generating electricity?

(A) Oil
(B) Coal
(C) Wind turbines
(D) Wood
(E) Diesel fuel

8. How much energy, in kWh, is used by a 100-watt computer running for 5 hours?

(A) 500 kWh
(B) 200 kWh
(C) 100 kWh
(D) 50 kWh
(E) 0.5 kWh

9. Photovoltaic cells produce electricity by

(A) a system of mirrors that focuses sunlight onto a heat collection device
(B) using the sun's energy to create a flow of electrons in a material such as silicon
(C) breaking down organic molecules and releasing energy
(D) warming air, which spins a turbine
(E) acting as a catalyst to burn oil cleanly

10. A sample of radioactive material has a half-life of 20 years. It has an activity of 2 curies. How many years does it take for the material to have an activity level of 0.25 curies?

(A) 20 years
(B) 40 years
(C) 60 years
(D) 80 years
(E) 100 years

11. The term vampire appliances correctly refers to appliances that

(A) generate more power than they consume
(B) consume electricity even when they are not operating
(C) are EnergyStar rated
(D) are programmed to turn themselves off at midnight each night
(E) have more than one transformer

12. All non-renewable resource power plants use heat to

(A) make hot aire that generates power
(B) create powerful magnetic fields that make electricity
(C) create powerful water jets that spin turbines
(D) produce steam to turn electric generators
(E) split water into hydrogen and oxygen that is then burned to make electricity

Free-Response Question

1. Nuclear power plants have been described as being part of the solution to the problem of the United States' dependency on foreign energy. Currently, some 20 percent of the electricity produced in the United States is generated by nuclear power.

(a) Describe the key parts of a nuclear power plant. Describe the roles of the following: core, fuel rods, coolant, and heat exchanger.

(b) Describe two practical methods of dealing with the long-term storage of the highly radioactive wastes produced by a power plant.

(c) Describe one positive impact that a nuclear power plant might have on air pollution.

(d) Opponents of nuclear power plants point out the problems caused by thermal pollution of nearby rivers. Describe how the thermal pollution occurs and one method to reduce this problem.

ANSWERS AND EXPLANATIONS

Multiple-Choice Answers

1. **D** Net energy yield is a comparison between cost of extraction, processing, and transportation and the amount of useful energy derived from the fuel. For example, the net energy ration of natural gas used to heat homes is 4.9 and the net energy yield for electrical heating is 0.3. When the two are compared, the net yield from gas is much higher because the costs of getting the gas to your home is very small compared to the costs of running a nuclear power plant.

2. **D** This question asks you to calculate the amount of light produced by a bulb. You know the amount of energy going into the bulb (1.00 joules) and its efficiency (3 percent). So, 3 percent of 1.00 is 0.03. (D) is the correct answer because the useful energy produced is light, not heat.

3. **C** Both methane and ethanol are created as bacteria breaks down biomass. An example of this is seen when farmers produce methane from decomposing manure to heat their barns. The manure is placed in underground pits, where bacteria break it down and release methane.

4. **E** The most common hybrid engines are gasoline-electric hybrids. The two engines work together to provide acceleration and power. When the car is driving slowly, less than 56 kph (35 mph), the electric engine powers the car.

5. **D** The only answer choice that describes a waste of energy is leaving room lights on. Most incandescent light bulbs have an energy efficiency rating of 3–5 percent. So, for every 100 units of energy, we only get 5 units of useful light.

6. **A** The correct formula for this problem is 4,500 tons × (2,000lb/1 ton) × (5,000 BTU/lb) = 4.5×10^{10}. It is much easier to use scientific notation here, so $(4.5 \times 10^3) \times (2 \times 10^3) \times (5 \times 10^3) = 45 \times 10^9$ or 4.5×10^{10}.

7. **C** CO_2 emissions are high in any process that releases energy by burning material. Therefore, burning coal, oil, diesel, and wood all generate CO_2. The processing and reprocessing of uranium into fuel rods generates a moderate amount of CO_2. The only noncombustion generation occurs by wind turbines.

8. **E** WATTS × TIME = kWh. 1,000 watts = 1 kWh, so $\frac{500}{1,000} = 0.5$ kWh

9. **B** Photovoltaic cells are constructed from silicon and boron. When sunlight strikes the cells, electrons are energized. These electrons can then flow freely, producing an electric current. By placing wires in the correct positions, this current can be used to power devices. Because the cells are expensive to make, the cost per kilowatt hour is high, but they are useful for applications in which there is no other source of electricity.

10. **C** Radioactive half-life is the amount of time it takes for half of a radioactive sample to disappear. In this question, there are 3 half-lives: the first is 2 curie → 1 curie, the second is 1 curie → 0.5 curie, and the third is 0.5 curie → 0.25 curie. According to the statement, each half-life lasts 20 years. So, 3 × 20 = 60 years.

11. **B** Appliances like televisions do not have an off switch. They continuously draw power to remain in an "instant on" mode.

12. D Coal, oil and natural gas are burned to generate heat and a nuclear reactor generates heat by radioacive decay. The heat turns water to steam and then steam spins a turbine that in turn spinds a generator.

Free-Response Answer

1. (a) The core is the place in a nuclear reactor where nuclear reactions occur. It is made of very high strength steel and other high-performance materials. Inside the core are the coolant, fuel rods, and moderators that control the reaction. The fuel rods are made of enriched uranium U-235. In the reactor, a chain reaction generates the heat, which is converted into steam to drive the electricity-producing turbines. The coolant prevents the melting of the uranium, or core, by removing the heat generated by the chain reaction. Some of the heat is used to turn water to steam that spins turbines. In most reactors, the heat produced in the core does not come in contact with the water that is vaporized; instead a device called a heat exchanger takes heat from the core (carried by water or molten sodium) and transfers it to water, which vaporizes.
(2 points maximum—1 point for each correct description)

(b) Currently all highly radioactive waste is stored on the grounds of the power plant in deep pools of water. Some materials are stored in steel drums that are housed inside storage containers with walls made of lead and concrete. The United States is currently studying the possibility of opening a deep underground storage at Yucca Mountain, Nevada. Low level radioactive materials are also stored in radioactive landfills.
(4 points maximum—2 points for a correct name and description of a storage technique)

(c) Because nuclear power plants do not use the combustion of fossil fuels to generate the heat to produce steam, there are no by-products of combustion. There is no particulate produced, no production of oxides of nitrogen or sulfur, and no release of heavy metals. Some CO_2 is generated, but this occurs primarily in the processing of the fuel rods.
(2 points maximum—1 point for describing the lowered emissions and 1 point for a correct example)

(d) Thermal pollution is generated from the turbines, which are powered by steam from the heat exchanger. These hot turbines must be cooled by water piped in from nearby oceans or rivers. This problem is mitigated by allowing the turbine coolant water to flow up a series of pipes built inside cooling towers. As cool air enters the bottom of the tower, it rises by convection and removes the heat from the water circulating in the pipes. The cooler water is then released.
(2 points maximum—1 point for describing how thermal pollution occurs and 1 point for a method to reduce it.)