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NONRENEWABLE ENERGY
SOURCES AND HOW THEY ARE USED

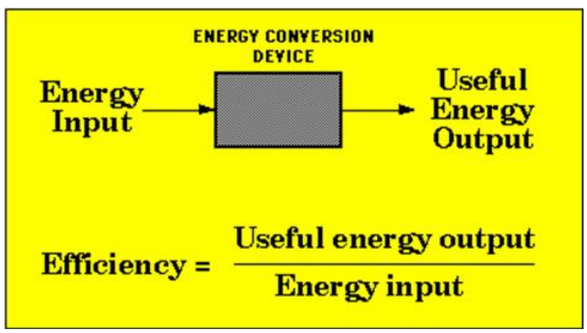
Unit Overview

In this unit, nonrenewable sources of energy will be defined and investigated. Their use in our society to provide for our basic needs of electricity, transportation, and heating will be discussed. Energy transformations will be noted, as well as the efficiency of those transformations.

We have studied the seven forms of energy. Some were classified as potential – nuclear, chemical, and mechanical energy (due to its position or condition). Others were classified as kinetic energy – active mechanical energy, sound or acoustic energy, thermal energy, electrical energy, and radiant energy. Now we will discuss where we get these forms of energy; that is, what are the sources of our energy. In this unit we will study the nonrenewable sources, those that cannot be replaced. As we discover the various uses for these sources, we will follow their transformations through the various energy forms.

Efficiency

If you remember from our earlier discussions of the energy pyramids, we noticed that energy transformations always involve some loss of useable energy to what we term waste heat. It is called waste because it serves no useful purpose. This is true in any conversion of energy from one form to another. A way to determine just how much useful energy is derived from the conversion is to determine efficiency. Mathematically, efficiency can be calculated by a fairly simple formula as seen in the diagram below. The total amount of energy put into the process which is measured in an energy unit such as joules is placed in the denominator of a fraction. The total amount of useful energy produced by the process, measured in the same energy units as the input, is placed in the numerator. The larger the numerator, the greater the efficiency of the process. To express the efficiency in a percent we simply multiply by 100. So if a process is 50% efficient that means that only half of the original input energy is being used.



Petroleum

An oil rig in the ocean.

The greatest source of energy in the United States is petroleum. This fossil fuel is found deep in the earth with the average oil well being 6000 feet below the surface. Because fossil fuels were formed over many, many years, perhaps millions of years, these cannot quickly be replaced. Over 38% of our energy in the United States comes from petroleum, but we provide only a little over 16% of this from our national resources. The rest is imported from other countries. We get most of our oil from Canada, Venezuela, Saudi Arabia, and Mexico. Texas produces more oil than any other state. The United States uses more petroleum than any other country in the world, with most of it (over 2/3) being used as a fuel for transportation. Other uses are for industry as a source of heat but also as raw material for making fertilizers, plastics, medicines, and other products. Only 6% of the petroleum is used for heating in homes and businesses and 1% for the production of electricity. But even before it can be used in any of these applications, it must first be refined. Nearly 30% of undiscovered reserves are thought to be offshore.

Pumping crude oil to the surface (left)

Crude oil, petroleum as it comes from the ground.(right)

Petroleum is known as crude oil when it comes from the ground. It is a mixture of many different hydrocarbons, chemicals composed of carbon and hydrogen. It can vary in color from near colorless to black, and it can be as thin as gasoline or as thick as asphalt due to the amounts of the various hydrocarbons that it contains. Refining consists of various processes in which the mixtures are separated into smaller groups and cleaned of contaminants. This requires heat, so about 9% of the petroleum is used in the refining process alone.

Once it has been separated into various components, such as gasoline, heating oil, diesel fuels, propane, jet fuel, asphalt, and others, it can be used.

A petroleum refining facility

What form of energy is found in petroleum? If you said chemical, you are right. The chemical energy was stored there by the plants that once lived and carried on photosynthesis. It is thought that dead sea animals and plants are the once-living matter that makes up petroleum. Of course, the animals got their food either directly or indirectly from the plants, so the initial source of the energy was radiant energy from the sun. As you recall, plants must have sunlight in order for photosynthesis to occur. When petroleum is used as gasoline in our cars, the conversion of energy continues. Inside the engine, the gasoline is burned, being ignited by the spark plugs. As in all burning, heat and light are produced, but that is not the end of the story. The rapid burning inside the cylinders of the engine causes a rapid expansion of the hot gases which pushes the piston upward. This motion through a system of gears is transferred to the wheels to make the car move. So we have kinetic mechanical energy in the end plus lots of waste heat. That is why we need a radiator and/or air to cool the engine so it does not overheat. It is wasted heat because it serves no useful purpose except for the occasional use of this heat to warm the inside of the car during the colder months of the year. This wasted heat escapes from the radiator or out the exhaust pipe and goes into the atmosphere. Because so much energy is wasted, such as this heat, most vehicles are not very efficient. Only about 25% of the energy in the gasoline is actually used to move the car, and 75% is wasted as heat. That makes the efficiency of the average automobile only 25%. To improve this efficiency, we often look for ways to get more miles to the gallon of gasoline. Manufacturers of automobiles have made some strides in this area by changing the engine, the design of the car, and the materials used in its construction.

Petroleum can also be used for heating. Fuel oil can be used for heating in manufacturing and in our homes. Here the conversion is from radiant energy from the sun to the stored chemical energy due to photosynthesis to heat and light as it is being burned just as it was in the automobile. The heat can be used to heat living areas or to provide heat for some manufacturing process. The efficiency here is much better, about 65%. A small amount of petroleum is used in electric power-generating plants. We will discuss the energy conversions that occur there later in this unit.

Coal

Strip or surface mining of coal

Like petroleum, coal takes many millions of years to form so it is known as a nonrenewable energy source. It is thought to have been formed in what were formerly swampy areas. As the dead plants and animals accumulated on the bottom, they were packed together by layers of dirt and water and subjected to heat and pressure. Over time oxygen was released leaving a rich energy source of hydrocarbons. Hydrocarbons are compounds consisting of only hydrogen and carbon. This hydrocarbon is coal and exists in seams within the earth anywhere from a fraction of an inch to hundreds of feet. The Pittsburgh seam which is seven foot thick may represent 2,000 years of rapid plant growth. So you can see just how much energy is packed into coal. The United States is the world leader in known coal reserves and if used at today's rate, we have enough to last 300 years. The state with the most coal deposits is Montana with Illinois, Wyoming, Kentucky, and West Virginia also having significant coal deposits. In the West, the federal government owns 60% of the coal with indirect control over another 20%. Western coal tends to be lower in sulfur than eastern coal and therefore creates less air pollutants.

Long wall mining deep underground

A continuous mining machine used in deep mines

Coal is an important energy source for the United States as it supplies 23%, almost one-fourth, of our energy needs. Most of its use (90%) is in the production of electricity. In fact, the Sammis Power Plant at Stratton, Ohio, and the Cardinal Power Plant at Brilliant, Ohio, are both coal-fired power plants. Another important use is in the production of coke to use in the steel-making plants. There is a coke producing plant in Follansbee, West Virginia. Coke is made by driving impurities from the coal using heat without the presence of oxygen. This coke is an excellent fuel for smelting or purifying metals, such as iron and copper. Whether coal is used directly as a fuel, as in electric-generating plants, or indirectly, as in the smelting of metals, it is always used as a heat source. To trace the energy transformations that occur, we would start with radiant energy from the sun to stored chemical energy in the fuel to heat when the fuel is burned.

Although both petroleum and coal are good sources of energy, neither is totally free of contaminants which create air pollution when they are burned. They also release carbon dioxide into the atmosphere which, as you will recall, is one of the gases responsible for global warming. These represent problems that challenge us. Solutions have been found for controlling some of the pollutants. Scrubbers use water and limestone to remove sulfur from the exhaust. Electrostatic precipitators remove fly ash, a fluffy, by-product particle produced during the burning of coal. This can be used as a road-building material, as a cement additive, and as pellets for oyster beds.

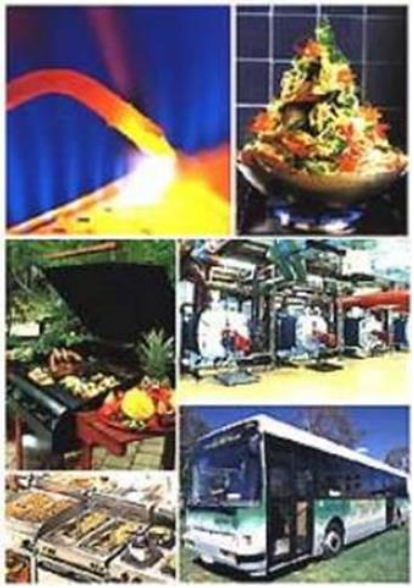
Natural Gas

Another fossil fuel that is in gaseous form is natural gas. Although there are renewable sources of this gas, most of it comes from deep underground trapped in porous rock by itself or with petroleum or coal deposits. Once it is brought to the surface, it is cleaned of impurities and separated into its various components. Most of natural gas is methane but it does contain some propane and butane, other hydrocarbon gases. The top five natural gas producing states in order are Texas, Louisiana, Oklahoma, New Mexico, and Wyoming. Natural gas supplies 22% of out energy needs or over one-fifth of our needs. About 25% of the world-wide production of natural gas occurs in the United States.

Natural gas is a very clean burning fuel with water vapor and carbon dioxide as the only products of combustion, which makes it a good choice for fuel. The biggest user of natural gas is industry where it is used as a fuel to produce heat but it is also used as an ingredient in fertilizers, photographic film, ink, glue, paint, plastics, laundry detergent, synthetic rubber, insect repellents, and synthetic fibers like nylon. The second largest use of natural gas is for home heating. Over half of the houses in the U.S. have natural gas furnaces. The efficiency of natural gas is fairly high at 85%. Next to coal and uranium, natural gas is the third largest producer of electricity in this country. It produces electricity more efficiently than does coal with much less concern for pollutants.

Natural Gas, a Clean Burning Fuel

Natural gas is transported through underground pipelines throughout the U.S



Some of the many uses of natural gas

The supplies of natural gas in this country are not unlimited. With today's known sources and using at today's rate, we have only a 50 year supply of natural gas. Scientists feel that there are enough reserves, areas thought to contain natural gas but not yet tapped, to last 200 years. However, getting to these reserves would require extended efforts and would thus raise the price of natural gas considerably.

Propane

Another fossil fuel, propane, is taken from natural gas and petroleum deposits. At normal temperatures and pressures, it is a gas, but it can be easily liquefied or changed into a liquid by placing it under pressure. If you remember from our discussion of the states of matter, the particles in a liquid are much closer together than those of a gas. For this reason, liquefied propane takes up much less space than gaseous propane. You have probably seen gas grills with the tanks of propane attached, or perhaps you know someone who heats and cooks with propane. A large tank of propane is somewhere nearby to supply these needs. In both cases, the tanks are filled with liquefied propane which turns into a gas when released from the pressure inside the tank. Because it can be easily liquefied and placed in tanks, it is more easily transported than some other fuels. People who live in rural areas may not have access to natural gas pipelines and instead can use propane as a fuel if they choose. Still propane serves only about 1.8% of our energy needs which is quite low.

Left: a forklift powered by propane has few emissions and is safe to operate inside.

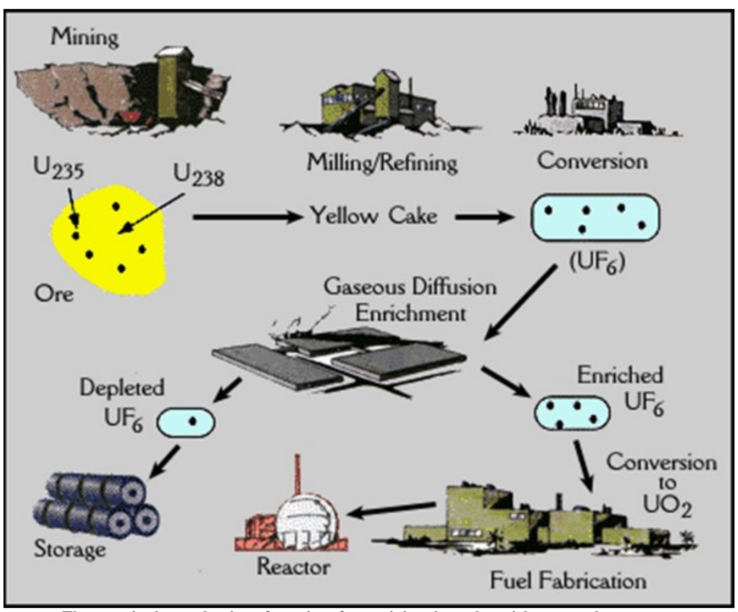
| **Right:** A truck fueled by propane is clean-burning and has less engine wear. |

The largest use for propane is in industry where it is used for cutting torches, soldering, vulcanizing (a process to make rubber suitable to be made into tires), portable heaters for construction sites, keeping asphalt at the proper consistency for highway work, and to power fork-lifts inside of warehouses. About one-third of the propane is for heating in homes, businesses, and farms. In addition to keeping dwellings warm, it is also used to cook and refrigerate foods, to dry clothes and crops, to provide lighting, to heat water, to ripen fruits, and to fuel vehicles like tractors and irrigation pumps. It is also used in recreation vehicles (RV's), and backyard grills. Like natural gas, it is a very clean-burning fuel that emits carbon dioxide but no other harmful pollutants. In addition, propane is a raw material for making plastic bags and other products.

Because it is made from petroleum or natural gas, propane's supply is limited. Currently 20-30% of the propane produced is produced from imported oil. In many ways, it is a superior fuel because it has as high or higher octane rating than gasoline. It produces fewer pollutants than regular gasoline and because of this extends the engine life. It is used less than gasoline because it is not as easily available as gasoline, engines need to be adjusted to burn propane, and there is a slight drop in the mileage when propane is used. If we look at the energy conversions that occur here, we will see that they are the same as with the other fossil fuels – radiant to chemical to heat and of course some light as in any burning process.

Uranium

Uranium is the heaviest of the naturally occurring elements. It is abundant all over the world but needs to be mined and processed before it can be used as a "fuel" for nuclear power plants. Uranium is a radioactive element, which means that it has an unstable nucleus or one that emits particles from time to time. To make this useful for a chain reaction, the uranium must be purified and processed. Only one form or isotope of uranium is useful for fission, Uranium-235. In order to concentrate this form, the uranium is first dissolved from its ore using acid. When dried, this form is called yellowcake. This purified uranium is then made into a gas called uranium hexafluoride and passed through filters with very tiny holes. Because uranium-235 is a smaller atom than uranium-238, it will pass through the holes leaving the other isotope behind. This process is known as enrichment because it increases the concentration of the needed uranium-235 isotope. Finally, at a fabrication plant the uranium is fused with a ceramic (clay product) and made into barrel-shaped pellets. This allows the uranium to be able to withstand very high temperatures. These pellets are then placed into 12-foot metal tubes that are bundled together and called fuel assemblies. These assemblies are now ready to go into the reactor. This is where the chain reaction of fission occurs. In addition water is used to provide cooling, and control rods are used to absorb neutrons to slow the reaction if needed.



The steps in the production of uranium from mining through enrichment to the reactor.

Fuel pellets are about the size of your fingertip but can provide as much energy as 120 gallons of oil! How can this be? Even though uranium is called a "fuel" for the nuclear reactor, it is not a fuel in the sense that it is burned. Instead, the nuclear reaction of fission is occurring. This involves the splitting of the uranium nucleus with a fast-moving neutron. When the nucleus splits, other neutrons from this nucleus fly off to strike other uranium nuclei. Two other smaller nuclei result from each split plus some matter is completely destroyed and converted to energy. This creates a huge amount of energy in the form of heat and light. Remember Einstein's familiar equation: $E = mc^2$ which shows us mathematically how a small amount of matter can create large amounts of energy. The energy transformation for uranium, therefore, is different from that for the fossil fuels. Here we begin with nuclear energy which is transformed into heat or thermal energy and light or radiant energy. From then on the transformations are the same as in any other electric power plant.

With such a huge supply of energy available through uranium you may wonder why only 8% of our energy supply is from this source. The answer is that there are some drawbacks to its use. Fortunately, there are no air pollutants since there is no actual burning with nuclear energy.

There are, however, waste products. When the pellets are no longer useful for the reactor because the radioactivity is too low, they cannot be carelessly discarded because they still contain enough radioactivity to be harmful to organisms. This spent fuel is now being stored temporarily at the nuclear power plants in deep pools of water. In one year 80% of the radioactivity will be lost and in ten years about 90% of it will be lost.

But this is to be only temporary storage until the fuel can be reprocessed to be used again or permanently stored. When the rods are removed about one-third of the fuel is still good, and reprocessing removes this fuel for suitable use. None is being reprocessed now because it costs more for reprocessing than to make new fuel from uranium. Permanent storage involves placing the radioactive material where it is shielded from living things. Such a place is called a geologic repository. This is a site deep underground surrounded by stable rock formations in an area that is not likely to have earthquakes or volcanic action. The U.S. government would like to store this waste at a site in Nevada called Yucca Mountain. This is in a very sparsely populated area, but so far the people of Nevada have not been in favor of this proposal. At present, there is no national repository for permanently storing nuclear wastes.

Still, nuclear energy is the second most used energy source for the production of electricity in the United States. While coal is still the number one fuel, one-fifth of the electricity generated in the United States is from nuclear power plants. Uranium supplies should last at least for 500 years at the present rate of use. Uranium itself is not an expensive commodity but the cost of construction, licensing, and inspecting nuclear plants is high. We have 66 nuclear power plants in operation, and no new plants are scheduled to be built. In contrast, France generates 75% of its electricity using nuclear power. Perhaps when we solve the problem of what to do with nuclear waste, we will increase our reliance upon this energy source.

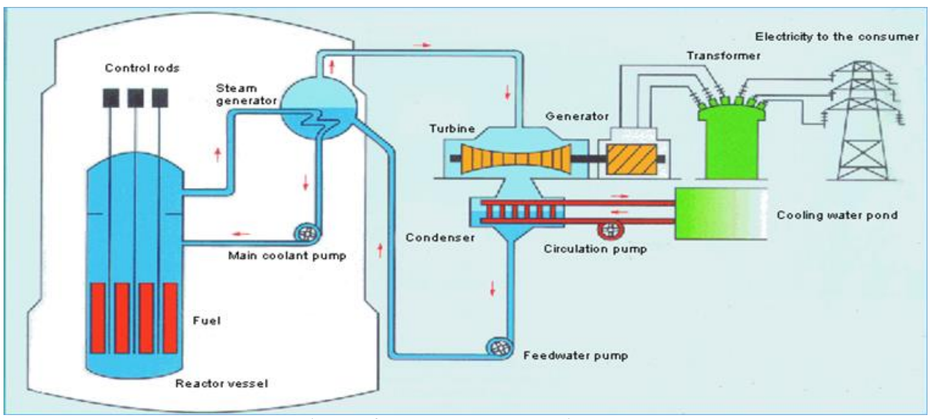
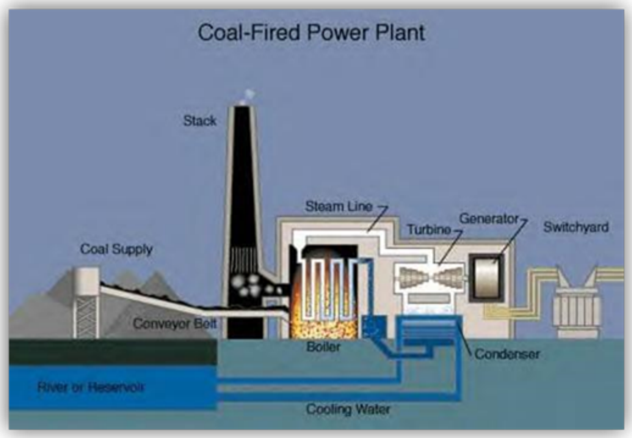


Diagram of a nuclear-powered generating plant.

The fuel rods are shown in red; the control rods are black. Hot water from the reactor heats other water and converts it to steam. The steam drives a turbine which turns a generator. It is the generator that creates the electricity. There are a number of energy conversions here: nuclear to heat to mechanical to electrical energy.

Electricity Production

Although electricity is not a source of energy, as we stated before, it is a very important energy form used in this country. Electricity is produced from several sources of energy – coal, uranium, petroleum, natural gas, and propane. All power plants are about 35% efficient which means that 65% of the original energy in the fuel is converted into wasted heat. Since most of these plants are coal-fired, we will study this plant in some detail. Look at the diagram on this page as each step is described. Most often, coal is brought to the power plant by rail or by river barge. River transportation using barges is the least expensive. Once at the plant, it is moved by conveyor belt into the boiler, a large furnace designed to heat water to the boiling point and above. Because the water is trapped in a closed area, it is under pressure and can be heated above 100 degrees Celsius. The super-heated steam is then taken through pipes to the turbine. The turbine is like a fancy fan with many different sizes of blades, in series one after another. The steam causes the turbine to spin just like wind blowing against a fan that is not turned on can cause it to move. The moving turbine moves a part of the generator, either the coils of wire or the magnet. In either case, an electric current is created in the coil of wire which is then sent to homes, industries, and businesses over wires after being transformed to the proper voltage at the switchyard. The steam is condensed back into water and sent back to the boiler. The water used to cool the steam is either sent to a cooling reservoir or a cooling tower. At the base of the stack, electrostatic precipitator plates remove much of the fly ash. Tracing the energy conversion in this process starts with radiant energy from the sun to stored chemical energy in the coal to heat and light from the burning of the coal to mechanical energy in the moving turbine and generator to electrical energy created in the generator.



Unit Conclusion

To summarize the conversion of nonrenewable energy sources, most are fossil fuels that are burned to produce heat and light for heating buildings, cooking food, purifying metals, or for manufacturing purposes. At times, this heat is used to boil water and create steam, which creates mechanical energy in a turbine, which connects to a generator which creates electricity. The exception to this is uranium a source of nuclear energy, which produces heat through nuclear fission. This heat is used to heat water to create steam just as the fossil fuels are. The more transformations of energy that are performed during a process, the more energy that is lost to wasted heat. This is reflected in the efficiency of the process with 100% efficiency signifying no wasted energy.