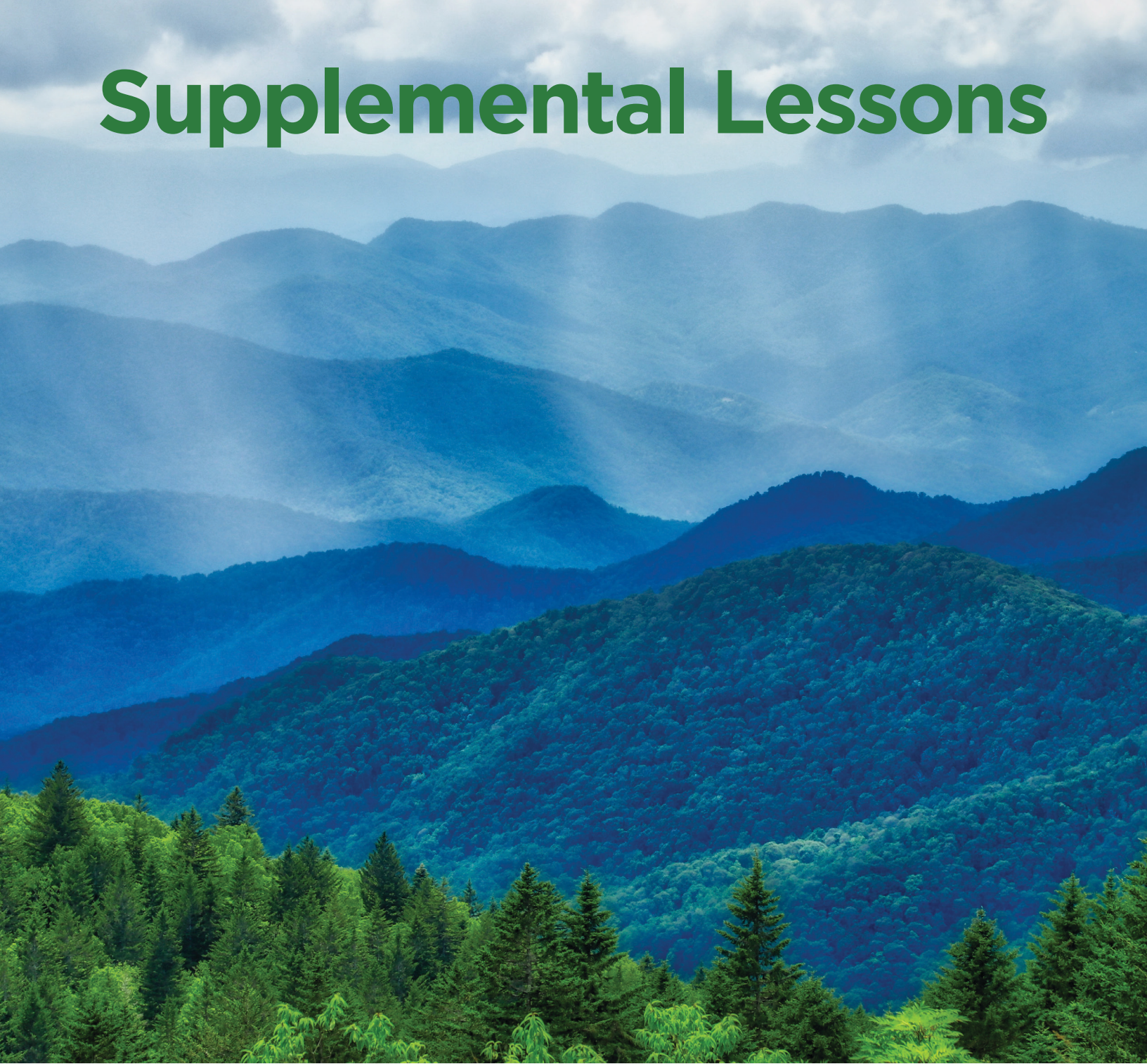


# Supplemental Lessons



## Appalachian Power Energy Innovation Program



An AEP Company

TAKE CHARGE™



National  
Energy  
Foundation

## Dear teacher,

The Appalachian Power Energy Innovation Program is providing students with TakeCharge Innovation kits. The goal of this program is to help students and families learn ways to use energy and water more efficiently.

Use these supplementary activities and lessons to meet the needs of your students for their energy education. Share lessons and activities throughout the school year to review energy concepts.

The lessons in this guide are multidisciplinary and are correlated to the West Virginia Learning Standards, STEM and Next Generation Science Standards. Each lesson contains an objective, materials needed and detailed learning standard correlations. Some lessons contain student sheets; others are to be done as class discussions or demonstrations.

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# West Virginia Correlations

## High School

Lesson Name

	Biology	9th Grade ELA	10th Grade ELA	11th Grade ELA	12th Grade ELA	Social Studies
Classroom Comfort and School Lighting Audit	S.B.25	ELA.9.23	ELA.10.23	ELA.11.23	ELA.12.23	
Conventional Electrical Power Generation Pros and Cons	S.B.23 S.B.25	ELA.9.19 ELA.9.23 ELA.9.30 ELA.9.34	ELA.10.19 ELA.10.23 ELA.10.30 ELA.10.34	ELA.11.19 ELA.11.23 ELA.11.30 ELA.11.34	ELA.12.19 ELA.12.23 ELA.12.30 ELA.12.34	
Conventional Electrical Power Generation Systems, Process and Fuel Sources	S.B.23 S.B.25	ELA.9.19 ELA.9.23 ELA.9.30	ELA.10.19 ELA.10.23 ELA.10.30	ELA.11.19 ELA.11.23 ELA.11.30	ELA.12.19 ELA.12.23 ELA.12.30	
Energy for Electricity	S.B.25	ELA.9.19 ELA.9.23 ELA.9.30	ELA.10.19 ELA.10.23 ELA.10.30	ELA.11.19 ELA.11.23 ELA.11.30	ELA.12.19 ELA.12.23 ELA.12.30	
History of Electricity and Transmission		ELA.9.19. ELA.9.30 ELA.9.33	ELA.10.19. ELA.10.30 ELA.10.33	ELA.11.19 ELA.11.30 ELA.11.33	ELA.12.19. ELA.12.30 ELA.12.33	SS.G.18
Renewable Energy Sources		ELA.9.19 ELA.9.23 ELA.9.30	ELA.10.19 ELA.10.23 ELA.10.30	ELA.11.19 ELA.11.23 ELA.11.30	ELA.12.19 ELA.12.23 ELA.12.30	
The Smart Grid		ELA.9.19 ELA.9.23	ELA.10.19 ELA.10.23	ELA.11.19 ELA.11.23	ELA.12.19 ELA.12.23	
The Transmission and Distribution Process	S.B.23	ELA.9.19 ELA.9.23	ELA.10.19 ELA.10.23	ELA.11.19 ELA.11.23	ELA.12.19 ELA.12.23	
Your State's Electrical Generation	S.B.23	ELA.9.19 ELA.9.23	ELA.10.19 ELA.10.23	ELA.11.19 ELA.11.23	ELA.12.19 ELA.12.23	SS.G.18

# History of Electricity and Transmission

## Objective:

Students will understand the history of electricity and research the history of local transmission processes.

Materials and Curriculum  
Correlations ▼

## ► Introduction

As early as 600 BC, ancient Greeks discovered static electricity. In the 1600s, the term electricity was coined from elektron, the Greek word for amber. We have progressed from understanding static electricity to transmitting electricity to millions of people via the grid. The history of electricity is a who's who of famous scientists and important advances in technology. How does electricity affect our lives? Where will the future take us?

### Procedure

1. Divide students into five groups. Give each group one page of the "Electricity Timeline." Give students about 10 minutes to discuss their information and organize how they will share with the class. End the group discussions and have each group share their information with the class.
2. Have students reassemble in their groups. Have each group make a 30 second video about one of the ways they use electricity. Have groups share their videos.
3. This timeline purposefully ends at 2001. Have students research significant events or inventions that have been made since 2001. Have groups discuss their choices and decide which events or inventions should make the timeline.
4. Direct students to research the timeline of the electricity generation in their city, town or local area. What was the date electricity was first supplied to the area? Was it in a residential, commercial or government building or an industrial area? When was the first high voltage transmission line put into service in your area? First substation? Any other event of significance?

## To Know and Do More

1. Have students research a scientist from “Electricity Timeline” and the event or invention listed. Determine if the scientist was involved with other inventions or discoveries besides those listed. Create a presentation to give to other students.
2. Direct students to write a short paragraph about their energy use if they lived 300 years ago.

## Materials Needed:

- Student sheet
- Paper
- Markers
- Internet

## Curriculum Correlations

K.RI.3	3.SL.1	HS-W.2
K.SL.1	4.RI.6	HS-SL.1
1.RI.3	4.RF.4	2.b
1.W.3	4.W.2	2.c
1.SL.1	4.SL.1	2.f
2.RI.3	5.RI.6	3.k
2.W.3	5.RF.4	7.a
2.SL.1	5.W.2	8.a
3.RI.6	5.SL.1	8.b
3.RF.4	MS-W.2	10.j
3.W.2	MS-SL.1	

# Electricity Timeline

- Around 600 BC** Thales (Greece) found that when amber was rubbed with silk, it became electricly charged and attracted objects. He had discovered static electricity.
- 1600** William Gilbert (England) first coined the term electricity from elektron, the Greek word for amber. Gilbert wrote about the electrification of many substances. He was also the first person to use the terms electric force, magnetic pole and electric attraction.
- 1660** Otto von Guericke (Germany) described and demonstrated a vacuum and then invented a machine that produced static electricity.  
Robert Boyle (Ireland) discovered that electric force could be transmitted through a vacuum and observed attraction and repulsion.
- 1675** Stephen Gray (England) distinguished between conductors and nonconductors of electric charges.
- 1745-46** Georg von Kleist (Germany) developed the first electric capacitor, a device for storing electricity.  
Pieter van Musschenbroek (Netherlands) independently developed an electric capacitor that would be called the Leiden jar after the University of Leiden where he worked.
- 1752** Ben Franklin (United States) tied a key to a kite string during a thunderstorm and proved that static electricity and lightning are the same thing.
- 1800** Alessandro Volta (Italy) invented the first electric battery. The term Volt is named in his honor.
- 1808** Sir Humphry Davy (England) invented the first effective lamp. The arc lamp was a piece of carbon that glowed when connected by wires to a battery.
- 1820** Separate experiments by Hans Christian Oersted (Denmark), Andre-Marie Ampere (France) and Francois Arago (France) confirmed the relationship between electricity and magnetism.
- 1821** Michael Faraday (England) discovered the principle of electromagnetic rotation that would later be the key to developing the electric motor.
- 1826** Georg Ohm (Germany) defined the relationship between power, voltage, current and resistance in Ohm's Law.
- 1831** Using his invention the induction ring, Michael Faraday (England) proved that electricity can be induced (made) by changes in an electromagnetic field. Faraday's experiments about how electric current works led to the understanding of electric transformers and motors. Joseph Henry (United States) separately discovered the principle of electromagnetic induction but did not publish his work. He also described an electric motor.

- 1832** Using Faraday's principles, Hippolyte Pixii (France) built the first dynamo, an electric generator capable of delivering power for industry. Pixii's dynamo used a crank to rotate a magnet around a piece of iron wrapped with wire.
- 1835** Joseph Henry (United States) invented the electric relay, which could send electric currents long distances.
- 1837** Thomas Davenport (United States) invented the electric motor, an invention that is used in most electric appliances today.
- 1839** Sir William Robert Grove (Scotland) developed the first fuel cell, a device that produces electric energy by combining hydrogen and oxygen.
- 1841** James Prescott Joule (England) showed that energy is conserved in electric circuits involving current flow, thermal heating and chemical transformations. A unit of thermal energy, the Joule, was named after him.
- 1844** Samuel Morse (United States) invented the electric telegraph, a machine that could send messages long distances across wires.
- 1860s** The mathematical theory of electromagnetic fields was published. J.C. Maxwell (Scotland) created a new era of physics when he unified magnetism, electricity and light. Maxwell's four laws of electrodynamics (Maxwell's Equations) eventually led to electric power, radios and television.
- 1876** Charles Brush (United States) invented the open coil dynamo (or generator) that could produce a steady current of electricity.
- 1878** Joseph Swan (England) invented the first incandescent light bulb (also called an electric lamp). His light bulb burned out quickly.  
Charles Brush (United States) developed an arc lamp that could be powered by a generator.  
Thomas Edison (United States) founded the Edison Electric Light Co. in New York City. He bought a number of patents related to electric lighting and began experiments to develop a practical, long-lasting light bulb.
- 1879** After many experiments, Thomas Edison (United States) invented an incandescent light bulb that could be used for about 40 hours without burning out. By 1880, his bulbs could be used for 1,200 hours.  
Electric lights (Brush arc lamps) were first used for public street lighting in Cleveland, Ohio.  
California Electric Light Company, Inc., in San Francisco, was the first electric company to sell electricity to customers. The company used two small Brush generators to power 21 Brush arc light lamps.
- 1881** The electric streetcar was invented by E.W. von Siemens.
- 1882** Thomas Edison (United States) opened the Pearl Street Station in New York City. The power station was one of the world's first central electric power plants and could power 5,000 lights. It used a direct current (DC) power system, unlike the power systems that we use today which use alternating current (AC). The first hydroelectric station opened in Wisconsin. Edward Johnson first put electric lights on a Christmas tree.
- 1883** Nikola Tesla (U.S. immigrant from Austrian empire) invented the Tesla coil, a transformer that changed electricity from low voltage to high voltage, making it easier to transport over long distances.

- 1884** Nikola Tesla (U.S. immigrant from Austrian empire) invented the electric alternator for producing alternating current (AC). Until this time, electricity had been generated using direct current (DC) from batteries. Sir Charles Algernon Parsons (England) invented a steam turbine generator, capable of generating huge amounts of electricity.
- 1886** William Stanley Jr. (United States) developed the induction coil transformer and an alternating current (AC) electric system.
- 1888** Nikola Tesla (U.S. immigrant from Austrian empire) demonstrated the first polyphase alternating current (AC) electric system. His AC system included all units needed for electricity production and use: generator, transformers, transmission system, motor (used in appliances) and lights. George Westinghouse, the head of Westinghouse Electric Company, bought the patent rights to the AC system. Charles Brush (United States) was the first to use a large windmill to generate electricity. He used the windmill to charge batteries in the cellar of his home in Cleveland, Ohio.
- 1893** The Westinghouse Electric Company used an alternating current (AC) system to light the Chicago World's Fair. A 22 mile AC power line was opened, sending electricity from Folsom Powerhouse to Sacramento (both in California).
- 1895–96** The Niagara Falls hydropower station opened. It originally provided electricity to the local area. One year later, when a new alternating current (AC) power line was opened, electric power from Niagara Falls was sent to customers over 20 miles away in Buffalo, New York.
- 1897** Joseph John Thomson (England) discovered the electron.
- 1901** The first power line between the United States and Canada was opened at Niagara Falls.
- 1903** The world's first all turbine station opened in Chicago. The world's largest generator (5,000 Watts) was opened at Shawinigan Water & Power. The world's largest and highest voltage line (136 kilometers and 50 kilovolts) brought power to Montreal.
- 1908** J. Spangler (United States) invented the first electric vacuum cleaner.
- 1909** The world's first pumped storage plant opened in Switzerland.
- 1911** W. Carrier (United States) invented electric air-conditioning.
- 1913** Thomas Edward Murray (United States) created the first air pollution control device, the cinder catcher. Arnold Goss (United States) invented the electric refrigerator.
- 1920** The Federal Power Commission (FPC) was established for licensing hydroelectric projects.
- 1921** Lakeside Power Plant, in Wisconsin, became the world's first power plant to burn only pulverized coal.
- 1922** Connecticut Valley Power Exchange (CONVEX) started pioneering interconnection between utilities.
- 1933** The Tennessee Valley Authority (TVA) was created. It was the first federal power authority and was designed to provide regional power.

- 1935** Some of the New Deal legislation passed during the Roosevelt administration was designed to regulate public utilities and to bring electricity to rural America. The Public Utility Holding Company Act of 1935 was designed to break up powerful holding companies that had bought up many smaller electric companies. The Federal Power Act of 1935 regulates utilities that transmit and sell power across state lines.
- 1936** Boulder (later renamed Hoover) Dam was completed. A 287 kilovolt power line stretched 266 miles from the dam in Boulder City, Nevada, to Los Angeles, California. The Rural Electrification Act of 1936 aimed at bringing electricity to farms across the country.
- 1937** The Bonneville Power project, a federal power marketing authority, was created.
- 1942** Owing to rural electrification, almost half of American farms had electricity, compared with 11 percent in 1932.
- 1946** The first general purpose electronic digital computer, the ENIAC (Electronic Numerical Integrator and Computer), was completed.
- 1947** Scientists at Bell Telephone Laboratories invented the transistor.
- 1950** Almost all American farms had electricity. John Hopps (Canada) discovered that if a heart stopped beating due to cooling, it could be started again by artificial stimulation using mechanical or electric means. This led to his invention of the world's first cardiac pacemaker.
- 1951** Charles Ginsburg (United States) invented the first videotape recorder (VTR). UNIVAC was the first commercially produced electronic digital computer in the United States.
- 1954** The world's first nuclear power plant (Russia) started generating electricity. The Atomic Energy Act of 1954 was passed. It allowed private ownership of nuclear reactors. Chaplin, Fuller and Pearson (United States) working for Bell Labs, invented the first solar cell.
- 1957** The Shippingport reactor in Pennsylvania was the first nuclear power plant to provide electricity to customers in the United States.
- 1958** The first commercial modem was developed.
- 1961** The first electronic desktop calculators were the ANITA Mark VII and Mark VIII which used vacuum tube technology.
- 1962** The Communications Satellite Act of 1962 encouraged the development of satellite communications. Steve Russell (United States) invented Spacewar, the first game intended for computer use.
- 1963** The U.S. and the former Union of Soviet Socialist Republics (USSR) agreed to establish a direct communications link.
- 1964** International Business Machines Corporation (now IBM) used light emitting diodes (LEDs) on circuit boards in an early mainframe computer.
- 1972** The arcade game Pong was created.

**1973** The first personal computer was developed.  
Dr. Martin Cooper (United States) invented the first portable handset phone.  
Robert S. Ledley (United States) was granted a patent for a diagnostic X-ray system, computerized axial tomography (also known as the CT Scan or CAT Scan).

**1976** The first commercial fiber optic cable was installed in Chicago for telephone signals.

**1981** The Osborne 1 computer, considered by many to be the first true portable computer, was created by Adam Osborne (United States).

**1990s** Advances in LED technology led to the development of white LEDs. The first PDAs, or personal digital assistants, were developed.

**1998** Computer and electronics companies cooperated to develop Bluetooth technology that allows wireless communication between mobile phones, laptops, PCs, printers, digital cameras and video game consoles.

**2001** The iPod, a portable media player, was launched by the Apple Corporation.

# Renewable Energy Sources

## Objective:

Students will understand renewable electric power generation energy sources.

Materials and Curriculum Correlations ▼

## ► Introduction

A renewable resource is any resource that can be naturally replenished. Some examples include water, the sun and wind. These resources can then be used as energy sources, including those that generate electricity for consumers. Each renewable has its own method for generating electricity, whether through chemical processes or conversion of kinetic energy.

The benefits of renewable resources are numerous, but their main appeal is that they produce less pollution. For example, hydrogen fuel produces water as waste and does not require combustion to generate electricity.

One of the main drawbacks of using renewables for power generation is the inconsistency of their availability. Wind power needs a strong wind. Solar needs low cloud coverage and biomass relies on the variable growth rate of living things.

## Procedure

1. Have students research various sources of renewable energy: wind, solar, biomass and geothermal.
2. Have students review information on renewable energy fuel sources such as geothermal, solar and wind.
3. Have students work individually or in groups to develop a creative delivery method of teaching the class about their chosen renewable fuel source. Delivery methods may be:
  - Create an edible replica of the fuel source (uncooked spaghetti wind turbine, gelatin and cookie layer landfill, peanut butter sandwich fuel cell, wafer cookie solar PV array, etc.). Replicas must list ingredients and what components they represent. Please ensure no one in your classroom has an allergy to any food items used.
  - Write a Haiku for each renewable fuel source.
  - Choose a song and rewrite the lyrics to reflect information about a renewable resource.
  - Develop a board game with informational cards and decision-making questions.
  - Have students write a brief report about their chosen renewable fuel source to accompany their project.

## To Know and Do More

Have students research the latest technologies that can advance the use of renewable fuel sources. Are there recent innovative developments?

## Materials Needed:

- Internet for research
- Art and craft supplies

## Curriculum Correlations

K-ESS2 - 2  
K-ESS3 - 3  
4-PS3 - 2

4-PS3 - 4  
4-ESS3 - 1  
5-ESS3 - 1

MS-ESS3 - 4  
HS-ESS3 - 1

# Conventional Electric Power Generation Systems, Process and Fuel Sources

## Objective:

Students will understand the components of conventional electric power generation systems, processes and fuel sources.

Materials and Curriculum Correlations ▼

## ► Introduction

Conventional electric power generation systems use one or more of the following energy sources: coal, natural gas, oil, uranium or water. Although hydropower uses a renewable resource and the others are nonrenewable, hydropower has been in existence for such a long time that it is considered a conventional generation type.

In 2023, natural gas was used for about 43 percent of the 4 trillion kilowatt-hours of electricity generated in the United States. Natural gas, in addition to being burned to heat water for steam, can also be burned to produce hot combustion gases. These gases pass directly through a gas turbine, spinning the turbine's blades to generate electricity. Natural gas turbines are commonly used when electricity use is in high demand. U.S. natural gas-fired power plants set a record, generating more than 7 million megawatt-hours (MWh) of electricity on August 2, 2024, according to U.S. Energy Information Administration's Hourly Electric Grid Monitor, making up almost half of all electricity generated in the contiguous United States that day. In 2023, 16 percent of U.S. electricity was fueled by coal.

Petroleum can be burned to produce hot combustion gases to turn a turbine or to make steam that turns a turbine. Residual fuel oil and petroleum coke, products from refining crude oil, are the main petroleum fuels used in steam turbines. Distillate (or diesel) fuel oil is used in diesel engine generators. Petroleum was used to generate less than one percent of all electricity in the United States in 2023.

Nuclear power was used to generate approximately 18 percent of all U.S. electricity in 2023. Nuclear power plants produce electricity with nuclear fission to create steam that spins a turbine to generate electricity. Most U.S. nuclear power plants are located in states east of the Mississippi River.

Nearly all hydroelectric capacity was built before the mid-1970s by federal agencies. Hydropower accounts for approximately 27 percent of all electricity generated by renewable resources in the U.S. in 2023.

(Source: [eia.gov](https://www.eia.gov), accessed January 2025)

## Procedure

1. Review with students the parts of the electric generation process. (boiler, turbine, generator, power line, transformer, consumer)
2. Discuss the basic components of conventional power plants (boiler, turbine and generator; except for hydropower which is just the turbine and generator).
3. Discuss the basic process for electrical generation of conventional power plants. (A fuel is burned to make steam to turn a turbine, which generates electricity.)
4. Discuss the basic fuel sources of conventional power plants. (coal, oil, natural gas, uranium and water)

5. Ask students to determine why hydropower is considered conventional. (It is a proven and reliable source of electrical generation for over 100 years. Due to the length of time this resource has been used it is considered conventional.)
6. Have students research the components of each type of conventional power plant and make a diagram labeling each part of the system.  
(Note: Search engines for “power plant diagrams” will result in many images. Students should look thoroughly.)
  - a. Coal power plants should include: boiler, coal, combustion system, compressor, condenser, cooling tower, generator, scrubber and a turbine.
  - b. Natural gas or oil power plants should include: combustion system, compressor, condenser, cooling tower, generator and a turbine.
  - c. Nuclear power plants should include: containment building, reactor, control rods, condenser, cooling tower, generator and a turbine.
  - d. Hydropower power plants should include: reservoir, penstock, intake, outflow, generator and turbine.
7. Have student research and describe how each of the above power plants obtain, prepare and use fuel. With hydropower, have students determine the parameters of choosing a river for a dam site.

## To Know and Do More

Locate and research the nearest conventional electric power generation plant. What is its fuel source? How did that fuel arrive at the power plant? How many customers does it serve? How much electricity can it generate at full capacity?

## Materials Needed:

- Internet

## Curriculum Correlations

4-PS3 - 4

4-ESS3 - 1

5-PS3 - 1

5-ESS3 - 1

MS-LS2 - 1

MS-ESS3 - 3

MS-ESS3 - 4

MS-ESS3.A

MS-ESS3.D

HS-LS2 - 1

HS-LS2 - 7

HS-LS2.A

HS-ESS2 - 4

HS-ESS3 - 1

HS-ESS3 - 2

HS-ESS3 - 3

HS-ESS3 - 4

HS-ESS3 - 5

HS-ESS3.A

HS-ESS3.C

HS-ESS3.D

# Conventional Electric Power Generation Pros and Cons

## Objective:

Students will understand the impact of conventional electric power generation systems, processes and fuel sources.

Materials and Curriculum Correlations ▼

## ► Introduction

How much does it cost to generate electricity? What is the efficiency of different types of power plants? How does the generation of electricity affect the environment?

Levelized cost of electricity (LCOE) is a measure of the overall cost of different generating technologies. It represents the per kilowatt-hour cost (in real dollars) of building and operating a generating plant over its projected lifespan. Key factors to calculating LCOE include capital costs (land, building materials for the power plant, etc.), fuel costs, fixed and variable operations and maintenance (O&M) costs, financing costs and a utilization rate for each plant type.

One measure of the efficiency of a generator or power plant that converts a fuel into heat and into electricity is the heat rate. The heat rate is the amount of energy used by an electrical generator or power plant to generate one kilowatt-hour (kWh) of electricity. Heat rates are expressed in British thermal units (Btu) per net kWh generated. Net generation is the amount of electricity a power plant (or generator) supplies to the power transmission line connected to the power plant. Net generation accounts for all the electricity that the plant itself consumes to operate the generator(s) and other equipment, such as fuel feeding systems, boiler water pumps, cooling equipment and pollution control devices.

To express the efficiency of a generator or power plant as a percentage, divide the equivalent Btu content of a kWh of electricity (which is 3,412 Btu) by the heat rate. For example, if the heat rate is 10,500 Btu, the efficiency is 33 percent. If the heat rate is 7,500 Btu, the efficiency is 45 percent.

In 2023, about 4.2 trillion kWh of electricity were generated in the U.S. Therefore, electricity consumption is an important portion of a consumer's environmental footprint. All forms of electricity generation have some level of environmental impact. Most of the electricity in the United States is generated from conventional fossil fuels, such as coal, natural gas and oil. All forms of electrical generation, from both nonrenewable and renewable sources, have their advantages and disadvantages. Air emissions in the United States from renewable energy generation produce much fewer sulfur dioxides and nitrogen oxides than energy produced from fossil fuels.

Using energy more efficiently through more efficient end uses or through more efficient generation, such as combined heat and power, reduces the amount of fuel required to produce a unit of energy output and reduces the corresponding emissions of pollutants and greenhouse gases. Electricity from renewable resources such as solar, geothermal and wind technologies generally does not contribute to climate change or local air pollution since no fuels are combusted in these processes.

U.S. natural gas-fired power plants set a record, generating more than 7 million megawatt-hours (MWh) of electricity on August 2, 2024, according to U.S. Energy Information Administration (EIA) Hourly Electric Grid Monitor, making up almost half of all electricity generated in the contiguous United States that day. In 2023, natural gas was used for about 43 percent of total electricity generation in the U.S., making it the largest source of power generation. In 2023, 16 percent of U.S. electricity was fueled by coal. This was a decrease from 2022, when coal accounted for 20 percent of the country's electricity generation. Nuclear power generated about 18 percent of all U.S.

electricity in 2023. Hydropower accounted for roughly 27 percent of all electricity generated by renewable resources in the U.S. in 2023. While hydropower makes up a significant portion of renewable energy, it only accounts for about 6 percent of total U.S. electricity generation.

(Sources: [epa.gov](http://epa.gov) and [eia.gov](http://eia.gov), accessed January 2025)

## Procedure

1. Either in groups or individually, have students research the cost, efficiency and environmental impacts for each type of conventional electric power generation fuel type: coal, natural gas, oil, nuclear and hydropower.
2. Have students create electronic presentations that deliver the above information.
3. Have the students, or student groups, give their presentations to the class.
4. Make copies of the student sheet grading rubric and have the class grade each presentation as they are given.
5. Discuss with students what direction they think electric power generation will take in 20 years. Will conventional power generation be the same? Will new generation systems be developed?

## To Know and Do More

What promising technology is on the horizon? What would be the most futuristic source type? If students could invent a new fuel type, what might it be?

## Materials Needed:

• Internet

• Student sheet

## Curriculum Correlations

4-ESS3 - 1

5-ESS3 - 1

MS-ESS3.A

HS-ESS3 - 1

HS-ESS3 - 2

HS-ESS3 - 3

HS-ESS3 - 4

HS-ESS3 - 5

HS-ESS3.A

HS-ESS3.C

# Conventional Power Plant

## Presentation Grading Rubric

Names of the Presentation Group:

COAL	Barely covered	Covered fairly well	Covered in depth	Total points
Cost	2	3	5	
Efficiency	2	3	5	
Environmental Impacts	2	3	5	
OIL	Barely covered	Covered fairly well	Covered in depth	Total points
Cost	2	3	5	
Efficiency	2	3	5	
Environmental Impacts	2	3	5	
NATURAL GAS	Barely covered	Covered fairly well	Covered in depth	Total points
Cost	2	3	5	
Efficiency	2	3	5	
Environmental Impacts	2	3	5	
NUCLEAR	Barely covered	Covered fairly well	Covered in depth	Total points
Cost	2	3	5	
Efficiency	2	3	5	
Environmental Impacts	2	3	5	
HYDROPOWER	Barely covered	Covered fairly well	Covered in depth	Total points
Cost	2	3	5	
Efficiency	2	3	5	
Environmental Impacts	2	3	5	

	Total points for each type of fuel presentation
COAL	
OIL	
NATURAL GAS	
NUCLEAR	
HYDROPOWER	
<b>TOTAL PRESENTATION GRADE (out of 75 points)</b>	

# Energy for Electricity

## Objective:

Students will describe energy transformations required to produce electric energy for homes.

Materials and Curriculum  
Correlations ▼

## ► Introduction

Electric generation requires many energy transformations. In this activity, students will complete the Electric Generation Student Sheet, which is like a puzzle showing the steps in the generation process. Students will learn how electricity is generated and delivered to their homes.

### Procedure

1. Ask students if they believe that energy is important to their lives. How would their lives be different without electricity?
2. Ask students where electricity comes from and how it is made. Tell them that the process of generating and delivering electricity requires many energy transformations.
3. Pass out pieces of the “Electric Generation Puzzle” and give students a few minutes to put the pieces in order. (boiler, turbine, generator, power line, transformer, consumer)
4. Go through each step of the puzzle, asking students to give the type and form of energy going in and coming out of each step. Point out that burning the fuel in the boiler is a chemical change that breaks the bonds of the hydrocarbons in the fuel to release thermal energy (and waste products such as carbon dioxide and sulfur dioxide). Compare the turbine to a pinwheel, demonstrating how steam can turn the turbine to create mechanical energy. The transformer’s job is to change the voltage, either up or down. Step-up transformers are needed to replace voltage lost as electricity is converted to thermal energy by electric resistance in the power lines. Many household electronic devices have step-down transformers, which are a miniature version of those on electric poles. These small transformers also commonly contain components to convert the alternating current (AC) from an outlet into direct current (DC).
5. Have students name some further energy transformations that occur once electricity is used in their homes.
6. Ask students how other energy sources would produce electricity differently. When using nuclear power, wind power, hydropower or solar power, which pieces would change or be removed? Distribute the energy source cards and have students work the original puzzle with the new energy sources.
7. Have students discuss the environmental effects of using renewable versus nonrenewable fuels.
8. List advantages and disadvantages of each method of producing electricity. Each energy source has benefits and drawbacks that must be considered and balanced.
9. Help students identify some of the economic and social impacts involved in changing our fuel mix.

## Description of Electric Generation Process

1. Boilers at a power plant convert chemical potential energy from fuel (fossil fuels, biomass, hydrogen) to thermal kinetic energy, changing water to steam. Light and chemical energy (new chemicals in the gases produced) are also formed but the energy does not contribute to the process of electric generation.
2. Turbines are turned by steam, converting thermal kinetic energy to mechanical kinetic energy. Thermal energy from friction within the mechanism is produced as well but does not contribute to the electric generation process.
3. Generators, turned by a turbine, rotate a coil of wire in a magnetic field converting mechanical kinetic energy to electric kinetic energy. Thermal energy from friction within the mechanism is produced as well but does not contribute to the electric generation process.
4. Power lines transmit electric energy at several thousand Volts. Resistance heating in wires converts electric energy back to thermal energy, resulting in a voltage drop and a loss of usable energy. High voltage lines from a power plant are called transmission lines. The transmission lines run to a substation which contains transformers and switches.
5. Transformers and substations may be step-up or step-down. Step-up transformers along the power lines increase voltage periodically; step-down transformers, on poles or in yards, reduce the voltage to a safe level for home use.
6. Consumers convert electric energy into many forms to run lighting and home appliances.

### To Know and Do More

1. Investigate how transformers work. The websites below are useful guides to show how transformers step voltage up and down and how household transformers also convert alternating current (AC) to direct current (DC).
2. Check out [explainthatstuff.com/transformers.html](http://explainthatstuff.com/transformers.html) and [science.howstuffworks.com](http://science.howstuffworks.com) for detailed information on how power grids work.
3. If you have access to a voltmeter, have students design and build transformers. Test the voltage in and out of transformers and compare to the number of turns of wire on each core. Have students see if they discover a pattern.

## Materials Needed:

- Copies of “Electric Generation student sheet,” cut apart
- Copies of “Energy Source Cards Electric,” cut apart
- Pinwheel (optional)
- Hand generator (optional)
- Transformer from a household item, such as a cell phone charger (optional)

## Curriculum Correlations

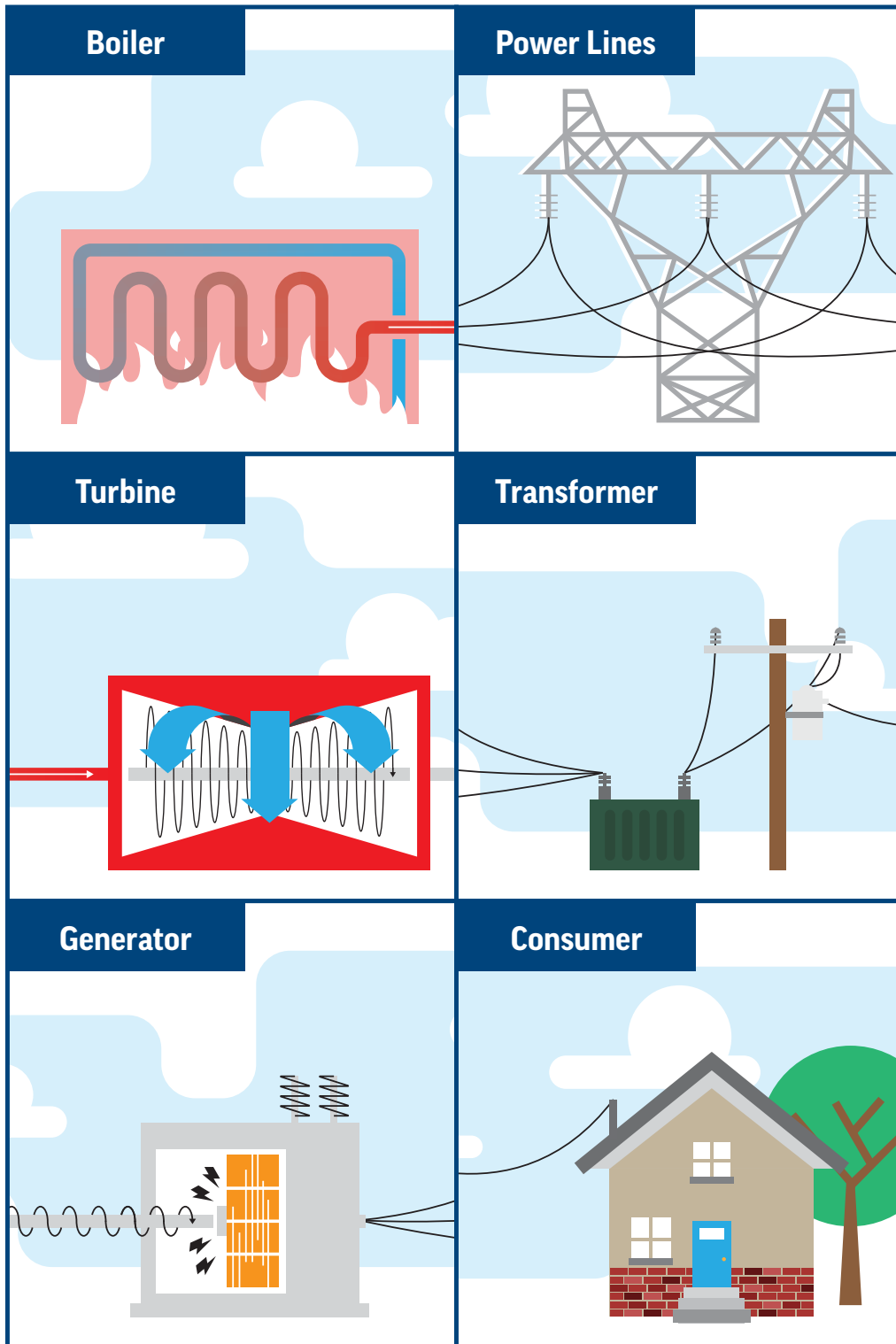
K-ESS2 - 2  
4-PS3 - 2  
4-PS3 - 4  
5-ESS3 - 1

MS-PS1 - 2  
MS-PS2 - 3  
MS-PS2 - 5  
MS-PS3.A

MS-PS3.B  
HS-PS1 - 4  
HS-PS3 - 1  
HS-PS3 - 2

HS-PS3.A  
HS-PS3.B  
HS-PS3.D

# Electric Generation



# Energy Source Cards Electric

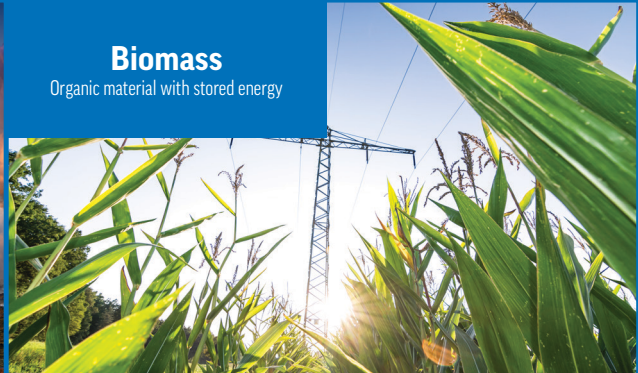
## Geothermal

Created with heat from inside the earth



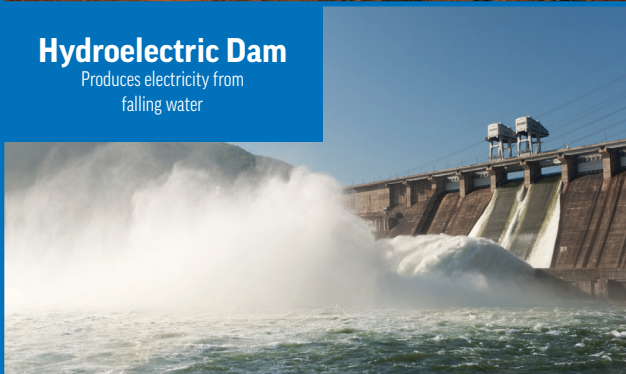
## Biomass

Organic material with stored energy



## Hydroelectric Dam

Produces electricity from falling water



## Wind Generator

Produces electricity from wind



## Photovoltaic Panel

Produces electricity from sunlight



## Power Tower

Produces heat from reflecting sunlight



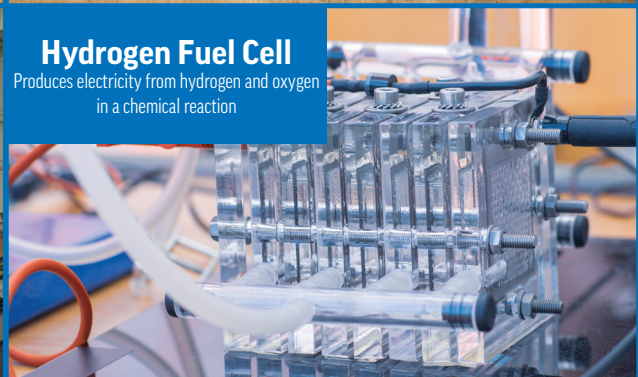
## Nuclear Reactor

Produces heat from uranium



## Hydrogen Fuel Cell

Produces electricity from hydrogen and oxygen in a chemical reaction



# The Transmission and Distribution Process

## Objective:

Students will understand electric power distribution processes and systems.

Materials and Curriculum  
Correlations ▼

## ► Introduction

To solve the problem of sending electricity efficiently over long distances, scientists developed a device called a transformer. A transformer also makes it possible to supply electricity to homes and businesses located far from electric generating plants.

A transformer changes the voltage of electricity in power lines. The electricity produced by a generator travels along cables to a transformer, which then changes the voltage of the electricity. Electricity can be moved long distances more efficiently using high voltage. Transmission lines are used to carry the electricity to a substation. Substations have transformers that change the high voltage electricity into lower voltage electricity. From the substation, distribution lines carry the electricity to homes, offices and factories that all use low voltage electricity.

### Procedure

1. Have students research the electric power grid. What are line losses?
2. Have students research step-up and step-down transformers for use at various locations: leaving the power plant, high voltage transmission, substation, pad mount and residential pole.
3. Have students make a chart of transformers by type, size (dimensions), weight, cost and voltage transformed.
4. Have students research how transformer coils are kept cool to dissipate heat while working.
5. Have students research how transformers are replaced when they fail.
6. Have students make a list of the many causes of power outages.
7. What are brownouts and blackouts? What are the various causes?
8. Have students research how transmission lines and transformers are sited. Sited means to understand the parameters involved in placing high voltage transmission lines, substations and transformers in residential and industrial areas, high population areas, low population and rural population areas. How do cost, property lines, roads, etc. influence decisions? Have students research how huge transmission towers are built in desolate areas, mountains, mesas, deserts or swamps?
9. Have students draw a map of the local transmission lines from their homes to the nearest substation and if possible on to the nearest power plant.

## To Know and Do More

1. Have students make a small transformer.
2. Watch videos from the American Association of Physics Teachers (AAPT) for more information and lessons plans.

## Materials Needed:

- Internet
- Pencil, pen
- Paper
- Local area maps

## Curriculum Correlations

K-ESS2 - 2  
3-PS2 - 3  
4-PS3 - 2  
4-PS3 - 4  
4-ESS3 - 1

4-ESS3 - 2  
5-ESS3 - 1  
MS-PS2 - 3  
MS-PS2.B  
MS-PS3 - 2

MS-PS3 - 5  
HS-PS3 - 1  
HS-PS3 - 5

# The Smart Grid

## Objective:

Students will learn about the smart grid.

Materials and Curriculum  
Correlations ▼

## ► Introduction

Smart grid technology allows multiple paths of communication between utilities, their customers and energy production sites. It uses computer based remote control and automation. These systems are made possible by two-way communication technology and computer processing that has been used for decades in other industries. They are now used on electricity networks, from the power plants and wind farms all the way to the consumers of electricity in homes and businesses. They offer many benefits to utilities and consumers, mostly improvements in energy efficiency on the electricity grid and in the energy users' homes and offices.

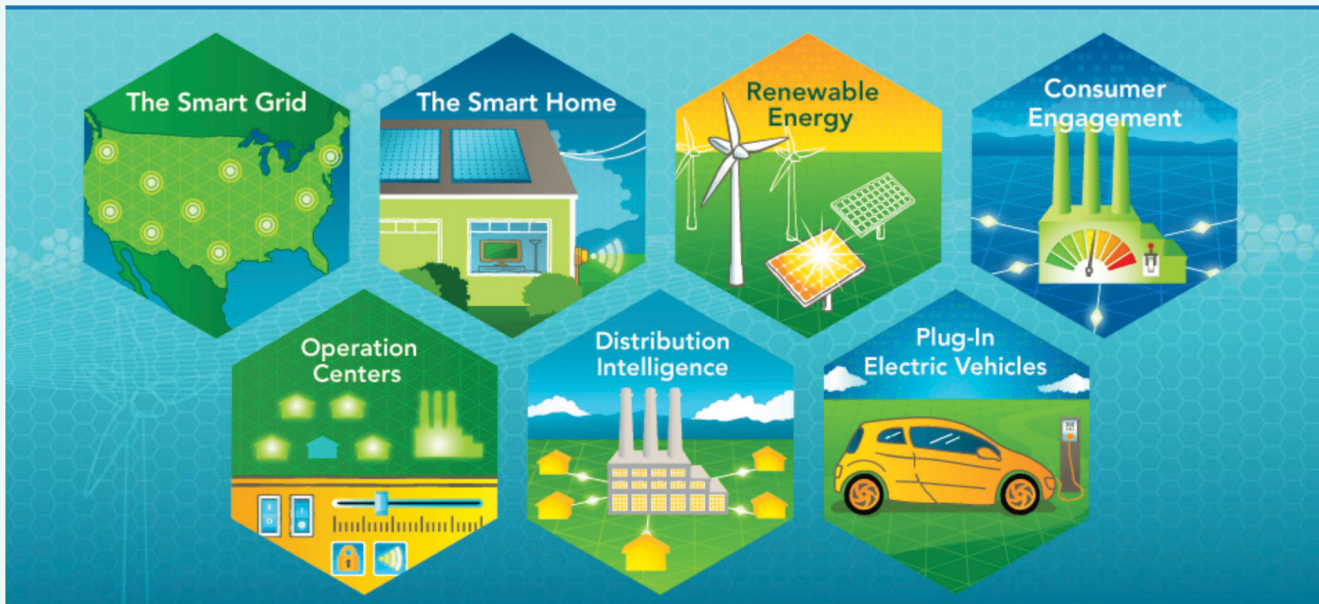
For a century, utility companies sent workers out to gather much of the data needed to provide information for electricity billing or damages. The workers read meters, looked for broken equipment and measured voltage. Today, most electric meter installations by utilities in the U.S. use smart metering infrastructure.

The grid amounts to the networks that carry electricity from the plants where it is generated to consumers. The grid includes wires, substations, transformers, switches and much more.

### Procedure

1. Research the Federal Energy and Regulatory Commission (FERC).
2. Research the North American Electric Reliability Corporation (NERC).
3. What is the relationship between either of these organizations and the smart grid?
4. What are other emerging technologies in electric power transmission and distribution? Consider automation technologies such as Supervisory Control and Data Acquisition (SCADA), Advanced Metering Infrastructure (AMI), automated transfer system and fuel cells.
5. Individually or as a group, have students watch the U.S. Department of Energy video about the smart grid at [youtube.com/watch?v=JwRTpWZRejk](https://www.youtube.com/watch?v=JwRTpWZRejk). Then have students answer the following questions.

# What is the smart grid?



(Source: [energy.gov/smart-grid](http://energy.gov/smart-grid), accessed February 2025)

1. What makes a grid “smart?”
2. What does a smart grid do?
3. How does a smart grid give customers control?
4. What are the components of the smart grid?
5. What does the smart grid have to do with home energy management systems?
6. What are smart appliances?
7. How can home power generation systems use the smart grid?
8. How can renewable energy be connected to the smart grid?
9. What is consumer engagement?
10. What are time of use programs?
11. What is net metering?
12. Describe several financial incentives in connection with the smart grid.
13. What are grid operation centers?
14. How can the smart grid be self-healing?
15. How can the smart grid help prevent blackouts?
16. What is distribution intelligence?
17. How does the self-healing power distribution system respond to outages?
18. How will the smart grid help to fuel plug-in electric vehicles (PEVs) and promote the infrastructure to charge PEVs in the future?

## To Know and Do More

1. Research your local utility and determine if they have installed smart meters in your area. If they don't, do they have plans to do so in the future?
2. List all possible careers that are needed to make the smart grid?

## Materials Needed:

- Internet

## Curriculum Correlations

K-ESS2 - 2

K-ESS3 - 3

4-PS3 - 2

4-PS3 - 4

4-ESS3 - 1

5-ESS3 - 1

MS-PS2 - 3

MS-ESS3 - 3

MS-ESS3.A

HS-PS3.B

HS-ESS3 - 1

HS-ESS3 - 4

# Your State's Electrical Generation

## Objective:

Students will research the local power plant, determining energy source, utility company and the type of utility, then generate a map of the area that is served by that utility.

Materials and Curriculum Correlations ▼

## ► Introduction

Despite its great importance in daily life, few people stop to think what life would be like without electricity. Like air and water, people tend to take electricity for granted. But people use electricity to do many jobs every day, from lighting, heating and cooling homes to powering televisions and computers.

Where is the nearest power plant to your location? Who owns and operates this power plant? What are its fuel source(s)? What type of utility business is it? (utility cooperative, municipal or investor owned)

A **utility cooperative** delivers a public utility such as electricity, water or telecommunications to its members. Profits are either reinvested for infrastructure or distributed to members in the form of “patronage” or capital credits, which are dividends paid on a member’s investment in the cooperative. Each customer is a member and owner of the business with an equal say as every other member of the cooperative, unlike investor owned utilities where the amount of say is governed by the number of shares held. Many such cooperatives exist in the United States. They often bring electric power to rural areas. Many electric cooperatives band together to form their own wholesale power cooperatives, often called G&Ts, for generation and transmission.

A **municipal utility** is a special purpose district that provides public utilities (such as electricity, natural gas, sewage treatment, waste collection/management, wholesale telecommunications and/or water) to residents. Local residents may vote to establish a municipal utility district, which is represented by a board of directors elected by constituents. As governmental bodies, they are usually nonprofit.

An **investor owned utility** is a business providing a product or service regarded as a utility (often termed a public utility regardless of ownership) and managed as a private enterprise.

## Procedure

1. Have students define the different utilities types (cooperatives, municipals, investor owned).
2. Either in groups or individually, have students research local power plants, determining the energy source(s), the utility company and the type of utility.
3. What is the generating power of the local power plant?
4. Research the past history of the power plant and what changes may have been made in the last five years, 10 years and 20 years (if applicable). Has the fuel type changed? Has the power plant been retrofitted with new emission controls?

5. Have students use markers or colored pencils and a local or regional map to show the local boundaries of the utilities' service area. If the service area covers a large part of the state, show this area on a state map.
6. Research the number and types of power plants for your state and their major fuel source. ([eia.gov/state](http://eia.gov/state))
7. Determine the rank of your state in electricity production and consumption. ([eia.gov/state/rankings/?sid=US](http://eia.gov/state/rankings/?sid=US))

## To Know and Do More

1. Go to the local utilities' website and research the features, services and products offered by the utility.
2. Write down at least three features and why they are of interest to a customer (how to lower your bill, understanding your energy usage, how to read your bill, emergency numbers, programs and rebates, payment information, FAQs, etc.).

## Materials Needed:

- Internet
- Colored pencils
- Local area, city and state maps

## Curriculum Correlations

4-ESS3 - 1

4-ESS3 - 2

4-PS3.B

5-ESS3 - 1

MS-LS2 - 1

MS-ESS3 - 3

MS-ESS3 - 4

MS-ESS3.A

HS-LS2 - 7

HS-LS2.A

HS-ESS3 - 1

HS-ESS3 - 2

HS-ESS3 - 3

HS-ESS3 - 4

HS-ESS3 - 5

HS-ESS3.A

HS-ESS3.C

HS-ETS1-1

HS-ETS1.A

# Classroom Comfort and School Lighting Audit

## Objective:

Students will calculate energy use and costs based on real world data.

Materials and Curriculum Correlations ▼

## ► Introduction

In this activity, students will conduct a lighting survey of their school and estimate the amount of money that could be saved by turning lights off for an extra 30 minutes a day. As students will need to leave the classroom to do parts of this activity, you may need to alert your building administration.

### Procedure

1. Speak to your school custodian to find out the wattages of the various bulbs used in your school. You may want to have a custodian bring some bulbs and show them to students before they begin the audit so that they can identify the bulbs when they see them throughout the building.
2. Instruct students on how to read a light meter, thermometer and hygrometer.
3. Produce the student sheets. You may also want to provide copies of a map of the school to students. Decide which locations in the school you will allow students to visit. Decide if the entire class will stay together or if you will break students into teams. If using teams, consider whether you need additional adult supervision.
4. Provide students with copies of "School Lighting Audit" and allow time to complete the building audit.
5. Assist students as needed in their calculations.

### To Know and Do More

6. Find out how much electricity your school used last month. Calculate your school's primary carbon footprint. Multiply the number of kilowatt-hours times .81 to get the approximate greenhouse gas emissions caused by the electricity used by your school.
7. Write an action plan for your school to reduce your electricity consumption and shrink your carbon footprint.

## Materials Needed:

- Calculator
- Student sheet
- Hygrometer
- Light meter
- Thermometer

## Curriculum Correlations

4-PS3 - 2  
4-PS3 - 4  
5-PS1 - 3  
5-PS1.B  
5-ESS3 - 1

MS-PS2 - 3  
MS-ESS3 - 3  
MS-ESS3.A  
HS-PS1 - 3  
HS-PS3.B

HS-ESS3 - 1  
HS-ESS3 - 2  
HS-ESS3.A  
HS-ESS3.C

# School Lighting Audit

In this activity, you will conduct a lighting survey of your school and estimate the amount of money that could be saved by turning lights off for an extra 30 minutes a day.

## Step One: Collect Data

Record temperature, humidity and light levels for each room in your school that you audit. Record in the spaces provided.

To calculate how much electricity your school uses to run the lights, you need to know the type of lights and wattages. Fill in the chart below to collect this data. Your school may not have all of these places, so just fill in the chart for those that you have. Blank spaces are provided for additional areas of your school not listed. Some spaces may have more than one type/wattage of light, so multiple lines are provided for you.

Area of the School	Room Comfort	Bulb Type	Number	Wattage	Total Wattage
Classrooms (Survey one classroom and use it as an estimate for all the classrooms in the school.)	Temperature	Incandescent			
	Humidity	Fluorescent			
	Light level	Other (halogen, CFL, LED, etc.)			
Total Number of Classrooms		Multiply by Classroom Wattage		Total Classroom Wattage	
Hallways	Temperature	Incandescent			
	Humidity	Fluorescent			
	Light level	Other (halogen, CFL, LED, etc.)			
Library/Media Center	Temperature	Incandescent			
	Humidity	Fluorescent			
	Light level	Other (halogen, CFL, LED, etc.)			
Cafeteria	Temperature	Incandescent			
	Humidity	Fluorescent			
	Light level	Other (halogen, CFL, LED, etc.)			

Area of the School	Room Comfort	Bulb Type	Number	Wattage	Total Wattage
Office	Temperature	Incandescent			
	Humidity	Fluorescent			
	Light level	Other (halogen, CFL, LED, etc.)			
Gymnasium	Temperature	Incandescent			
	Humidity	Fluorescent			
	Light level	Other (halogen, CFL, LED, etc.)			
Auditorium	Temperature	Incandescent			
	Humidity	Fluorescent			
	Light level	Other (halogen, CFL, LED, etc.)			
Additional Spaces to Audit					
	Temperature	Incandescent			
	Humidity	Fluorescent			
	Light level	Other (halogen, CFL, LED, etc.)			
	Temperature	Incandescent			
	Humidity	Fluorescent			
	Light level	Other (halogen, CFL, LED, etc.)			

## Step Two: Calculate

Electrical energy is measured in kilowatt-hours. Follow the procedure below to calculate the energy used by the lights in your data table. Use a separate sheet of paper or a spreadsheet on the computer.

1. For each fluorescent tube (not CFLs), add 5 Watts to the wattage you recorded in your data table. This represents the additional electricity used by the ballast. Different types of fixtures have ballasts that use different amounts of electricity but this is a good average.
2. Multiply the number of lights times the wattage of each light for each line of your data table to get the total wattage. Record this information. Add the incandescents, fluorescents, CFLs, LEDs and other lights' wattages together to get a total wattage for the classroom you surveyed. Record this number.
3. Multiply the total wattage for your sample classroom by the number of classrooms in your school. Record this number as the total classroom wattage in the data table.
4. Repeat step 3 for the other areas of your school: hallways, cafeteria and so on. Record these numbers in the data table.
5. Add the total wattages for all of the areas you surveyed. This will be a BIG number.

6. Now it is time to convert to kilowatt-hours. First, we need to convert from Watts to kilowatts (1 kilowatt = 1000 Watts).
7. Talk to your school's custodian or make your best guess of how many hours lights are on in your school each day. Multiply the kilowatts you calculated above by the number of hours your school's lights are on. Now you have kilowatt-hours!
8. Find the cost of 1 kilowatt-hour of electricity in your area. Your school may not pay the same rate for electricity as you do at home. Ask your school district's facilities group for the rate your school pays or just make your best estimate.
9. Multiply the rate per kilowatt-hour times the number of kilowatt-hours your school uses in a day. Take the number from step 8 times the number from step 9.

## Questions:

1. If your school runs its lights for 180 days (the number of days in a typical school year), how much does it cost to run the lights in your school?
2. If you reduced the hours your school's lights were running by half an hour a day, how much could you save per school year?
3. This survey produces an estimate of the electricity used for lighting your school. What are some sources of error in your data? What could be done to increase the accuracy of your estimate?
4. List other things in your school that use electricity.
5. What other ways can your school reduce the amount of electricity it uses?

6. Review the temperature, humidity and light levels of various classroom, hallways and other areas of your school. Discuss with a teacher or custodian if these readings or levels are within guidelines for a comfortable educational setting?
  
7. Discuss variables that affect each type of reading (e.g. season, time of day, entryways open to outside, interior entryway, etc.).
  
8. Graph the temperature and humidity levels in classrooms.