STUDENT GUIDE

Energy Industry Fundamentals

CEWD
CENTER FOR ENERGY WORKFORCE DEVELOPMENT

MODULE

1

HISTORY AND ORGANIZATION OF THE INDUSTRY

STUDENT GUIDE

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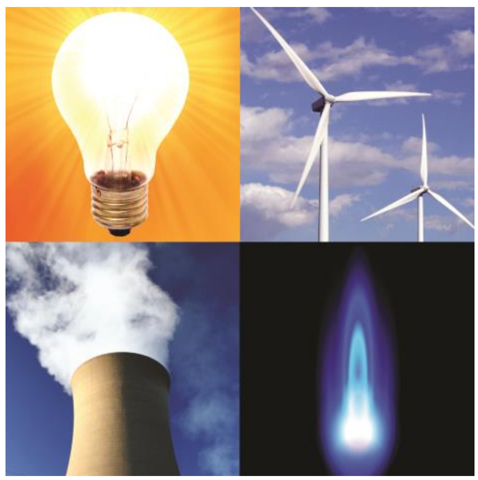

MODULE

1

HISTORY AND ORGANIZATION OF THE INDUSTRY

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UNIT A: HISTORY OF THE U.S. ENERGY INDUSTRY AND INFRASTRUCTURE

When we think of the history of electricity, we usually think of Benjamin Franklin. But his famous kite experiment with lightning didn't occur until 1752. The first recorded observations of the properties of electricity—notably its ability to shock—were made by ancient Egyptians observing electric fish in the Nile River. Much later, in about 600 BC, Greek philosopher Thales of Miletus added to our knowledge of electricity by describing the attraction that develops when amber is rubbed with fur or a piece of silk. Today we observe the same phenomenon, **static electricity**, when we pull socks from a warm clothes dryer or rub a balloon across our hair—static "cling" from the attraction between two objects with different charges, positive (+) and negative (−). While static electricity can give you quite a shock when **electrons** are discharged, it is not useful as power. Power comes from **current** electricity, the flow of electrons along a path composed of a **conductor** material such as water or specific metals.

Focus on …

Franklin's Famous Kite

…it occurred to him that he might have more ready access to the region of clouds by means of a common kite. He prepared one by fastening two cross sticks to a silk handkerchief, which would not suffer so much from the rain as paper. To the upright stick was affixed an iron point…. Where the hempen string terminated a key was fastened…. He placed himself under a shade to avoid the rain; his kite was raised; a thunder-cloud passed over it; no sign of electricity appeared. He almost despaired of success, when, suddenly, he observed the loose fibers of his string to move towards an erect position. He now presented his knuckle to the key, and received a strong spark.

MEMOIRS OF BENJAMIN FRANKLIN, 1839

Until 1821, when Michael Faraday developed a very rudimentary electric motor, discoveries about electricity were primarily confined to the realm of scientific theory and had no value to the average citizen. Starting in the mid-1800s, however, clever inventors began to see the potential for harnessing its power to benefit society. Samuel Morse invented the telegraph in 1835, revolutionizing communication by allowing messages to be transmitted long distances via wires. In 1844, Congress authorized funding to construct a telegraph line from Washington to Baltimore. Telegraph lines quickly proliferated throughout the United States and attracted the attention of Thomas Edison, who served as a telegraph operator in cities throughout the Midwest from 1863 to 1867 and then moved to the main Western Union telegraph company office in Boston in 1868. He soon turned his efforts toward inventing refinements to the telegraph system, such as the ability to send multiple messages at once. His continuing experimentation led to multiple patents and his establishment of a research facility at Menlo Park, New Jersey.

Critical Thinking

Truth or Urban Legend?

Jordan ran out of gas while mowing the lawn. He drove his pickup truck to the gas station to fill a portable container to take back to his lawnmower. Rather than lift a heavy can full of gas back into the bed of the truck, Jordan reasoned that it would be easier just to fill the can while it sat in the truck bed. He put the nozzle into the gas can and flipped the pump switch to the “on” position. A spark flew and the truck caught fire. Jordan escaped with minor burns, but the truck was damaged beyond repair. *Could this really happen? Why or why not?*

Of the 1,093 patents granted to Edison, 356 dealt with electric lighting and the generation and transmission of electricity. Did you know, however, that Edison didn’t invent the electric incandescent light bulb? Joseph Swan did in 1876. The trouble was that Swan’s light bulbs burned out quickly. Two years later, Thomas Edison founded the Edison Electric Light Company in New York City and, seeing great potential for commercialization, bought a number of patents related to electric lighting. After many experiments, he developed a light bulb that could burn for 40 hours, and by 1879 his bulbs would last 1,200 hours. Prior to this time, from 1816 onward in the U.S., natural gas was burned for illumination. The metered system of measuring and paying for consumer gas usage eventually became the model for electricity purchase. Metering allows suppliers to bill for the actual amount of energy used rather than the number of lights illuminated per month.

On September 4, 1882, Edison opened the Pearl Street Station—one of the first electricity-generating plants. Powered by steam engines, it provided **direct current** (DC) only and could distribute electricity to customers within a one-mile radius. In lieu of overhead transmission lines, Edison designed a system of underground tubes called conduits through which he ran thick, electricity-conducting copper wire. A few weeks later, a **hydroelectric** electricity-generating plant began operation in Appleton, Wisconsin. Consumer demand for electric service quickly increased with the advent of labor-saving devices such as the electric iron and fan that same year.

Quick Facts

The Chicago Worlds’ Fair

Credit: Brooklyn Museum Archives

- 120,000 incandescent lights were used
- The power plant to run them cost $1,000,000 to build

Another technological breakthrough was the installation of the nation's first large-scale electric streetcar system covering twelve miles in Richmond, Virginia. Thomas Sprague, a former researcher in Edison's laboratory, improved upon the safety and efficiency of others' designs and successfully launched the line in 1888. Just as electric illumination eventually replaced the use of gas lighting—a transformation greatly aided by the public display of incandescent lighting at the 1893 World's Columbian Exhibition in Chicago—so also electric streetcars replaced horse-drawn public transportation.

Critical Thinking

DC vs. AC

Why does a regular battery lose power?

What are the benefits of AC over DC as a household power source?

The advent of the induction core and **transformer** and the ability to use high-voltage **alternating current** (AC) rather than just DC further developed the efficiency of our modern power system. The system allows voltage to be **stepped-up** and the high-voltage power to be transmitted long distances and **stepped-down** for consumer use at the outlet. In 1888, George Westinghouse, a rival inventor to Edison, bought the patents to Nikola Tesla's AC current system and to Charles Bradley's rotary converter.

The resulting improvements to the electric power system resulted in

1) **economies of scale** in generation,
2) the need for only one wiring grid,
3) the ability of generating stations to serve a wider area, and
4) the new system's productivity increasing from **load diversity**.

Focus on ...

Public Utilities

A **public utility** provides and maintains the infrastructure for providing a public service. Municipal or county utilities not only provide electric service but also often include provision of water and waste-disposal service to homes and businesses. Consumers have more choices in selecting gas, electric, and telecommunications providers. Each state has a Public Utility Commission or Public Service Commission that governs issues such as rates, safety, reliability, market competitiveness, and consumer complaints.

Origin of Economic Laws and Regulations

With the scale-up of power companies, entrepreneurs began buying smaller public utilities and creating larger ones—**holding companies**—in an effort to benefit from economies of scale. In an address before a convention of the National Electric Light Association (1898), Samuel Insull, a major investor in electric utilities, outlined the profit structure:

Some companies have adopted the scheme of allowing certain special discounts provided the income per month per lamp connected exceeds a certain amount. Other companies charge one rate for energy used during certain specified hours of the day and a much lower rate for that used during the remaining hours of the day. A third method is a system of discounts based on the total consumption of energy during a given period, *considered in connection with the maximum consumption at any time during the same period. These various methods all have the same object in view—the meeting of the conditions of each individual consumer, and yet at the same time earning a fair return on all of the investment provided for all of your customers.*

Insull went on to argue that burgeoning electric utilities were essentially **natural monopolies** to which exclusive regional franchises should be granted in exchange for public control of the prices charged for service. Because monopolies in the United States were outlawed by the **Sherman Antitrust Act** of 1890 (followed by the **Clayton Antitrust Act** of 1914), regulation of the utilities was a necessity. Power companies were exempt from competition and, in return, subject to regulation at first primarily by state agencies, due to the local nature of electricity generation. In 1920, the **Federal Power Commission** (FPC) was created to coordinate **hydroelectric power** projects under federal control. The commission was unfunded until 1928 when Congress allocated the money for a five-person bipartisan committee given the power to regulate the sale and distribution of electricity under the **Federal Power Act** and later natural gas facilities.

With the expansion of the electric utility companies, holding companies such as those owned by Insull began to take advantage of the business structure by building pyramid-type schemes in which a few stockholders controlled electric companies nationwide. It was difficult for states to regulate utility holding companies because they conducted business across many different states. In fact, the Supreme Court determined that states could not regulate sales of electricity and natural gas in interstate commerce. Ultimately, consumers suffered from the increased cost of electricity.

As a result, the **Federal Trade Commission** launched an investigation into the practices of large utility holding companies in 1928, continuing through the stock market crash of 1929 (which destroyed **holding company** value), the establishment of the **Securities and Exchange Commission** (SEC), and into Franklin Roosevelt's presidential campaign. Following his re-election, Roosevelt signed into law the **Public Utility Holding Company Act (PUHCA) of 1935**.

The PUHCA accomplished the following:

1) Required giant interstate utility holding companies to rid themselves of several layers of holdings until they each were a smaller, consolidated system serving a specific geographic area.
2) Prohibited energy holding companies from engaging in business other than operation of a single utility.

Did you know?

Obligation to Serve

Because consumers have traditionally had few choices for utilities service under the natural monopolies concept, regulatory agencies were established to help ensure that those utilities meet their **obligation to serve**. Under this concept, service is expected to be reliable (uninterrupted) and safe; equipment must be adequate to handle the **load**; and prices should be affordable. Individual states have their own utilities commissions (the Florida Public Services Commission, for example) that oversee rates, market competition, and service.

3) Required holding companies to be incorporated in the state where the utility operates so the company can be regulated by that state; or, if incorporated in several states, to be regulated by the SEC.
4) Required holding companies to register with the SEC. Allowed the SEC to authorize restructuring of holding companies if they failed to streamline as required under the Act.

Critical Thinking

What are the limits of obligation to serve?

Are there utilities or services similar to utilities that do not operate under an obligation to serve?

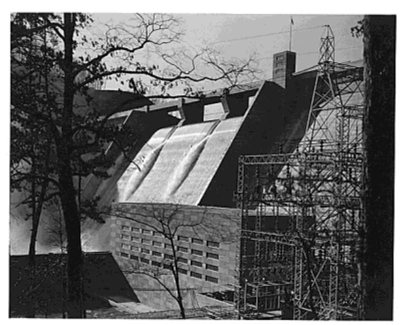
While the PUHCA was targeted at the electric utility industry, it also applied to natural gas companies. The Act prevented non-utility holding companies from acquiring gas utilities and engaging in activities unrelated to efficient operation of a single integrated utility system. PUHCA has shaped both the gas and electric utility industries and their relationships with each other with respect to mergers, acquisitions, and overall business strategies. Another law regulating the gas industry, the **Natural Gas Act** of 1938, restricted the price gas companies—operating as natural monopolies just like electric companies—could charge consumers.

The demand for natural gas for use in the production of electricity did not grow until after World War II, with a notable increase during the oil supply crisis of the 1970s. In 1977, Congress reorganized the FPC as the **Federal Energy Regulatory Commission** (FERC), increased the breadth of its powers, and soon thereafter passed the **Public Utilities Regulatory Policies Act** (PURPA). PURPA was intended to reduce U.S. dependency on foreign oil, promote energy efficiency, develop alternative fuel sources, and diversify the electric power industry. Part of that diversification involved allowing non-utilities to generate and sell power. PURPA required electric utilities to restructure their rates, but more importantly, to purchase power from independent companies that produce electricity as a by-product of other activities. This is accomplished through **cogeneration**, a process in which electricity and heat are produced at the same time from the same fuel or energy source. Natural gas often serves as the fuel in cogeneration systems where steam is produced along with electricity. Because of the restrictions placed on electric utilities under PURPA and PUHCA, however, increase in natural gas as a direct fuel source for electricity generation was limited. This changed in 1992 with the passage of the **Energy Policy Act**, which helped promote significant growth in gas-fired, electricity-generating capacity and marked the beginning of competition in the electric power industry. FERC could not mandate that an electric utility open its

Focus on ...

Providing Electricity Beyond Large Cities

President Franklin D. Roosevelt created the Tennessee Valley Authority (1933) and the Rural Electrification Administration (1935) to ensure that electricity could be distributed to outlying areas. At Norris Dam, pictured below, the force of falling water is used to generate electric power.



Credit: Franklin D. Roosevelt Presidential Library and Museum transmission system for wholesale electric trade until this Act amended the Federal Power Act and essentially deregulated the power industry economically.

The postwar era also saw the establishment of the concept of the **electrical power grid**—a network we usually envision as transmission lines but actually consisting of many interconnected electric generation, transmission, and distribution systems over a broad geographic area. The grid system is designed to provide enough electricity during **peak load**. The U.S. power grid is comprised of three major sections called Eastern, Western, and Texas, connecting not just regions of the continental U.S. but also parts of Mexico and all of Canada. Within this grid, more than 3,000 utilities operate approximately 10,000 power plants which are owned by several hundred private and public entities and overseen by **balancing authorities**. Multiple balancing authorities within each of the regional power grids ensure the reliable flow of power to customers. To put it simply, **reliability** means having uninterrupted access to electricity. A power outage can occur when a power line is damaged in a storm, a system component fails, or demand for electricity outweighs supply. This fact was driven home in November 1965 when a massive **blackout** shut down an 80,000-square-mile area, encompassing Ontario, New York, New Hampshire, Vermont, Massachusetts, Connecticut, Rhode Island, and parts of New Jersey and Pennsylvania. Four million homes in New York City alone were without power, and hundreds of thousands of commuters were stuck in the subway system until midnight. President Lyndon B. Johnson, in a strongly worded memo, directed the Federal Power Commission to investigate the failure. Investigators found that one transmission line relay failed, leading to a power surge followed by power grid overload and subsequent generator shutdown. One month later, in his report to the President, the FPC Commissioner sagely noted that:

The problem arises not because service is poor but because the universal and increasing dependence of the American public on this form of energy makes any wide-scale interruption seriously disruptive. The prime lesson of the blackout is that the utility industry must strive not merely for good but for virtually perfect service.

In response to this event, Congress proposed the creation of an agency charged with coordinating electric reliability. The U.S. Electric Power Reliability Act of 1967 did not become law but, urged by industry leaders, the FPC recommended the establishment of the **North American Electric Reliability Corporation** (NERC). NERC consisted of nine regional reliability organizations that urged voluntary compliance by electric utilities with its procedures for ensuring the reliability of the power system. For the good of the industry, utilities generally complied, although NERC had no enforcement power until the passage of another **Energy Policy Act in 2005**. Due to constantly increasing demand for electricity and regular occurrence of national disasters, temporary power outages are unfortunately not a thing of the past. The power industry, the U.S. Department of Energy's Office of Electricity Delivery and Energy Reliability, regulatory bodies, and consumers anticipate that equipment modernization and implementation of a **smart grid** system will decrease the number and severity of these events.

☼ CAREER PROFILE: Compliance Manager

As Compliance Manager at a power company serving a large metropolitan area on the East Coast, Jennifer L. wears many hats. Today, for example, she's leading a training seminar for System Operators on reliability standards established by the North American Electric Reliability Corporation (NERC). NERC is a self-regulatory organization but is still subject to oversight by the U.S. Federal Energy Regulatory Commission (FERC) and governmental authorities in Canada. Tomorrow she will be working with the plant's Security Manager on revision of the company's plans for preventing and reporting acts of theft and sabotage and breaches of cybersecurity. With the increased spotlight on global terrorism, protection of what is known as the country's critical infrastructure has become a bigger part of her job. Her plant is less likely to be crippled by physical sabotage than by a computer virus. A day-to-day issue, however, is the theft of valuable copper wire from power substations. Copper theft threatens the reliability of electricity delivery systems. In Florida, 4,000 consumers were left without power after thieves stripped copper wire from a transformer. Jennifer and her team are examining the feasibility of a two-pronged approach to curbing theft: a public awareness campaign and the installation of video cameras at substations.

Origin of Environmental Laws and Regulations

In addition to regulations and commissions governing the market for electricity and its availability to consumers, environmental laws affect the operation of utilities. The significance of air quality on human health became apparent in 1948, when 20 people died and 7,000 were hospitalized in Donora, Pennsylvania, due to complications from breathing toxic smog resulting from a combination of industrial **emissions** and a weather condition called a temperature inversion. In 1952, the Great Smog of London captured global attention as an opaque, yellowish-black cloud caused by a mixture of emissions from coal-fired power plants, household furnaces, and vehicle exhaust settled over the city. Thousands of people died, and the situation only got worse when ambulances stopped running after visibility dipped to zero. Researchers have analyzed public health insurance claims, hospital admission rates for cardiac and respiratory disease, pneumonia cases, mortality records, influenza reports, recorded temperatures, and air pollutant

Focus on ...

The Air We Breathe

Keeping the air breathable has long been a human concern—recorded in ancient civilizations, the Classical period, Medieval times, and up through the present era. We may think of environmental quality commissions as a relatively new development, but they are not. In 1285, a London commission was set up to investigate the smoke coming from burning coal. It met again in 1288 and 1306, at which time a ban against burning coal was decreed (but largely ignored). Fast-forward to 1854, when prolific writer Charles Dickens not only fictionalized the blackened skies of industrial London in his novel *Hard Times* but also outlined, in his essay "Smoke or No Smoke," methods for complying with Lord Palmerston's Smoke Abatement Act. He first examined the use of coal gas, commonly used for gaslight, in which "one pound of coal suffices to make four cubic feet of luminiferous gas." He proceeded from there to argue for improved smokestack and home grating systems designed for more efficient—and less smoky—combustion of coal.

concentrations for December–February 1952–1953 and compared the figures with those for the previous year. Mortality rates during and following the Great Smog were dramatically higher than the previous year. In addition to the 3,000 who died immediately during the event, the researchers found an additional 12,000 who subsequently died from smog-related illnesses. These disasters served as a catalyst for laws in many countries designed to protect public health.

From 1955–1967, Congress passed a series of air pollution and air quality acts that funded research into techniques for monitoring and controlling air pollution. The Air Quality Act of 1967 signaled the beginning of federal enforcement of environmental standards. The establishment of the U.S. **Environmental Protection Agency** (EPA) coincided with the passage of the **Clean Air Act of 1970**. The Act and its amendments are designed to:

- reduce the concentration of outdoor air **pollution** that causes smog, toxic rain, and other problems
- reduce emissions of toxic chemicals that cause cancer or other serious health problems
- phase out the production and use of ozone-depleting chemicals
- require companies that release pollution into the air to obtain a permit stating which chemicals they release, how much, and their plan for reducing pollution
- strengthen EPA enforcement of air quality standards

☼ LAB ACTIVITY: Smog in a Jar

Materials needed for each group of 3 or 4 students:

- 2 glass canning or mayonnaise jars (or 1 to re-use if you have access to a sink)
- paper towels
- 2 tablespoons salt
- matches
- 6 ice cubes
- aluminum foil
- a small amount of water

Trial 1 Directions:

1) Create a tight lid for the jar out of aluminum foil. Press a small indentation into the top.
2) Twist a piece of paper towel into a rope.
3) Light the paper towel rope and drop it into the dry jar. Cover immediately with the foil lid.
4) Place 3 ice cubes in the indentation and sprinkle 1 tablespoon of salt on the ice.

Observation: What happens inside the jar?

Trial 2 Directions:

1) Repeat steps 1 and 2 with the second jar.
2) Tilt the jar and pour a few drops of water into the jar. Wet the sides only.
3) Repeat steps 3 and 4 (above).

Observation and Critical Thinking: What happens inside the jar this time? What conclusions can you draw about smog from the behavior of the smoke under each set of circumstances?

The EPA enforces rules requiring power plants that burn fossil fuels to reduce emissions of particle pollution, ground-level ozone, carbon monoxide, sulfur oxides, nitrogen oxides, lead, and mercury. The **Clean Air Act of 1990** established a system of emissions trading ("cap and trade") designed to lower sulfur dioxide and nitrogen oxides released into the air. Under this system, there is a limit to the amount of emissions a company may release, but utilities can buy and sell emission permits called allowances. The incentive for participation is financial—pollution reduction has a market value. And this, in turn, provides an incentive for investment in technologies that reduce regulated emissions.

Particle pollution (also called particulates, particulate matter, PM_{10}, and $PM_{2.5}$) is produced naturally from blowing dust but also any time fuels such as coal, oil, diesel, or wood are burned. Particulate matter is much, much smaller in diameter than a human hair. Particles with a diameter of up to 2.5 micrometers are labeled $PM_{2.5}$ and with a diameter of up to 10 micrometers are PM_{10}. The smaller particles are more dangerous to human health because they can penetrate the lungs more easily and also because they tend to be composed of more dangerous substances such as heavy metals and toxic organic compounds. The EPA calculates the Air Quality Index (AQI) for five of the air pollutants regulated under the Clean Air Act, including particulates. Each day more than a thousand monitors throughout the country gather and report air quality data.

Community Connections

Your Air Quality Forecast
You can check your local AQI by visiting http://www.airnow.gov/ to view your regional conditions and forecast.

☼ ACTIVITY: Why Regulate Emissions?

Various federal, state, and local agencies regulate what can and cannot be discharged into the environment. In this activity, you will research regulated pollutants (nitrogen oxides, sulfur dioxide, and particulate matter) and their potential health and environmental impacts and complete the table on the worksheet provided by your instructor.

Power plants and other industries that burn fossil fuels have various technologies for mitigating air pollution. **Wet scrubbers** remove sulfur dioxides and some particulates from smokestacks by allowing exhaust gases to pass through a fine water spray that contains lime, a compound that absorbs most of the sulfur. Cyclones, sometimes described as centrifugal separators, consist of cylinders through which polluted air is passed. As the particulates hit the walls of the cylinder, they fall to the bottom and can then be removed. A dry or semi-**dry scrubbing system**, unlike the wet scrubber, does not saturate the flue gas stream that is being treated with moisture. In some cases, no moisture is added, while in others only the amount of moisture that can be evaporated in the flue gas without condensing is added. Therefore, dry scrubbers generally do not have stack steam plume or wastewater handling/disposal requirements. Dry scrubbing systems are used to remove acid gases (such as SO_2 and HCl) primarily from combustion sources. **Electrostatic precipitators**, which remove about 99 percent of the particulates, use an electric field that charges the pollutant particles. These particles then are attracted to the walls of the precipitator, which has an opposite charge. When the power is turned off, the walls no longer hold their charge and the particulates detach and fall into a collection chamber.

Carbon dioxide emissions, while monitored, are not regulated at this time although the EPA has studied the issue in depth and Congress has proposed legislation for a cap and trade system for regulating this **greenhouse gas**. The EPA also regulates **effluents**—polluted water discharged into wastewater—to a lesser degree. Plants generating power from nuclear energy produce radioactive waste, release non-radioactive emissions, and create thermal effluents—overheated water that can impact marine life. Regulation of these outputs is overseen by the **Nuclear Regulatory Commission**.

☼ ACTIVITY: CO_2 Cap and Trade: Pro or Con?

The need for capping carbon emissions has been vigorously debated by scientists, elected officials, regulatory agencies, industry representatives, and the general public. Divide into 10 groups of 2 or 3 students. Each group will be assigned an affiliation (scientist, for example) and a side (for or against carbon cap and trade) and will investigate the issues and concerns of interest to their affiliated group.

Equipment required: Computer with Internet access for research

Optional: PowerPoint, poster board, and markers

Research questions to be addressed:

- Who is your affiliated group?
- Why are you interested in carbon emissions?
- What is your point of view (pro or con)?
- What will happen if your affiliated group is not able to persuade others?

You will be asked to present your persuasive argument to the class.

Unit A Glossary

alternating current (AC)—an electric current that reverses its direction at regularly recurring intervals

balancing authority—a regional organization responsible for planning for and maintaining the balance of electricity resources and electricity demand

blackout—power loss affecting many consumers over a large geographical area for a significant period of time

Clayton Antitrust Act of 1914—building on the Sherman Antitrust Act, this law allows the Federal Trade Commission and Department of Justice to approve all proposed mergers

Clean Air Act of 1970 and Clean Air Act of 1990—laws that define the EPA's responsibilities for protecting and improving the nation's air quality and the stratospheric ozone layer

cogeneration—process in which electricity and heat are produced at the same time from the same fuel or energy source

conductor—a material along which electrons easily flow; the opposite of a conductor is an insulator

current—a flow of electrons along a path, such as a conductive wire

direct current (DC)—current that moves in only one direction; DC results from a constant polarity power source (see "polarity" in Glossary)

dry scrubbing—dry scrubbing systems are used to remove acid gases (such as SO_2 and HCl) primarily from combustion sources

economies of scale—when cost of production falls because output has increased

effluent—substance released into a body of water

electrical power grid—interconnected electric generation, transmission, and distribution systems over broad geographic areas—Eastern, Western, and Texas

electron—negatively charged particle outside the nucleus of an atom

electrostatic precipitator—a device for removing small particles (such as smoke, dust, or oil) from a gas, such as air, by passing the gas first through an electrically charged screen that gives a charge to the particles, then between two charged plates where the particles are attracted to one surface

emissions—substances released into the environment; usually used to refer to substances discharged into the air

Energy Policy Act of 1992—marked the beginning of competition in the electric power industry

Energy Policy Act of 2005—gave NERC enforcement power for reliability standards

Environmental Protection Agency (EPA)—agency tasked with enforcing laws protecting human health and the environment

Federal Energy Regulatory Commission (FERC)—independent regulatory agency within the Department of Energy and the successor to the Federal Power Commission; it governs interstate electricity sales, wholesale electric rates, hydroelectric licensing, natural gas pricing, oil pipeline rates, and gas pipeline certification

Federal Power Act of 1928—provided funding for the Federal Power Commission, a five-person bipartisan committee given the power to regulate the sale and distribution of electricity

Federal Power Commission of 1920—created to coordinate hydroelectric projects under federal control

Federal Trade Commission (FTC)—created in 1914 to enforce laws against monopolies; has since evolved into the agency that also administers consumer protection laws

greenhouse gas—gases that trap heat in the atmosphere such as carbon dioxide, methane, nitrous oxide, and hydrofluorocarbons

holding company—a company which owns or holds stock in other companies, which it then manages and operates

hydroelectric power—power generated by using moving water to power a turbine generator to produce electricity

load—device or customer that receives power from the electric system. Load should not be confused with demand, which is the measure of power that a load receives or requires

load diversity—when the peak demands of a variety of electric customers occur at different times

Natural Gas Act of 1938—legislation restricting the prices gas utilities could charge consumers

natural monopoly—a situation in which smaller companies are not able to compete with big companies in a particular industry sector and as a result a large company dominates the market; this results from the large company benefiting from economies of scale (meaning that the bigger company is able to operate more efficiently and offer services more cheaply to the consumer) and/or requires huge capital investments for equipment (meaning that no other companies want to spend the money needed to compete in the market)

North American Electric Reliability Corporation (NERC)—formed in 1968 in response to the 1965 blackout, NERC is the electric reliability organization certified by the Federal Energy Regulatory Commission to establish and enforce reliability standards for the bulk-power system. All bulk power system owners, operators, and users are required to register with NERC

Nuclear Regulatory Commission (NRC)—regulates nuclear power plants and other uses of nuclear materials, such as nuclear medicine, while protecting humans and the environment

obligation to serve—the obligation of a utility to provide electric service to any customer who seeks that service, and is willing to pay the rates set for that service; traditionally, utilities have assumed the obligation to serve in return for an exclusive monopoly franchise

peak load—time of highest demand for and use of electricity

polarity—the orientation of the positive and negative poles of a power source

pollution—the introduction of harmful contaminants into the environment

public utility—maintains the infrastructure for providing a public service such as gas, electric, water, and waste-disposal service

Public Utilities Regulatory Policies Act of 1978 (PURPA)—a law passed promoting more efficient use of fossil fuels and greater use of renewable energy for generating electricity.

Public Utility Holding Company Act of 1935 (PUHCA)—law that severely limited acquisition of any wholesale or retail electric business through a holding company and restricted ownership of an electric business by non-utility corporations

reliability—the power system is able to meet the electricity needs of customers even when equipment fails or other factors reduce the amount of available electricity; consists of the adequacy and security of the electricity supply to consumers

Securities and Exchange Commission (SEC)—agency created by Congress in 1933; regulates interstate transactions in corporate securities and stock exchanges

Sherman Antitrust Act of 1890—outlawed monopolies in the United States

smart grid—modernization of the current grid technology; has the ability to monitor energy flow and communicate data back to utility companies; uses smart meters; takes advantage of distributed generation allowing smaller power sources to feed energy back into the grid; stores energy generated in off-peak hours and distributes it during peak hours

static electricity—an electrical charge that cannot move, created when two objects have been in contact and then are separated—leaving them with either too many or too few electrons (an electric charge)

stepped-down—conversion of high voltage electricity to lower voltage through the use of transformers at power substations

stepped-up—conversion of low voltage electricity to higher voltage through the use of transformers; a step-up transmission substation receives electric power from a nearby generating facility and uses a large power transformer to increase the voltage for transmission to distant locations

transformer—a device that changes the voltage of an electric current

wet scrubbers—installed on smokestacks to remove sulfur dioxides and some particulates by allowing exhaust gases to pass through a fine water spray that contains lime, a compound which absorbs most of the sulfur

Unit A References

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Unit A Photo Credits

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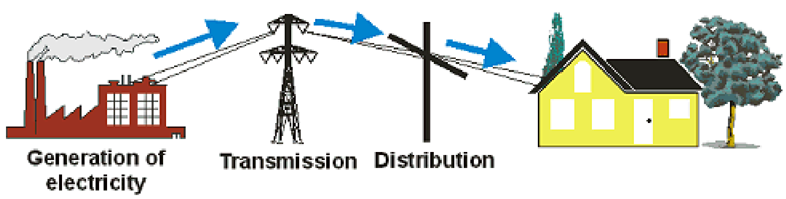
Unit B: The Energy Industry: Structure and Organization

UNIT B: THE ENERGY INDUSTRY: STRUCTURE AND ORGANIZATION

Overview of the Energy System

Energy is essential in our daily lives. Americans use an enormous amount of energy in their daily lives, at home, on the job, during recreation, in transportation, and the list goes on and on.

What is energy? Energy is the ability to do work, to lift an object, or to start it moving, for instance. Energy is needed to provide us with heat and light and power. When we need heat and light and power, we need energy. To get to us, electrical energy is generated, transmitted, and distributed. In the United States, our main sources of energy are the **fossil fuels** oil, natural gas, and coal.



U.S. Energy Information Agency

Energy from Petroleum

The petroleum-based segment of the energy industry includes the exploration, extraction, production, storage, processing, transportation, control, and distribution of crude and refined petroleum-based products. You use many petroleum-based products on a daily basis such as diesel, gasoline, and heating oil and also non-energy petroleum products like plastics. While petroleum is a very versatile compound, in the U.S. its use is primarily as fuel for transportation.

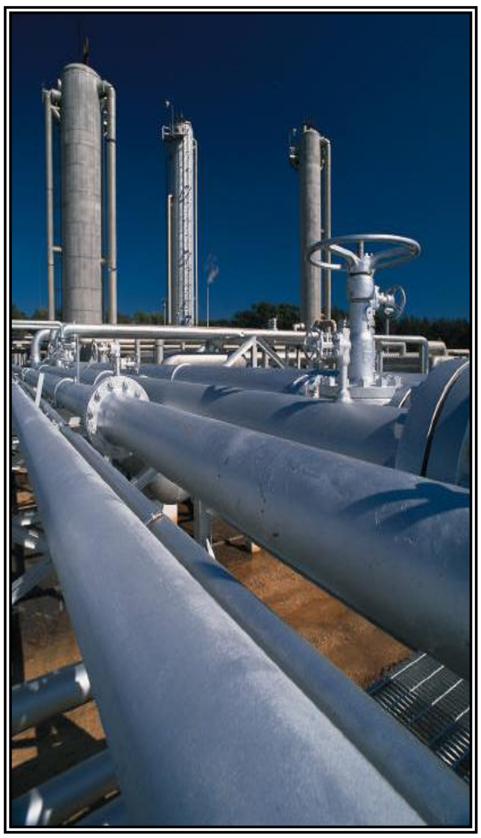
> Focus on ...
>
> **Oil and Natural Gas Systems**
>
> Exploration and Extraction
>
> Processing and Storage
>
> Control Systems
>
> Transport and Distribution

Pipelines play an important role in the petroleum energy sector. While pipelines are used for the transportation of various goods, perhaps the most widespread use of pipeline transportation is for the transfer of petroleum products.

Energy from Natural Gas

Natural gas is a fuel that can be used to cook food, heat water, heat and cool homes, and perform thousands of useful tasks in shops, plants, and factories. It is made mostly of methane, an odorless, colorless, and tasteless gas. You are probably familiar with the distinctive odor of natural gas, however. Because of the hazards associated with gas leaks, as a safety precaution a scented chemical is injected into the gas. Even small gas leaks can then be detected and stopped. Most of the gas in pipelines, and all of the gas in city utility systems, is treated this way.

There are similarities between the petroleum and natural gas sectors of the utility industry. For example, both offer the opportunity for careers in exploration, extraction, production, storage, processing, transportation, control, and distribution. Both also rely heavily on pipelines. The natural gas industry has constructed over 200,000 miles of large-diameter pipelines for transporting gas.



The natural gas system starts with exploration and extraction through gas wells. Once natural gas is extracted from the ground in onshore or offshore fields, it is processed through cleaning and treatment systems before it enters the long-distance pipelines.

Did you know?

Natural Gas Storage

Natural gas can be liquefied for the purpose of transportation or storage. Liquefied Natural Gas (LNG) takes up about 600 times less space than gaseous state natural gas.

To move natural gas from the places where it is produced to the places where it is needed, the natural gas industry has constructed more than 200,000 miles of large-diameter pipelines. After cleaning and processing, pipelines then move the gas to a compressor station or a gas storage field before being fed again into high-pressure transmission lines. Transmission lines may be buried or suspended to cross rivers or other obstructions. Regulators on the transmission lines reduce pressure for high- and low-pressure distribution mains. Distribution mains connect to local valves, which provide a way to isolate sections of the main for maintenance or repair. Individual service connections are attached to each home or business.

A local gas company receives natural gas from the long-distance pipeline at what is called a city gate station. This is the connecting point where the pipeline joins the local gas company's system of underground piping, the local distribution system.

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. These principal underground pipes are called gas mains.

Local gas distribution systems are divided into sections. Each section can be shut off by closing a valve in the street main. These valves can be closed in emergency situations. The service pipes that supply gas to consumers' homes are usually one or two inches in diameter. A service pipe extends from the street main underground to a home gas meter. Gas flows through the meter into the pipes that supply your range, water heater, home heating furnace or boiler, and the other gas appliances in your home.

☼ ACTIVITY: Pipeline Transportation Systems

Using resources in the library or online sources, find general information regarding pipeline transportation and specific information regarding pipeline transportation of petroleum products.

Research, explore, and analyze the following concepts as they pertain to pipeline transportation systems:

- Advantages and disadvantages
- Cost-effectiveness
- Product time in transit
- Lead time for suppliers
- Consistency (delivery time variability)
- Flexibility (adjustment to shipper's needs)
- Loss or damage
- Safety
- Accessibility

Hypothesize and research what variables affect quality-assurance factors in pipeline transportation systems.

Research what government regulations and environmental constraints apply to pipeline transportation systems.

☼ CAREER PROFILE: Pipeline Engineer

Monica M. is a pipeline engineer for a petroleum company. Monica directs, reviews, and approves the preparation of pipeline project drawings and other engineering documents required for permitting, right-of-way acquisition, bidding, and construction of pipelines for her company. Monica must have knowledge of compliance with contract information requirements, codes, and standards regulated by clients, governmental agencies, regulatory departments, environmental and land subcontractors, landowners, and others.

Monica says, "My favorite part of my job is performing technical engineering assignments like pipeline route selection. It's like solving a puzzle. I have to take many variables into consideration such as constructability, the environmental, and right-of-way impacts." Monica uses her knowledge of construction methods to create pipeline designs for intrastate and interstate pipeline systems.

Monica travels to job sites and project meetings as necessary and also serves as a technical expert in meetings with customers and vendors. Monica says she enjoys the challenges of analyzing data to solve problems and is proud of the quality-control functions she performs that ensure safe and efficient pipeline operations.

Electrical Energy

The electrical energy system has to generate and transfer electricity based on the demand of customers, which requires the system to immediately respond to customers' energy needs. This requires the careful coordination of generation, transmission, and distribution of electrical energy for customers 24 hours a day, 365 days per year.

Historically, electric companies were **vertically integrated** in that electric utility companies provided generation, transmission, and distribution services. This has changed somewhat to less vertically integrated structures due to recent regulatory changes occurring in the industry in which generation, transmission, and distribution services are now commonly separate entities.

The source of electricity used by consumers varies. Some utilities generate all the electricity they sell, while other utilities actually purchase some of their needed supply on the wholesale market from other power producers.

Electric Power Generation

At generating plants, electrical power is generated by a number of different methods and then **stepped-up** by a **transformer** to a higher voltage to be sent out over the transmission lines. **Electric power generation** is decentralized, and the majority of generating plants are privately-owned and subject to federal and state laws and regulations.

Electricity can be generated through:

- Magnetism (generators and alternators)
- Chemical Reaction (batteries and fuel cells)
- Light (solar cells)
- Static Charges (lightning)
- Piezoelectric (Pressure) (microphone and telephone)
- Heat (thermocouple)

The majority of electrical energy used today is produced through magnetism. Electrical energy is created in a generator when a conductor is moved through a magnetic field or a magnet is moved across a conductor.

Although there are many fuel sources for powering the mechanical processes that generate electricity, the majority of the electricity used in the U.S. is generated by three main fuels: coal, natural gas, and nuclear.

Fossil Fuel

The burning of fossil fuels (such as coal, gas, and oil) is the most common method of electric generation in the U.S.

Coal is mined at its source and then transported, usually by rail, to power plants for use in generation. Natural gas and oil are also removed from their sources and transported by pipelines to power-generating plants. Fossil fuels are burned to create high-pressure steam or hot combustion gases that turn turbine-generator units that produce electricity.

Nuclear

There has been a recent resurgence in the interest of nuclear power. In nuclear power generation, steam is produced by the heating of water by nuclear fission. The steam passes through turbines, creating mechanical energy that produces electrical current. After the steam leaves the turbine, it is usually condensed back to water and pumped back into the nuclear-fueled boiler for the process to begin again.

Hydroelectric and Renewable Sources

In **hydroelectric power** plants, the mechanical energy to rotate the generator comes from the force of falling water pushing against the blades of a water turbine. The source of water for hydroelectric generation is usually a lake or reservoir located several hundred feet above the level of the water turbine and generator. Smaller hydroelectric plants can operate with less of a distance, as little as 20 feet. However, all hydroelectric plants need a constant flow of water in order to operate efficiently.

In power plants comprised of wind turbines, the mechanical energy that is used to create electricity comes from the force of wind pushing against the blades of a windmill. The output capacity of windmills is limited by the size of the windmill blades and volume of wind. Usually, multiple windmills will be located along mountains or hilltops, so that the output of the windmills can be combined in order to provide usable capacity levels.

Hydroelectric, windmill, and other renewable power generation sources are a small but growing percentage of electrical power generated in the U.S. More in-depth information regarding alternative energy sources will be covered in Module 3.

Electric Power Transmission

Electric power transmission is the bulk transfer of high-voltage electrical energy from its source at generating plants to substations. The electric power transmission system consists of power lines, substations, and control centers. Transmission lines provide the network that moves electricity from generation plants to distribution substations. As mentioned earlier, electrical transmission networks are interconnected in order to provide reliable and redundant routes for electrical power transmission.

The bulk energy transmission system can be compared to an interstate roadway network. Large amounts of electrical energy flow along the transmission system and enter and leave the interstate highway at key intervals. In the electrical transmission system, the entry and exit points are:

- Power plants that generate electrical energy and can be located several hundred miles away from the customers.
- Switching stations that provide control facilities for monitoring system operation and also provide interconnection with other transmission systems, even if they operate at a different voltage level.
- Other power grids, which can extend the interconnection of production facilities and allow for alternative routing in the event of operating emergencies and maintenance.
- Customers requiring high volumes of energy at high voltages, such as manufacturing plants or research facilities, are sometimes directly connected to transmission lines.
- Substations that lower the voltage so that electrical energy circuits are permitted to be routed to commercial and residential areas.

In 1996, the **Federal Energy Regulatory Commission** (FERC) opened the transmission lines owned by **investor-owned utilities** to all suppliers. This allowed an enormous influx of suppliers to compete for use of the lines in the wholesale electricity market.

As mentioned earlier, FERC also encouraged transmission-owning utilities to turn over control of transmission systems to **Regional Transmission Organizations** (RTOs) and **Independent System Operators** (ISOs) to ensure fair access to the transmission grid.

☼ ACTIVITY: Debate

Students should form two debate teams. One team will take the "Pro" position and another team will take the "Con" position on the topic.
An example topic might be: **Open transmission access is always best for the community.**
Teams should take time to prepare their position.
Have teams take five minutes for opening statements, five minutes each for rebuttal statements, and five minutes for closing statements.
Make sure large teams allow an opportunity for everyone to participate during the debate.
If time allows, have teams switch positions and repeat.

Electric Power Distribution

Electric power distribution is the transfer of high voltage electrical energy from substations to the end customer. The majority of customers are supplied from a distribution system that is an output of a substation, rather than the transmission or sub-transmission systems. The electric power distribution system consists of power lines, substations, and control centers.

Distribution lines provide the network that moves electricity from distribution substations to the end customer. Distribution systems are routed along local streets on overhead and underground distribution circuits. Distribution circuits have a **stepped-down** voltage to provide lower voltages for specific customer applications.

The Utility Industry

We rarely think about the vital presence of energy in our daily lives until there is some type of interruption in services that provide our modern-day conveniences. An enormous number of people and systems must work together on a local and national scale to meet the constant energy needs of consumers in the United States.

A Trip to the Power Company

Shawn and Brianna got married after she graduated from college and he returned from his second tour in Iraq. When they moved into their first house, they were shocked when they started getting piles of bills each month for water-sewer-trash pickup, electricity, Internet, cell phone, satellite dish, and natural gas, on top of their rent and car payments. They quickly determined that they needed to find out more about each of their bills, and how they could minimize them. Since their electricity bill was one of the highest and also one where they felt they could have better control over the amount they paid each month, they decided to start there. So they made a trip to their electric company's local business office. When they paid their bill, they asked to speak to someone who could explain the bill to them and help them figure out how they could save money on future bills. Madyson referred them to Corey in customer relations.

"How may I help you?" asked Corey.

"Our electric bill seems really high," said Shawn, "and we want to understand what all these charges are." Brianna added, "And we want to know what we can do to save money on electricity in the future."

"Let's take a look then and see what's going on." Corey took their electric bill and walked them through the information on the bill, describing what each section and charge on the bill meant.

☼ ACTIVITY: Reading Your Electricity Bill

Materials Needed:

- Copies of electricity bill(s), yours or one given to you by your teacher.
- Copy of the worksheet, *Reading Your Electric Bill,* for each student.

Answer the questions from the worksheet for the bill(s) you were given. Make a chart on the board of the total kWh used on each bill. Compare the information from your worksheet with others in the class. What was the highest usage for a month? What was the lowest usage? What was the highest cost per kWh? What was the lowest cost?

Research*: What steps can be taken to lower your energy bill? In class or small groups, create a brochure, fact sheet, or website that will help others save on their energy bills. Include a range of steps from simple, low-cost ideas to ones that will require greater effort and more expense. If possible, estimate the amount of energy each step could save.*

When Corey explained that the usage was based on their meter reading each month, Brianna interrupted to ask how the meter was read. "Our meter is on the back of the house, and we have a pit bull that goes crazy barking if someone even walks by the house on the road. Not too many people would be brave enough to go back in the yard to read the meter. Not that he has ever bitten anyone, the sweet lummox."

"That's a good question. In the past, we used analog meters that required a meter reader to come and read the dials on your meter each month. Now, most of our customers have been switched to digital 'smart' meters that relay information back to the company without the need for someone to read them each month. If you haven't been switched to the new meters, you will be in the next several months."

"Will all meters be switched to the smart type all over the country?"

"Eventually yes, but it will take time. Different utility companies in different states will have their own schedules for the phase-in process."

☼ Career Profile: Customer Service Representative

Corey S. from the scenario above is a customer service representative at an electrical energy retailer. He assists customers that come into the office with questions about their electricity bills and electrical service. Sometimes he goes to customers' homes and conducts energy audits to help customers identify things they can do to save electricity.

Most customer service representatives use computers, telephones, and other technology extensively in their work. They might deal with customers in person, by phone, or by e-mail, online chats, or other means. Customer service representatives may have to deal with difficult or irate customers, which can be challenging. However, the ability to resolve customers' problems can be rewarding also.

Most customer service representative jobs require a high school diploma; however, some companies are requiring an associate's or bachelor's degree. It is essential that the customer service representatives have good communication and problem-solving skills. They must be able to listen and discern customer problems. Basic to intermediate computer skills are required, as well as good interpersonal skills. The ability to deal patiently with problems and complaints and to remain courteous when faced with difficult or angry people is critical. Employers look for people who are friendly and possess a professional demeanor.

Often, customer service jobs are a good introduction to a company, and employees may choose to move into other areas of the company as they learn more about the industry.

What Is a Public Utility?

Public utilities, such as electricity, gas, and water, provide vital services that have a significant impact on our daily lives. Public utility is a term commonly used to refer to a group of businesses that supply vital services, which are subjected to the regulation of rates and service practices. Public utilities usually include water service, phone service, waste-management service, and electric service.

Public utilities differ from other regulated business sectors in the way in which they provide and charge for services. In addition to providing energy, communications, and water services, public utilities play a major role in the American economy by contributing to business activities such as investment opportunities, tax revenues, and employment.

In the previous unit, the historical and legal precedent for regulation of the energy industry was reviewed. A key point is the involvement of government in the regulation of prices and quality of services in sectors whose services are vital to society.

Historically, utility companies were established as vertically integrated entities, which means the companies were involved in multiple steps for accomplishing the creation, production, and distribution of the goods or service they provided. While traditional vertically operated utilities are still the most common, a multitude of new companies have emerged as energy regulations, standards, and markets have changed.

Utility Service Standards

The primary purpose of the energy and utility industries is to provide safe, adequate, and reliable services to the public. Service standards that ensure safe, adequate, and reliable service are critical to the infrastructure of energy utilities. As mentioned in the previous unit, historically, the electric power industry operated in a strictly regulated environment well into the early 1980s, when a regulatory shift began to occur. Presently, the industry is changing again due to factors such as retail competition, wholesale competition, deregulation, and re-regulation. The industry is being restructured and becoming increasingly diverse to include new entities that produce, sell, transmit, or distribute electricity.

☼ ACTIVITY: Energy Audit/Efficiency Spokesperson

Invite a spokesperson from a local energy utility to speak about measures to save energy in the home. Ask the speaker to discuss the costs and effectiveness of energy efficiency measures and strategies for reducing monthly bills.

Utility Company Structures

The term "public utility" refers to the nature of the business, not to the ownership of the organizations. Most public utilities in the United States are investor-owned. Governmental organizations and the service users own the remaining public utilities.

Investor-Owned Utilities (IOU)

Privately invested electric power companies were the earliest form of business structure for the electric power industry. Investor-owned utilities are the most predominant type of utility in the U.S. today. There are more than 180 investor-owned utilities in the U.S.

Investor-owned utilities are privately owned by individual investors, private funds, and private pension plans that purchase shares or stocks in the investor-owned utility for the purpose of receiving a financial return on investment. Investors of any company take on a risk that the company will be profitable and provide an annual return. These investors elect a board of directors who select the management and leadership teams that operate the organization.

These organizational leaders use investors' money to build, upgrade, and maintain the business system. The organization charges customers for the use of the delivery system based on the amount of energy that they purchase from the energy producer of the customer's choice.

Most investor-owned utilities perform generation, transmission, and distribution functions and work in a vertically integrated manner.

The Edison Electric Institute (EEI) is a nonprofit organization that serves as an advocate for shareholder- (investor-) owned utilities. The Electric Power Research Institute (EPRI) is another industry association that conducts research regarding generation, delivery, and use of electricity.

Municipal Utilities (Muni)

Local municipalities are the most numerous type of utility. There are more than 2,000 community-owned utilities in the United States. Historically, **municipal utilities** were created to provide service to their respective local community in cases where service needs were not being met by other providers.

Municipal utilities are nonprofit entities that are publicly owned and controlled by local government agencies. Municipal utilities may include the following services: natural gas, water, sewage, and telecommunications.

Municipal Electric Utilities

Most municipal electric utilities just distribute power to their customers, but a small number actually generate and transmit electricity too.

American Municipal Power (AMP) and the American Public Power Association (APPA) are nonprofit organizations that serve as advocates for public (municipal) electric utilities.

Cooperatives (Co-op)

Cooperative energy utilities are nonprofit entities that are owned by the customers who are supplied with the services. Historically, utility cooperatives were formed to serve areas that were not serviced by larger, privately owned utility providers. Cooperatives were created to provide rural Americans with electric and phone service. Today, cooperatives serve consumers a variety of public utility needs.

Electric Cooperatives

There are more than 900 **electric cooperatives** in the United States. Electric cooperatives were originally created and financed by low-cost, federal government loans to ensure the supply of electric service to rural areas. These cooperatives were financed through the Rural Electrification Administration (REA), a bureau of the U.S. Department of Agriculture, starting in 1935.

Electric cooperatives operate in a manner similar to an investor-owned utility. Electric cooperative customers each own a share in the company, which enables them to elect a board of directors, who select the management and leadership teams that operate the organization. Profits are reinvested into capital improvements, loan payments, human resource expenditures, and any excess is returned to shareholders on an annual basis.

Electric cooperatives are typically distribution cooperatives that do not own generation, but gather electricity from a variety of sources and distribute it to customers. However, a small number of co-ops are generation and transmission co-ops that create and send power to customers.

The National Rural Electric Cooperative Association (NRECA) is the national nonprofit organization dedicated to representing the national interests of cooperative electric utilities and their customers.

Government-Owned

Government-owned utilities include entities such as local authorities, local agencies, and county-governing powers. Profits from government-owned utilities are used to pay for operating costs such as interest on loans, taxes, labor, and other human resources.

Federal

Authorities such as Bonneville Power Authority (BPA), Tennessee Valley Authority (TVA), and New York Power Authority are considered to be among the largest federal and state energy utilities. Some of these were originally established for the dual purpose of flood control and energy production in the 1930s. Federal electric utilities primarily sell electricity to municipalities and public-utility districts.

Federal agencies that are a part of federal utilities include:

- The Department of the Interior (Bureau of Indian Affairs and Bureau of Reclamation)
- The Department of State (The International Boundary and Water Commission)
- The Army Corps of Engineers
- The Department of Energy Power Marketing Administrations:
  – The Bonneville Power Administration
  – The Southeastern Power Administration
  – The Southwestern Power Administration
  – The Western Area Power Administration
- The Tennessee Valley Authority

Did you know?

The Bonneville Power Administration (BPA) is the largest supplier of electricity in the Pacific Northwest. The BPA sells the output of 31 federal hydroelectric dams and one non-federal nuclear power plant.

The Tennessee Valley Authority, the Bureau of Reclamation, and the Army Corps of Engineers are involved in the building and operation of the facilities that produce the majority of the power that is sold by the federal government.

Independent Power Producers (IPP)

An **Independent Power Producer** (IPP), also known as a Non-Utility Generator (NUG), is an entity which is not a public utility, but which owns facilities to generate electric power to sell, usually to public utilities. There are more than 1,700 IPPs in the United States. IPPs must use the transmission capabilities of other utilities to transmit the power they generate.

Cogeneration

Cogeneration, also known as combined heat and power (CHP), is the use of a primary fuel to simultaneously produce heat and electricity. Cogeneration accounts for the largest part of the IPP sector. Cogeneration typically involves the coproduction of power and useful heat from an energy source such as a steam turbine, gas turbine, or internal combustion engine. Cogenerators use the heat and electricity that is generated to power their own operations and often sell excess power back to local utilities.

Small Power Producers

Small Power Producers are small power plants that generate power for resale to others through renewable technologies such as biomass, geothermal, wind, and solar. To meet the criteria for the Public Utility Regulatory Policies Act (PURPA) classification for a small power producer, renewable resources must provide at least 75 percent of the total energy input.

Merchant Generators

Merchant generators are businesses that have been formed to own power plants and market their output. A merchant plant is one that has been built without a specific end user selected, which allows the plant to be more competitive in the wholesale energy market.

☼ ACTIVITY: Energy Utilities Business Structures

Break into five student groups. Each group should be assigned one of the different types of business structures listed above. Using the library or other resources, research the advantages and disadvantages of the assigned business structure.
Research what types of utility business structures are in your area. What factors might have influenced the selection of the business structures in your area (rural, urban, suburban)?
Share research findings as a class, and create a master list or table showing the advantages and disadvantages of the different business structures.

Demand for Electrical Energy

Electricity is an essential modern convenience. Consumers depend on reliable, adequate, and safe electricity. The electric power industry provides for the generation, transmission, and distribution of electric power to consumers. Consumers of electricity can be classified into three main categories: residential, commercial, and industrial.

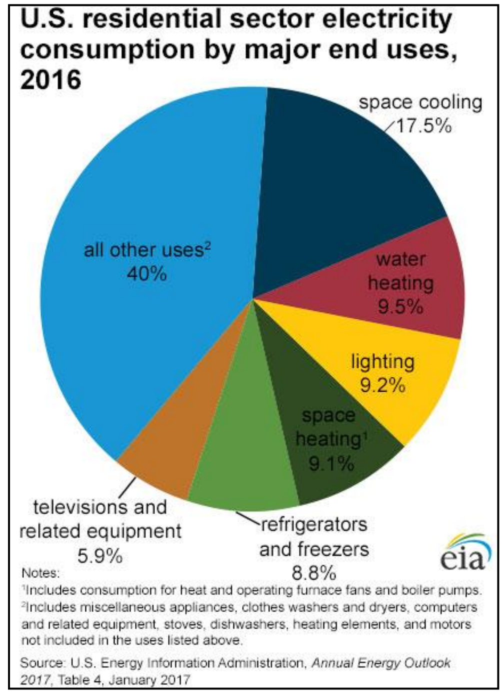
☼ ACTIVITY: Electricity Demand Questionnaire and Poll

Create a brief questionnaire and conduct an informal poll of people you know to find out how electricity is used in their homes and workplaces. Ask participants to be as specific as possible in their answers.
As a class, compile the results of the collected information to come up with a list of ways electricity is used. Are there any trends in the information? What general conclusions can you make about electricity use from the information collected?

Residential

In the residential category, electricity is most commonly used for the following:

- Air conditioning and heating
- Water heating
- Lighting
- Cooking
- Refrigeration
- Clothes washing and drying
- Miscellaneous appliances



☼ ACTIVITY: Residential Electricity Demand

Make a list of the ways you use electricity in your home. Are there 50? 100?
Compare your list with lists made by other classmates.
What similarities and differences do you see in residential electricity uses among the class? What general conclusions can you make about electricity use from the information collected?
Conduct research on what appliances could be classified as “energy hogs.” Does residential energy demand include many high-energy-use appliances? What are ways that you can reduce the impact of high-energy-use appliances?

Commercial

In the commercial category, electricity is most commonly used for the following:

- Powering commercial buildings
- Retail and Service: Shopping centers, gas stations, restaurants, and others
- Office: Professional offices, banks, and others
- Education: Schools, colleges
- Health Care: Hospitals, medical offices
- Lodging: Hotels, motels
- Miscellaneous social and religious institutions and their facilities

☼ ACTIVITY: Commercial Electricity Demand

In groups, investigate the commercial sector's electricity demand in your area by interviewing a company representative or by using the library or other sources.
Present your information to the class.
As a class, develop a table of electricity use that lists local commercial consumers and the major functions of electricity in that sector.

Industrial

In the industrial category, electricity is most commonly used for the following:

- Powering industrial facilities
- Powering industrial equipment
- Powering military bases

The most common industrial energy users are agriculture, forestry, manufacturing, refining, mining, and construction.

☼ ACTIVITY: Industrial Electricity Demand

Identify the major industries in your area and answer these questions about them:

- How do the industries use electricity?
- How would the industries in your community be affected by electricity shortages?
- How might electricity shortages otherwise affect your community?
- How might regulatory issues related to electricity affect each industry?

As a class, discuss which industries are likely to have the greatest impact on electricity demand.

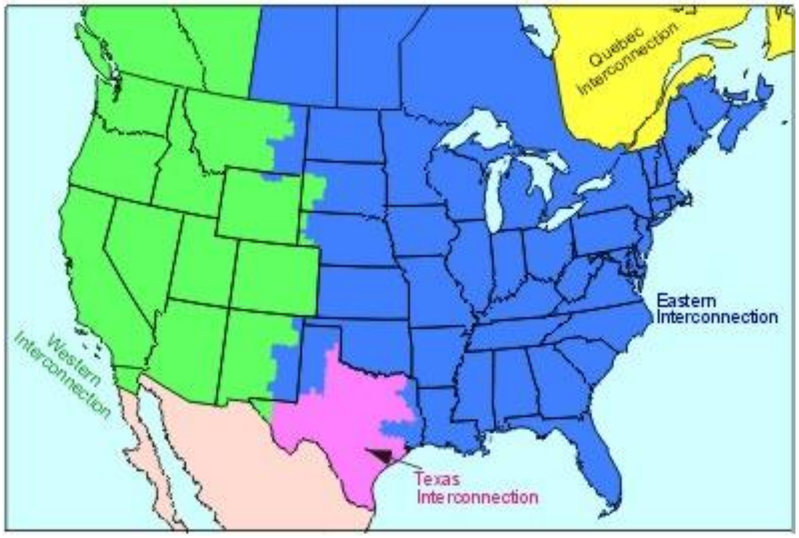
The National Electricity System

The U.S. electric power system is an integrated system of interconnecting networks composed of generating plants, transmission facilities and lines, and local distribution facilities and lines. Generation, transmission, and distribution entities must work in a cooperative manner to provide reliable, adequate, and safe power to customers.

In the U.S., there are nearly 160,000 miles of high-voltage transmission lines that move electric power from generating plants to local distribution systems to be sent to customers. These high-voltage transmission lines are also referred to as the **electrical power grid**, or simply the "grid."

The U.S. electric power system is an interconnection of three major systems, or grids: the Eastern Interconnection, the Western Interconnection, and the Texas (ERCOT) Interconnection.

Main Interconnections



Source: U.S. Energy Information Administration (Nov 2010)

Each of the three interconnections are designed to have systems of connections between individual utilities to allow for the transfer of power from one network to another to maximize coordination and planning that ensures system reliability.

The Texas Interconnection is not connected to the Western or Eastern Interconnections, and the Eastern and Western Interconnections have limited connection to one another. Both the Western and Texas Interconnections have connections to parts of Mexico, and the Eastern and Western Interconnections have connections to Canada.

The three major interconnections are monitored, controlled, and operated by Independent System Operators (ISOs) and Regional Transmission Organizations (RTOs) to ensure equitable and reliable service.

☼ ACTIVITY: Electricity Reliability

Using the library or other resources, research the occurrence of electricity service disruptions in your community.
Has your community experienced brownouts, blackouts, or other service issues?
Research the circumstances behind any service disruptions and discuss research findings as a class.

Organizations

North American Electric Reliability Council (NERC)

As a result of the 1965 **blackout** of the East Coast that affected 30 million people, the industry formed the **North American Electric Reliability Council** (NERC). The overall reliability and coordination of the national interconnected power systems are the responsibilities of NERC.

> **Quick Facts**
>
> NERC's mission is to "ensure the bulk power system in North America is reliable."

NERC's major areas of responsibility:

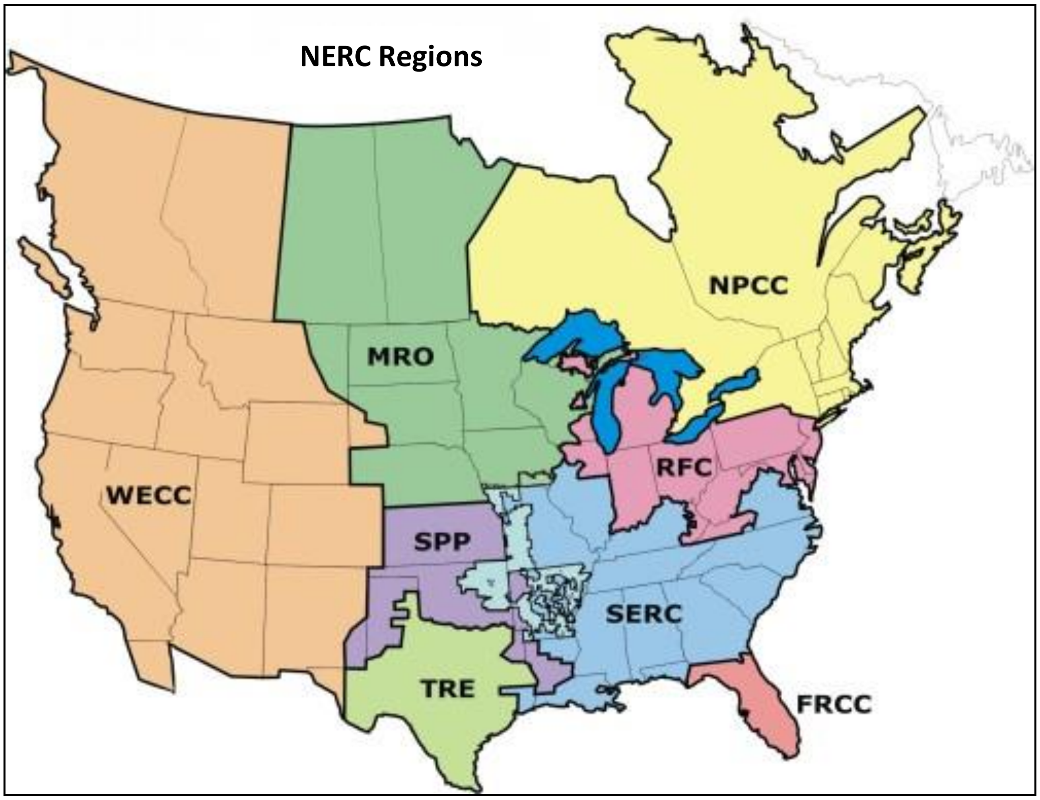
- Developing, monitoring, and enforcing standards
- Providing education and training
- Analysis and assessment of system operations including disturbances and failures

NERC is composed of regional entities that are responsible for the coordination of the adequacy and reliability of power in their respective region.

NERC Regional Entities:

- Florida Reliability Coordinating Council (FRCC)
- Midwest Reliability Organization (MRO)
- Northeast Power Coordinating Council (NPCC)
- Reliability*First* Corporation (RFC)
- SERC Reliability Corporation (SERC)
- Southwest Power Pool, RE (SPP)
- Texas Reliability Entity (TRE)
- Western Electricity Coordinating Council (WECC)

Within the regional entities, there are typically multiple **balancing authorities** that operate control centers that monitor the national grid. Balancing authority operators are responsible for maintaining the load/interchange/generation balance within the control area.



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Federal Energy Regulatory Commission (FERC)

In 1977, the Federal Energy Regulatory Commission (FERC) was created to provide additional standards to ensure the reliability of electric power.

FERC's Regulatory Functions:

- Regulate wholesale sales of electricity
- Interstate transmission transactions
- Interconnections and power agreements
- Rates set by federal power marketing administrations
- Hydroelectric licensing

In 1996 and 1999, FERC issued orders that affected operations for all generation, transmission, and distribution entities.

FERC Orders Number 888 and 889

In Orders 888 and 889, FERC acknowledged that barriers to competitive wholesale markets existed and should be removed. Through FERC Orders 888 and 889, FERC required transmission owners to provide nondiscriminatory access to transmission lines while permitting utilities to recover stranded costs associated with providing open access to transmission.

To comply with FERC directives and assure the operation of transmission lines in an independent and equitable manner, generation, transmission, and distribution entities collaborated to form Independent System Operators (ISOs).

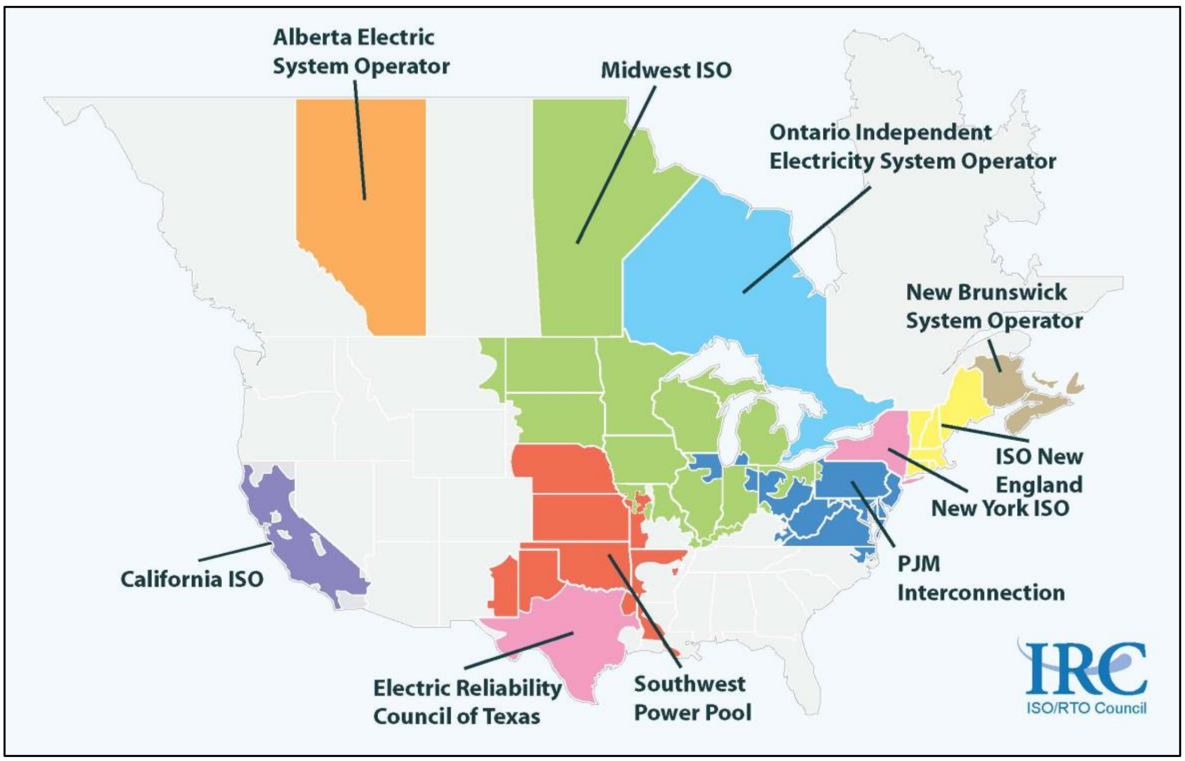
FERC stated that ISOs could provide assurance of independence from transmission owners and the elimination of multiple rates to transmit electricity over long distances, which allows for open access rule and fair access to the competitive wholesale market.

FERC Order Number 2000

FERC Orders 888 and 889 were created with the idea of facilitating open access to transmission with a provision for equitable information access, too. FERC Order Number 2000 formally outlined the requirements and mandates for Regional Transmission Organizations (RTOs). Similar to ISOs, RTOs are designed to administer the transmission grid on a regional basis. FERC stated that entities desiring to be qualified as RTOs must first meet a specific list of characteristics and functions.

FERC's establishment of ISOs and RTOs as regulatory bodies helps to maintain the coordination, control, and monitoring of electric transmission to ensure safe, secure, and reliable electric service.

North American ISOs and RTOS



Independent System Operators

As mentioned earlier, Independent System Operators (ISOs) were formed under the authority of FERC from Orders 888 and 889. FERC established ISOs as a way to provide non-discriminatory access to transmission.

ISOs are nonprofit organizations that combine the transmission capabilities of multiple transmission providers into a single transmission system that can be accessed by many other energy entities. By combining transmission capabilities into one equally accessed system, ISOs can ensure unbiased transmission service.

ISOs coordinate, control, and monitor the operation of the electric power system in their respective geographical area.

Current ISOs operating in North America:

- Alberta Electric System Operator (AESO)
- California ISO (CAISO)
- Electric Reliability Council of Texas (ERCOT)
- Independent Electricity System Operator (IESO), (Ontario, Canada)
- New York Independent System Operator (NYISO)
- New Brunswick System Operator (NBSO)

☼ ACTIVITY: Independent System Operator

Using the library or other resources, find the ISO that is responsible for your geographic region.
Contact local electricity providers in your community and ask them how they work with the ISO to maintain safe, reliable, and adequate services.

Regional Transmission Organizations

As mentioned earlier, Regional Transmission Organizations (RTOs) were formed under the authority of FERC from Order Number 2000. FERC encouraged transmission-owning utilities to turn over control of transmission systems to RTOs. Order Number 2000 also specified twelve standards that an entity must comply with in order to become an RTO.

RTOs coordinate, control, and monitor the operation of the transmission grid in their respective geographical area. RTOs provide equal access to the electric transmission network. RTOs differ from ISOs in that they are required to meet specific FERC regulations.

There are currently four RTOs operating in North America:

- Midwest Independent Transmission System Operator (MISO)
- ISO New England Inc. (ISO-NE)
- PJM Interconnection LLC (PJM)
- Southwest Power Pool (SPP)

☼ ACTIVITY: Regional Transmission Operator

Using the library or other resources, find the RTO that is responsible for your geographic region.
Contact local electricity providers in your community and ask them how they work with the RTO to maintain safe, reliable, and adequate services.

Unit B Glossary

balancing authority—a regional organization responsible for planning and maintaining the balance of electricity resources and electricity demand

blackout—power loss affecting many consumers over a large geographical area for a significant period of time

cogeneration—process in which electricity and heat are produced at the same time from the same fuel or energy source

cooperative energy utilities—nonprofit utility entities that are owned by the customers who are supplied with the services

electric cooperatives—commonly known as co-ops; nonprofit utility entities that are owned by the customers who are supplied with the services; originally created and financed by low-cost federal government loans to ensure the supply of electric service to rural areas

electric power distribution—the transfer of high-voltage electrical energy from substations to the end customer

electric power generation—process of creating electrical energy from other forms of energy

electrical power grid—interconnected electric generation, transmission, and distribution systems over broad geographic areas

electric power transmission—the bulk transfer of high-voltage electrical energy from its source at generating plants to substations

Federal Energy Regulatory Commission (FERC)—an independent regulatory agency within the Department of Energy and the successor to the Federal Power Commission; FERC governs interstate electricity sales, wholesale electric rates, hydroelectric licensing, natural gas pricing, oil pipeline rates, and gas pipeline certification

fossil fuels—carbon-rich energy sources such as petroleum, coal, or natural gas, which are derived from the decomposition of ancient (fossilized) living matter

government-owned utilities—these include entities such as local authorities, local agencies, and county governing powers. Profits from government-owned utilities are used to pay for operating costs such as interest on loans, taxes, labor, and other human resources

hydroelectric power—power generated by using moving water to power a turbine generator to produce electricity

independent power producer (IPP)—also known as a Non-Utility Generator (NUG); an entity which is not a public utility, but which owns facilities to generate electric power to sell, usually to public utilities

independent system operator (ISO)—created under the authority of FERC; designed to administer the transmission grid on a regional basis in a neutral manner

investor-owned utilities (IOU)—utility entities that are privately owned by individual investors, private funds, and private pension plans that purchase shares or stocks for the purpose of receiving a financial return on investment

merchant generators—businesses that have been formed to own power plants and market their output; a merchant plant is one that has been built without a specific end user selected, which allows the plant to be more competitive in the wholesale energy market

municipal utilities (muni)—nonprofit entities that are publicly owned and controlled by local government agencies; municipal utilities may include the following services: natural gas, water, sewage, and telecommunications

North American Electric Reliability Corporation (NERC)—formed in 1968 in response to the 1965 blackout, NERC is the electric reliability organization certified by the Federal Energy Regulatory Commission to establish and enforce reliability standards for the bulk-power system; all bulk power system owners, operators, and users are required to register with NERC

public utility—maintains the infrastructure for providing a public service such as gas, electric, water, and waste-disposal service

regional transmission organization (RTO)—created under the authority of FERC; designed to administer the transmission grid on a regional basis in a neutral manner. FERC stated that entities desiring to be qualified as RTOs must first meet a specific list of characteristics and functions

small power producer—small power plants that generate power to resell to others through renewable technologies such as biomass, geothermal, wind, and solar

stepped-down—conversion of high-voltage electricity to lower voltage through the use of transformers at power substations

stepped-up—conversion of low-voltage electricity to higher voltage through the use of transformers; a step-up transmission substation receives electric power from a nearby generating facility and uses a large power transformer to increase the voltage for transmission to distant locations

transformer—a device that changes the voltage of an electric current

vertically integrated—a business structure in which the same company owns several or all levels of the production processes for a product or services

Unit B References

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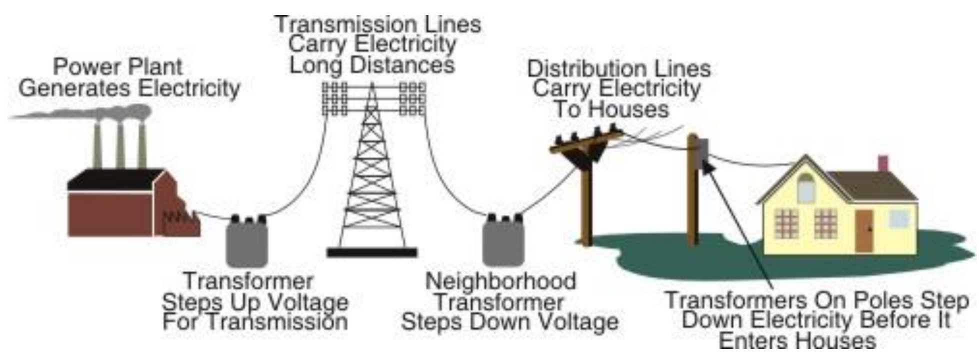
Unit C: Energy Flow: Generation, Transmission, and Distribution

UNIT C: ENERGY FLOW: GENERATION, TRANSMISSION, AND DISTRIBUTION

Overview of Electric Power System

Energy and utility companies must provide customers with instant access to reliable energy service 24 hours a day, 365 days a year. The creation and delivery of **electrical energy** for customers occurs through three main steps: electric power **generation**, **transmission**, and **distribution**. Electric power generation is the process of creating electricity from other sources of energy. Electric power transmission is the transfer of electric energy in bulk between the generation point and points at which it is transformed for delivery. Distribution is the delivery of electric energy to consumers through overhead or underground distribution lines.



Simple Power Plants

Generation is the first step in the delivery of electric power service to consumers. A discussion of energy generation from steam power plants can begin with a simple wind-powered generating plant. As wind strikes the blades of the windmill, they begin to turn. In this process, the energy of the wind is converted to mechanical energy as shown in Figure 1C.1. When the windmill shaft turns, the **generator** changes the mechanical energy into electrical energy that, in turn, illuminates the bulb.

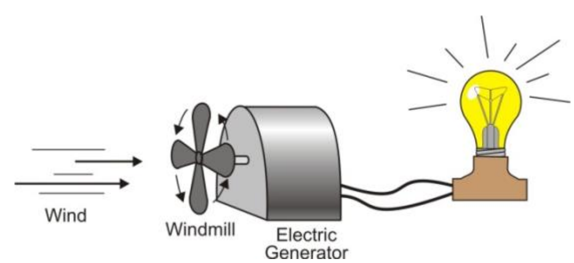


Figure 1C.1 Wind power plant

Simple power plants such as this windmill actually work; in fact, such plants are being used today, but wind is not a dependable source of energy in many locations.

Simple Steam Power Plant

In the search for a reliable source of power, steam has long been recognized as a source more dependable and controllable than wind.

The "Tea Kettle" System

One possible source of power could be a tea kettle. When a tea kettle is placed over a source of heat, the water inside the kettle begins to boil and steam is discharged from the spout.

Steam, like controlled wind, can be used to turn blades on a shaft to generate electricity to illuminate a light bulb. Blades turned by steam are the basic principle on which steam power plants operate. The actual equipment in a steam power plant is much more sophisticated, yet the principle remains the same.

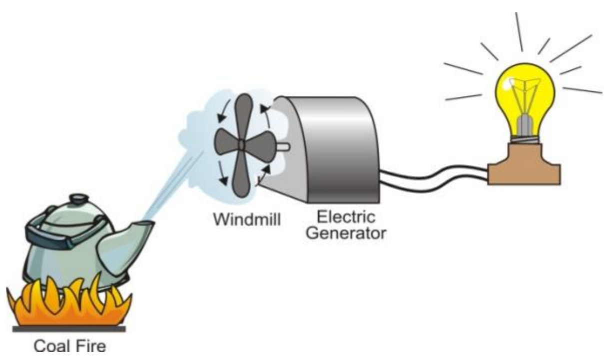


Figure 1C.2 "Tea kettle" power plant

At this point in the course, it is enough to know that an electric generator is a rapidly rotating magnet inside a stationary coil of wire that creates an electric **current**.

A simple generator, such as the one depicted in Figure 1C.2, consists of a bar magnet spinning inside a stationary coil of wire. As the magnetic field issuing from the ends of the magnet moves across the turns of wire in the stationary coil, an electric current is set up in the wire. By winding a large number of turns of wire into a ring or doughnut, the initial current is added to the current in the other turns of wire creating a more powerful current.

Improving the "Tea Kettle" Power Plant

Now let's return to the "tea kettle" power plant to see if some improvements can be made to increase the efficiency of the overall operation. We'll use actual steam-electric generation plant terminology to describe equipment and processes from now on. The major components of the power plant are the **furnace**, the

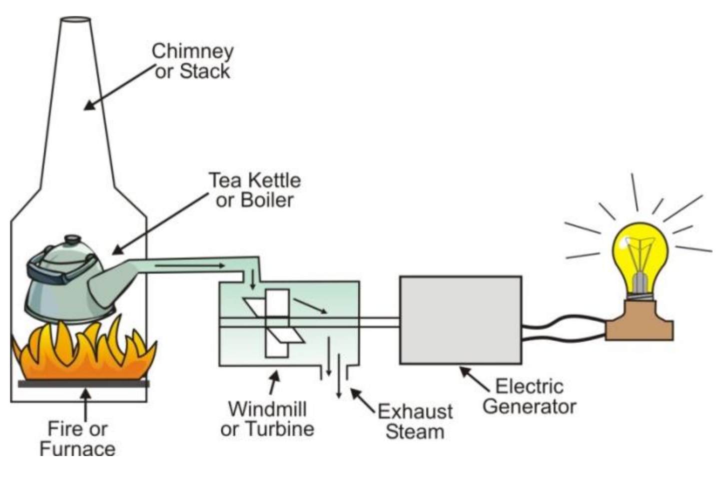


Figure 1C.3 Improved "tea kettle" power plant

boiler, the **turbine**, and the generator. Note that in the diagram in Figure 1C.3, several pieces of equipment have been enclosed.

The portion containing the fire and fuel-burning equipment is called the furnace. The tea kettle, now known as the boiler (or steam generator), is the equipment that converts water to steam when heated by the furnace. To the furnace structure is added a chimney, which in power plant terms is called a stack.

The windmill has also been enclosed and is now known as a turbine, even though it still has the same function. Each component is becoming more complicated and specialized, but the principle is still the same as in the "tea kettle" power plant.

Science Connections

The Chemistry of Combustion

Pure carbon would burn following the equation below:

$$C + O_2 \rightarrow CO_2 + \text{heat}\uparrow$$

or in words

carbon + oxygen → carbon dioxide + heat

When there is insufficient oxygen present, the equation may become:

$$2C + O_2 \rightarrow 2CO + \text{heat}\uparrow$$

or

$$3C + O_2 \rightarrow 2CO + C + \text{heat}\uparrow$$

where carbon monoxide (a poisonous gas) is produced, and some carbon may remain totally unburned. In actuality, incomplete combustion will generally produce some carbon dioxide, some carbon monoxide, and some unburned carbon.

Additionally, impurities in the coal such as sulfur are burned, releasing various oxides of sulfur (SO_x). Pollution control equipment such as scrubbers remove SO_x.

Generating Plant Components

The Furnace

The furnace is the site of one of the basic energy processes, or conversion, from one form of energy to another. In the furnace, the chemical energy of the fuel is converted into thermal energy (heat) through combustion. The three most common fuels used in fossil-fueled plants today are natural gas, oil, and coal, which are all chemically classified as **hydrocarbons**. Because of the relative cost and availability of the various fuels used in plants today, coal is the first choice. Hydropower and nuclear power do not require a furnace, as combustion is not part of the hydroelectric power or nuclear power generation processes.

The Boiler

In a coal-fired plant, the heat energy that is released as the coal burns is absorbed by water in the boiler, converting it to steam.

The Turbine

The third major component of a steam-electric generating station is the turbine. The turbine and associated equipment are used to convert steam energy to mechanical energy. To review, this power plant explanation began using a simple windmill. The blades were then enclosed, and the windmill became a turbine. The turbine is essentially a windmill, but it is far more complex. It has hundreds of blades, some of which rotate and some of which are stationary. The turbine blades are arranged in groups called stages.

The Generator

The main function of a generator is to convert the heat energy of steam into more easily used electrical energy. An analogy for a generator is a pump pushing water through a pipe. Only instead of pushing water, a generator uses a magnet force to push electrons along. This is an oversimplification, but it paints a helpful picture of the properties at work in a generator. A water pump moves a certain number of water molecules and applies a certain amount of pressure to them. In the same way, the magnet in a generator excites electrons in the **conductor** and generates an electrical force. It should be noted that a single electron doesn't flow through a conductor and return. Instead, electrons act more like a Newton's cradle—the toy in which aligned spheres on strings are set to knock against one another, one conveying energy to another in sequence. Similarly, while going through a conductor, one electron from one atom will become excited to the point it will leave its atom. It might collide with another atom, knock an electron free, and then join the atom with which it collided.

A generator in a power plant may operate by itself or in tandem with other generators. Most electrical power utilities have more than one power plant, each plant having more than one generator. During low **system load** periods, only a few generators will be in operation. As the customer demand for electric power increases, more generators are placed in operation to meet the demand. All generators are supplying the common load and are said to be operating in parallel. In cases where a system is small or a system has only one power plant, it is possible that only one generator is supplying the total system demand. A single generator operating to supply the demand is called an isolated generator.

Better Plant Efficiency

If a power plant is basically this simple, one may ask why people continue to complicate things. The answer is efficiency. Like the person who wants the most miles per gallon of gas from a car, station designers and operators strive to obtain the maximum number of **kilowatt hours** of electricity from the least amount of fuel.

Seventy-five years ago, electric-generating plants used more than three pounds of coal to produce one kilowatt hour of electricity. Today the national average is less than one pound of coal per kilowatt hour. In other words, seventy-five years ago, three times as much fuel was required to produce the same amount of electricity.

The main reason for the reduction in fuel consumption is the gradual improvement of generating stations. Both the individual pieces of equipment and the system as a whole have been made more efficient.

Overview of Electric Power Transmission

Electricity has unique properties that make it not easily stored. The electricity that is created by generation plants must be delivered as it is generated. To deliver electricity to millions of customers, electricity travels from generation plants to customers though transmission lines. **Electric power transmission** is the second of three steps in the electric power system.

Historically, early electric power **transmission systems** encountered two main obstacles: proximity to a generation source and incompatibility of different **voltages**. Industrialization and new technologies allowed for the voltages used in the bulk transmission of electricity to gradually increase over time. Conflicting, isolated systems evolved into compatible, interconnected grids. This system continued to progress into what we now consider a critical part of our country's infrastructure.

Focus on ...

Common Concepts for Electric Power Transmission

Voltage: Voltage is electrical force or potential measured in volts (V) or kilovolts (kV) for transmission applications. The voltages of transmission lines affect their transmitting ability.

Current: Current is a measurement of the rate of electricity flow. Current flow is measured in amperes (amps). Transmission line current is a measurement of the amount of electricity that is flowing through the transmission line.

Power: In the context of electricity transmission, power is defined as a rate at which electricity (electrical energy) is produced. Power is measured in watts (W) or megawatts (MW). Power is a variable that must be considered when dealing with transmission system capability and capacity design and function.

Electrical Energy: Electrical energy is the generation or use of electric power over a specified amount of time. Electrical energy is expressed in kilowatt hours (kWh).

Argonne National Laboratory, 2007

Electric power transmission is the bulk transfer of electrical energy from power generation plants to **substations** along various interconnected systems within the **electrical power grids**.

The Transmission System

The electrical energy transmission system is designed to step-up the output voltage from the production system generation units to high voltages that can be used to interconnect various production sources and power grids.

The transmission system used to transmit electrical energy long distances can be compared to the interstate roadway network. Large amounts of electrical energy flow along the transmission system much as traffic from towns and cities, other major highways, or expressways enter and leave the interstate highway at key intervals. In the electrical transmission system (Figure 1C.4), the entry and exit points are:

- Power plants that generate electrical energy, which can be located several hundred miles away from the customers.
- Switching stations that provide control facilities for monitoring system operation and provide interconnection with other transmission systems, even if they operate at different voltage levels.
- Other power pools or power grids, which can extend the interconnection of production facilities and allow for alternative routing in the event of operating emergencies and maintenance.
- Customers requiring high volumes of energy at high voltages.
- Substations that lower the voltage so that electrical energy circuits are permitted to be routed to commercial and residential areas.

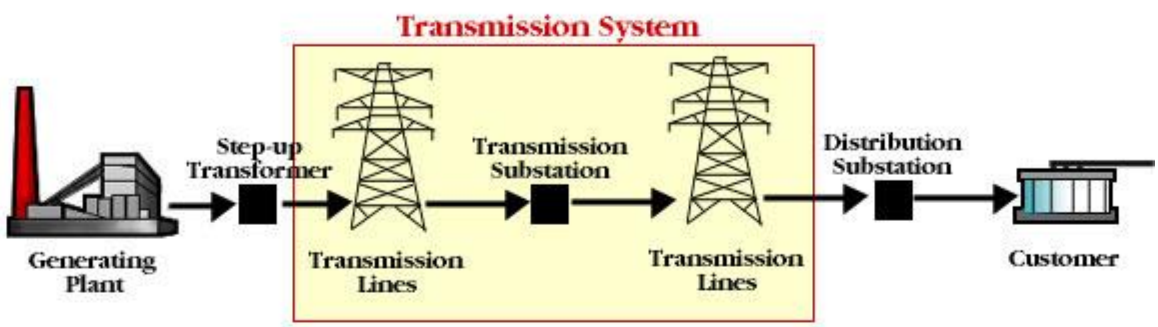


Figure 1C.4 Transmission System (Apogee Energy)

The transmission system operates at high voltages in ranges from 138,000 to more than 1,000,000 volts. These high voltages are established at production sources where the voltages are stepped-up so that more electrical energy can be transferred from one point to another with a minimum of loss. The high-voltage transmission system lines are carried on tall steel or aluminum towers or poles well above the ground.

According to the National Council on Electricity Policy, at the start of the twenty-first century, the transmission system in the United States was an interconnected network with more than 150,000 miles of high-voltage (greater than 230 kV) transmission lines. Additionally, some power is transmitted underground, but this is much more expensive since coolant must be circulated through the pipes carrying the electrical cables.

Some customers are connected directly to the transmission system at these high voltages. The customers requiring these extremely high levels of electrical energy, such as manufacturing processes and research facilities, are sometimes directly connected to transmission lines. Examples might include electrical component manufacturers, research nuclear reactors, and steel recycling facilities.

Transmission System Interface

The interface between the power generation plant and the transmission system takes place in a switching station. Power generated in a power plant passes from the generation plant into the transmission system through a **switchyard**. A switchyard contains all the equipment necessary to transform and route power.

Transformers

A **transformer** is an electrical device by which alternating current of one voltage is changed to another voltage. A transformer can only transfer power, not produce it. Besides the main power transformer that steps up voltage to transmission levels, a variety of other transformers are found along the transmission and distribution lines that adjust voltages for the power grid and step-down voltages to the voltages needed by various consumers. Transformers step-down the voltage from transmission voltage, which ranges from 44,000 volts (44 kV) to 500,000 volts (500 kV) to distribution voltage, which ranges from 4,000 volts (4 kV) to 35,000 volts (35 kV).

The transmission system delivers power to transmission substations of the utility and to larger industrial consumers at voltages of 69 kV and above. The subtransmission system delivers electrical power to large commercial customers at voltages between 4 kV and 69 kV. The **distribution system** delivers electrical power to residential customers and to smaller commercial customers at voltages of 4 kV and below. The transmission system is generally connected to a subtransmission system, which in turn is connected to a distribution system.

Overview of Electric Power Distribution

Electric power distribution begins with the flow of electric power from a substation and ends with the final delivery of electrical power through a customer's electric meter (Figure 1C.5).

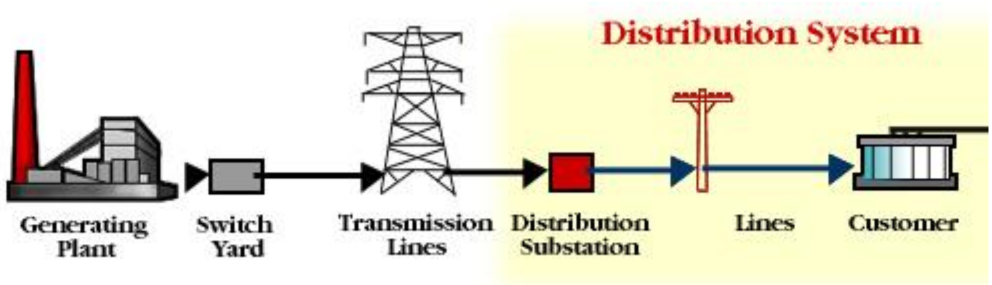


Figure 1C.5 Transmission System (Apogee Energy)

A distribution system takes power from the transmission grid and steps down the voltage from a high transmission voltage level to a lower distribution voltage level. Lower voltages are required for the safe distribution of electric power to customers. The lower voltage of electricity in the distribution system also allows for the construction of smaller power lines within neighborhoods and enables economical underground distribution abilities.

While the electric power transmission system is often compared to an interstate highway network, the electric power distribution system is similar to state highways and city streets, as it has multiple interconnections that provide opportunities for input and output at key junctions.

The distribution system is connected by the following main links:

- **Distribution Substations** – Substations lower voltages so that electrical energy is at an appropriate level to be routed to commercial and residential customers.
- **Commercial and Industrial Connections** – Some commercial and industrial customers require a higher voltage of electrical power service because they require high volumes of energy or operate equipment or machinery that requires special voltages.
- **Residential Connections** – Residential customers typically require distribution voltage levels to be stepped-down to 120/240 single phase service.

Did you know?

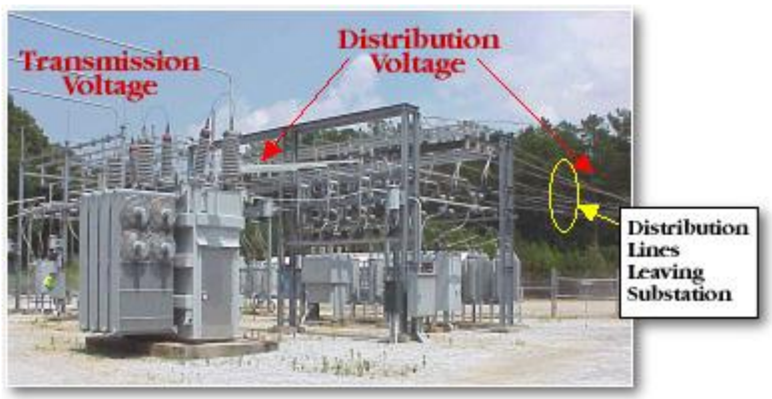
Early Distribution

Thomas Edison originated the concept and implementation of electric power generation and distribution to homes and businesses. In 1880, Edison patented the first electric power distribution system.

In 1882, the "Edison Illuminating Company" began to distribute electrical power to 59 customers in New York City. Edison received many awards for his developments in power distribution systems.

Residential Distribution

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



The majority of customers are supplied from distribution circuits that are the outputs of the substation, rather than the transmission or subtransmission systems. The distribution circuits are routed along local streets on overhead and underground distribution circuits. Typically, distribution circuit voltages of 4 and 13 kV are stepped-down at designated intervals to provide lower voltages for specific customer applications. The customer application voltages are referred to as secondary and service voltages.

Common customer voltage levels are:

Residential (Single-Phase Services)

- 120 volts
- 120/240 volts
- 120/208 volts

Commercial and Light Industrial (Three-Phase Services)

- 120/208 volts (three-phase **wye**)
- 277/480 volts (three-phase wye)
- 120/240 volts (three-phase **delta**)
- 240 volts (three-phase delta)
- 480 volts (three-phase delta)

☼ ACTIVITY: Electricity Flow

Voltage in electric circuits is similar to pressure in fluid circuits. All pipes and tubes resist the flow of water, just as all electrical devices have some resistance to charge flow.

Working in teams, using an approximately constant-pressure water source (e.g., faucet), measure and compare fill time for a large bucket using different lengths of garden hose and other smaller-diameter types of plastic tubing.

What variables do you notice with long versus short lengths of tubing?

What variables do you notice with smaller-diameter tubing?

How do these findings relate to how electricity is transferred through the transmission system?

In the distribution system, the poles are generally shorter and often made of wood. Within cities they may be built with breakaway metal poles to reduce injuries in case a vehicle runs into one. Examples of distribution poles and transformers are below.

☼ Activity: Scavenger Hunt

Work in small groups. Find each of the following and record its location. If available, use digital cameras to take pictures of your "finds." Bring your completed assignment to the next class. If your instructor allows, this activity can be completed virtually using the Internet.

- ☐ The nearest generating station
- ☐ Transmission substation
- ☐ Distribution substation
- ☐ **Step-down transformer**
- ☐ **Step-up transformer**
- ☐ Residential transformer
- ☐ High-voltage transmission lines
- ☐ Analog electric meter
- ☐ Digital electric meter

Unit C Glossary

boiler—a device for generating steam for power; heat from an external combustion source is transmitted to water contained within the waterwall tubes that line the furnace walls

conductor—materials such as copper and aluminum that allow electrical current to flow freely through them

current—a flow of electrons along a path, such as a conductive wire

distribution system—the portion of electric system that is dedicated to delivering electric energy to an end user

delta—a method of wiring for a three-phase connection in which three windings of a transformer or generator are connected end to end; when drawn in a line diagram, the shape resembles the Greek letter “delta” (Δ)

energy—the capacity to do work

electrical energy—potential energy and kinetic energy associated with the position or movement of electrical charge

electrical power grid (the “grid”)—interconnected electric generation, transmission, and distribution systems over broad geographic areas

furnace—the portion of the generating unit containing the fire and fuel-burning equipment; the site where the chemical energy of the fuel is converted to thermal energy

generator—the portion of the generating unit where the rotating mechanical energy is converted to electrical energy; it consists of a stator containing the armature windings and a rotor (center shaft) that is turned by the turbine to produce the magnetic field

hydrocarbons—simple compounds containing only the elements hydrogen and carbon; fossil fuels are made of hydrocarbons

kilowatt hours—the unit which expresses how much electrical energy a consumer uses

step-down transformer—a transformer that has more turns in the primary winding than in the secondary winding; voltages are higher in the primary circuit than in the secondary circuit; used to lower voltage

step-up transformer—a transformer that has fewer turns in the primary winding than in the secondary winding; the voltage in the primary circuit will be less than in the secondary circuit; used to increase voltage

substation—a location along a transmission or distribution route containing equipment to transform and route power

switchyard—the area at the generating station that steps up voltages from the generator and routes it to the transmission lines

system load—the amount of electric power required by consumers

transformer—a device that transfers power from one circuit to another; step-up transformers increase voltage from the primary to the secondary circuit while lowering current proportionally, while step-down transformers lower voltage from the primary to the secondary circuit while raising current proportionally

transmission system—an interconnected group of electric transmission lines and associated equipment for moving or transferring electric energy in bulk between points of supply and points at which it is transformed for delivery over the distribution system lines to consumers or to other electric systems

turbine—a machine for generating rotary mechanical power from the thermal energy of steam

voltage (volts)—the difference in electrical potential between any two conductors or between a conductor and ground. It is a measure of the electric energy per electron that electrons can acquire and/or give up as they move between the two conductors

wye—a method of wiring for a three-phase connection in which all three phases are connected to a common point, usually an electrical ground; when drawn in a line diagram, the shape resembles a "Y"

Unit C References

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