Innovation Teacher Supplemental Activities

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Electricity: Conventional and Renewable Power Plants

Introduction

Electricity is generated at power plants and moved to consumers through complex systems. A power plant may have one or more generators and some generators may use more than one type of fuel.

Conventional energy comes from sources that are not replenished after use. Sources of conventional energy include: coal, oil, natural gas, uranium and water. These sources are generally used for electricity generation. Water is considered a conventional fuel for electricity generation because of its use for over 100 years. It is also considered a renewable resource.

Renewable energy comes from a source that is naturally occurring and replenishes after use. Sources of renewable energy include: wind, solar, geothermal, biomass and water for hydroelectricity/hydropower. These energy sources are used for both electricity generation (sometimes as backup for times of peak demand) and heating.

Alternative energy comes from conventional resources but produces fewer emissions than conventional energy. Sources of alternative energy include: natural gas cogeneration, fuel cells, use of waste energy and electricity and natural gas that is used for transportation. These energy sources are used for heating, backup electricity and for transportation fuels.

Energy for Electricity

Objective

The student will describe energy transformations required to produce electrical energy for homes.

Curriculum Focus

Science
Technology

Materials

- Copies of "Electical Generation Puzzle," cut apart
- Pinwheel (optional)
- Hand generator (optional)
- Transformer from a household item such as a cellular phone charger (optional)

Key Vocabulary

Boiler
Generator
Transformer
Turbine

Next Generation Science Correlations

4-PS3 - 2
4-PS3 - 4
5-ESS3 - 1
MS-PS1 - 2
MS-PS2 - 3, 5
MS-PS3.A-B
HS-PS1 - 4
HS-PS3 - 1-2
HS-PS3.A-B, D

Introduction

Electrical generation requires many energy transformations. In this activity, students will complete a puzzle showing the steps in the generation process and see how electricity is delivered to homes. Though it is a simple puzzle, students generally have no idea how electricity is produced until they have completed this activity.

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 the "Electrical 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 electrical resistance in the power lines. Many household electronic devices have step-down transformers, which are a miniature version of those on electrical poles. These small transformers also commonly contain components to convert the alternating current from an outlet into direct current.

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 than the fossil fuel power plant shown in the puzzle. When using nuclear power, wind power, hydropower or solar power, which pieces would change or be removed?

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 Electrical Generation Process

1. Boilers 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 electrical 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 electrical generation process.

3. Generators, turned by a turbine, rotate a coil of wire in a magnetic field converting mechanical kinetic energy to electrical kinetic energy. Thermal energy from friction within the mechanism is produced as well but does not contribute to the electrical generation process.

4. Power lines transmit electrical energy at several thousand Volts. Resistance heating in wires converts electrical 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 electrical energy into many forms to run lighting and home appliances.

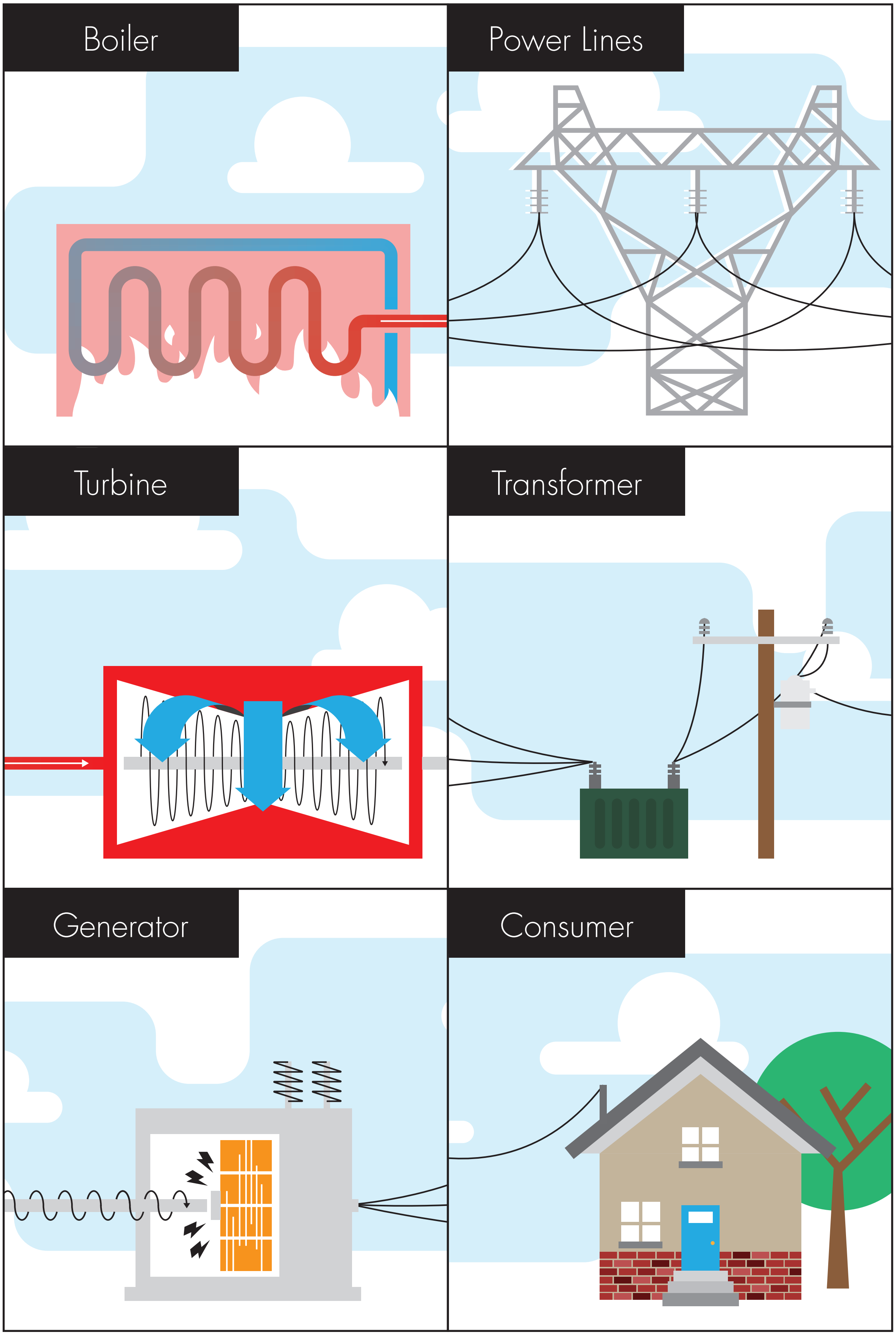
To Know and Do More

1. Investigate how transformers work. The website below is a useful guide to show how transformers step voltage up and down and how household transformers also convert AC to DC current.

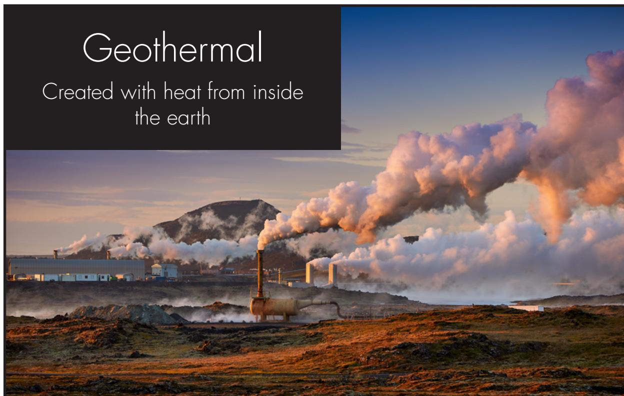
2. Check out *explainthatstuff.com/transformers.html* and *science.howstuffworks.com* for detailed information on how power grids work.

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.

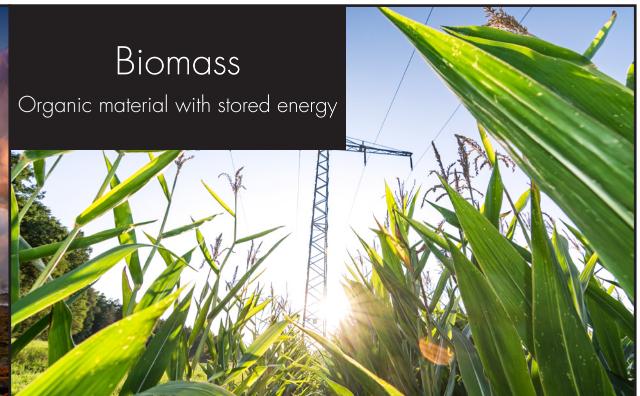
Electrical Generation Puzzle



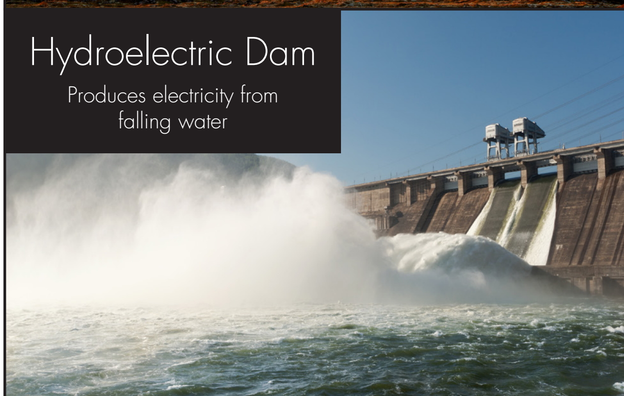
Energy Source Cards: Electrical



Geothermal
Created with heat from inside the earth

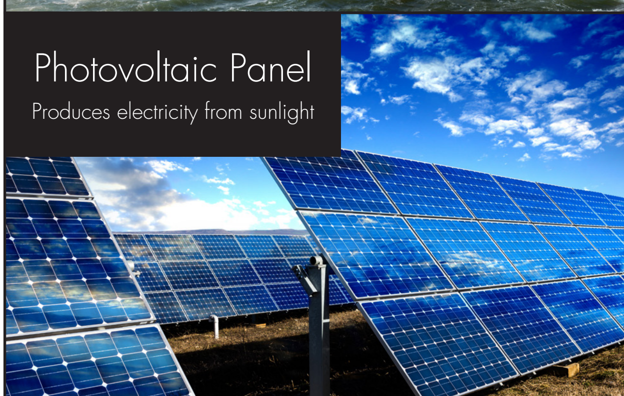


Biomass
Organic material with stored energy



Hydroelectric Dam
Produces electricity from falling water

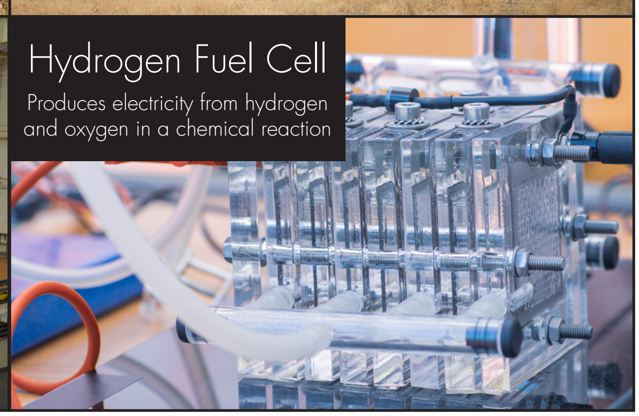
Wind Generator
Produces electricity from wind



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

Conventional Electric Power Generation Systems, Process and Fuel Sources

Objectives	Materials	Key Vocabulary	Next Generation Science Correlations
The student will understand the components of conventional electric power generation systems, processes and fuel sources. **Curriculum Focus** Science Technology		boiler, coal, combustion system, compressor, condenser, containment building, cooling tower, emissions, fuel, furnace, gas turbine, generator, hydropower, intake, natural gas, nuclear power, oil, outflow, penstock, reactor, reservoir, scrubber, turbine, uranium	• 5-PS1 - 3 • 5-ESS3 - 1 • MS-LS2 - 1 • MS-ESS3 - 3-4 • MS-ESS3.A, D • HS-LS2 - 1, 7 • HS-LS2.A • HS-ESS2 - 4 • HS-ESS3 - 1-5 • HS-ESS3.A, C-D

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 2021, natural gas was used for about 38 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. In 2021, 22 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 2021.

Nuclear power was used to generate approximately 19 percent of all U.S. electricity in 2021. 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 and much of it is at dams that are operated by federal agencies. Hydropower accounts for approximately 31.5 percent of all electricity generated by renewable resources in the U.S. in 2021.

(Source: *eia.gov/tools/faqs/faq.php?id=427&t=3*, accessed April 2022, and *eia.gov/kids/energy.cfm?page=electricity_in_the_united_states-basics*, accessed March 2023

Procedure

1. Review with students the activity from the lesson "Energy for Electricity." Have students redo the puzzle pieces, if necessary.
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 at least 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?

Conventional Electric Power Generation Pros and Cons

Objectives

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

Curriculum Focus

Science, Technology
Social Studies, Math

Materials

- Internet

Key Vocabulary

Carbon dioxide
Cost
Efficiency
Habitat
Mercury compounds
Nitrogen oxide
Spent fuel
Sulfur dioxide
Thermal water pollution

Next Generation Science Correlations

- 5-ESS3 - 1
- MS-ESS3.A
- HS-ESS3 - 1-5
- HS-ESS3.A, C

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 an assumed financial life and duty cycle. 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 2022, about 4.24 trillion kWh of electricity were generated in the U.S. (Source: *eia.gov*, accessed March 2023) 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. The average air emissions rates in the United States from non-hydro renewable energy generation are 1.22lbs/MWh (megawatt-hour) of sulfur dioxides and 0.06 lbs/MWh of nitrogen oxides.

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.

(Sources: *epa.gov/ghgemissions and energy.gov/eere/energy-efficiency*, accessed March 2023)

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. Using the "Presentation Grading Rubric" 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?

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	
TOTAL PRESENTATION GRADE (out of 75 points)	

Renewable Energy Sources

Objective
The student will understand renewable electric power generation energy sources.

Curriculum Focus
Science
Technology
Social Studies
Language Arts

Materials
- Internet

Key Vocabulary
Biomass
Cogeneration
Fuel cell
Geothermal
Hydrogen
Landfill gas
Solar energy
Wind energy

Next Generation Science Correlations
5-ESS3 - 1
MS-ESS3.A
HS-ESS3 - 1-5
HS-ESS3.A, C

Background

Renewable resources are 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 carbon 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 power generation. 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:
   - 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.

- 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?

Electrical Generation in Your State

Your Local Power Plant

Despite its great importance in daily life, very 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 tasks every day, from lighting, heating and cooling homes to powering televisions and computers.

Who owns and operates your nearest power plant? What is the primary fuel source? Is it an electric cooperative, a municipal or is it investor owned?

Your local power plant could produce electricity from a variety of sources: coal, oil, natural gas, uranium, the sun, wind, biomass, water or even geothermal. Do you know how the fuel arrives at the power plant: train, pipeline, barge, truck, local mine or well?

Your Local Fuel Mix

Determining your local area fuel mix can be as easy as typing in the key word “fuel mix” into your utilities’ search function or reading the “About Us” section and looking for power plant names and descriptions. Calling the customer service number of your local utility is another way to obtain information. Some utilities purchase power for peak times from other utilities.

Emissions for Your Local Power Plant

Depending upon the source of fuel used and the energy consumption of your local power plant, emissions of greenhouse gases may be released into the atmosphere. Many chemical compounds found in the earth’s atmosphere act as greenhouse gases. When sunlight strikes the earth’s surface, some of it is radiated back toward space as infrared radiation (heat). Greenhouse gases absorb this infrared radiation and trap its heat in the atmosphere. Many gases exhibit these greenhouse properties. Some occur naturally. Some are produced by human activities and some gases are exclusively human made like industrial gases.

There are several major greenhouse gases the United States emitted as a result of human activity. They are included in U.S. and international emissions estimates: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O); industrial gases: hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride (SF_6).

Although the air around us is necessary for our survival, many of us do not know what constitutes air or what is contained in our atmospheric environment. Air is almost entirely made up of invisible gases. Of these, the most abundant is nitrogen.

We may think that oxygen is the main component. Actually, oxygen makes up only about 21 percent of the air around us. Nitrogen makes up 78 percent of that air. Common pollutants are formed as fossil fuels burn (a chemical reaction) in power plants or from vehicle exhaust. The air’s gases, water droplets and these pollutants often react with each other to form different compounds. Oxygen easily combines with sulfur and nitrogen to form nitrogen oxides and sulfur dioxide. Carbon dioxide and water vapor react to form carbonic acid, which makes rain slightly acidic (even without the addition of air pollution). Ozone, carbon monoxide and lead are other common pollutants.

The amount of carbon dioxide the average U.S. house produces from human activities like electricity use, transportation and travel is called a carbon footprint.

Your State's Electrical Generation

National Energy Foundation
cultivating energy literacy

Objectives

The student 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.

Curriculum Focus

Science, Social Studies

Materials

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

Key Vocabulary

Cooperative
Investor owned utility
Municipal utility district

Next Generation Science Correlations

- 5-ESS3 - 1
- MS-LS2 - 1
- MS- ESS3 -3-4
- MS-ESS3.A
- HS-LS2 - 7
- HS-LS2.A
- HS-ESS3 - 1-5
- HS-ESS3.A, C

Background

Despite its great importance in daily life, few people probably 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 is tasked with the delivery of 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 are created to bring electric power to rural areas, when the nearest investor-owned utility would not provide service, believing there would be insufficient revenue to justify the capital expenditures required. Many electric cooperatives have banded together to form their own wholesale power cooperatives, often called G&Ts, for generation and transmission, to supply their member owners with electricity.

A municipal utility district is a special-purpose district, or other governmental jurisdiction, that provides public utilities (such as electricity, natural gas, sewage treatment, waste collection/management, wholesale telecommunications and/or water) to district 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 organization, providing a product or service regarded as a utility (often termed a public utility regardless of ownership) and managed as private enterprise rather than a function of government or a utility cooperative.

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*)
7. Determine the rank of your state in electricity production and consumption. (*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.).

Your Local Area Fuel Mix

Objectives

The student will research the fuel mix for the local area power plant and explain the importance of fuel mix diversity.

Curriculum Focus

Science, Social Studies

Materials

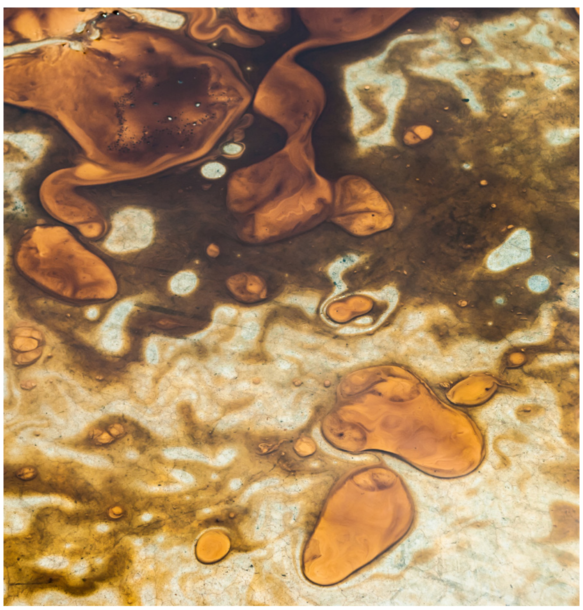
- Internet
- Local area, city and state maps

Key Vocabulary

Diversity
Fuel mix

Next Generation Science Correlations

- 5-ESS3 - 1
- MS-LS2 - 1
- MS- ESS3 -3-4
- MS-ESS3.A
- HS-LS2 - 7
- HS-LS2.A
- HS-ESS3 - 1-5
- HS-ESS3.A, C



Procedure

1. Go to your local utility's website and research the fuel mix of their power plant(s).
2. How does the fuel arrive at the power plant? (local mine, train, pipeline, barge, truck, river)
3. Is there a reason the utility chose this type of fuel?
4. Does the utility have a diverse mixture of fuel types in their company?
5. Why is diversity important? (Some answers might be: if the company has only one fuel source then supply and demand, scarcity and price can affect the customers if the company has problems obtaining fuel. Routes for supplying the power plants with fuel can be damaged by weather, such as floods, tornadoes, hurricanes or earthquakes.)

To Know and Do More

1. Research the history of the power plant. What year was it planned? When was it built? When did it begin electricity production? What is its expected lifespan?
2. Has the fuel mixture changed with time and technology?

Greenhouse Gas Emissions and Your Local Fuel Mix

Objectives

The student will determine the greenhouse gas emissions of conventional power plants and for the local fuel mix and energy consumption.

Curriculum Focus

Science
Social Studies

Materials

- Internet

Key Vocabulary

Carbon dioxide
Emissions
Greenhouse gas
Methane
Nitrogen dioxide
Sulfur dioxide
Water vapor

Next Generation Science Correlations

- 5-ESS3 - 1
- 5-ESS3.C
- MS-ESS3 -3
- MS-ESS3.A
- HS-ESS3 - 1-5
- HS-ESS3.A-D

Introduction

Many chemical compounds found in the earth's atmosphere act as greenhouse gases. When sunlight strikes the earth's surface, some of it is radiated back toward space as infrared radiation (heat). Greenhouse gases absorb this infrared radiation and trap its heat in the atmosphere. Many gases exhibit these greenhouse properties. Some occur naturally. Some are produced by human activities and some gases are exclusively human-made, such as industrial gases.

There are several major greenhouse gases emitted in the United States as a result of human activity. They are included in U.S. and international emissions estimates: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O); industrial gases: hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride (SF_6).

There are other greenhouse gases that are not counted in U.S. or international greenhouse gas inventories. Water vapor is the most abundant greenhouse gas but most scientists believe that water vapor produced directly by human activity contributes very little to the amount of water vapor in the atmosphere.

Ozone is technically a greenhouse gas because it has an effect on global temperature. However, at higher elevations in the atmosphere (stratosphere), where it occurs naturally, ozone is needed to block harmful ultraviolet (UV) light. At lower elevations of the atmosphere (troposphere), ozone is harmful to human health and is a pollutant regulated independently of its warming effects.

Procedure

1. Research conventional power plant emissions.
2. Make a chart of all emissions with headers for "type," "average amounts" and "resulting environmental effects."
3. Discuss the factors that affect the amount of emissions generated, such as type of fuel used and energy demand or consumption needed by the people of the community the power plant serves. Research your local power plant's emissions, if any. (Remember, thermal emissions [hot water] introduced into a local water system can have an affect on the local environment.)
4. Research other sources of greenhouse gas emissions. The Environmental Protection Agency (EPA) website is an informative source. (*epa.gov*)
5. Discuss how one person can help reduce the emissions generated. (use less electricity, install energy saving technologies, install alternative energy technologies)

To Know and Do More

1. Research the types and amounts of emissions from electrical generation of your state.
2. Research the types and amounts of emissions from transportation sources and how that compares with electrical generation.

Electrical Transmission, Distribution and Safety

Introduction

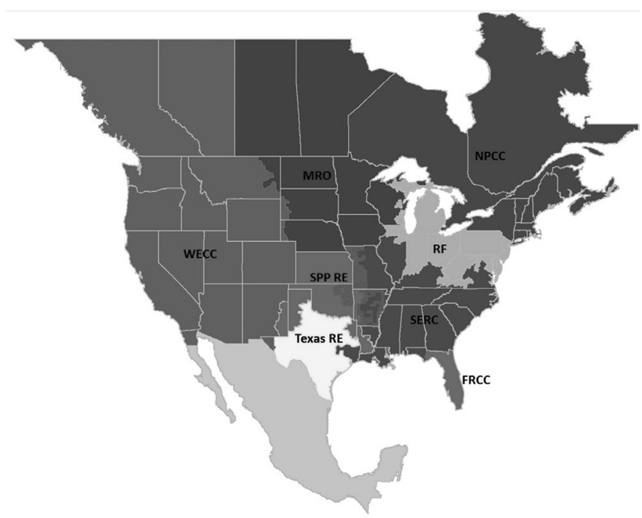
Electrically charged objects have been studied since the time of the Greeks. In the 1600s, William Gilbert first coined the term electricity from electron, the Greek word for amber. How did we get from a shocking experience with static electricity to transmitting electrical energy to millions of people via the grid? The history of electricity is a who's who of famous scientists in the early 1800s followed by massive growth and regulations to the many and varied products that use electricity. Where will the future take us?

As large generators spin, they produce electricity with a voltage of about 25,000 Volts. The electricity first goes to a transformer at the power plant that boosts the voltage up to 400,000 Volts. When electricity travels long distances, it is efficiently transferred at high voltages.

The long thick cables of transmission lines are made of copper or aluminum because they have a low resistance. The higher the resistance of a wire, the warmer it will get. Some of the electrical energy is transformed into heat energy.

The power lines that carry the electricity traverse the entire country. In the United States, the network of nearly 160,000 miles of high voltage transmission lines is known as the grid.

Most of the existing grid was built during a highly structured, highly regulated era. The existing grid was designed to ensure that everyone in the United States had reasonable access to electricity service. Utility customers, through fees authorized and regulated by state regulatory commissions, generally pay for developing and maintaining the grid.



(Source: nerc.com/aboutnerc/keyplayers/pages/default.aspx, accessed March 2023)

This map shows North American Electric Reliability Corporation (NERC) regions: Midwest Reliability Organization (MRO), Northeast Power Coordinating Council (NPCC), Reliability First (RF), SERC Reliability Corporation (SERC), Texas Reliability Entity (Texas RE) and Western Electricity Coordinating Council, (WECC).

Many local grids are interconnected for reliability and commercial purposes, forming larger, more dependable networks that maximize coordination and planning of electricity supply. These networks extend throughout many states.

NERC was established to ensure that the grid in the United States was reliable, adequate and secure. Some NERC members have formed regional organizations with similar missions. These organizations are referred to as Independent System Operators (ISOs) and Regional Transmission Organizations (RTOs). They are part of a national standard design advocated by the Federal Energy Regulatory Commission (FERC). Some organizations have members who connect to lines in Canada or Mexico. Most organizations, depending on the location and the utility, are indirectly connected to dozens and often hundreds of power plants. Some electricity consumed in the United States is imported from Canada and Mexico.

The physical properties of the power lines and other safety and reliability factors may limit the capacity of individual lines and power systems.

- Physical limits. Colliding electrons in a high-voltage AC power line cause electrical resistance and resistance interferes with current in a wire, producing heat. If current flows beyond engineering limits, wires can melt or start a fire. More current can flow over a wire in colder weather, since air cools the line.
- Sag and safety limits. As wire heats up, it softens. Since power lines are heavy, their weight makes them sag as heat builds. If trees, buildings, vehicles, water or other obstructions touch sagging wires, they may disable the wires. The National Electric Safety Code describes how to cap power flows within the physical limits of the line and how to build lines to ensure that sag does not threaten safety. Sagging lines that come into contact with trees or other vegetation have, nonetheless, caused many blackouts. Measures as simple as tree trimming can prevent many small and large scale blackouts.
- Contingencies. Transmission system operators leave some unused capacity on power lines in case an unexpected event (a contingency) occurs somewhere on the system. If, for example, a large power line drops out of service, the power flows will shift to other lines at the speed of light. The power system operator’s job is to ensure that none of those power lines overloads. For example, a power line from Quebec into New England is capable of carrying 2,000 MW. If it should fail, however, sudden power flows from Pennsylvania through New York and into New England would result and could cause uncontrollable overloads. Therefore, the capacity of this line is capped at around 1,400 MW.
- Limits on transformers. Transformers exchange power between systems with different voltages, moving it from low to high voltages and from high to low voltages. Such transfers release a great deal of heat. The amount of power a transformer can move is limited by the current-carrying capacity of the wire and the ability of internal oil coolers to keep the apparatus within operating temperature limits.
- Congestion. Congestion describes a situation in which power cannot reach its market because the transmission system does not have enough capacity to carry the power. Congestion is an economic problem, not a reliability problem. Congestion tends to raise costs overall, since it limits the constrained markets to nearby resources. Congestion does not always increase prices.

High voltage transmission lines carry electricity long distances to substations. The power lines go into substations where transformers change high voltage electricity back into lower voltage electricity. A local distribution system of smaller, lower-voltage distribution lines delivers power from substations and transformers to customers.

In your neighborhood, another small transformer mounted on pole or in a utility box (pad mount) converts the power to even lower levels to be used in your house. The voltage is eventually reduced to 220 Volts for larger appliances, like stoves and clothes dryers and 110 Volts for other smaller appliances.

When electricity enters your home, it must pass through a meter. To know how much electricity you used, your utility company can have a worker read the meter or use a smart meter. A smart meter is an electronic device that records consumption of electrical energy in intervals of an hour or less and communicates that information at least daily back to the utility for monitoring and billing. Smart meters enable two-way communication between the meter and the central system. Smart meters can also gather data for remote reporting. Advanced metering infrastructure (AMI) differs from traditional automatic meter reading (AMR) in that it enables two-way communications with the meter.

After being metered, the electricity goes through a circuit breaker panel or fuse box into your home. The fuse box protects the house in case of problems. When a circuit breaker (or a fuse) “blows” or “trips” something is wrong with an appliance or something was short-circuited. A fuse is a low resistance device that acts as a sacrificial device to provide overcurrent protection of a load or source circuit. If too much electricity or current is being drawn into the household circuit, the metal strip in the fuse melts, interrupting the circuit it is connected to. The fuse or circuit breaker “blows” to prevent damage by overheating.

History of Electricity and Transmission

National Energy Foundation
cultivating energy literacy

Objectives

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

Curriculum Focus

Science
Social Studies

Materials

- Copies of "Electricity Timeline"
- Paper
- Markers
- Internet

Key Vocabulary

Alternating current (AC)
Ampere
Direct current (DC)
Frequency
Joule (J)
Ohm
Volt
Watt

Next Generation Science Correlations

MS-PS1 - 2
MS-PS2 - 3, 5
MS-PS3.A-B
HS-PS1 - 4
HS-PS3 - 1-2
HS-PS3.A-B, D

Introduction

As early as 600 BC, the Greeks discovered static electricity. In the 1600s, William Gilbert first coined the term electricity from electron, 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 the students into five groups. Give each group one page of the "Electricity Timeline." Give the students about ten 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 students discuss their choices as a class 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 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. Write a short paragraph about your energy use if you lived 300 years ago.

Electricity Timeline

Around 600 BC	Thales (Greece) found that when amber was rubbed with silk, it became electrically 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 electrical 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.

Electricity Timeline

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 electrical 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 electrical relay, which could send electrical currents long distances.
1837	Thomas Davenport (United States) invented the electric motor, an invention that is used in most electrical appliances today.
1839	Sir William Robert Grove (Scotland) developed the first fuel cell, a device that produces electrical energy by combining hydrogen and oxygen.
1841	James Prescott Joule (England) showed that energy is conserved in electrical 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.

Electricity Timeline

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 uses 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) electrical 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)

Electricity Timeline

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; and 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 Creation of the Securities and Exchange Commission. Creation of the Bonneville Power project, a federal power marketing authority.

Electricity Timeline

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 was aimed at bringing electricity to farms across the country.
1942	Owing to rural electrification, almost half of American farms had electricity, compared with 11 percent in 1932.
1943–46	The first general purpose electronic digital computer was built, the ENIAC (Electronic Numerical Integrator and Computer).
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 owing to cooling, it could be started again by artificial stimulation using mechanical or electric means. This lead to his invention of the world's first cardiac pacemaker.
1951	Charles Ginsburg (United States) invented the first videotape recorder (VTR).
1953	IBM's 701 EDPM (Electronic Data Processing Machine) was invented as the first commercially successful general purpose computer.
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 by AT&T.
1961	The first commercially available integrated circuits were produced by the Fairchild Semiconductor Corporation (United States). All computer manufacturers started using chips instead of the individual transistors and their accompanying parts. The first electronic desktop calculators were the ANITA Mk VII and Mk 8, which used vacuum tube technology.

Electricity Timeline

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	A direct communications link was established between the former Union of Soviet Socialist Republics (the USSR) and the United States.
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 by Nolan Bushnell.
1973	Scelbi, the first personal computer, was designed by Nate Wadsworth and Bob Findley (United States) and came with 1KB of programmable memory, with an additional 15KB of memory available. Dr. Martin Cooper (United States) invented the first portable handset phone.
1975	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 is installed in Chicago for telephone signals.
1977	The first network of automated teller machines (ATMs) was developed.
1981	The Osborne 1 computer, considered by most historians to be the first true portable computer, was created by Adam Osborne (United States).
1990s	Advances in LED technology led to the wide-scale commercialization of blue and green solid-state sources as well as the development of white LEDs.
1993	The first PDAs, or personal digital assistants are released by the Apple Corporation (United States).
1998	Ericsson, IBM, Intel and Nokia 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.
2004	With the full color range of the high-power LEDs, more advanced architectural designs and stage and studio lighting were developed. Colored LEDs reduce power consumption.

Westinghouse versus Edison: AC versus DC

Objectives

The student will understand the application of different electric power transmissions including alternating current (AC) and direct current (DC).

Curriculum Focus

Science
Social Studies

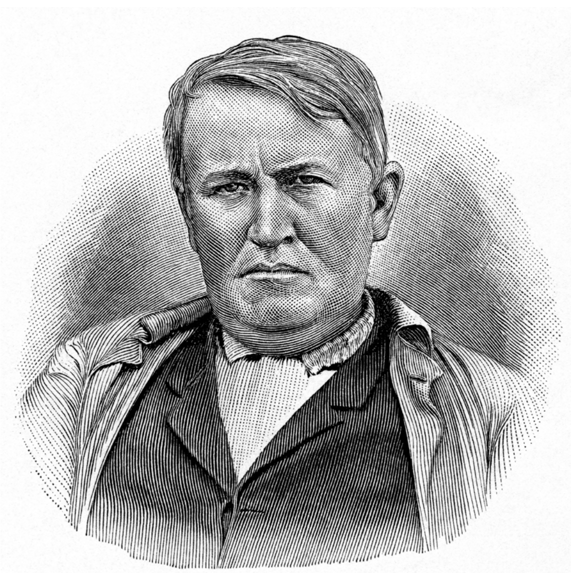
Materials

- Internet

Key Vocabulary

Alternating current (AC)
Direct current (DC)
Transformer
Transmission

Next Generation Science Correlations



Thomas Alwa Edison.

Introduction

The 19th century inventors who first began to harness electricity for useful purposes did so by putting their small generators right next to the machines that used electricity. The earliest distribution system surrounded Thomas Edison's 1882 Pearl Street Station in lower Manhattan. Another built by Edison was in Menlo Park, New Jersey.

These, like most of the systems constructed during the subsequent years, distributed power over copper lines, using direct current (DC). This method of distribution was so inefficient that most power plants had to be located within a mile of the place using the power, known as the load. It appeared at the time that the power industry would develop into a system of many small power plants serving nearby loads.

All of the early power systems were, what most people now refer to as, distributed generation systems. Generators were located close to the machines that used electricity.

By the 1890s, other inventors, many of whom were former partners or employees of Edison, further developed this system of power distribution. The most important development was high-voltage power transmission lines using alternating current (AC). Alternating current is a wave of electrons flowing back and forth through a wire and allowed power lines to transmit power over much longer distances than the direct current (DC) system that Edison preferred. In 1896, George Westinghouse built an 11,000 Volt AC line to connect a hydroelectric generating station at Niagara Falls to Buffalo 20 miles away. From that point on, the voltage of typical new transmission lines grew rapidly.

Procedure

1. Research on the internet for the best Edison versus Westinghouse informational video.
2. As a class watch the informational video choices and develop a timeline for the history of electricity transmission and distribution.
3. How is direct current being used today in modern electronics? (AC chargers supply energy to a battery, the battery supplies power to a cell phone, laptop, etc.)
4. Renewable energy systems such as solar, wind and hydropower create direct current electricity. How are large volumes of DC transmitted?

To Know and Do More

1. Who was Nikola Tesla?
2. What were his involvements in electricity, inventions and innovations throughout his career?

The Transmission and Distribution Process

Objectives

The student will understand electric power distribution processes and systems.

Curriculum Focus

Science, Social Studies

Materials

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

Key Vocabulary

Blackout
Congestion
Grid
Fuse
Line losses
Load
Megawatt
Outage
Substation
Transformers

Next Generation Science Correlations

- MS-PS2 - 3
- MS-PS2.B
- MS-PS3 - 2, 5
- HS-PS3 - 1, 5

Introduction

To solve the problem of sending electricity efficiently over long distances, scientist 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 does 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

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

Transmission Heat and Temperature

Objectives

The student will understand that transmission of electricity generates heat and leads to line losses.

Curriculum Focus

Science
Math

Materials

For each student or student group

- Electrical Flow Student Sheet
- 1.5 Volt D or C cell battery
- 6 Volt battery
- 9 Volt battery
- Digital thermometer
- Multimeter
- Thermal gloves
- Enamel coated magnet
- Wire (gauges 24, 26, 30)
- Ruler or meter stick
- Scissors
- Timing device

Key Vocabulary

Line losses
Transmission

Next Generation Science Correlations

- 5-PS1 - 3
- MS-PS1 - 2
- MS- PS2 - 3
- MS-PS2.B
- MS-PS3 - 5
- HS-PS3 - 2

Introduction

In many ways, electricity moves like water. Electricity begins its journey where it is first generated, whether that be a wind farm or a coal-burning power plant. It then courses through thick wires, akin to fire hoses, toward individual cities. The power travels to those cities on thinner wires, comparable to garden hoses. Finally, it runs into individual neighborhoods and homes through an even thinner wire, akin to soda straws. The force through which the electricity flows is measured in Volts.

Like water flowing through a large network of pipes, sometimes electricity needs to be sped up or slowed down. This happens through a series of pumps called transformers. The entire network of electric generators, transformers, and wires is called the grid. As electricity courses through the grid, some leaks out of the wires in a process called line loss. The amount of such waste varies, depending on the size of the wire and the distance the electricity travels.

The complexity of the grid exists in part to limit line loss. The bigger, more powerful lines operate at higher voltage, meaning the electricity flows faster with less waste. Waste happens because the electrons that carry the energy crash into each other and generate heat in a process called resistance. The bigger the wire and the higher the voltage the less resistance because the electrons essentially have more room to roam. Resistance is measured in a unit called ohms. Smaller voltage wires are necessary, even if they are less efficient, in order to limit the flow of electricity to a useful amount. After all, one would not want a kitchen tap operating with the power of a fire hose.

Procedure

1. Cut 20 inch lengths of each gauge of enamel-coated magnet wire for each student or student group.

2. Using the smallest diameter or gauge of wire (30), place the thermometer anywhere along the length of the wire, measure the temperature, and record.

3. Wear thermal gloves to protect your fingers against heat.

4. Connect the wire ends to the positive and negative ends of the 1.5 Volt battery.

5. After 30 seconds, measure the temperature of the wire at the same point on the wire as in step 2 and record.

6. Use the multimeter to measure the wire's resistance.

7. Disconnect the wire from the battery.

8. Keeping the same gauge wire, repeat steps 2 through 7 but replace the 1.5 Volt battery with a 6 Volt battery and record both temperatures.

9. Keeping the same gauge wire, repeat steps 2 through 7 but replace the 6 Volt battery with a 9 Volt battery and record both temperatures. What conclusions can you make about the temperature of the wire with the increase in voltage?

10. Repeat the experiment with the larger gauges of wire and record data. What conclusions can you make about the temperature of the wire with the increase in the thickness or gauge of the wire?

To Know and Do More

Research sag in transmission lines due to heat generation.

Electrical Flow Student Sheet

Gauge of Wire	Initial Temperature	Voltage	Final Temperature	Resistance (Ohms)
30		1.5 Volts		
30		6 Volts		
30		9 Volts		
26		1.5 Volts		
26		6 Volts		
26		9 Volts		
24		1.5 Volts		
24		6 Volts		
24		9 Volts		

The Smart Grid

Objective

The student will learn about and understand the smart grid.

Curriculum Focus

Science
Social Studies

Materials

- Internet

Key Vocabulary

AMI
Distribution intelligence
FERC
Home energy management system
NERC
Net-metering
SCADA

Next Generation Science Correlations

- MS-PS2 - 3
- HS-PS3.B

Introduction

Smart grid generally refers to a class of technology being used to bring utility electricity delivery systems into the 21st century. 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 beginning to be 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 have had to send workers out to gather much of the data needed to provide information for electricity billing or damages. The workers read meters, look for broken equipment and measure voltage. Most of the devices utilities use to deliver electricity have yet to be automated and computerized. Now, products and services are available to the electricity industry to modernize it.

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. Using the website *smartgrid.gov/the_smart_grid*, have the class, as a whole or each individual student, click on each of the seven hexagons for information about the smart grid. Watch the short video, read the information found underneath the video clip and answer the following questions.

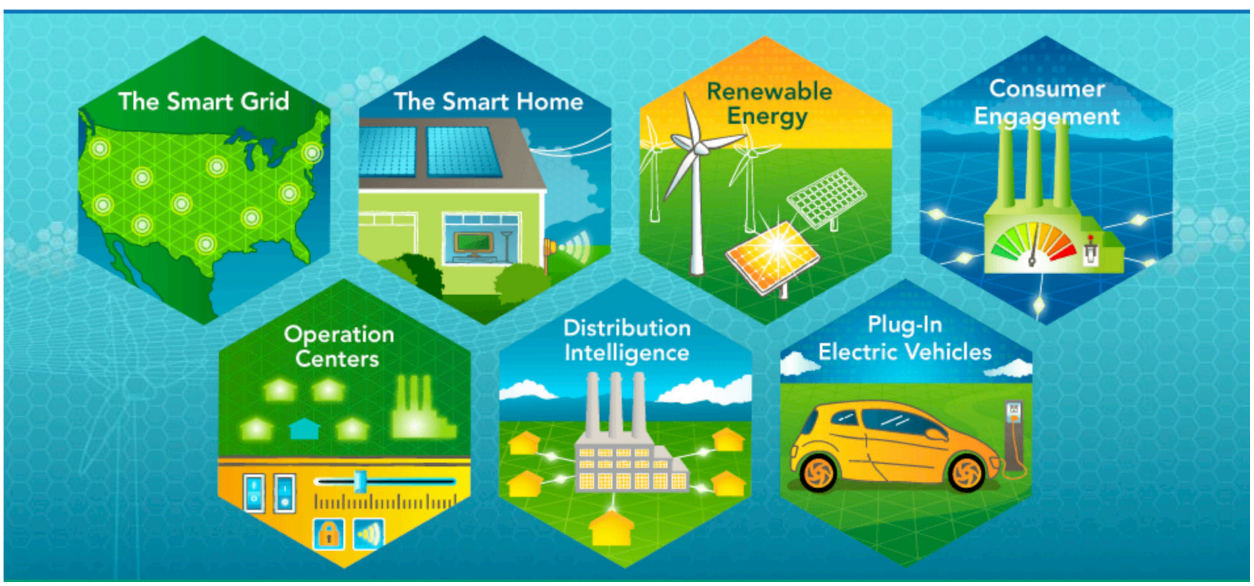
   (Source: *smartgrid.gov/the_smart_grid/*, accessed November 2022)

   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?

5. 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.

What is the smart grid?



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?

Surveying Electrical Safety

Objectives

The student will conduct a survey and investigate common misconceptions about electrical safety.

Curriculum Focus

Science
Math

Materials

- Volunteers
- Graph paper
- Copies of "Electric Safety Survey"

Key Vocabulary

Electricity
Voltage
Substation
Transformer
Insulate
Lightning

Next Generation Science Correlations

- MS-PS2 - 3
- MS-PS3 - 2
- HS-PS3.B

Introduction

Electricity sparks many house fires every year causing injuries and sometimes even deaths. Downed power lines and unsafe use of electricity can cause serious injury. Accidents can happen when people do not know proper electrical safety principles. Do you know how to be safe around electricity? How about your friends and family? Use the "Electric Safety Survey" to test the knowledge of the people around you.

Procedure

1. Distribute copies of the "Electric Safety Survey."
2. Instruct the students to give the survey to 10 people they know. These can be classmates, teachers, friends and family members. Students may survey some of the same people as long as no two students survey an identical list of people.
3. Allow students time to complete a graph of their findings.
4. Review the results in class. Ask which questions were answered correctly the most often and which questions were most often wrong.

To Know and Do More

1. Compare and graph the results according to age or gender. Who was more likely to know the correct answers?
2. Careers in Energy Connection – Have students research careers associated within electrical safety. Careers can include technicians for installation and electrical repair, or careers of first responders such as firefighters, police officers and emergency medical technicians.

Answers to the questions on "Electric Safety Survey"

1. False, 2. False, 3. True, 4. False, 5. True, 6. True, 7. True, 8. False, 9. True, 10. False, 11. True, 12. True. 13. False, 14. True, 15. False, 16. True, 17. False, 18. False

Electric Safety Survey

True or False

1. Power lines going to your house from the transformer are covered and are safe to touch.
2. It is safe to climb a tree located near a power line if the branches are not touching the line.
3. Birds can sit safely on power lines that would kill people.
4. It is safe to touch a power line with a piece of wood, metal tool or other items.
5. Stay at least 100 feet away from downed power lines and call your electric provider.
6. Call 811 before digging in your yard because there could be buried power lines.
7. Any level of voltage can hurt or kill people.
8. Using a land line or corded telephone during a thunderstorm is safe.
9. Electricity travels at the speed of light.
10. Because rubber tires insulate, they are what make a car safe in a thunderstorm.
11. About 20 people die every year in the United States from being struck by lightning.
12. Electricity always seeks the ground.
13. Any electrician is qualified to do electrical work in your home.
14. If you see someone touching a downed power line, do not attempt to rescue them yourself, instead call 911.
15. If your ball goes over an electric substation's fence, you can climb the fence to get it.
16. Stay in your car if a live electrical line falls on it.
17. It is safe to swim during a thunderstorm.
18. Lightning never strikes the same place twice.

When Lightning Strikes

Objectives	Materials	Key Vocabulary	Next Generation Science Correlations
The student will investigate the dangers of lightning strikes and learn life saving procedures. **Curriculum Focus** Science Language Arts	• Volunteer for CPR demonstration • Copies of "When Lightning Strikes"	Cardiopulmonary resuscitation (CPR) Electricity Lightning Thunderstorms	• 5-PS1 - 3 • MS-PS3 - 2, 5 • HS-PS2 - 6 • HS-PS3.B

Introduction

If you can hear it, clear it. If you can see it, flee it. Stay inside during thunderstorms. Did you know that it takes about 10,000 Volts to create a one inch spark of lightning? Lightning contains millions of Volts and easily can jump 10 to 20 feet! Go indoors as quickly as possible during lightning storms. There is no safe place outside except for a permanent structure or inside a metal vehicle with all its windows closed.

Procedure

1. Distribute copies of the "When Lightning Strikes."
2. Instruct the students to conduct further research either individually or in groups on lightning strikes and thunderstorms. Possible topics can include the frequency and cost of damages from lightning in your state, the country or globally. Other potential topics can be unusual occurrences of lightning, lightning in hurricanes or the types of jobs that expose people to lightning. Encourage the students to think of more topics to choose.
3. Allow students time to write a report or prepare a presentation of their findings.
4. Invite an American Red Cross certified instructor to demonstrate CPR to the class and discuss the various jobs where certification in cardiopulmonary resuscitation is required.

To Know and Do More

1. Research the term "catatumbo lightning" and add it to your report or presentation.
2. Careers in Energy Connection – Electrical technicians, line workers and first responders are careers

that involve working after lightning strikes. Meteorologists study the weather to predict dangerous storms and potential risk of lightning strikes. Invite a local meteorologist to talk to the class.

When Lightning Strikes

What causes lightning? Air rising into the clouds carries moisture. When the moisture reaches freezing temperatures ice crystals form. Heavier ice pieces then fall, colliding with more rising crystals creating a charge. Larger ice pellets become negatively charged and the smaller are positively charged. The opposite charges spread until the upper part of the cloud is negative and the lower is positive. When a charged cloud passes over ground which has too great of a charge difference, the two connect, discharging their power as lightning. The conductive channel of air between the cloud and ground rapidly heats to as much as 50,000 degrees F. Lightning bolts carry so much energy that a one second long flash could power a lamp for three months. The sudden cooling of the air is what produces the sound of thunder.

All thunderstorms are dangerous. Lightning can strike before rain falls and even after it looks like the storm is over. Most victims of lightning are struck while looking for shelter, only they waited too long to find a safe place away from the thunderstorm. If you can hear thunder, you are in danger of being struck by lightning while outside. How do you know how close the thunderstorm is to you? When you see lightning flash, count the number of seconds until you hear the sound of thunder. Divide that number by five to find the approximate number of miles away that the lightning struck the ground. What about when you see lightning but hear nothing? This "heat lightning" is a thunderstorm that is too far to hear. However, this does not mean it is safe to be outside. Lightning can strike as much as ten miles away from rainfall. Wait at least 30 minutes after the last sound of thunder before going outside.

In a car, the rubber tires do not protect you from lightning or from any other electricity. The car frame is made of steel that conducts the lightning into the ground. You are safe while you are not touching metal. It is still possible to be hurt if lightning strikes your car but you are safer inside it than outside in the storm. Scientists estimate there are 18 million thunderstorms around the world in a year and about a hundred lightning strikes per second. The odds of a person being struck by lightning in their life are about one in 3,000. An average of about 20 people die from lightning and over 300 are injured each year.

When lightning strikes:

- Seek shelter in an enclosed building with four walls or if there are no safe structures, get into a car.
- Stay away from trees and other tall objects. Anything tall can be struck by lightning no matter what it is made of.
- Stay out of large open spaces. You become a tall object in a field and could be struck.
- Keep away from all water: ponds, lakes, even puddles.
- Do not touch anything metal, this includes fences or railroad tracks.
- If you cannot find shelter, make yourself a smaller target. Sit on the ground and grab your ankles while tucking your head down. Never lay flat on the ground.
- Even when safely inside a building, do not touch water or use any corded appliance, not even a corded telephone, until the storm has passed.
- If you are in a car during a storm, do not touch anything metal inside of it and stay inside until it is safe to leave it.

If someone is struck by lightning, call 911 for immediate medical attention. It is safe to help the victim because they no longer carry an electrical charge. If the victim is not breathing or lacks a pulse, begin CPR. Treat burns with sterile gauze only. Look for both entry and exit wounds on the victim's body. Even someone without burns should see a doctor to check for internal injuries.

Energy Consumption and Efficiency

Introduction

Electricity is measured in units of power called Watts. A Watt is the unit of electrical power equal to 1 Ampere under a pressure of 1 Volt. It was named to honor James Watt, the inventor of the steam engine.

One Watt is a very small amount of power. Some devices require only a few Watts to operate, while others require larger amounts. The consumption of electricity by small devices is usually measured in Watts, while the consumption of electricity by larger devices is measured in kilowatts (kW) (1kW = 1,000 W).

Electricity generation capacity is typically measured in multiples of kW, such as megawatts (MW) and gigawatts (GW). One MW is 1,000 kW and one GW is 1,000 MW.

Electricity use over time is measured in Watt hours.

A Watt hour is equal to the energy of 1 Watt supplied to, or taken from, an electric circuit steadily for 1 hour. The amount of electricity a power plant generates or an electric utility customer uses, over a period of time is typically measured in kilowatt-hours (kWh), which is the number of kilowatts generated or consumed over one hour.

For example, if you use a 40 Watt (0.04 kilowatt) light bulb for five hours, you have used 200 Watt hours, or 0.2 kilowatt-hours, of electrical energy.

Utility companies measure and monitor electricity use with meters.

Electric utilities measure the electricity consumption of their customers with meters that are usually located on the outside of the customer's property where the power line enters the building. In the past, all electricity meters were mechanical devices that had to be read manually by a utility employee. Automated reader devices have been developed which report electricity use from mechanical meters with an electronic signal on a periodic basis. Electronic smart meters can be used to measure electricity consumption on a real-time basis and can provide access to the data using wireless networks and the internet. Some smart meters can even measure the use of individual devices and allow the utility or customer to control electricity use remotely.

Energy Efficiency

All statistical research available agrees that world consumption of natural resources is increasing every year. Population growth ensures that the demand for renewable and nonrenewable energy sources necessary to maintain our living habits will continue to increase. This creates a problem with the use of nonrenewable resources. Nonrenewable resources are just that — resources that cannot be renewed. If we continue to use energy at our present rate, the demand will actually increase.

Conservation, though not providing more of these resources, can help stretch out the availability and give scientists a greater chance of finding alternatives for the nonrenewable resources in the meantime. Using energy wisely is a learned behavior. The way each person uses energy today has a direct effect on the availability of natural resources tomorrow. Through education, individuals can learn to modify their actions, resulting in wise energy choices.

(Source: *eia.gov/energyexplained/index.cfm?page=electricity_measuring*, accessed October 2022)

What's in a Watt?

Objectives	Materials	Key Vocabulary	Next Generation Science Correlations
The student will calculate the wattage of various appliances and electronics. **Curriculum Focus** Science, Math	• Calculator • Copies of "What's in a Watt?" • Kill a Watt™ power monitor • Pen or pencil • Various appliances or electronics	Plug load	• 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 - 1-2 • HS-ESS3.A, C

Introduction

A Kill a Watt™ meter is designed to help identify energy use by devices or appliances that require a standard outlet, called plug loads. A home typically has a 110 Volt electrical system and includes many different loads. A load is any device that is powered by an electrical system and requires electricity to do its work. Everything that plugs in can be a load; managing the plug load of a building helps save electricity and money. Unplugging infrequently used electronics can save money on utility bills at work and at home. It is especially important to examine what equipment needs to be plugged in and what is not really necessary. Items that are not used daily could be unplugged or plugged into a power strip that can be turned off when the devices are not in use. An advanced power strip automatically turns off the items that aren't needed.

Procedure

1. Distribute copies of "What's in a Watt?" to students.
2. Have students use the Kill a Watt™ meter to determine the wattages of various appliances and electronics.
3. In column A, locate the appliance or electronic device tested and compare to the average wattage noted in column B.
4. Have students estimate the amount of time in minutes that each appliance or electronic device would be used and record in column C.

5. Convert column C in minutes to hours and record in column D.

6. Perform the calculations in columns E – H using a calculator. Substitute the local cost per kilowatt-hour (kWh) in column G.

7. Discuss the annual cost of frequently used items, such as water heater, computer, gaming system, ceiling fan.

8. Discuss how to save money while still using these devices for daily living.

To Know and Do More

1. Use the Kill A Watt™ meter to determine the actual power consumed by an appliance or electronic device for a 48 hour period, usually during typical use period.

2. Discuss ways to use this device more efficiently, if possible.

Using a Kill a Watt™ Meter

A Kill a Watt™ meter is designed to help identify energy use by devices or appliances that require a standard outlet, called plug loads. An American home typically has a 110 Volt electrical system and includes many different loads. A load is any device that is powered by an electrical system and requires electricity to do its work. Everything that plugs in can be a load; managing the plug load of a building helps save electricity and money. Unplugging infrequently used electronics can save money on utility bills at work and at home. It is especially important to examine what equipment needs to be plugged in and what is not really necessary. Items that are not used daily could be unplugged or plugged into a power strip that can be turned off when the devices are not in use.

Using the Kill a Watt™ Meter to Calculate Plug Loads

To use a meter for plug load simply plug the device you are testing, such as your laptop, into the meter then plug the meter into the wall. The meter can measure many different things, but it is the kWh setting that is the most useful for determining electrical costs. The meter has a timer so that you can see how a device performs over a long period of time. This is especially useful for appliances which cycle on and off, such as refrigerators and air conditioning units.

Quick Steps to Calculate Plug Loads

Steps if the device cycles on and off:

(Examples of devices that cycle on and off include refrigerators and window air conditioning units.)

1. Plug the meter into an outlet.
2. Press the kWh button.
3. Plug in the item to be tested. Make sure it is turned on.
4. Read the meter after one hour. The meter has a built-in timer, if you care to use it. Press the kWh button again to display the timer.

Steps if the device does not cycle on and off:

1. Plug the meter into an outlet.
2. Press the Watt button.
3. Plug in the item to be tested. Make sure it is turned on.
4. Read the meter.
5. Divide the reading by 1000 to change Watts to kilowatts. This is equal to the kWh/hour used by the device.
6. Electric utility companies bill by how many kWh are used.

Note: To test kWh, plug in the appliance and push the kWh button on the meter and let it stand for one hour.

Use the reading from the meter with the tables to calculate the kilowatt-hours of electricity used each month and the associated costs of running the device.

What's in a Watt?

A	B	C	D	E	F	G	H
Appliance	Average Wattage	Minutes Used per Day	Hours Used per Day (C/60)	Watt Hours (BxD)	kWh (E/1000)	Daily Cost (F x rate $0.135)	Annual Cost (G x 365)
EXAMPLE	100	240	4	400	0.4	$0.054	$18.25
Central Air	2000 – 5000						
Aquarium	63						
Charger, Laptop	4.5 (standby power)						
Clock Radio	1						
Coffee Maker	800						
Clothes Iron	1100						
Clothes Dryer (electric)	4000						
Dehumidifier	46						
Electronic Games	20						
Electric Blanket	200						
Hair Dryer	1000–1500						
Heater (portable)	1500						
Microwave Oven	1000						
Personal Computer (CPU)	68						
Laptop	20–75						
Refrigerator (frost-free, 16 cubic feet)	475						
Satellite Station	25 (15 standby power)						
On – TV off	15.95						
On – TV on	16.15						
Off – by remote	15.66						
Off – by switch	15.47						
Televisions (color)							
LCD	150						
36" Plasma	300						
Toaster	800–1500						
Toaster Oven	1500						
VCR – On	40						
Vacuum Cleaner (upright)	200–700						

Sources: *altestore.com/howto/reference-materials/power-ratings-typical-for-common-appliances/a21/* and *hes-documentation.lbl.gov/calculation-methodology/calculation-of-energy-consumption/major-appliances/miscellaneous-equipment-energy-consumption/default-energy-consumption-of-mels* accessed December 2017)

Classroom Comfort and School Lighting Audit

Objective

The student will be able to calculate energy use and energy costs based on real world data..

Curriculum Focus

Math
Science

Materials

- Calculator
- Copies of "School Lighting Audit"
- Hygrometer
- Light meter
- Thermometer

Key Vocabulary

Audit
Carbon footprint
CFL
Greenhouse gas emissions
Hygrometer
LED

Next Generation Science Correlations

5-PS1 - 3
5-PS1.B
5-ESS3 - 1
MS-PS2 - 3
MS-ESS3 - 3
MS-ESS3.A
HS-PS3 - 1
HS-PS3.B
HS-ESS3 - 1-2
HS-ESS3.A, C

Background

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 activity 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.

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6. Assist students as needed in their calculations.

To Know and Do More

1. Find out how much electricity your school used last month. Calculate your school's primary carbon footprint. Multiply the number of kilowatt-hours times 1.98 pounds/kWh to get the approximate greenhouse gas emissions caused by the electricity used by your school.
2. Write an action plan for your school to reduce your electricity consumption and shrink your carbon footprint.

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.

<table>
<tr><th>Area of the School</th><th>Room Comfort</th><th>Bulb Type</th><th>Number</th><th>Wattage</th><th>Total Wattage</th></tr>
<tr><td rowspan="3">Classrooms (Survey one classroom and use it as an estimate for all the classrooms in the school.)</td><td>Temperature</td><td>Incandescent</td><td></td><td></td><td rowspan="3"></td></tr>
<tr><td>Humidity</td><td>Fluorescent</td><td></td><td></td></tr>
<tr><td>Light level</td><td>Other (halogen, CFL, LED, etc.)</td><td></td><td></td></tr>
<tr><td colspan="2">Total Number of Classrooms</td><td colspan="2">Multiply by Classroom Wattage</td><td colspan="2">Total Classroom Wattage</td></tr>
<tr><td rowspan="3">Hallways</td><td>Temperature</td><td>Incandescent</td><td></td><td></td><td rowspan="3"></td></tr>
<tr><td>Humidity</td><td>Fluorescent</td><td></td><td></td></tr>
<tr><td>Light level</td><td>Other (halogen, CFL, LED, etc.)</td><td></td><td></td></tr>
<tr><td rowspan="3">Library/Media Center</td><td>Temperature</td><td>Incandescent</td><td></td><td></td><td rowspan="3"></td></tr>
<tr><td>Humidity</td><td>Fluorescent</td><td></td><td></td></tr>
<tr><td>Light level</td><td>Other (halogen, CFL, LED, etc.)</td><td></td><td></td></tr>
<tr><td rowspan="3">Cafeteria</td><td>Temperature</td><td>Incandescent</td><td></td><td></td><td rowspan="3"></td></tr>
<tr><td>Humidity</td><td>Fluorescent</td><td></td><td></td></tr>
<tr><td>Light level</td><td>Other (halogen, CFL, LED, etc.)</td><td></td><td></td></tr>
<tr><td rowspan="3">Office</td><td>Temperature</td><td>Incandescent</td><td></td><td></td><td rowspan="3"></td></tr>
<tr><td>Humidity</td><td>Fluorescent</td><td></td><td></td></tr>
<tr><td>Light level</td><td>Other (halogen, CFL, LED, etc.)</td><td></td><td></td></tr>
</table>

Area of the School	Room Comfort	Bulb Type	Number	Wattage	Total Wattage
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 one 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 you pay 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.

Food for Humans

Objectives

The student will be able to describe energy flow in a system.

Curriculum Focus

Science

Materials

- Frozen beans (optional)
- Fresh beans (optional)
- Copies of "Energy and Life"
- Copies of "Conflict of Energy versus Food Production"
- "Energy Chains"
- "Energy and Agriculture"

Key Vocabulary

10 percent rule
Consumer
Food chain
Producer

Next Generation Science Correlations

- 5-PS3 - 1
- 5-PS3.D
- 5-LS1 - 1
- 5-LS2 - 1
- 5-LS2.A
- 5-ESS3 - 1
- MS-LS2 - 1, 3
- HS-LS1 - 5
- HS-LS2 - 1, 4, 7
- HS-LS2.A
- HS-ESS3 - 2

Introduction

This activity traces energy chains as they relate to food chains.

Procedure

1. Before class, review the activity sheets and make appropriate copies.
2. Introduce the activity by informing students that this will be a lesson on how we use energy to produce our food. Ask them first to think of an animal that they know something about and to trace the animal's food back as far as they can (eventually to the sun). Ask them to draw this as a diagram using arrows to indicate energy flow as in Figure 1. Review student answers.

Sun ---------> Grass ---------> Insect ---------> Frog

Figure 1. A simple food chain

3. Establish that this is called a food chain and that it will be modified to describe the energy inputs and called an energy chain. Review that in any energy conversion process the quality of the energy degrades (the entropy increases). Explain that producers store about one percent of the solar radiation they intercept. Consumers convert about 10 percent of the energy in the plants or other animals they eat into useful energy. This is called the 10 percent rule. The remaining 90 percent is not digested, but converted to "waste" energy as heat, etc. as the organism carries out life processes. Use a figure of 100,000 J at the sun and then trace how much food energy is available to an animal. See if students can compute the overall conversion

efficiency of sunlight into animal matter. In the food chain above, the grass would store 1,000 J, the insect 100 J and the frog 10 J of the original 100,000 J from the sun.

4. Outline the pyramid energy flow including the different trophic levels.

5. For this activity, you can divide the class into groups. Explain that in our food system, energy is required to do more than produce the food. Ask students what other energy inputs are required in our food system, such as processing, retailing and consumption.

6. Put the headings processing, retailing and consumption on the board and ask each group to include as many different energy activities as they can think of for each category. Some answers would include: processing (cooking, freezing and packaging); retailing (transportation and refrigeration); consumption (refrigeration and cooking).

   The approximate energy use in each of these areas is

   Processing—20 percent

   Retailing—17 percent

   Consumption—38 percent

   with the remaining 25 percent going into producing the food.

7. Show the frozen beans and the fresh beans (you can use any vegetable here). Using the fresh beans, draw an energy chain on the board.

   I grow beans — I eat beans.

   Introducing more energy into the system:

   I grow beans — I cook beans — I eat beans.

   Ask students to follow the same form and to write down the food chain if someone else grows the beans and you buy them at a market. Repeat the same question but introduce the frozen beans. Allow a few minutes for students to work on this. You may wish to use the "Energy Chains Embodied Energy" sheet at this time.

8. Discuss student responses.

9. Ask each group to choose a food item from a shop (including such things as hamburgers, hot dogs, chocolate bars, etc.). Ask students to do an energy chain for the food item, including the energy chains for each ingredient in the food. Discuss responses with the class.

10. Discuss with students the fact that our present food system uses about seven units of energy for every unit of energy it produces — a very inefficient system. At the turn of the century, our agricultural system was much more efficient, producing more energy from the food it produced than was consumed in producing it. This is still true for some countries today. Discuss why this would be so.

11. Ask your students to think about this:

    In the United States, agriculture uses a lot of energy to grow the food which gives us energy. This energy can be measured in Petajoules (PJ), which is 10^{15} J or 1,000,000,000,000,000.

    Some food products supply a small amount of usable energy as compared to the amount of energy required to produce them. Other products are not so energy intensive.

    The "Energy and Agriculture" sheet shows some of these energy inputs and outputs. In addition to direct fuels and electricity, energy inputs from fertilizers, chemicals, irrigation, vehicles, buildings, fodder and transport have been included.

12. Have students note the ratio of energy input to food energy output for the different items listed

on “Energy and Agriculture.” The meat products (e.g., cattle) have a ratio of 40 PJ of energy in to every 1 PJ of energy out, but for corn there is only 0.25 PJ of energy put in to produce 1 PJ of energy. Nearly 40 times as much energy goes into producing meat as we obtain from eating meat. It is much more energy efficient to produce “grain crops” than animal products.

13. Discuss with students the conflict of using land for energy production vs. food production. Refer to “Conflict of Energy vs. Food Production.”

Energy and Agriculture

FOOD	RATIO ENERGY INPUT : OUTPUT
Meat (Cattle)	
Eggs	
Milk (Cattle)	
Chicken	
Vegetables	
Corn	

(*Source: "Sustainability of Meat-Based and Plant-Based Diets and the Environment" by David and Marcia Pimental in Journal of American Clinical Nutrition, 2003.*)

Here are some facts from John Robbins' book, Diet for a New America:

- 1.3 billion people could be fed by the grain and soybeans eaten by U.S. livestock.
- 20 vegetarians can be fed on the land needed to feed one meat-eating person.
- 60 million people could be fed by the grain saved if Americans reduced their beef consumption by 10 percent.
- 60 million people will starve to death this year.
- One-half of all water used in the U.S. is for livestock production.
- 200 liters (50 gallons) of water are needed to produce one kilogram (2.2 lbs) of wheat; one kilogram of meat requires 20,000 liters (5,000 gallons).

Energy and Life

Of the small fraction of the sun's radiant energy that reaches the earth, a large portion of it is absorbed and converted to heat (45 percent). Much of it (35 percent) is reflected back to space and another large fraction (20 percent) evaporates water. A very small amount is used in photosynthesis, the process by which plants trap and store solar energy for later use. About one-fiftieth of one percent of insolation (incoming solar radiation) supports all life. Because we are so dependent on that small fraction of solar energy, however, it deserves more than a small fraction of our attention.

Energy is the basis of life. Every living thing is an energy converter and a temporary energy storage tank as well. Even though it is hard to say what energy is exactly, we can see its effects in the growth, movement and changes that mark the lives of people, animals and plants.

Energy from the sun fuels all life on earth. Aquatic and land plants build complicated hydrocarbons from simple ingredients like water and carbon dioxide, given the necessary power from sunlight. Some of the solar input is effectively stored in these hydrocarbons (sugars, starches, oils, proteins and cellulose in particular). We benefit from them when we eat food from plants or eat animals who have eaten plants. Some of the chemical energy stored in plant or animal products is released in our bodies, keeping us warm and giving us strength to move and work.

There are unavoidable losses in any energy transformation. Under natural conditions, most plants convert only one to two percent of the sunlight they absorb into chemical energy. Less than half of that is stored and thus available to other living things. More than half of the light that plants absorb is converted directly to heat and then lost to their environment. The rest of the solar energy that plants use goes to transport water through their system and then evaporate it.

Not all of the food stored in plants is available to a particular eater. Supportive tissues of large land plants, such as stems, branches and trunks, are indigestible to most consumers. In contrast, leaves concentrate nitrogen and are especially nutritious for animals. Seeds and fruits of flowering plants also are usually high in food value. But there are "losses" in each step of the food chain that dilute the solar input to a smaller and smaller fraction of its original size.

As already stated, only about .002 percent of the earth's solar energy budget supports all life on this planet. The original transfer of energy from the sun to net storage by plants is usually much less than one percent. After that, each additional transport of energy through the steps in the food chain is approximately 10 percent efficient. This relationship is called the 10 percent rule of energy in ecosystems.

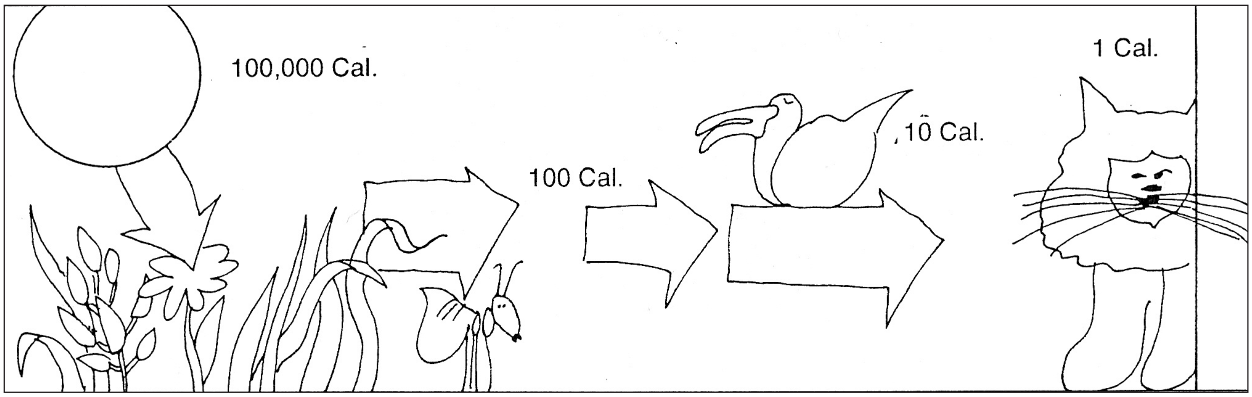
The grasshopper, for example, stores about 10 percent of the chemical energy available from the grasses it eats. Of the other 90 percent, some of the plant tissue is indigestible to the insect and passes out of his body as solid waste. This becomes food for decomposers (earthworms, bacteria, fungi). Much of the chemical energy he absorbs drives his life processes, is converted to heat and then is lost into the environment. The 10 percent of the energy-containing materials stored are stored as new living material in the grasshopper's body. Of this material, only some will be digestible to other animals like the bird who may eat the grasshopper.

The bird who eats the grasshopper stores about 10 percent of the insect's energy or one percent of the plant energy the grasshopper originally consumed. The cat who catches the bird stores (again) only about 10 percent of the bird's energy or 0.1 percent of the plant's production. That, in turn, is 0.001 percent or less of the sunlight originally absorbed by that living solar cell, the plant.

Most of the losses are due to energy used to perform work or energy lost as heat. Birds and mammals use much of the energy they consume while moving around and searching for prey. Using lots of energy in the hunt means less is available for storage. Birds and mammals also usually maintain a body temperature significantly higher than that of their surroundings. That is another reason for their low energy efficiency compared to a creature like a sea anemone that just waits for ocean currents to carry food to it. The anemone also needs little for warmth, operating successfully at the temperatures of its relatively unchanging environment.

The energy lost as heat is no longer available to the community of the living. This is an example of entropy or the "handling charge" that every energy transformation costs. This energy generally becomes unavailable for further recycling by other organisms.

Plants store less than one percent of the energy they receive. Each subsequent consumer in the food chain stores approximately 10 percent of that energy in animal tissues. So for every 100,000 calories received by a plant, only about 1,000 calories are stored for the grasshopper's lunch. The insect, in turn, stores about 100 calories of that original gift of solar energy. The bird nets about 10 calories of it and the cat gains approximately one calorie.



Conflict of Energy vs. Food Production

Land based energy crops will probably be limited to areas unsuitable for providing food crops. This land is often situated on the margins of present crop growing sites. Due to current food shortages in some countries, it is unlikely that good agricultural land will be used to grow biomass solely for fuel. Marginal lands, however, would be ideal for growing fuel crops such as switch grass, which needs less care than our food staple crops.

In successful crop growing seasons, it may be economically feasible for the farmer to sell or use excess crops for energy. This action would obviously receive criticism from people of the world who have shortages of food. As supplies of oil are depleted and the cost increases, it may become more profitable for the farmer to grow only sugar cane or cassava instead of food crops. This could create even greater criticism and conflict.

The production of food and fuel only partly compete when we consider that people cannot use the cellulose part of the plant as food except for a small but important proportion in their diet as roughage. They mainly can only use the starch, sugars and protein. In the processing of the world's food crops, millions of tons of cellulose residues, such as cereal straws and grain husks, are discarded every year.

These could be collected, perhaps briquetted to facilitate handling and burned to raise steam in energy industries located close to areas where the wastes are produced. Alternatively, cellulose wastes may be broken down to produce methane gas and liquid fuels. Cellulosic ethanol is a major area of research in the biomass industry.

Energy Chains – Embodied Energy