Energy Industry Fundamentals for New Employees

Welcome to the Energy Industry

Dear New Employee:

On behalf of the Center for Energy Workforce Development (CEWD), welcome to the energy industry! The company for which you are now employed is a member of our national non-profit organization focused on helping to build a diverse, qualified energy workforce. Our member companies are located across the country in every region and are involved in the generation, transmission, and distribution of electricity and natural gas.

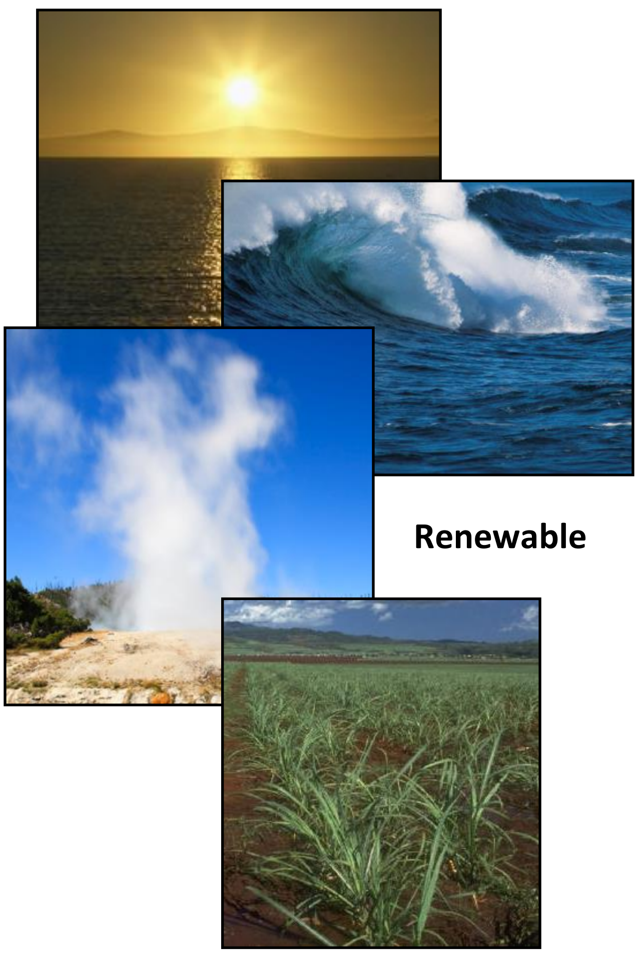
CEWD is providing this Energy Industry Fundamentals booklet to help you learn more about the energy industry. The services energy companies provide are quite varied—some are responsible for generating power, while others may focus on transmission and distribution of power or natural gas to the consumer. Whatever your company's mission may be, it is helpful to learn a little bit about the energy industry as a whole and how your employer fits into the big picture. We have taken portions of our Energy Industry Fundamentals (EIF) course, which is offered through community colleges and in high school career & technical education programs, to compile this booklet. Individuals who complete the full EIF course can earn a certificate issued by CEWD—over 3,000 have already earned this distinction!

We hope you enjoy the information provided here that offers a look at the industry, and insight that should give you a great head start in your new career. We hope that you will share this booklet with your family and friends as well as you embark on an exciting career in our industry!

OVERVIEW OF GENERATION FUEL SOURCES

There are many different sources of **energy** that can be used to meet our energy needs. All of the sources have advantages and disadvantages. Various factors influence the types of fuels used as energy sources by a power plant to **generate** electricity. Price stability, resource availability, efficiency, transportation costs, and environmental concerns are all examples of factors that are considered when a particular fuel source is selected.

Fuel sources are often classified as **renewable** or **nonrenewable**. Renewable resources are those that can be replenished in a relatively short amount of time. Fuel sources such as solar, wind, geothermal, and hydropower are all considered renewable resources. Nonrenewable resources are those with limited supplies. Fuel sources such as oil, coal, and natural gas are nonrenewable resources.



Renewable

Nonrenewable

Generation Fuel Source: Petroleum/Oil

As a fossil fuel, petroleum consists almost exclusively of the chemical elements hydrogen and carbon. As mentioned earlier, hydrocarbons are a diverse family of materials including natural gas, gasoline, kerosene, lubricating oils, paraffin wax, turpentine, and rubber.

Most scientists accept the organic theory of petroleum formation. According to this theory, petroleum was formed over a span of millions of years in prehistoric waters that covered most of the Earth. Tiny plants and animals lived in the shallow depth of the water and along the coastlines. As the plants and animals died, their remains settled on the muddy bottoms of the water. Sediment, in the form of fine sand and silt, drifted down over the plant and animal matter. As the amount of sediment grew into heaps and piles, the amassed weight pressed them into hard, compact beds of sedimentary rock. Throughout the rock-forming process, bacterial pressure and other natural forces worked to change the plant and animal remains into petroleum.

Oil as a Power Generation Fuel Source

Oil provides the United States with an enormous source of energy. While the majority of this oil is used for transportation, a small percentage is used to fuel electric power generation plants.

Fuel oils are the petroleum products used to generate electrical power. The oils are produced to comply with the several specifications prepared by the American Society of Testing Materials and adopted as a commercial standard by the United States Bureau of Standards. The standards have been revised several times in past years, and further alterations are expected to satisfy international changes in supply and demand.

Oil used for firing steam power plants is that portion left after distillation of crude oil to produce gasoline, hydrogen, and carbon. This oil, like coal, is a mixture of organic compounds, containing:

- Carbon
- Nitrogen
- Oxygen
- Sulfur
- Hydrogen

The two primary classes of fuel oils are distillate and residual. **Distillate fuel oils** are made up entirely of material that has been vaporized in a **refinery** distillation tower. These fuels are clean, free of sediment, comparatively low in **viscosity**, and free of inorganic ash. **Residual fuel oils** contain **fractions** that cannot be vaporized by heating. These fractions are black and heavy and retain any inorganic ash components that were in the original crude oil.

Fuel oils are graded according to gravity and viscosity, the lightest being No. 1 and the heaviest being No. 6. The latter is most widely used for steam generation because it is least expensive of the graded oils.

Drilling

Oil is found in deep underground reservoirs. Since oil is a liquid in its natural state, it can be extracted from special wells just as water is. A special "rig" is used to carry out the drilling process. Once the rig has been used to drill the well, a special pump is attached to the well to pump out the oil at a controlled rate. Oil drilling rigs can be found on land, shallow water, or offshore at sea.

Processing

The modern petroleum industry refines crude oil taken from the earth to produce useful products to meet requirements of the commercial market. Hydrocarbons give special characteristics to the parts, or fractions, of petroleum. Some of these fractions, such as gasoline and kerosene, need little change, but refineries must change other fractions before they can be used. Separating the fractions and converting them to useful products are the main functions of an oil refinery. Gasoline and diesel oil are refinery products. Both are important sources of heat energy, but neither is used normally for steam generation.

Like coal, oil cannot be burned in the delivered state. Before the oil can be burned as a fuel source, it must be atomized (broken into fine particles or a mist). Atomizing of the oil is done in the burner. Atomizing the fuel oil into fine droplets and injecting the droplet spray into a combustion chamber with a stream of combustion air ensures efficient combustion. Boilers that use fuel oil require specially-designed oil-burning equipment. In addition to atomizing the fuel, the equipment must handle large volumes of oil per hour.

Transportation

Transportation of oil for fuel usage is an important economic factor in steam power plant location decisions. In plants that use fuel oil as the main fuel for steam generation, the oil is typically delivered to the plant by pipeline, truck, rail, or barge. Another important economic factor considered in site location is fuel oil storage, with associated fire protection.

When the oil is delivered to the plant, it is stored in tanks. Like gas powered plants, oil powered plants have an intricate piping system as well. This system includes many safety features, pumps, valves, controls, gauges, instruments, regulators, alarms, and trips, and is interlocked to protect it from incorrect operation or malfunctions.

Environmental Issues

Similar to the use of coal as a fuel source, the burning of fuel oil to generate electricity causes the release of pollutants such as nitrogen oxides, sulfur dioxide, carbon dioxide, and **methane**. These pollutants can negatively affect air quality, water quality, and land quality.

In addition to the air pollutants that are released, oil-fired power plants also require a significant amount of water for cooling and other plant processes; this can negatively affect local water resources and habitats. Solid wastes are also created as by-products of the power generation process and must be handled with care as well to reduce the impact on the environment.

Focus on ...

Fuel Oil Power – Summary of Advantages and Disadvantages

Advantages

Relatively inexpensive

Easy to obtain/many sources

Disadvantages

Nonrenewable

Creation of **greenhouse gases** and other environmental pollutants

Creation of solid wastes

Large volumes of water are used.

Generation Fuel Source: Coal

Many millions of years ago, trees, plants, and other organic matter fell into the surrounding water and decayed, creating “peat bogs.” Successive geological changes buried these peat bogs under many layers of sand and silt. Today, coal is mined from these prehistoric peat bogs.

An analysis of coal by chemical means shows the following components to be present:

- Carbon
- Oxygen
- Hydrogen
- Nitrogen
- Sulfur
- Ash
- Water (moisture)

Coal as a Power Generation Fuel Source

Coal is the most abundant fossil fuel source in the United States. More than 90% of the coal that is used in the United States is used to generate electricity. In the United States, and worldwide, coal is the most common fuel source for electric power generation.

Coal Classification

Coal has many subcategories that consist of different types and characteristics. Coal is considered a primary fuel for burning in steam boilers in any of its mined types or formations. Fundamentally, coal is comprised of three components:

- Coal itself (organic matter)
- Mineral content (prehistoric plant fibers)
- Moisture (water)

When coal burns under controlled test conditions, it gives up a certain amount of heat, which is referred to as its "heating value." For U.S. coals, this figure ranges from 9,000 **British thermal units (Btu)**/lb to 15,000 Btu/lb, depending upon the source mine location. Therefore, even though it is highly desirable to have a boiler that can burn a wide range of coals, none performs equally as well with every type.

Present standards call for two classifications for coal. The first is according to rank, which is determined by the amount of alteration and compaction the coal has undergone. North American coal may be ranked as follows:

- Anthracite
- Bituminous
- Sub-bituminous
- Lignite

Difference in coal rank is measured by a progressive increase in water and in volatile matter, and by a progressive decrease in carbon and heat content. Relative amounts of water, volatile matter, carbon, and heat content determine how well the coal will withstand transportation, handling, and storage, and how well it will burn.

Anthracite is classified as a hard coal and makes up only a small part of the world's coal supply. It is very high in carbon and is low in water and volatile matter. Anthracite is jet black in color and is free of soot when burning. It requires more heat and effort to begin combustion, but, when started, it burns with a steady, clean, hot, blue-colored flame, and it burns longer than coal of lower rank. Anthracite is more expensive than bituminous coal.

Bituminous coal, classed as a soft coal, is the most plentiful rank of coal. It is the chief fuel in industrial plants that generate electricity with steam. Bituminous coal withstands transportation well, and has a slightly higher heat content than anthracite.

Sub-bituminous coal has a lower heat content than bituminous. It possesses a tendency to crumble when exposed to weather and also tends to crumble during transportation. Sub-bituminous is not mined extensively where coal of a higher rank is available.

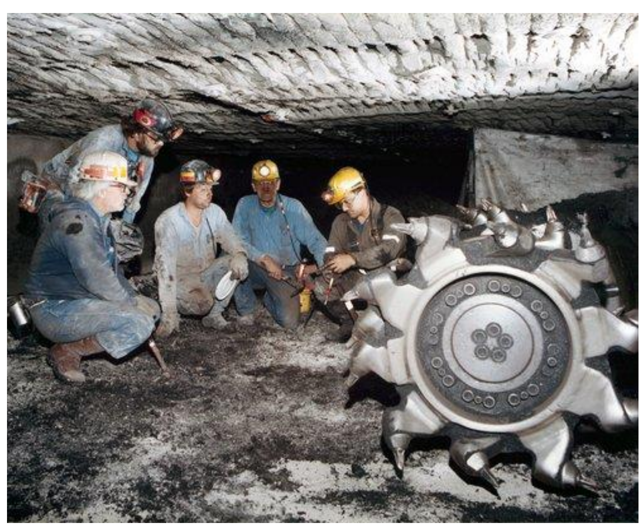
Lignite is a brown-colored coal with a distinctive woody texture. It is little changed from peat. Lignite has a high moisture content; it also crumbles when exposed to weather and during transportation, and is subject to spontaneous combustion. Lignite is the lowest rank of coal in that it has the lowest energy content.

The second method of coal classification is according to grade. Grade is determined by evaluation of ash-producing substances, sulfur, and other detrimental ingredients.

Grade is a term used to express quality. (Rank is used to express degree of coal alteration and compaction.) It is possible that a low-rank coal such as lignite may be of high grade, and a high-rank coal such as anthracite may be of low grade.

Relative amounts of sulfur- and ash-producing substances in a coal are the primary factors in determining a coal's grade. High-grade coal has less sulfur and produces less ash than low-grade coal; therefore, the high grade is more desirable and more expensive.

Sulfur is an undesirable ingredient of coal, even in small quantities. When coal is burned, most of the sulfur is discharged into the atmosphere as sulfur dioxide and sulfur trioxide—serious pollutants. When sulfur is combined with oxygen and water, it becomes sulfuric acid. This acid can corrode boilers in steam-electric power plants where coal is used as the fuel to heat boiler water.



Coal with a high content of ash-producing substances is undesirable because ashes add useless weight that must be handled both before and after burning. Some ash contributes to air pollution, and ash components may fuse to form clinkers that could foul grates and hinder the burning process.

☼ ACTIVITY: Coal Power

Assume the electricity that you use at your home is produced by a lignite coal-fueled power plant. Figure out how much coal must be burned each year to supply your home electricity.

Here are two facts that you will need to solve this problem:

- One kilowatt is approximately equal to 860,000 calories of energy (a calorie is a unit of energy).
- Lignite coal has approximately 4,000 calories of energy per gram (or 4,000,000,000 calories per ton). The energy per gram of lignite is the heat content for lignite. Each fuel has its own heat content.

What other information or records do you need to research in order to solve this problem?

Mining

Coal must be mined from the ground by giant machines. There are different types of mining methods used depending on the type of coal and the location of the coal deposit.

Deep-shaft mining: Large shafts are drilled down from the surface of the ground to the coal seam, and then tunnels follow the coal seam.

Surface mining (also called strip mining): All the rock and soil above the coal seam is removed. Then the coal is removed and the pit is filled in with the original material. This method is usually the most economical for coal seams within 200 feet of the surface.

Auger mining: A large pit is dug down beside the seam of coal. Then large drills or augers are used to bore into the coal seam. Enough space must be left between the holes in the seam to prevent cave-ins. This means that miners can't recover all of the coal from the seam.

Transportation

The cost of transporting coal is often higher than the cost of mining it. The majority of coal used in power plants is transported from mines by rail. An individual rail car can carry up to 120 tons of coal. Coal is also commonly transported by truck, ship, and barge.

Processing

After coal has been transported to the power plant, it is unloaded for storage and usually processed in some manner. Before use, coal may be cleaned to remove impurities such as ash, metals, and sulfur. Coal is cleaned at the storage site if it was not cleaned prior to transportation. Coal cleaning, through a variety of physical and chemical methods, reduces the size of the coal particle but increases its efficiency and reduces emissions released when burned.

In addition to cleaning, coal may be pulverized or crushed before it is fed into the plant's combustion system. By grinding the coal, the surface area is increased, which greatly increases its combustion and heating capacity, resulting in greater plant efficiency.

Environmental Issues

Coal mining can cause adverse effects on the environment. Mining debris and water quality issues are examples of common environmental concerns associated with coal mining. Since environmentalism, conservation of land, and preservation of the environment are of national concern, Federal legislation requires utility companies throughout the United States to rehabilitate or reclaim the land to minimize the adverse effects.

Coal-fired power plants are subject to federal guidelines that regulate pollution. Pollution control devices and systems such as electrostatic precipitators, filters, and particulate collectors operate with the intent of reducing the release of pollutants into the environment.

Did you know?

New Coal Technologies

Traditional methods of burning coal for electricity generation can emit pollutants that reduce air and water quality. The U.S. government supports special programs that focus on the development and implementation of new "clean coal" technologies that reduce the environmental impact of the use of coal for electricity generation.

The goal of clean coal technologies is to remove some of the coal's pollutants before, during, or after the coal is burned.

Coal Washing: Removes unwanted minerals from the coal prior to burning.

Coal Gasification: Process that converts coal into a gas before it is burned.

Scrubbers: Remove sulfur dioxide by spraying coal combustion exhaust gases with limestone and water to form synthetic gypsum.

Generation Fuel Source: Natural Gas

As its name suggests, natural gas is not man-made. It was formed from natural materials through the action of natural forces. Scientists believe that natural gas was formed by the decay of organic matter in a source rock, such as clay or shale or limestone. The gas then passed from this source to a reservoir rock such as sand or other porous stone where the gas was held in the tiny spaces between the solid particles.

In prehistoric days, the source rocks and reservoir rocks in many areas were covered with thick layers of impermeable rock, an upper seal through which the natural gas could not pass. This cap rock held the gas in store for centuries. The bottom seal of such a reservoir frequently was water, usually salt water, or another layer of impermeable rock.

Natural gas is found in these inclined strata, in dome-like formations, or in traps that were created by great fractures in the earth, and in various combinations of these underground formations.

Pure natural gas, like solid petroleum, is made up of the chemical elements hydrogen and carbon. Although natural gas is actually a mixture of several gases, it is largely made up of a gas called methane, which is the lightest hydrocarbon. Other gaseous hydrocarbons usually present in natural gas include ethane, propane, and butane. Common types of fuel gases include natural gas and LP (liquefied petroleum) gas.

Natural Gas as a Power Generation Fuel Source

Natural gas is a familiar fuel that can be used to cook food, heat water, heat and cool homes and other buildings, and perform thousands of useful tasks in shops, plants, and factories all over this country. Natural gas can also be used as a fuel source for power generation plants.

The heating value of gas and its ease of transportation and storage, either above or below ground, and its relatively clean burning make it preferable to oil for fueling power plants.

Drilling

Natural gas generally is found wherever crude oil is found. Natural gas is often found on top of oil deposits, or dissolved in them, because the same natural forces formed both fuels. But, paradoxically, there are many natural gas wells that yield no petroleum.

Processing

In most producing areas, natural gas is processed before it enters into long-distance pipelines. Natural gas may include two undesirable components: 1) sand, which can be removed at the wellhead, and 2) hydrogen sulfide, which may be removed before the gas is distributed. Raw gas from wells is run through several kinds of equipment to clean the gas and make it suitable for use. During processing, valuable by-products are recovered, such as light oils, natural gasoline, and other petroleum gases such as ethane, propane, and butane. As mentioned earlier in the text, since natural gas is odorless, a harmless but pungent odorizer, Mercaptan, is added to the gas during processing as a safety precaution.

Transportation

Texas, Louisiana, Oklahoma, New Mexico, and Kansas have the majority of the natural gas source reserves in the United States. To carry gas from the places where it is produced to the places where it is needed, the natural gas industry has constructed more than 225,000 miles of large-diameter pipelines.

Natural gas in a pipeline is pushed along at about 15 miles per hour. This means that on a 1,000-mile line, it takes about three days for gas to travel from the wells to the last customer. In winter, when more gas is needed for heating, the flow may be speeded by increasing the pressure in the line.

Pipeline dispatchers can control the flow of gas throughout the length of the line. They can increase or decrease the pressures as needed, spot troubles at any point by signals returned to them through automatic control systems, and can direct crews as needed to correct any problems.

Power generation plants that are fueled by natural gas are typically built in proximity to gas pipelines, or they must have gas pipelines constructed to the facility.

Environmental Issues

While the use of natural gas as a power plant fuel source causes fewer emissions than coal- or oil-fueled power plants, the combustion process does still release nitrogen oxide and carbon dioxide. Methane, another greenhouse gas, is also released by natural gas operations.

Natural gas power plants also rely on large volumes of water for plant processes. These operations may result in a variety of impacts on water resources.

Natural gas drilling can lead to other environmental concerns such as the impact on the natural habitat and wildlife.

Focus on ...

Natural Gas Power – Summary of Advantages and Disadvantages

Advantages

Relatively clean burning—less overall emissions than coal or oil

Minimal particulate matter or solid wastes

Readily available and easily transported

Relatively economical

Disadvantages

Nonrenewable

Methane and other greenhouse gas emissions

Fluctuations in fuel price

Environmental impacts of drilling

Generation Fuel Source: Hydroelectric

Water has been used as a power source since ancient times. Historically, hydropower was used to grind grains, for mining, and to perform other tasks. Most **dams** in the United States were constructed for the purpose of providing flood control and irrigation. Only a small percentage of the total dams constructed in the United States were actually constructed for the purpose of electricity generation.

Most of the larger **hydroelectric power** plants in the Unites States (Hoover, Grand Coulee) are operated by the federal government. However, there are also numerous smaller hydroelectric plants that are run by other business entities.

Water as a Power Generation Source

When the hydro **turbine** (water wheel) was invented, it introduced a new perspective on cost-efficient ways to use natural resources in the form of energy.

Hydroelectricity is electricity produced from the kinetic energy of moving water. In conventional hydroelectric power plants, the hydroelectric power comes from the potential energy of dammed water driving a water turbine and **generator**.

☼ CAREER PROFILE: Hydrologist

Christa P. is a hydrologist who works for a civil engineering firm. The firm does environmental studies for businesses and the government.

"A hydrologist has to incorporate a basic knowledge of water properties and how those properties affect the use of water in a wide variety of ways," says Christa. "I do work that relates to controlling river flooding and soil erosion. Other hydrologists might focus their careers in the areas of environmental protection, city planning, or research."

Some hydrologists spend the majority of their time outside, while others might spend most of their time in a laboratory. Christa says, "When I got my first hydrologist job out of college, I spent a lot of time in the lab testing samples. I knew that I eventually wanted to find a position that would allow me to spend more time outside doing field work."

Regardless of where hydrologists work, they must apply a knowledge of scientific and mathematical applications to help solve a variety of water-based issues.

Water Power

The amount of energy that can be derived from hydroelectric power is determined by the strength of the flow or fall. Hydroelectricity can only realistically be utilized in areas that have a moving water resource such as a river, and that are not too far from the end user, since the energy must be transferred to an electrical grid for use. When planning construction for a hydroelectric plant, there are many considerations such as elevation, water flow, water volume, precipitation levels, and high initial cost. These stipulations make hydroelectric power useful only in specific places.

Hydroelectricity Energy Losses

The power extracted from water depends on the volume and on the difference in height between the source and the water's outflow. Energy losses occur in the use of hydroelectric power similar to other fuel sources. These energy losses are **frictional** drag and turbulence.

Environmental Issues

While hydropower is considered to be a relative "clean" renewable source of electricity, hydroelectric power plants can have environmental impacts. When a dam is constructed, there are some environmental ramifications.

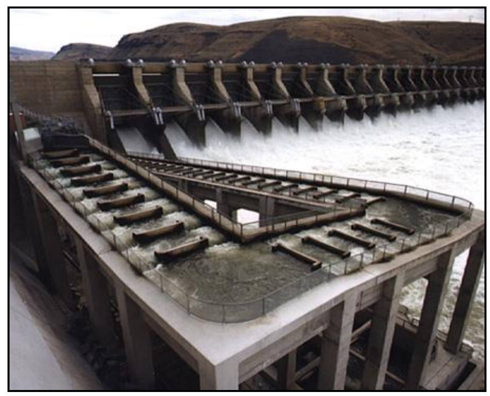
Diverting rivers or streams can cause changes in the environment in areas adjacent to the dam, reservoir, and river/stream. Fish and other wildlife may be affected by the change in the environment. Hydroelectric power plants can also have an effect on vegetation and erosion. Dams may block the natural transfer of sediment, causing silt to be deposited behind the wall of the dam.

The environmental impact of a dam varies between significant or minute depending on the location of the dam, the design of the facility, the status/health of the environment before construction, and the precautions that are taken to reduce potential issues.

The federal government plays a role in licensing hydroelectric power plants in an effort to reduce and regulate negative environmental impacts.

Did you know?

Fish ladders or "fishways" are structures that are constructed around a dam that help remedy negative impacts on fish migration that may be caused by a dam. Fish ladders enable fish to pass around a dam by swimming up a series of relatively low steps into the waters on the other side of the dam.



Focus on ...

Hydroelectric Power – Summary of Advantages and Disadvantages

Advantages

Renewable

Limited/no direct waste

Limited greenhouse gas emissions

Economical to run and maintain once built

Efficient energy conversion

Quick start-up and response time

Disadvantages

Reliance on water levels

High initial construction cost

Possible environmental impacts

Generation Fuel Source: Nuclear/Uranium

Nuclear reactions have been happening inside the Earth since the beginning of time. Radioactive elements such as uranium constantly undergo spontaneous **fission** at a very slow rate (**radioactive decay**).

Early scientists understood that chemical chain reactions were the source of increasing rates in reactions such as chemical explosions, but harnessing the power of nuclear fission is a relatively recent occurrence.

Nuclear energy is the energy that comes from the **nucleus** of an atom. Nuclear energy is released from an atom through one of two processes: nuclear fusion or nuclear fission. In nuclear fusion, energy is released when the nuclei of atoms are combined (fused). The sun produces its energy through nuclear fusion.

In nuclear fission, energy is released when the nuclei of atoms are split apart. Nuclear fission is the process that creates energy in nuclear power plants that is converted to electricity.

Uranium as a Power Generation Fuel Source

The fuel source that is most widely used to power nuclear power plants is uranium. Uranium is selected because it is a radioactive element. It is unstable in that its atoms are easily split, which facilitates the fission chain reaction process.

Nuclear fission takes place inside the reactor of a nuclear power plant. At the center of the reactor is the core, which contains the uranium fuel source.

Did you know?

One uranium fuel pellet provides as much energy as:

149 gallons of oil

180 pounds of coal

1700 cubic feet of natural gas

NRC File Photo

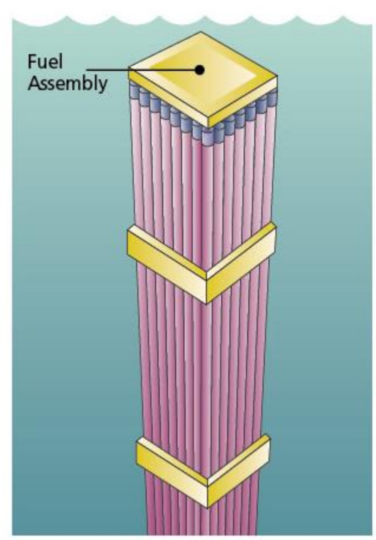
Source

Uranium is considered to be a relatively common element found in the Earth's crust, but at low concentrations, in a variety of geographical locations. Uranium **ore** is mined from the ground, through underground or **open pit mining**. Another mining method is through "solution mining," also known as **in-situ leach mining**, in which special chemicals are used to extract the uranium ore.

Processing

Once uranium ore is extracted, it is further processed by milling. Once the uranium ore has been ground up into smaller particles, the ore is chemically treated to extract the uranium. The uranium is converted into a more compact and stable form, **yellowcake**, for transport to additional processing facilities. The next step in uranium processing is enrichment. In enrichment facilities, uranium is **enriched** to be the appropriate composition to be used in nuclear reactor rods.

After enrichment, the uranium is fabricated in small pellets. These pellets are stacked into long, slender metal rods. These filled rods are called **fuel rods**. Multiple fuel rods put together are referred to as a fuel assembly. A nuclear power plant reactor usually contains multiple fuel assemblies.



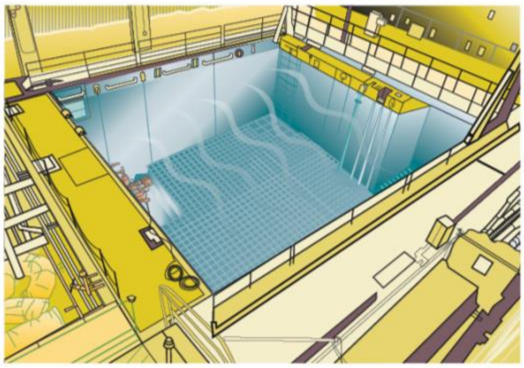
NRC File Photo

Transportation

Since nuclear materials such as uranium reactor rods are radioactive, special safety regulations and procedures have been enacted to ensure the safe transport of radioactive materials. Nuclear reactor rods are shipped by truck to the power plants to be stored until they are needed.

Storage and Disposal

Typically, fuel rods are operational inside a reactor for about six years. Once the fuel rods reach the end of their usefulness, they are referred to as **spent nuclear fuel**. Spent nuclear fuel must be stored with special procedures within special facilities.

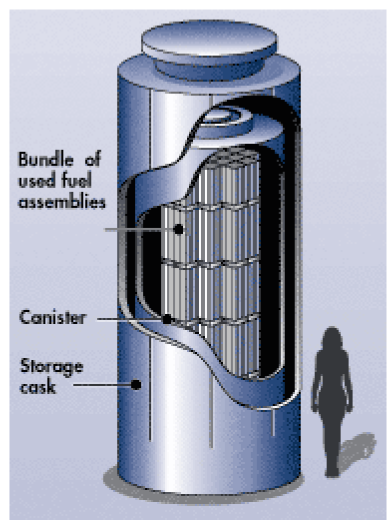


NRC File Photo

Initially, fuel rods are stored in a spent fuel pool. Even though the fission reaction has stopped, the spent fuel continues to give off a substantial amount of heat due to the continued decay of the radioactive elements. The water in the spent fuel pool cools the fuel and contains the radiation.

After the fuel rods have cooled a few years in the spent fuel pool, they are prepared for final storage/disposal.

Since radioactive materials pose a high threat to humans and the environment, nuclear wastes are stored in special steel and concrete containers called casks. High-level toxic waste is stored in high-security permanent underground repositories.



NRC File Photos

Spent fuel can also undergo **reprocessing** prior to its final disposal or storage. Through specialized chemical procedures, nuclear reprocessing involves the separation of potentially useful components from spent nuclear fuel. Reprocessing of spent nuclear fuel helps to reduce the volume of highly radioactive nuclear waste that must be stored.

Currently, reprocessing is more expensive than making new uranium fuel. Because of this, most of the nuclear power plants in the United States do not reprocess much of their spent nuclear fuel.

☼ CAREER PROFILE: Nuclear Health Physics Technician

Mike H. is a nuclear health physics technician. Mike received his training as an engineering lab tech in the Navy. After the Navy, he worked in various technician positions until he got a job as a health physics technician at a nuclear power plant.

As a health physics tech, Mike is responsible for ensuring compliance with many standards and procedures required by regulatory agencies. Mike's duties include taking samples of exhaust air both in and from the auxiliary buildings, conducting "swipe" tests for radiation contamination in the auxiliary and turbine buildings, and going with chemical technicians and operations personnel when they take samples and make necessary inspections.

He also surveys work areas for contamination hazards and then outfits workers with proper shielding. When carrying out a worksite task where radiation exposure is a possibility, Mike works with the shift supervisor to do a "make-ready" on the area. Then he trains the workforce.

Mike's other duties include doing respirator fit tests, calibrating instruments and pocket dosimeters, monitoring radioactive waste shipments, inventorying emergency equipment, and doing whole-body radiation counts of workers.

"This job has so much versatility. I don't have to do the same thing every day. I can do something different every day if I want to. The opportunity for me to increase my knowledge is always there," says Mike.

Environmental Issues

The main environmental concern related to nuclear power production is the creation of nuclear wastes. Nuclear power plants create radioactive waste materials. Radioactive wastes are very harmful to people and the environment and must be carefully stored and safeguarded for thousands of years.

Uranium mining can also cause negative environmental impacts similar to those caused by coal mining. Nuclear power plants also use a large volume of water for cooling and other plant processes. This water use can have negative impacts on water resources and other habitats in the environment.

OVERVIEW OF EMERGING AND ALTERNATIVE GENERATION TECHNOLOGIES

The use of **alternative energy** and **renewable energy** technologies for the generation of electricity has become a hot topic in today's society. With growing concerns about global climate change and the use, cost, and reliability of fossil fuels, research on feasible renewable alternatives has experienced a resurgence.

While the continued development and application of alternative and renewable power generation technologies is important for the cause of reducing the environmental impact of fossil fuel use, unfortunately at this time, most "green" technologies are more expensive. This unit will review the following electric power technologies: solar, wind, geothermal, **biomass**, and ocean/tidal.

Solar Energy

Solar energy is radiant energy from the sun. Solar energy is considered a renewable energy source because the chemical reactions that power the sun are expected to keep generating sunlight for many billions of years.

People have used solar energy since ancient times. Historically, people used simple magnifying glasses to concentrate the light of the sun to catch wood on fire for warmth and cooking.

There are several ways to use the sun as a source of energy and electricity; these include **passive solar heating**, **photovoltaic energy**, and **active solar heating**.

Passive Solar Heating

The use of the sun to provide energy is not new. For years, homes have been built with most of the windows on the side providing maximum sunlight to the living areas in the winter. (In the Northern Hemisphere, where we live, the sun is always angled toward the south.) This use of sunlight is called passive solar heating. It has little impact on the environment, and it helps to decrease reliance on fossil fuels for heating. Passive solar, however, rarely completely provides enough heat to overcome the need for a secondary heat source, such as an electric or gas heater.

Critical Thinking

Passive Solar Heating
Research why passive solar energy rarely completely provides enough heat to overcome the need for a secondary heat source.

☼ ACTIVITY: Passive Solar Heating

Obtain two white cans, two black cans, and two cans of another color. Fill the cans nearly to the top with water.

Measure and record the temperature of the water in each can. (The temperature should be the same in all of the cans at the start.)

Place one white, one black, and one colored can in direct sunlight. Place the remaining cans in a dark area.

Record the temperature of the water in each can every 10 minutes for a set period of time such as one hour. Make a data table to organize your data.

When you complete your recordings, make a graph of the temperatures. Explore the findings.

Electric Power Generation through Solar Sources

Two examples of systems that generate electricity through solar energy are photovoltaic systems and solar steam systems. The production of energy from solar sources is comparatively dependable. Even though solar energy as a whole is dependable, solar electricity generation depends on a few variables. One variable is the amount of sunlight an area receives, which is affected by the time of day, weather, and the seasons. Additional conditions that affect the amount of solar energy a specific location receives depend on the latitude of the area and the topography. See Photovoltaic Solar Resource, Figure 3C.1.

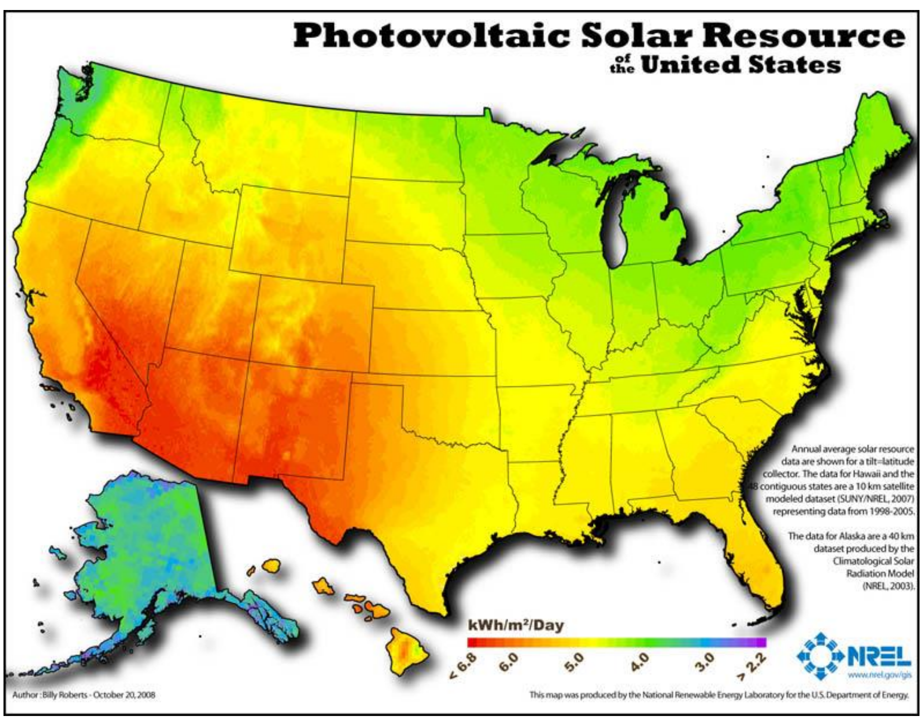


Figure 3C.1 Photovoltaic Solar Resource

Solar Energy: Photovoltaic Systems

Solar photovoltaic energy relies upon chemical reactions to generate electricity. Certain materials produce electricity when they are exposed to light. These materials are made into flat plates with electrical contacts and leads attached to them. These assemblies are called **photovoltaic cells**, or solar cells. Most solar cells used today are composed of thin sheets of purified silicon. Multiple cells are arranged together to form solar panels.

How It Works

Photovoltaic systems rely on the **photovoltaic effect** (see Figure 3C.2). The photovoltaic effect is the creation of an electric current in a material when it is exposed to light. Sunlight is composed of photons, or bundles of radiant energy. When sunlight shines on a solar cell, a chemical reaction occurs, photons give off energy, and this energy is transferred to the electrons. The electrons get excited from the energy given off from the photons and therefore conduct an electric current by moving through the material in the solar cell. Current flows up and out of the cell by way of the contacts and leads. Solar cells produce electricity in DC form, which must be converted to AC form by an inverter. Solar cells are encased behind glass plates to protect them from the environment.

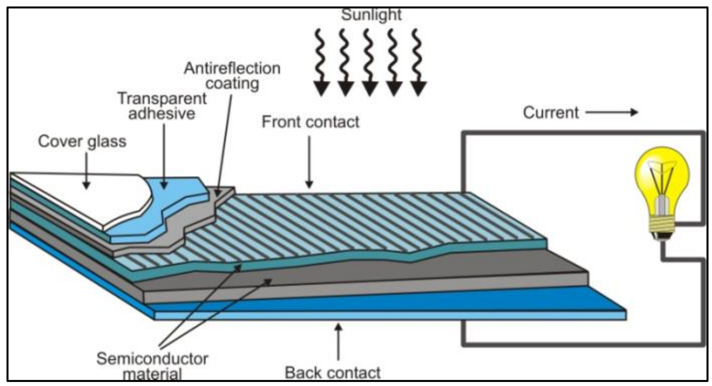


Figure 3C.2 Photovoltaic cell construction

The amount of electricity a solar cell produces depends on the size of the solar cell, its conversion efficiency, and the intensity of the light source. For electric energy applications, cells are connected to form photovoltaic modules called solar panels. An arrangement of multiple connected solar panels is called an array.

For personal or small household use, multiple arrays would be needed. The majority of private-use photovoltaic systems require the use of a battery to store energy since photovoltaic systems cannot store electricity.

For mass electricity generation such as generation in solar power plants by utility companies, large numbers of arrays are arranged across many acres of land, hence the term "solar farm." Most solar power plants are tied into the electrical grid and do not use batteries or other energy storage devices.

☼ CAREER PROFILE: Solar Energy Company Owner

As energy costs have risen, harnessing solar energy has become more popular and as a result, many new solar energy businesses have been created. An owner of a small solar energy company might sell solar energy systems to residential and commercial clients. When designing a solar energy system for a client, the energy needs of the client will be analyzed, and then a system will be designed and installed at the specified location.

In addition to knowledge regarding solar technologies, a small businessperson has to manage all aspects of the business, including hiring personnel, bookkeeping, maintaining inventory, and advertising. Communication skills are very important to maintaining a successful business, as a businessperson will be working with a wide variety of people.

Concentrating Solar Power Basics

Many power plants today use fossil fuels as a heat source to boil water. The steam from the boiling water spins a large **turbine**, which drives a **generator** to produce electricity. However, a new generation of power plants with concentrating solar power systems uses the sun as a heat source. The three main types of concentrating solar power systems are: *linear concentrator*, *dish/engine*, and *power tower systems*.

Linear concentrator systems collect the sun's energy using long, rectangular, curved (U-shaped) mirrors. The mirrors are tilted toward the sun, focusing sunlight on tubes (or receivers) that run the length of the mirrors. The reflected sunlight heats a fluid flowing through the tubes. The hot fluid then is used to boil water in a conventional steam-turbine generator to produce electricity. There are two major types of linear concentrator systems: parabolic trough systems, where receiver tubes are positioned along the focal line of each parabolic mirror; and linear Fresnel reflector systems, where one receiver tube is positioned above several mirrors to allow the mirrors greater mobility in tracking the sun.

Figure 3C.3 Parabolic trough

Figure 3C.4 Linear collector system

A dish/engine system uses a mirrored dish similar to a very large satellite dish, although to minimize costs, the mirrored dish is usually composed of many smaller flat mirrors formed into a dish shape. The dish-shaped surface directs and concentrates sunlight onto a thermal receiver, which absorbs and collects the heat and transfers it to the engine generator. The most common type of heat engine used today in dish/engine systems is the Stirling engine. This system uses the fluid heated by the receiver to move pistons and create mechanical power. The mechanical power is then used to run a generator or alternator to produce electricity.

Figure 3C.5 Dish/engine system

A power tower system uses a large field of flat, sun-tracking mirrors known as heliostats to focus and concentrate sunlight onto a receiver on the top of a tower. A heat-transfer fluid heated in the receiver is used to generate steam, which, in turn, is used in a conventional turbine generator to produce electricity. Some power towers use water/steam as the heat-transfer fluid. Other advanced designs are experimenting with molten nitrate salt because of its superior heat-transfer and energy-storage capabilities. The energy-storage capability, or thermal storage, allows the system to continue to dispatch electricity during cloudy weather or at night.

Figure 3C.6 Power tower system

Solar Reserves Crescent Dune CSP Project

Environmental Impacts

Even though solar energy systems operate without the production of air emissions, pollutants, or solid wastes, there are a few other environmental concerns associated with them. Certain photovoltaic systems require a large area of land for their solar panels. It is possible that the use of land may have environmental implications such as interference with habitats. The other concern some people have is that the appearance of the large groups of solar panels has a negative aesthetic impact on the environment.

Focus on ...

Solar Energy – Summary of Advantages and Disadvantages

Advantages

Renewable

No carbon dioxide or pollutants released

Minimal environmental impact depending on system installed

Low operating costs

Disadvantages

Visual impact

High initial cost

Wind Energy

Similar to hydropower, energy has been harnessed from the wind for thousands of years. Just like early water wheels, early windmills were used for pumping water and grinding grain.

Wind power is becoming an attractive alternative energy source for many people. Similar to solar power, wind is an inexhaustible renewable resource. Simply stated, wind is caused by a difference in atmospheric pressure that results from the uneven heating of the Earth's surface by the sun.

To harness the power of wind, large towers are erected to carry small, wind-powered generators called wind turbines. Most of the larger wind power plants are privately owned and the electricity they produce is sold to power companies. This lets power companies cut back on the amount of electricity that is generated using fossil fuels. Of course, on days without much wind, the wind turbines are less effective.

The energy produced by wind turbines varies from a few hundred **watts** to several **megawatts**. The amount of energy produced by a wind turbine depends on the wind speed at that specific location and the size of the wind turbine.

While wind is an inexhaustible resource, it is also a variable resource depending on the wind farm location. Typically, wind farms (large clusters of wind turbines built close together) are placed where there is a minimum average wind speed of around 13 miles per hour. If wind speed is too low, turbines cannot generate electricity. Scientists measure and record wind speed and other factors at proposed wind farm sites for many years before construction ever begins.

How It Works

There are many different designs of wind turbines with varying blade shapes that are customized for the location of the turbine to maximize electricity generation. Regardless of the design of the wind turbine, they all operate on the same principle.

In wind turbines, the mechanical energy to rotate the generator comes from the force of the wind pushing the blades of the turbine. The force of the wind causes the turbine blades to rotate. Since the turbine blades are directly connected to the generator, rotation of the blades moves the magnetic field over the coils of the generator, producing electrical current.

The output capacity of wind turbines is limited by the size of the turbine blades and volume of wind. Usually, multiple wind turbines will be located along mountains or hilltops, so that the output can be combined in order to provide usable capacity levels.

Wind turbines have the following basic parts: blades/rotors, tower, gear box, generator, and shaft. Different styles of blades and different sizes of turbines operate most efficiently at different wind speeds and locations. See Figure 3C.7.

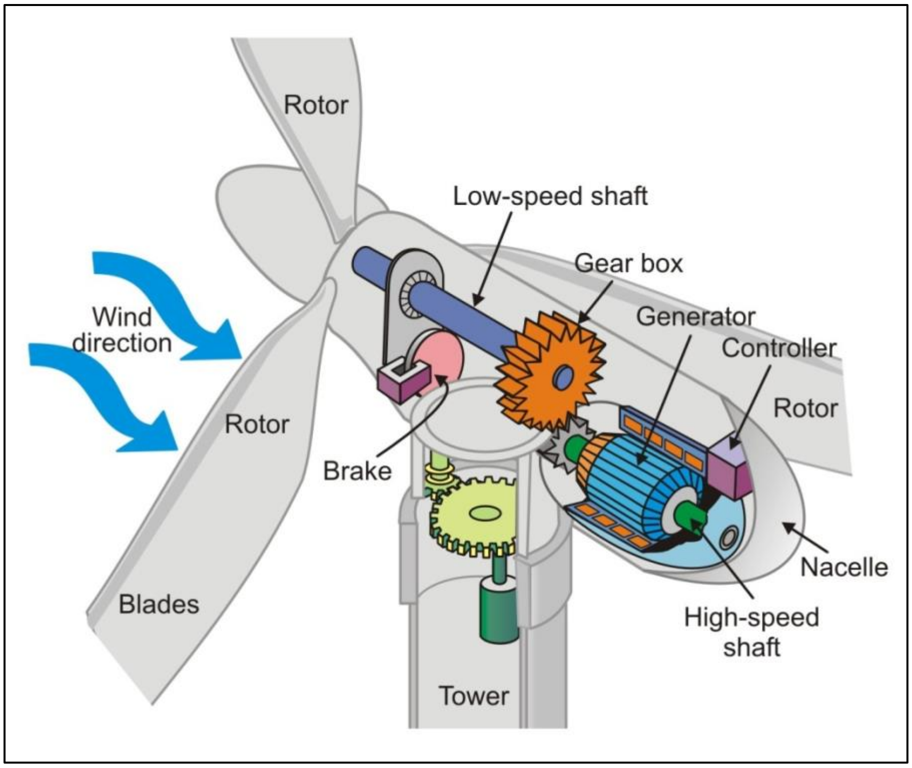


Figure 3C.7 Wind turbine components

Environmental Impacts

Wind plants do not produce any greenhouse gases or other types of air pollution. They also do not require large volumes of water for cooling. Even though wind plants are considered to be "green," there are some environmental impacts associated with wind plants. Some people feel that the appearance of the large wind towers has a negative aesthetic impact on the environment. Some wind turbines make noises that can be heard in the vicinity of the wind farm. Another environmental impact of wind turbines is the possible impact on bird populations. Many newer turbine technologies are working to resolve these negative impacts.

Focus on …

Wind Energy – Summary of Advantages and Disadvantages

Advantages

Renewable

No carbon dioxide or pollutants released

Does not require consumption of water

Disadvantages

Noise

Visual impact

Possible impact on local wildlife

Electromagnetic interference

Weather/seasonal dependence

High initial cost

☼ CAREER PROFILE: Wind Turbine Technician

Curtis E. is a wind turbine technician for a private energy company. Curtis travels to different wind farms in his region to maintain, troubleshoot, and fix wind turbines owned by the company he works for. “Typical tasks that I am responsible for include inspecting the entire turbine system, performing routine maintenance, and repairing any mechanical or electrical problems on the turbines,” says Curtis.

Curtis says he has always had an interest in construction and technology. “Sometimes I get called to work on the installation of turbines at a new wind farm, but most of the time I work on pre-existing turbine systems collecting data and making repairs. The data I collect helps us test the health of the system and to know what adjustments or repairs might need to be made to ensure safe and efficient operation of the turbine.”

The work Curtis does is essential to ensuring that the wind turbines operate reliably and at their maximum efficiency. “This job is never boring,” says Curtis. “Aside from the heights that you are required to work at, technology is always changing and improving, so there is always something new or different to do.”

Geothermal Energy

Water beneath the Earth's surface is sometimes superheated by the Earth's immense internal heat. The superheating of underground water reservoirs produces steam. This steam can be piped to buildings for heating or for driving machinery. The steam also can turn turbines to produce electricity. This type of energy is called **geothermal energy**. You might be familiar with geothermal energy in the context of its occurrence in nature, such as in the form of volcanoes and hot springs. Geothermal energy is relatively nonpolluting, clean, and safe.

Geothermal energy has been used historically for cooking and bathing. Modern geothermal electricity generation technologies are relatively new.

While geothermal energy is classified as naturally sustainable, there are only so many places on Earth where geothermal energy can be tapped, since it is dependent on certain geological formations. Among these are New Zealand, Iceland, and some parts of the United States. Each of these places uses geothermal energy to one degree or another.

Geothermal Power Plants

There are three main types of technology used to generate electricity from a geothermal source. Geothermal production wells are drilled to provide access to the geothermal source.

Dry Steam Plant

A **dry steam plant** (see Figure 3C.8) uses superheated steam that comes directly from the heat source. The steam travels up a well and is routed directly into a turbine. The superheated steam expands when passing through the turbine, causing the blades/shaft to rotate. The exhaust steam condenses to liquid form which drops the pressure across the turbine. Gases and wastewater are re-injected into the ground.

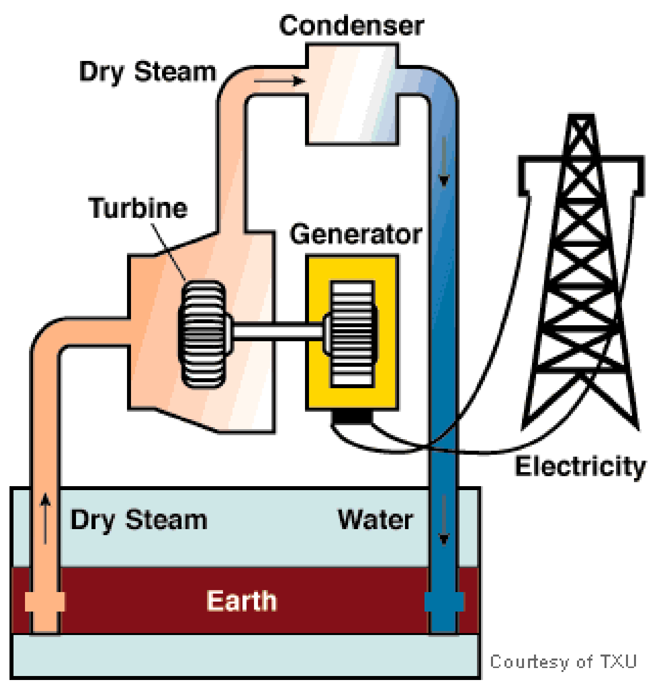


Figure 3C.8 Dry steam plant

Flash Steam Plant

A **flash steam plant** typically uses high-pressure hot water. Pressure differences between the well and the storage device cause the water to vaporize into steam that turns a turbine and generates electricity.

Binary Cycle Plant

A **binary cycle plant** uses heat from lower-temperature geothermal resources to vaporize a secondary fluid with a lower boiling point than water. The temperature difference between the two fluids causes the creation of vapor, which drives a turbine to generate electricity.

Environmental Impacts

Geothermal plants release a minimal amount of emissions into the atmosphere in comparison to other power generation technologies. Since geothermal source fluids are coming from deep under the Earth's crust, gases from within the Earth are released through the well. Plants designed with special technologies can capture and reduce the release of these gases into the atmosphere.

Even though geothermal plants are considered to be "green," there are some environmental impacts associated with them. Sometimes during geothermal well drilling, poisonous gases may escape into the atmosphere.

Did you know?

The country of Iceland is well-known for its geologic formations that contain extensive reservoirs of geothermal energy. It is estimated that more than 29% of Iceland's electricity is generated by geothermal sources (in comparison to only about <1% in the U.S.).

Subsidence, or gradual sinking of land, may occur in areas in proximity to geothermal plants due to the large volumes of fluids that are removed from the Earth.

Another environmental concern is the disposal of wastewater, or used geothermal fluids. These fluids must be disposed of appropriately to prevent pollution of the environment.

Focus on ...

Geothermal Energy – Summary of Advantages and Disadvantages

Advantages

Renewable

Small amount of emissions

Small amount of land needed for development

Reliable—fuel source not dependent on weather or price fluctuations

Low operating costs

Disadvantages

High initial cost

Limited are of application—site must have specific geothermal qualities

Wastewater disposal

Noise

Biomass Energy

Once a very small part of the renewable technology sector, **biomass power generation** is making great strides in becoming a more widely used source of renewable energy. Biomass is probably the oldest source of energy after the sun. Since ancient times, people have burned wood or other organic materials to heat their dwellings and cook their food.

Biomass technology involves the generation of energy from organic materials. **Bioenergy** is a term used to describe energy derived from materials such as sugar cane, straw, animal manure, or other organic materials that were living matter a relatively short time ago in comparison to fossil fuels.

Biomass Sources

The term biomass encompasses diverse fuels derived from four main types—wood and agricultural products, solid wastes, landfill gas and biogas, and alcohol fuels. Biomass fuels can be in liquid, solid, or gas form as long as they are composed of organic wastes.

Wood and Agricultural Products

Wood

Wood energy sources are derived from wood harvested for the direct purpose of serving as a biofuel, and from wood wastes from sawmills, pulping, and paper industries, such as the following.

Forestry Residues: Wood-based organic materials that remain after timber has been harvested from forests.

Milling Residues: Wood-based organic materials that remain after timber product manufacturing.

Urban Wood Waste: Wood-based organic materials that would otherwise be sent to a landfill such as construction waste and wooden pallets.

Agricultural

Agricultural energy sources are derived from crops such as switchgrass that are cultivated for the direct purpose of serving as a biofuel feedstock, and from agricultural wastes from the agricultural industry.

Agricultural residues are generated after the harvesting of an agricultural crop. These residues include materials such as stalks, straw, fruit pits, peanut hulls, and corncobs.

Solid Wastes

Waste energy sources include municipal solid waste (MSW) and manufacturing waste.

Power plants that burn garbage as their fuel source are called “waste-to-energy plants.” These plants function in a manner similar to coal-fired plants, but garbage serves as the fuel source instead of coal.

Municipal solid waste is not all biomass; perhaps half of its energy content comes from plastics, which are made from petroleum and natural gas.

Did you know?

One ton (2,000 pounds) of garbage contains about as much heat energy as 500 pounds of coal.

Landfill Gas and Biogas

Biomass can be converted to other usable forms of energy such as methane gas. Rotting garbage and agricultural and human waste release methane gas, which is also called “landfill gas” or “biogas.”

Landfill Gas

Rotting and decay of landfill waste can result in the creation of methane gas as the waste breaks down. Most landfills are required to collect methane gas for safety and environmental reasons. Landfills can collect the methane gas, purify it, and use it as fuel.

Biogas

Methane gas can also be produced from agricultural and human wastes using special biogas digesters. Biogas anaerobic digesters are airtight containers or pits lined with steel or bricks. Waste is put into the containers where it ferments without the presence of oxygen and produces a methane-rich gas.

Alcohol Fuels

Agricultural crops such as corn and sugarcane can be fermented to produce transportation fuels. Ethanol is a common biomass alcohol fuel that can be used as a fuel source by itself or added to gasoline.

Another biomass fuel source called “biodiesel” is a fuel made from left-over vegetable oil and animal fats.

Biomass Energy Conversion Technologies

There are a variety of biomass energy conversion technologies available to convert biomass fuels into electricity. Conversion technologies may release the energy directly, in the form of heat, or the energy source may be converted to liquids or gases.

Biochemical Conversion

Biochemical conversion technologies involve the use of biochemical processes to break down the composition of biomass materials. Biochemical conversion technologies utilize enzymes, bacteria, and other micro-organisms to break down biomass materials. Examples of biochemical conversion processes include **anaerobic digestion** and fermentation.

Anaerobic Digestion

Biodigesters recover methane gas from biomass materials such as animal manure, through anaerobic digestion. The anaerobic processes require an airtight tank, “digester,” or a covered lagoon.

Methane-producing bacteria cause the decomposition process. A variety of factors affect the rate of decomposition and biogas production. The most important factor is temperature. Keeping the digester at a consistent temperature maintains consistent bacterial digestion.

Biogas produced in anaerobic digesters consists mostly of methane and carbon dioxide. The percentage of the gases in biogas depends on the feed material and management of the process.

Fermentation

Agricultural crops can be fermented to produce biomass alcohol fuels. Ethanol is the most common biomass alcohol fuel. Ethanol is created by the process of fermentation.

☼ ACTIVITY: Ethanol Production

Anaerobic fermentation of sugar cane and corn syrup has been introduced as a means of commercially producing ethanol in the United States. Additionally, methanol (used in making biodiesel) can be produced from wood pulp.

Investigate the production of ethanol from corn syrup and the production of methanol from wood pulp. Possible sources of information include the U.S. Department of Agriculture and the U.S. Department of Energy. Research and discuss the following questions:

- Where are these types of biomass alcohol fuel production taking place?
- Which microorganisms are used in the fermentation process?
- What kinds of jobs are related to ethanol and methanol production from plant feedstocks such as pulp and corn syrup?

Thermal Conversion

Thermal conversion technologies involve the use of heat to convert the biomass fuel into electrical energy. Examples of thermal conversion processes include **gasification**, pyrolysis, and combustion.

Pyrolysis and Thermal Gasification

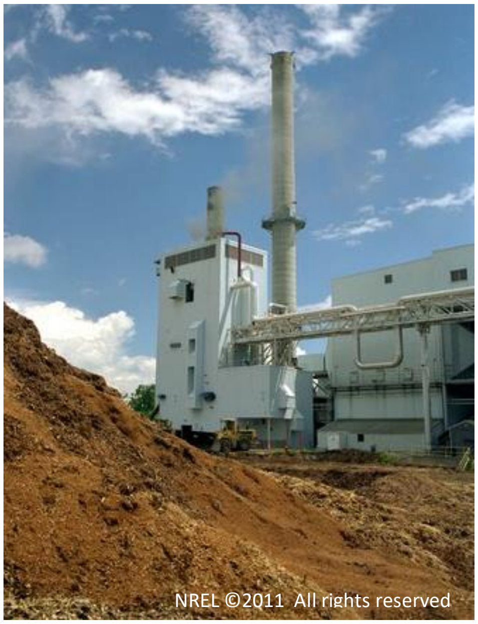
Pyrolysis and thermal gasification are related technologies. The pyrolysis process heats biomass material to high temperatures in the absence of gases such as air or oxygen. Pyrolysis creates a mixture of combustible gases, liquids, and solid residues.

Thermal gasification is different from pyrolysis in that the thermal decomposition takes place in the presence of a small amount of oxygen or air. The gases that are produced in these processes can be used to heat boilers or processed further to be used in combustion turbine/generators.

Combustion

Biomass combustion power plants include both dedicated biomass and biomass co-firing plants. Trucks bring in loads of refuse to storage bays or pits at the power plant. Heavy equipment is used to sort and mix the waste before it is combusted.

In many cases, municipal solid waste can be directly combusted with minimal processing. This process is referred to as “mass burning.” For more specialized combustion processes, waste may be subjected to more extensive processing before being combusted.



Dedicated Biomass

Dedicated biomass plants are also known as direct-fired power plants. In these systems, the fuel used to heat the system’s boiler is all biomass fuel. Similar to other steam-generated power plants, steam from the boiler is captured and rotates a turbine that generates electricity.

Biomass Co-Firing

Biomass co-firing plants combine biomass fuel materials with coal in coal-fired boilers. In co-firing plants, biomass fuels substitute for a portion of coal, which helps reduce emissions and dependence on non-renewable fossil fuel sources.

Economic Implications

Economic implications that affect biomass power plants include regional availability of biomass fuel sources, transportation costs, and available technology. Since fuel sources vary by region, biomass fuel prices are also subject to regional variations.

Biomass power plant size is often limited by the proximity of biomass fuel source availability. Transportation costs associated with the movement of bulky materials is very high. Unless the power plant is located in close proximity to rail or shipping routes, transportation costs might be a severe cost-limiting factor for a plant’s development.

Environmental Impacts

When biomass fuels are combusted, they generate air emissions such as carbon dioxide, carbon monoxide, nitrogen oxides, particulates, and other various pollutants depending on the biomass fuel used and the energy technology processes applied.

Focus on …

Biomass Energy – Summary of Advantages and Disadvantages

Advantages

Renewable

Preserves landfill space

Disadvantages

Bulky and expensive to collect and transport long distances

Long-term storage is problematic due to degradation

Burning releases carbon and other emissions

Ocean Wave/Tidal Energy

A relatively new emerging area of renewable energy is hydrokinetics. **Hydrokinetic energy** refers to energy that is the result of water movement such as tides and currents. The constant motion of the ocean contains energy that can be used to generate electricity.

Ocean Wave Energy

Ocean waves are a form of renewable energy created by wind currents passing over the open water of the ocean. Improved methods of capturing the energy from ocean waves has been a focus of recent research in alternative energy sources.

In addition to wind currents, the strength of ocean waves is affected by tides, weather, and other natural marine occurrences. The power of ocean waves is currently collected to generate electricity in two main ways, through fixed and floating devices.

Fixed Devices

Oscillating water columns are fixed devices that are partially submerged in the water. As a wave flows in and out of the column, air within the column is forced in and out. This air movement causes the turning of a turbine that generates electricity.

TAPCHAN systems are another example of a fixed system. TAPCHAN stands for tapered channel. In a TAPCHAN system, a reservoir (or “catch basin”) within a cliff has a tapered channel connected to it. Waves progressively move through the channel. As the channel narrows, the energy of the waves becomes more concentrated, causing the waves to spill over the sides of the channel. When the waves spill over the sides of the channel into the reservoir, the stored water in the reservoir is essentially pushed out and directed though a turbine to generate electricity. See Figure 3C.9.

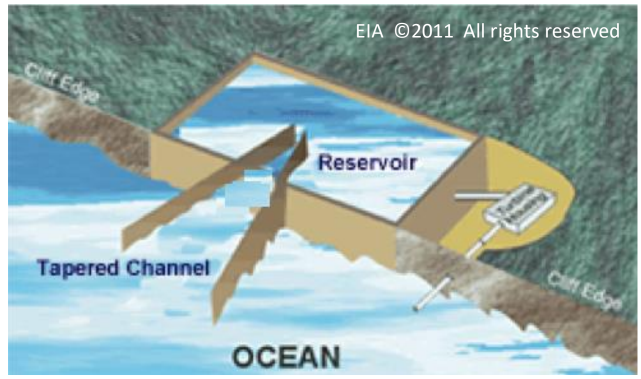


Figure 3C.9 TAPCHAN System

Floating Devices

There are a variety of floating devices that can be used to generate electricity from ocean waves. The basic premise of floating devices is that the movement or “bobbing” of the floating part of the device creates energy that can be converted into electricity.

Tidal Energy

Ocean tides are a result of the interaction of the gravitational forces of the Earth, moon, and sun. These gravitational forces cause high and low tides to occur. In areas where there is a significant difference between the tides, there is an opportunity to utilize hydrokinetic energy systems. Hydrokinetic energy conversion systems convert the energy from the movement of tides (without impeding the movement).

Tidal Barrage Power

A **tidal barrage** is essentially a tidal power station. A tidal barrage is a **dam**-type structure built across an **estuary** with gates and turbines installed to funnel and use tidal forces to generate electricity. A tidal barrage makes use of the difference in water levels (high tide/low tide) to capture the water flow, direct it to a turbine, and generate electricity.

“**Ebb generation**” in a tidal barrage allows water to enter the barrage through the gates without the turbines running. The water is trapped at high tide by closing the gates. Then the water is released at low tide to generate power.

“**Flood generation**” in a tidal barrage generates power by allowing the turbines to operate as the high tide “comes in.”

“**Two-way operation**” in a tidal barrage generates power by allowing the turbines to operate as the high tide comes in and as it recedes.

Tidal Stream Power

In additional to tidal barrages that take advantage of hydrokinetics through the capture of energy from high and low tide differences, tidal power can also be captured from strong, underwater ocean currents. In tidal stream power technology, submerged turbines are driven by flowing water currents.

Environmental Considerations

Some tidal power systems can negatively affect the surrounding environment by the change in water levels caused by the use of tidal barrages. Water turbidity (cloudiness caused by suspended particles) can increase as an effect of tidal barrage construction. Increased turbidity, wildlife migration, and fish spawning may or may not be affected by tidal barrages, depending on their design and efforts to minimize environmental impacts.

Focus on ...

Ocean Wave/Tidal Energy – Summary of Advantages and Disadvantages

Advantages

Renewable

Limited/no direct waste

Limited greenhouse gas emissions

Little visual impact

Low noise generation

Disadvantages

Reliance on water levels

Output fluctuations

Integration into the power grid

Seasonal wave energy availability

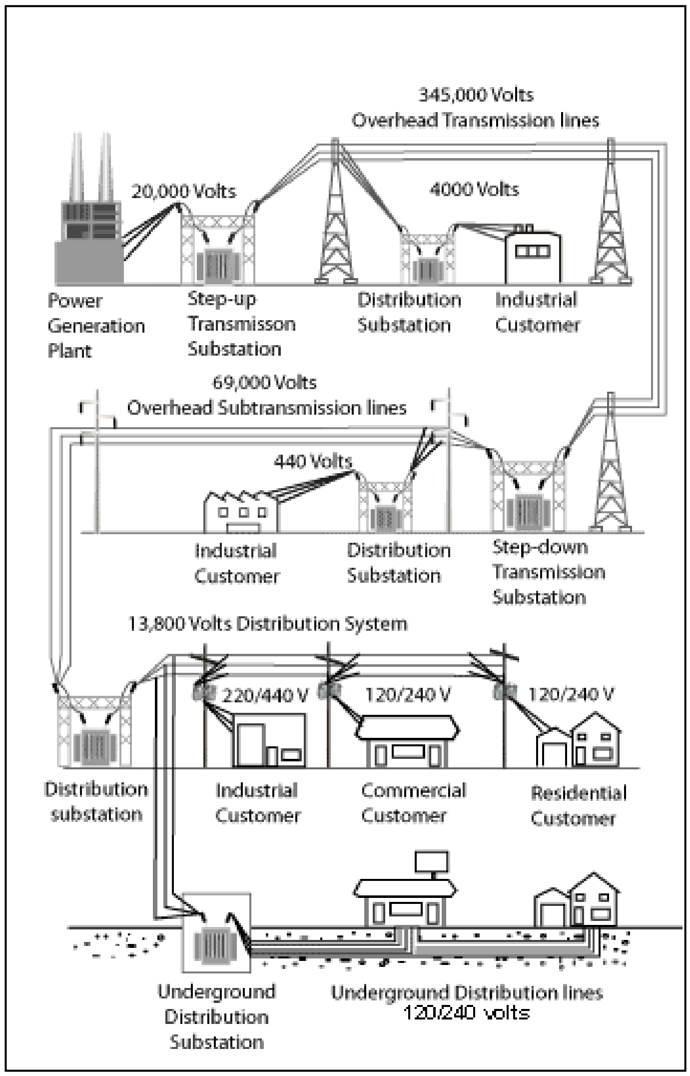
High initial cost

Possible environmental impacts

INTRODUCTION TO ELECTRIC POWER TRANSMISSION

Module 3 covered many different ways of generating electrical **power**. Regardless of what type of method is used to generate power—nuclear, gas, wind, or other—all power generation plants use a **transmission system** to send the electrical power they produce to end users. Generation sources require specially designed transmission systems to **step-up** the output **voltage (volts)** from the production system to higher voltages for interconnection with power pools/grids.

The transmission system delivers power directly to **substations** of a specific utility company and to larger industrial consumers at voltages of 69 kV and above. The transmission system is generally connected to a **subtransmission system**, which delivers electrical power to large commercial customers at voltages between 35 kV and 69 kV. The subtransmission system is also connected to a **distribution system**. Distribution systems deliver electrical power to residential customers and to smaller commercial customers at voltages of 35 kV and below.



Transmission System Overview

Electric power transmission, also referred to as high voltage electric transmission, can be defined as the bulk transfer of **electrical energy** from power generation plants to substations. The transfer of electrical energy from substations to the customer is referred to as distribution, which is the focus of Module 5.

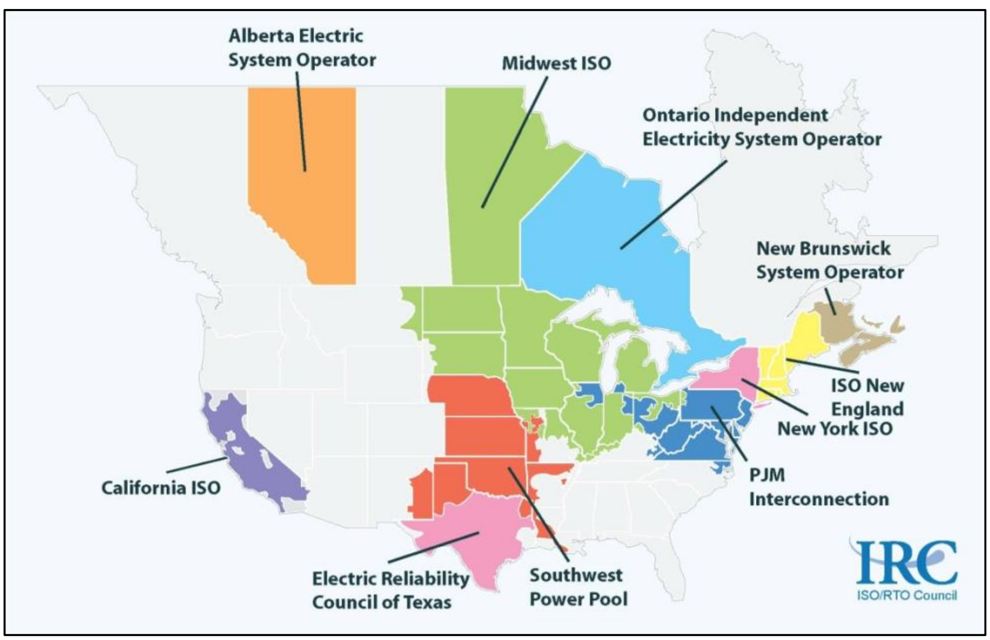
Transmission serves two main purposes, to transfer electricity from generation plants and to interconnect various systems. This interconnection of transmission lines is often referred to as **electrical power grids** or, simply, “the grid.” Most of the power generated in the station passes through the **generating plant switchyard** to the transmission system.

About 5–8% of the generated power is used within the plant to operate the equipment necessary to run the plant. The switchyard contains all the equipment necessary to transform and route power: buses, **circuit breakers**, disconnects, **transformers**, protective relays, monitoring and controlling devices, **insulators**, and supporting structures, which together move the power from the **generator** to the transformer and then to the transmission system. (A bus is a specially designed **conductor** having low **resistance**.) Other switchyards house similar protective relays, monitoring and controlling devices, insulators, and supporting structures, which move the power from the transmission system to the distribution system.

> **Did you know?**
>
> **Early Transmission**
>
> In the 19th century when electricity was first being used for larger purposes, the generation source had to be right next to the equipment or system that was using the electricity that was generated. Even when electricity was first being transmitted through early transmission lines, it was so inefficient that the lines were not longer than one mile from the power generation source.

Various Power Pools/Grids

A power pool or power grid consists of interconnected networks for delivering electricity from suppliers to consumers. The transmission system serves to connect different power pools or grids. Examples of the different entities that make up power grids were covered in Module 1. Power grids and their operating authorities are responsible for the safe and reliable operation of the electric transmission system from producer to customer.



Major power pool or power grid interconnections are often connected by **direct current (DC)** lines. Using direct current connections addresses the need to synchronize **alternating currents (AC)** from interconnected systems. This will be discussed in more detail later in this module.

Very High Capacity Customers

Some customers are connected directly to the transmission system at high voltages. Examples of some of these types of customers include manufacturing and industrial operations, nuclear plants, technology and research operations, educational institutions, and hospitals.

Substations and Subtransmission Systems

The high voltages that are required for bulk electricity transmission are too high for the voltages that are needed for most consumer applications. Lower voltage levels are required for electricity to flow safely through smaller cables and distribution lines, save money, and protect customers.

At transmission interconnection intervals such as substations, some of the electrical energy is tapped off of the transmission lines. These substations step the voltage down to lower voltage levels with large power transformers.

Substations are interconnected and dispersed within high-voltage transmission lines and subtransmission lines to provide additional system control facilities to detect abnormalities that could cause system interruptions by monitoring the lines' **currents (amps)**, voltages, and power flows. Transformer circuit breakers protect equipment from being overloaded. The lower-voltage output circuits from the substations are called **distribution circuits**.

500 kV to 230 kV single-phase transformer

500 kV gas breaker

Substations vary in size depending on the system they are servicing. Most substations are constructed in an area where the vegetation has been removed and the lot is filled with gravel. They are typically fenced and gated for safety and security.

Substations are interconnected to the transmission system and distribution system by two methods:

- High-voltage transmission circuits directly **step-down** electrical energy to distribution connections, such as 138 kV or 230 kV transmission circuits supplying substations that normally provide 13 kV distribution circuits.
- High-voltage transmission circuit-supplying **switching stations** step-down voltages to a subtransmission level voltage, commonly in the range of 26 to 34 kV. The subtransmission circuits' voltage level can easily be routed along public streets on wood poles or through underground cables to industrial, commercial, and utility substations. These subtransmission-supplied substations provide system monitoring and control for distribution circuits in the 4 to 13 kV range.

Substations can also perform **transmission switching**, which is the connecting and disconnecting of transmission lines or other components to and from the system.

☼ Career Profile: Electrical Engineer

Sarah H. is an electrical engineer. Most electrical engineers design, develop, test, and supervise the manufacture of electrical equipment. Some of this equipment includes electric motors; machinery controls; radar and navigation systems; and power generation, control, and transmission devices used by electric utilities.

Sarah's job is that of a more traditional electrical engineer in that she works for a power company, and her job focuses on the supply and transmission of electrical power. Sarah specializes in power-systems engineering, and she is classified as a substation engineer.

Sarah is tasked with a lot of engineering design projects. She researches and prepares high-voltage substation schematics and calculations, so she utilizes her knowledge about design, specifications, layouts, and management of high-voltage substations.

As far as her education, Sarah says, "A bachelor's degree in engineering is required for almost all entry-level engineering jobs. In addition to a bachelor's degree, engineers that want to offer their services directly to the public must be licensed as well."

Sarah says, "In addition to performing my on-the-job duties, it is important for me to find time to keep up with continuing education credits so I can try to stay up-to-date with rapidly changing technologies." Engineers trained in one specialty may work in related specialties. This flexibility allows employers to meet staffing needs in new technologies and specialties.

Electric Power Transmission Process

The movement of electricity through the transmission system is a complex process. Electricity produced by power generation plants is first routed to substations at or near the plant. These substations use transformers to “step-up” the voltage of electricity in preparation for movement through the transmission lines. Required voltage levels depend on the distance that electricity must travel through the transmission system. Electricity then exits the transmission system at distribution substations where it is “stepped-down” to lower voltages for distribution to consumers.

Focus on ...

Voltage Differences

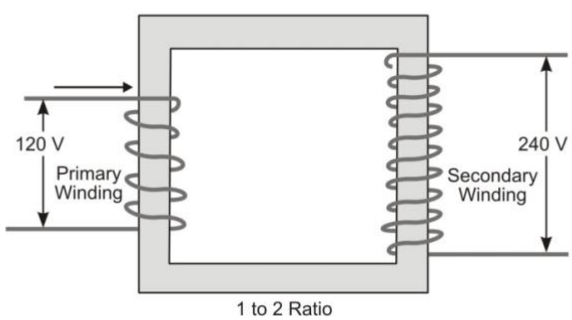
A generating plant’s typical output voltages are between 12 kV and 30 kV.

Typical transmission voltages range from 138 kV to 765 kV.

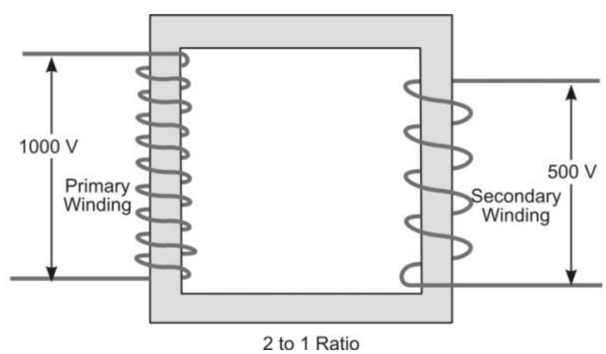
Transformers

Power that is generated at power plants must be collected and delivered to the transmission system at the voltages that match transmission requirements. In modern power plants, the electrical power leaving the generator travels to a main power transformer, which steps up the generated voltage to local grid levels.

A transformer is an electrical device by which alternating current of one voltage is changed (transformed) to another voltage. They operate on the theory of mutual inductance. A basic transformer consists of two sets of windings, or turns, coiled around an iron core and placed in a covered tank. The primary winding is connected to the source (input) voltage. The secondary winding is connected to the **load** (output). There is no physical connection between the windings.



Step-up transformer



Step-down transformer

As alternating current flows in the primary winding of the transformer, a magnetic field or flux is developed in the iron core. As the current reverses direction, the magnetic field also changes direction. This action induces an alternate voltage in the secondary winding, and if the secondary circuit is closed, an alternating current will flow. When there is the same number of turns in the primary and secondary windings, the voltage will be the same in both the source and the load circuits.

Focus on ...

Transformers

Transformers operate on two basic principles:

1) Whenever an electric current flows, there is magnetism around it.

2) Whenever a magnetic field changes (by moving or by changing strength), voltage is created. If there is a wire close by when this happens, then a current will flow in the wire as the magnetism changes.

Step-Down Transformer © 2011, OSHA

If there are more turns in the secondary winding than in the primary winding, the transformer is said to be a **step-up transformer** and the voltage in the secondary circuit will be greater than the voltage in the primary circuit. A **step-down transformer** has less turns in the secondary winding than in the primary winding, and voltages are higher in the primary circuit than in the secondary circuit.

A transformer can only transfer power, not produce it. Besides the main power transformer that steps voltage up to transmission levels, a variety of other transformers are found along the transmission and distribution lines that adjust voltages for the power grid and that step-down voltages to levels needed by various consumers.

If there could be an "ideal" transformer with no power losses, the power in the primary would equal the power in the secondary exactly. In any AC circuit, the power equals the voltage times the current ($P = I \times E$). An ideal step-up transformer with a one-to-two ratio would double the voltage, but the current will be reduced by half. For example, if 200 amperes of current were flowing at 1,000 volts in the primary winding, 100 amperes of current would be flowing at 2,000 volts in the secondary winding. In a step-down transformer, the voltage is decreased; therefore, the current will increase at the same ratio.

Science Connections

Voltage and Current

Voltage is a measure of energy carried by a charge. Voltage is supplied by a power source. Current is the rate of flow of charge.

Voltage attempts to make a current flow. Voltage is sometimes described as the "push" or potential energy of the electricity. Current is the flow of energy.

It is possible to have voltage without current, but current cannot flow without voltage.

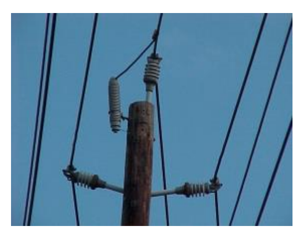
Transmission Switching Stations

Transmission system switching stations provide control facilities for monitoring the system operation and provide connections to other transmission systems. Switching stations function as a transmission system control facility by monitoring the lines' currents, voltages, and power flows to detect abnormalities that could cause systems interruptions.

These stations are also used to interconnect transmission circuits that operate at different voltage levels. Switching stations increase the overall delivery system reliability through their interconnection of power production sources and regional power pools. These interconnections increase system reliability by increasing the potential sources of energy for the delivery system and alternate paths for routing electrical energy in the event of an operational emergency or to perform line construction/maintenance.

Transmission line outages for construction/maintenance can be especially difficult, or sometimes impossible, during peak customer load periods. This has caused many utilities to develop work practices and improve the technical skills of associates to maintain transmission lines/circuits while they remain in service carrying energy to customers.

Typical subtransmission-level customers are moderately large users of electrical energy commonly requiring multiple circuits to supply their needs. The multiple circuits may be required because of the customers' load requirements or necessary for increased reliability. Examples of subtransmission customers are colleges, hospitals, and industrial processes.



A subtransmission line

INTRODUCTION TO ELECTRIC POWER DISTRIBUTION

Distribution System Introduction

As discussed earlier, electricity created by generation plants travels though transmission lines, then through distribution lines to reach the end user.

Electric power distribution is the third and final step in the electric power system. We will cover the distribution of electricity in this module.

While transmission and distribution both refer to the movement and transport of electrical power, it is important to understand the distinction between the two systems.

The electric transmission system typically provides electric power to other intermediate systems. Electrical power distribution refers to supplying electric power to retail or end-use customers. Distribution lines normally run from **substations** through a distribution-line network to individual customers. Geographically speaking, distribution networks are smaller and cover less distance than transmission systems.

Another distinction between distribution and transmission systems is the operating **voltage**. Transmission systems operate at higher voltage levels than distribution systems.

Historically, early **electric power distribution systems** encountered obstacles similar to those experienced by early transmission systems: mandatory proximity to a generation source and incompatibility of different voltages. Today's extensive distribution systems were not possible as there was no efficient means of changing voltages, and technology regarding the safe distribution of residential power was primitive.

Focus on ...

Transmission vs. Distribution

Transmission

- Higher operating voltages
- Longer distances
- Larger coverage area
- Provides power to other systems

Distribution

- Lower operating voltages
- Shorter distances
- Smaller coverage area
- Provides power to individual customers

Distribution System Overview

Distribution Substations

As explained in Module 4, the voltages that are required for bulk electricity transmission are too high for most consumer applications. Lower voltage levels are required for electricity to flow safely through smaller cables and distribution lines. At transmission interconnection intervals such as substations, some of the electrical energy is tapped off the transmission lines. These substations step the voltage down to lower voltage levels with large power **transformers**.

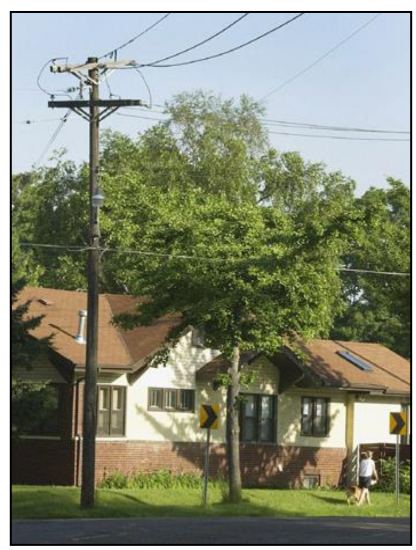
Substations are interconnected and dispersed among high-voltage transmission lines and distribution lines. They vary in size depending on the system they are servicing. Most substations are constructed in an area where the vegetation has been removed, and the lot is filled with gravel and is fenced and gated for safety and security.

Substations are interconnected to the transmission system and distribution system by two methods:

- High-voltage transmission circuits carrying 138 kV or 230 kV directly **step-down** voltage to distribution connections carrying 13 kV.
- High-voltage transmission, circuit-supplying **switching stations** step-down voltages to a **subtransmission** voltage level commonly in the range of 26 to 34 kV. The subtransmission circuit's voltage level can easily be routed along public streets on wood poles or through underground cables to industrial, commercial, and utility substations. These subtransmission-supplied substations provide system monitoring and control for distribution circuits in the 4 and 13 kV range.

Commercial and Industrial Connections

Some customers need higher voltage levels than what is typically provided from a residential distribution circuit but do not need voltages that are high enough to warrant a direct connection to the transmission system. These high-use customers are serviced by special distribution connections at voltages ranging from 7.2 kV to 14.4 kV through a **service drop** line that comes from a transformer on or near a distribution pole to the customer's end-use structure.



Residential Connections

Residential customers require electricity that is distributed at a reduced voltage, typically 120/240 **volts** (single phase). This reduced voltage is usually achieved through a pole-mounted or pad-mounted transformer.

Electrical power is delivered to residential customers through what is referred to as a service drop line, which leads from the distribution pole transformer to the customer's structure via overhead distribution lines. The service line can also be buried, as is the case with underground distribution lines. Residential connections and key components will be discussed in more detail later in this unit.

Focus on ...

Electric Power Distribution Pathway

- Substation steps down voltage from transmission lines
- Primary distribution lines route power to a specific service area
- Secondary distribution lines route power to smaller areas within a service area
- Transformers step down the voltage to the appropriate level to be routed directly to a building's service line and through an electric meter

☼ ACTIVITY: Types of Distribution Networks

Collect information on the varying types of distribution networks. Research the advantages and disadvantages of the different types of networks, and find out what type of distribution network serves your local area.

Answer the following questions:

"Are there any specific factors in your area that influenced the development of one type of network design over another, such as geography, proximity to transmission lines, or generation sources?"

"Do local utilities have contingency plans in place based on the type of system they are operating in the event of a system problem or outage?"

Distribution Networks

Distribution networks are usually either radial or interconnected. **Radial distribution networks** are systems with a single power source for a group of distribution customers. In radial systems, distribution lines stem from a single power source and continue through the service area without a connection to additional power supplies. This is the cheapest type of distribution network, but also the least reliable as there are no redundant or back-up power sources. This type of system is more common in remote locations or in locations with a low population density.

© 2011 NREL

Interconnected distribution networks are composed of multiple connections to power supply sources. Interconnected systems are configured in a "loop" with power sources located in various locations along the loop, or in a "web" with power sources interconnected within a complex framework. Interconnected systems are more expensive than radial systems, but they offer a much higher level of reliability due to the redundancy of power sources.

Focus on ...

Important Factors for Electric Power Distribution Systems

- System power demand requirements
- Distance the system must cover
- Projected operation and maintenance required and associated costs
- Physical clearances and requirements for system components
- Potential environmental and community impacts
- Integration into the national grid

Siemens, 2016

Distribution Systems and Equipment

Designing distribution systems requires significant planning and forethought. Numerous systems and essential equipment comprise a distribution system.

Focus on ...

Electric Power Distribution System Components

- Substations
- Distribution Feeder Circuits
- Switches
- Primary Circuits
- Secondary Circuits ("Secondaries")
- Services ("Service Drops")

OSHA, 2011

Most of us are familiar with the sight of electrical transformers on poles in residential neighborhoods or **electric meters** attached to our homes. These transformers and meters are examples of important components of the electrical distribution systems that serve our communities.

Distribution Substation

We have mentioned that we need higher voltages to move large amounts of electricity long distances with minimum losses (voltage drops). However, we also need lower voltages to allow smaller power lines and associated equipment to be built for residential purposes. This also allows customer equipment and appliances to operate at standardized voltages.

A key element in the distribution system is the distribution substation. Substations are fenced-in areas that contain switches, transformers, and other specialized electrical equipment that convert electric power from the transmission system to a distribution voltage level. Distribution substations are where distribution circuits originate, are monitored, and are adjusted. See Figure 5A.1.

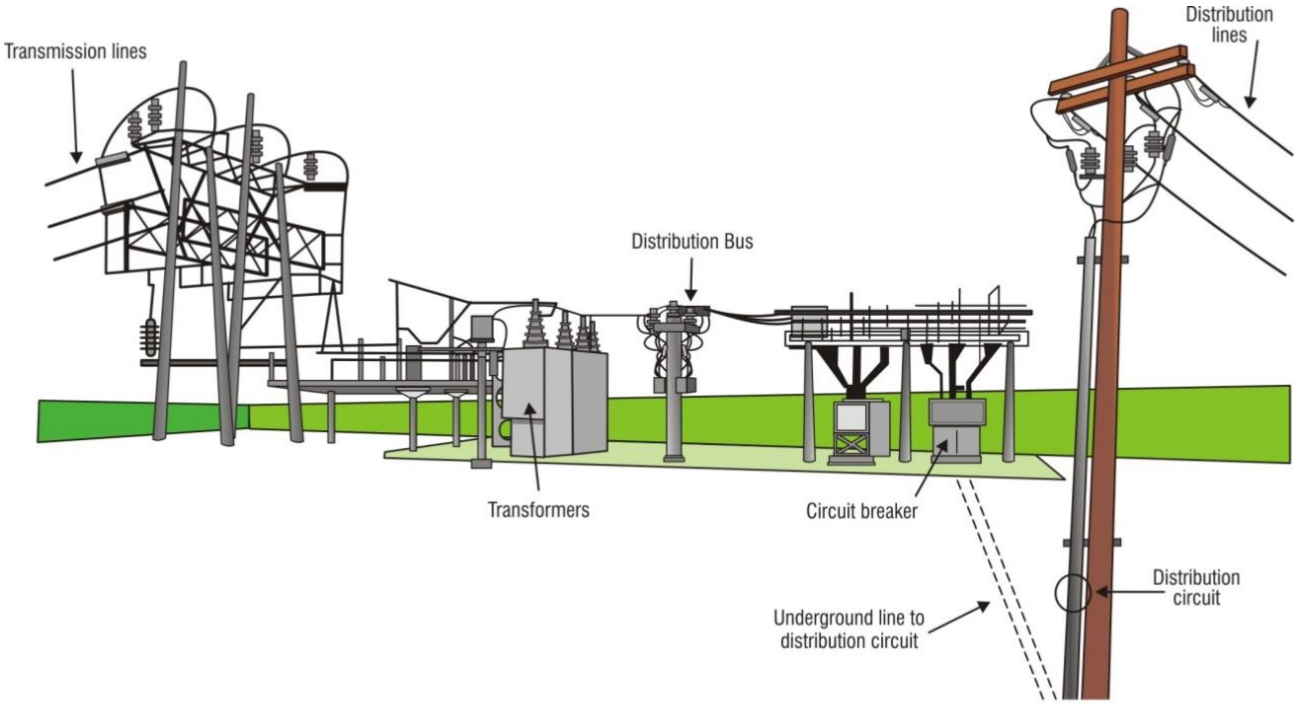


Figure 5A.1 Distribution Substation

NATURAL GAS DISTRIBUTION

Natural Gas Energy

Electric power lines aren't the only source of energy in homes and businesses. As you have learned in previous modules, natural gas can be used as a source of energy for electric power generation. Natural gas can also be used as a source of energy through direct combustion for cooking and heating.

As mentioned in Module 1, pure natural gas, like solid petroleum, is made up of the chemical elements hydrogen and carbon. Although natural gas is actually a mixture of several gases, it is largely made up of a gas called methane, which is the lightest hydrocarbon. This segment of the energy industry includes the exploration, extraction, processing, storage, transportation, and distribution of natural gas.

Natural Gas System Overview

The entire natural gas system starts with exploration and extraction of gas through wells. Once extracted from the ground, the gas moves through cleaning and treatment processing, and then to a compressor station or a storage field before being routed to a high-pressure transmission pipeline. Transmission pipelines utilize specialized regulators to reduce pressure for connections to high- and low-pressure **distribution mains**. Distribution mains connect to **street mains**, which branch out into **individual service connections** that run to a home or business. See Figure 5C.1.

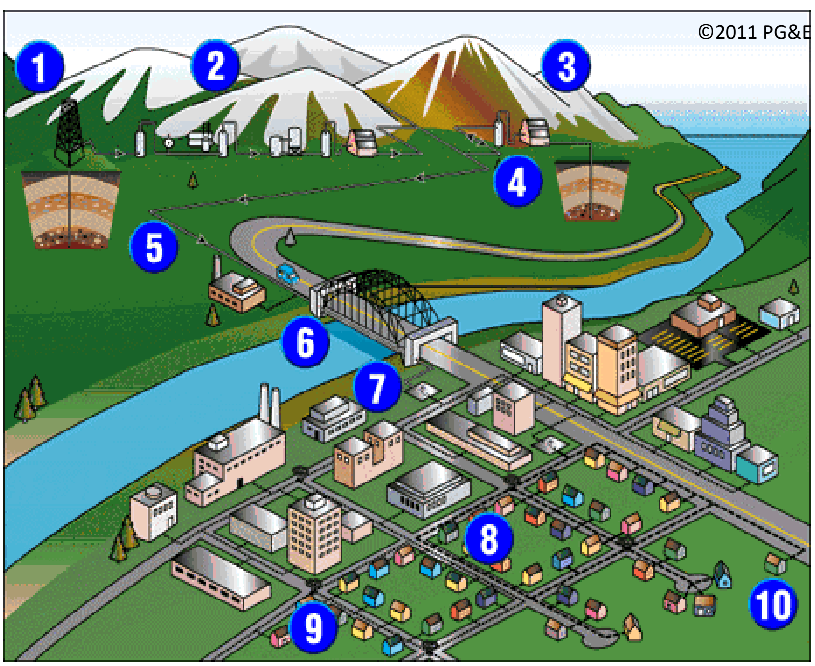


Figure 5C.1 Natural Gas System

1. Gas wells
2. Gas cleaning and treatment
3. Compressor station
4. Gas storage field
5. High-pressure transmission lines
6. Suspended transmission lines
7. Regulators
8. High- and low-pressure distribution mains
9. Valves
10. Service connections

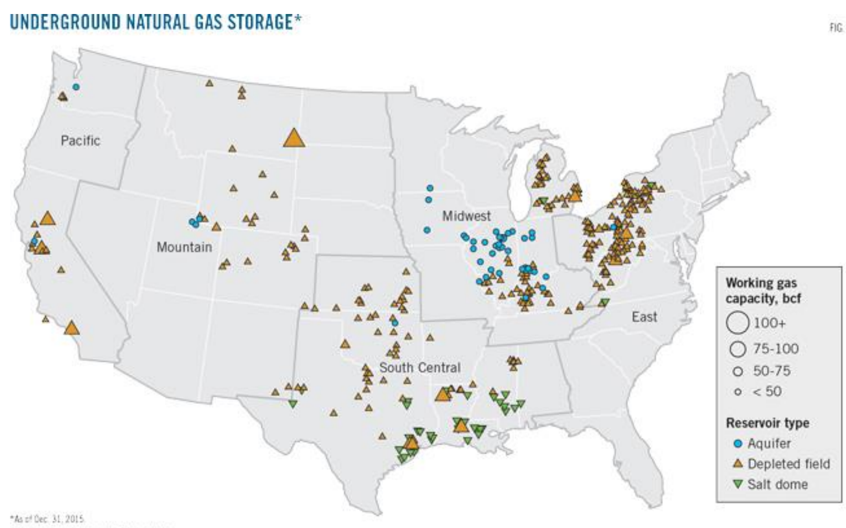
Natural Gas Procurement and Processing

©2011 Argonne National Laboratory

Natural gas is typically procured through pumping of deep wells. Texas, Louisiana, Oklahoma, New Mexico, and Kansas have the majority of the natural gas source reserves in the United States.

Gas must be processed before it enters into long-distance pipelines. Raw gas from wells must go through cleaning to make it suitable for use in homes and factories. Natural gas may include two undesirable components: 1) sand, which can be removed at the wellhead, and 2) hydrogen sulfide, which may be removed before the gas is distributed. During processing, valuable by-products are recovered, such as light oils; natural gasoline; and other petroleum gases such as ethane, propane, and butane. As mentioned earlier in this text, since natural gas is odorless, a harmless but pungent odorizer, “mercaptan,” is added to the gas during processing as a safety precaution.

Natural Gas Storage



Because the demand for natural gas fluctuates with the seasons, it may not be needed right away. Reserves are injected into underground storage facilities such as depleted gas reservoirs, salt caverns, and aquifers. Three quarters of our national natural gas reserves are stored in depleted gas reservoirs. These consist of underground locations from which natural gas has already been extracted. Depleted gas reserves have two advantages—they’ve already shown that they can successfully contain natural gas, and they generally have a pipeline infrastructure associated with them. Salt caverns are created from underground salt domes by dissolving a large pocket or “cavern” in the dome with water. They are smaller than depleted gas reservoirs or aquifers. Aquifers are spaces underground that contain large amounts of water. They can be repurposed as storage areas for natural gas, but this is expensive.

Natural Gas Transmission and Distribution

As with electric power, once natural gas is procured and processed, it must travel through transmission and distribution networks to be delivered to customers. To carry gas from the places where it is produced to the places where it is needed, the natural gas industry has constructed hundreds of thousands of miles of large-diameter pipelines.

The U.S. natural gas pipeline network is similar to the electric power system in that it is a highly integrated grid-type network. The transportation of gas through the grid is possible to and from almost any location in the lower 48 states.

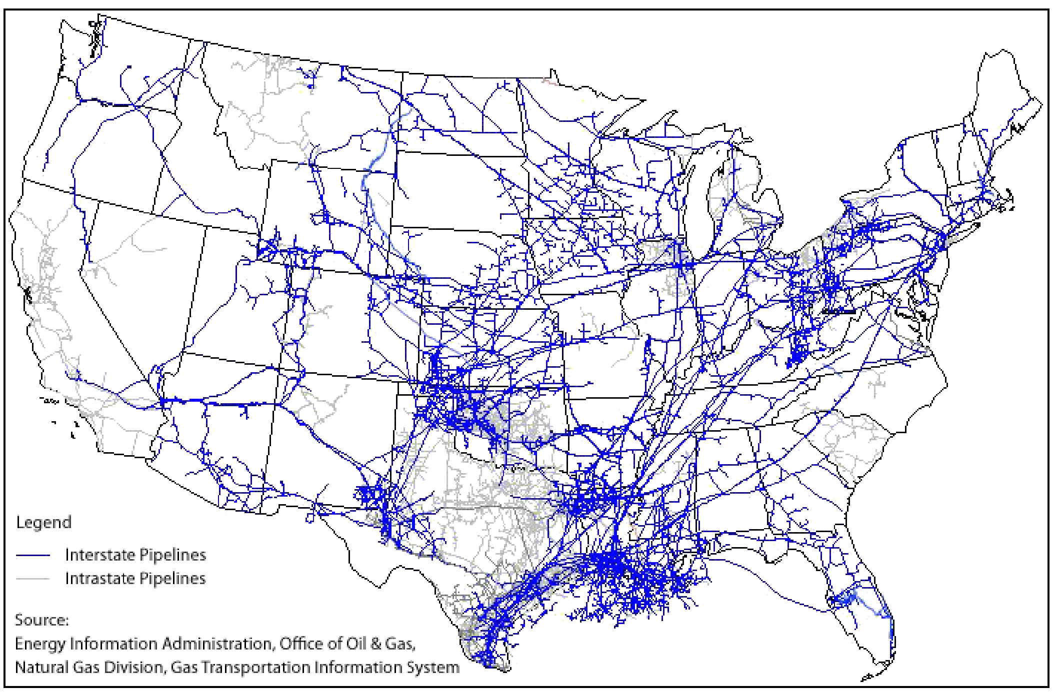
The movement of natural gas from its source to a customer's home meter involves several physical transfers and multiple processing steps. The natural gas grid is capable of meeting customer demand through the carefully planned interconnection of procurement and processing establishments, storage sites, and transmission and distribution pipelines.

Focus on ...

U.S. National Pipeline Grid

- More than 210 natural-gas pipeline systems.
- More than 305,000 miles of interstate and intrastate transmission pipelines.
- More than 1,400 compressor stations.
- More than 11,000 delivery points, 5,000 receipt points, and 1,400 interconnection points.
- More than 400 underground storage facilities.
- More than 49 locations for import/export via pipelines.

U.S. Energy Information Administration, 2017



Regional Transmission

After cleaning and processing, gas moves through pipelines to a compressor station or a gas storage field before being fed again into high-pressure transmission lines. High-pressure transmission pipelines consist of interstate and intrastate pipelines.

Interstate pipelines are long-distance, wide-diameter (20–42 inches), high-capacity pipelines that are responsible for transporting the vast majority of natural gas throughout the United States.

Intrastate pipelines operate within a state's borders and interconnect gas producers, local distributors, and the interstate network.

Transmission pipelines may be buried or suspended to cross rivers or other obstructions. As natural gas travels through pipelines, some pressure is lost due to friction caused by the natural gas rubbing against the inside walls of the pipelines. The loss of pressure is compensated for at compressor stations located about every 50 to 100 miles along transmission pipelines.

> **Did you know?**
>
> **Pipeline Safety and Security**
>
> The Office of Pipeline Safety ensures safety in the design, construction, operation, maintenance, and emergency response planning of the nation's pipelines.
>
> In accordance with the Federal Pipeline Safety Improvement Act of 2002, companies must develop and implement a transmission integrity management plan (IMP) that addresses the monitoring and maintenance of transmission pipelines for community safety.
>
> PG&E, 2011

Natural gas in a pipeline is pushed along at about 15 miles per hour. This means that on a 1,000-mile line, it takes about three days for gas to travel from the wellheads to the last customer. In winter, when more gas is needed for heating, the flow may be speeded by increasing the pressure in the line.

©2011 PG&E

Pipeline dispatchers can control the flow of gas throughout the length of the line. They can increase or decrease the pressure as needed and spot troubles at any point by signals returned to them through automatic control systems. They can then direct crews to correct any problems. Regulators on the transmission lines are adjusted to reduce pressure for high- and low-pressure distribution mains.

Pressure in the gas transmission system is constantly monitored and maintained at safe levels. Pressure-limiting stations control pressure at critical points by limiting the pressure in lines regardless of how the demand or supply changes. Line-rupture control valves are also installed on pipelines to avoid excessive loss of gas when a line break occurs.

Supervisory Control and Data Acquisition (SCADA) system technologies, similar to those used in electric power transmission and distribution systems, are also used in gas transmission and distribution systems. The systems collect and use automated data to monitor and control the flow of gas through transmission and distribution pipelines.

☼ CAREER PROFILE: Corrosion/Cathodic Protection Technician

Julie S. works as a corrosion technician for a large, multistate natural gas company. Her job takes her around the country as well as offshore. "My job is to inspect pipelines for signs of degradation. Over time, they can be worn away by many environmental factors, and we have methods for protecting them, but they are not 100 percent effective," explains Julie. "Sometimes the corrosion is on the outside; sometimes it's on the inside."

Her job requires her to collect, record, and analyze historical and current data and new critical information in order to monitor and correct the cathodic protection system's performance. Julie's two-year degree in electrical engineering technologies gave her the background knowledge for working with a complex electrical system. Her coursework also included topics such as the basis of materials science and electrochemistry.

Since her graduation, Julie has worked in the natural gas industry for five years. This year she will be taking the Corrosion Society (formerly the National Association of Corrosion Engineers) course on internal corrosion and the certification test.

Science Connections

A Closer Look at Corrosion

Corrosion refers to the wearing away of metal that takes place through a chemical reaction. Rust is a familiar example. When iron is exposed to water and oxygen, it undergoes a process in which the iron (Fe) has its electrons stripped away, and it becomes iron oxide (Fe++). Iron oxide is the common name for rust. Thinking about the rust that you've seen—with the metal crumbling into orange flakes—you can see how corrosion would be a problem for large metal structures such as pipelines or offshore drilling rigs.

Corrosion can be controlled by applying a noncorrosive coating to the metal surface and by using cathodic protection equipment. One method of cathodic protection involves connecting metals that are more likely to corrode (more electrochemically active) to the metal that needs to be protected. Metal can also be protected by a flow of DC power.

©2011 FERC

Local Distribution

The natural-gas distribution system consists of high-pressure distribution mains, semi-high-pressure distribution mains, and low-pressure distribution mains. Operating pressures are regulated from 60 psi down through 25 psi to less than 1 psi for final delivery to a customer.

☼ CAREER PROFILE: Gas Distribution Technician

811®
Know what's below.
Call before you dig.

Howard K. has been a gas distribution technician for ten years. "I got here through an apprenticeship," he notes. "And I recommend that career path to others who want to get into this industry." Howard is responsible for the maintenance and operation of distribution mains. He also works closely with construction and excavation crews to find, locate, and mark pipeline locations before digging. In cases of large main breaks, he coordinates his efforts with local officials to ensure public safety. He's also on a rotating schedule to respond to the One-Call 8-1-1 system. By law, you must call before you dig—giving the utility enough time to mark your property. (State laws vary from 48 to 72 hours, most excluding weekends and legal holidays.)

© Common Ground Alliance

Community Connections

Have you seen these flags?
A gas distribution technician will mark various underground utility locations with flags color-coded to indicate the type of service.

- •Red–Electric
- •Orange–Communications, Telephone/CATV
- •Blue–Potable Water
- •Green–Sewer/Drainage
- •Yellow–Gas/Petroleum Pipe Line
- •Purple–Reclaimed Water
- •White–Premark site of intended excavation

U.S. Department of Transportation, Pipelines and Hazardous Materials Safety Division

Regional transmission pipelines connect to lower-pressure distribution mains that connect to local valves. A "**city gate station**" is the term used for the location at which a local gas company receives natural gas from long-distance pipelines. Large cities may have multiple gate stations. These are the connection points where the transmission pipeline network joins a local gas company's system of underground piping, the local distribution system.

Focus on …

Essential City Gate Functions

- Cleaning of incoming gas to remove any impurities that may have been picked up during transport in transmission pipelines.
- Reduction of pressure to lower levels suitable for the local distribution system.
- Measurement of gas received through the transmission network.
- Addition of chemical odorant for safety purposes.

PG&E, 2011

☼ CAREER PROFILE: Metering and Regulating Technician

Jorge Y. is a metering and regulating (M&R) technician for a municipal utility. It's his job to maintain the city gate, a vital part of the natural gas distribution system. He installs, operates, and maintains odorizers and meters; calibrates instruments; checks on delivery pressure in the pipelines and operation of all valves; and makes corrections or repairs where needed. Jorge enjoys his job because, "It's both mechanical and technical. I get to work with my hands, but I also have to know math for calculating the volume of gas flow to customers and understand computers for some of the automated functions."

Before working as an M&R technician, Jorge worked as a service technician. His job experience made him want to know more, so he enrolled in and completed a year-long certificate program at a nearby college. He uses his skills and knowledge to ensure that an adequate flow of natural gas to customers is maintained.

After passing through the city gate station, the gas enters the underground network of pipes of the local distribution system. Pipes carry the gas under the streets to buildings in the community. Many gas mains are made of cast iron. In recent years, steel pipe has been used in the construction of new mains and for replacement of old piping. Steel pipe is coated with various kinds of rustproof materials to enhance the longevity of its service life.

Local gas distribution systems are divided into sections. Each section can be shut off by closing a valve in the street main. These local valves provide a way to isolate sections of a main for maintenance, repair, or in emergency situations. Individual service connections branch off of the street main and are attached to each home or business.

Did you know?

Distribution Pipelines

There are over 3 million miles of city mains and service pipelines in the U.S.

U.S. Energy Information Administration, 2017

☼ ACTIVITY: Pipeline Construction, Design and Components

Research how materials and processes have changed for the design, manufacturing, and construction of pipeline systems.

What variables in materials (iron, steel, plastic) and design (safety and control features such as sectional design and valves) affect quality assurance factors in pipeline transportation systems?

Individual Service Connections

The individual service connections, commonly called "service pipes" or "gas services," are the pipes that connect the distribution mains to a customer. These service pipes are usually 1 or 2 inches in diameter. The service pipe extends from the street main underground to a home gas meter. Service regulators located at a customer's meter reduce the gas pressure to a lower standard delivery pressure.

Gas Meters

Gas flows through a meter into the pipes in a home to supply the oven, cooktop, water heater, home-heating furnace or boiler, and other gas appliances.

Service shut-off valves are located at a customer's meter and can be used to turn off the supply of gas to a house in the event of an emergency.

Did you know?

Meter Capacity

Gas meter manufacturers are utilizing new materials and designs to produce smaller, more accurate, and longer lasting meters.

New smaller meters have about the same capacity as the lungs of an average man.

When a man breathes normally, he inhales about 1/10 to 1/7 of a cubic foot of air. If he inhales at the normal rate of 14 times a minute, he is taking in about 80 to 120 cubic feet of air an hour, which is much the same capacity as a small gas meter.

PG&E, 2011

☼ CAREER PROFILE: Gas Service Technician—Emergency Response

As with many of the jobs in the utility industry, communication is key to Shelly R.'s success as a "first responder" to potential gas emergencies. "I'm called out, sometimes in the middle of the night if I'm on rotation for that time, when customers believe they smell a gas leak. My first task is to arrive quickly and make sure the building's residents are safe. If it's a family home, they may be scared. The dispatcher may have asked them to leave the premises and to wait for me to arrive to investigate the fumes. I have to be calm and professional and verify what they told the dispatcher."

As a gas service technician, Shelly uses equipment to detect leaks indoors and outdoors, inspects service lines and house lines, performs pressure checks, shuts off gas service if necessary, and restores service when the problem is corrected. Under less routine or more hazardous situations, she may need to establish immediate contact with her supervisor or with local authorities such as the fire department.

"The bottom line is safety," says Shelly. "A gas leak has the potential to be deadly. Our company has technicians on-call 24/7 who can make it out to a site within an hour or less. My job is to get there, troubleshoot the situation, and make repairs or make the location safe so that the problem can be remedied asap."

New Metering Technology

Innovations in gas metering include the use of advanced, electronic meter-reading systems. These systems allow for the remote transfer of meter information.

☼ ACTIVITY: Comparing Advanced Metering Technology

Compare and contrast the technology advancements in electric power metering and natural gas metering.

Has one industry experienced more technological advancements over the other? What factors have led to advancements in both of the industries?

☼ CAREER PROFILE: Gas Service Technician—Operations and Maintenance

Sal Q. is a gas service technician called out for routine, nonemergency situations. "It may not technically be an emergency," says Sal, "but a furnace that goes out in the middle of winter feels like an emergency to my customers. I'm glad to be able to help them." A typical day may involve installing gas meters and service regulators; installing new appliances such as ovens, dryers, and hot water heaters; testing pipeline connections for gas pressure and flow; and repairing worn or defective parts.

Formed in March 2006, the Center for Energy Workforce Development (CEWD) is a non-profit consortium of electric, natural gas, and nuclear utilities, contractors and their associations—Edison Electric Institute, American Gas Association, American Public Power Association, Nuclear Energy Institute, National Rural Electric Cooperative Association, and Distribution Contractors Association.

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