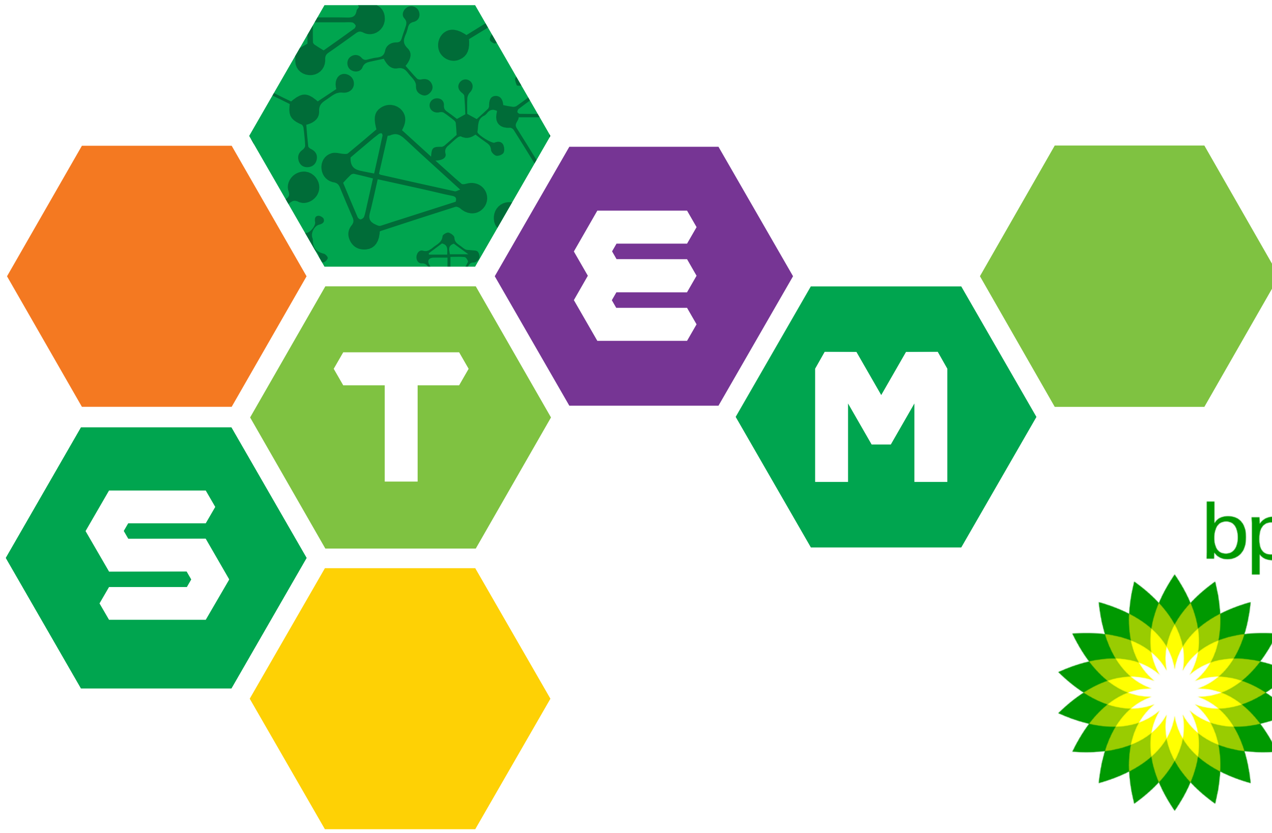
HIGH SCHOOL ENERGY EXPERIMENTS

SECONDARY

National Energy Education Development



FUELING THE NEXT GENERATION OF INNOVATORS

Science, technology, engineering, and math (STEM) affect nearly every aspect of our lives — from the cars we drive, to the food we eat, to the smartphones we use to communicate.

Innovation is the key to helping the U.S. stay competitive in today's globalized, technology-driven world. As a result, STEM jobs are in high demand and typically pay significantly better than non-STEM fields. To fill the high-skilled jobs that will power the American economy in the future, the U.S. needs more students to study STEM.

Additionally, BP depends on people with strong foundations in STEM to help solve the world's energy challenges. These engineers, scientists, and other professionals find ways to produce and deliver the energy that heats our homes, powers our schools, cooks our food, and fuels our cars. The information and activities in this booklet will help you understand the important role STEM plays in the energy industry.

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Introduction to Energy

What Is Energy?

Energy does things for us. It moves cars along the road and boats on the water. It bakes a cake in the oven and keeps ice frozen in the freezer. It plays our favorite songs and lights our homes at night. Energy helps our bodies grow and our minds think. Energy is a changing, doing, moving, working thing.

Energy is defined as the ability to produce change or do work, and that work can be divided into several main tasks we easily recognize:

- Energy produces light.
- Energy produces heat.
- Energy produces motion.
- Energy produces sound.
- Energy produces growth.
- Energy powers technology.

Forms of Energy

There are many forms of energy, but they all fall into two categories–potential or kinetic.

POTENTIAL ENERGY

Potential energy is stored energy and the energy of position, or gravitational potential energy. There are several forms of potential energy, including:

- **Chemical energy** is energy stored in the bonds of atoms and molecules. It is the energy that holds these particles together. Foods we eat, biomass, petroleum, natural gas, and propane are examples of stored chemical energy.

  During photosynthesis, sunlight gives plants the energy they need to build complex chemical compounds. When these compounds are later broken down, the stored chemical energy is released as heat, light, motion, and sound.

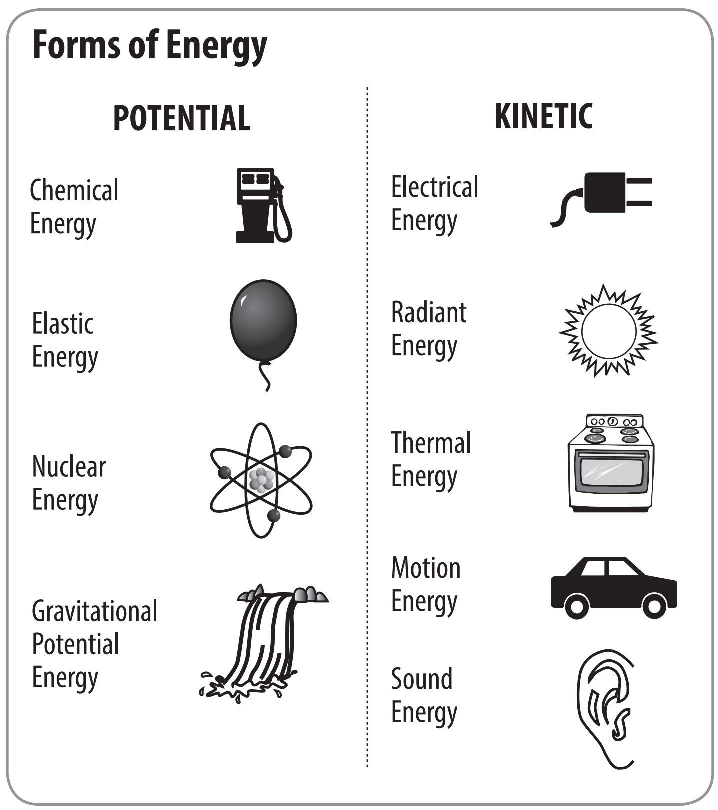
- **Elastic energy** is energy stored in objects by the application of a force. Compressed springs and stretched rubber bands are examples of elastic energy.
- **Nuclear energy** is energy stored in the nucleus of an atom—the energy that binds the nucleus together. The energy can be released when the nuclei are combined or split apart. Nuclear power plants split the nuclei of uranium atoms in a process called fission. The sun combines the nuclei of hydrogen atoms into helium atoms in a process called fusion. In both fission and fusion, mass is converted into energy, according to Einstein's Theory, $E = mc^2$.
- **Gravitational potential energy** is the energy of position or place. A rock resting at the top of a hill contains gravitational potential energy because of its position. Hydropower, such as water in a reservoir behind a dam, is an example of gravitational potential energy.

Energy at a Glance, 2013

	2012	2013
World Population	7,020,760,225	7,098,495,231
U.S. Population	313,873,685	316,128,839
World Energy Production	513.695 Q	524.501 Q
U.S. Energy Production	79.219 Q	81.942 Q
• Renewables	8.838 Q	9.298 Q
• Nonrenewables	70.381 Q	72.644 Q
World Energy Consumption	518.086 Q	528.743 Q
U.S. Energy Consumption	96.705 Q	97.785 Q
• Renewables	8.798 Q	9.298 Q
• Nonrenewables	87.907 Q	88.487 Q

Q = Quad (10^{15} Btu) see Measuring Energy on page 6.

Data: Energy Information Administration



KINETIC ENERGY

Kinetic energy is motion—the motion of waves, electrons, atoms, molecules, substances, and objects.

- **Electrical energy** is the movement of electrons. Everything is made of tiny particles called atoms. Atoms are made of even smaller particles called electrons, protons, and neutrons. Applying a force can make some of the electrons move. Electrons moving through a wire are called electricity. Lightning is another example of electrical energy.
- **Radiant energy** is electromagnetic energy that travels in transverse waves. Radiant energy includes visible light, x-rays, gamma rays, and radio waves. Solar energy is an example of radiant energy.
- **Thermal energy**, which is often described as heat, is the internal energy in substances—the vibration and movement of atoms and molecules within substances. The faster molecules and atoms vibrate and move within a substance, the more energy they possess and the hotter they become. Geothermal energy is an example of thermal energy.
- **Motion energy** is the movement of objects and substances from one place to another. According to Newton's Laws of Motion, objects and substances move when an unbalanced force is applied. Wind is an example of motion energy.
- **Sound energy** is the movement of energy through substances in longitudinal (compression/rarefaction) waves. Sound is produced when a force causes an object or substance to vibrate. The energy is transferred through the substance in a wave.

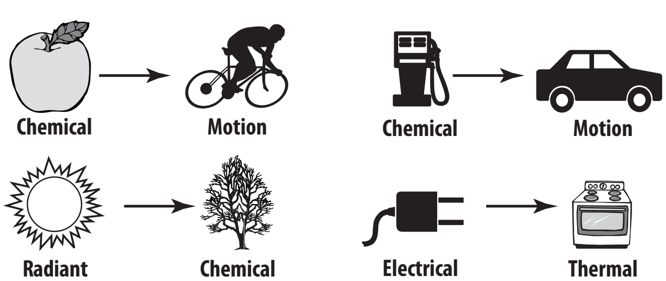
Conservation of Energy

Your parents may tell you to conserve energy. "Turn off the lights," they say. But to scientists, conservation of energy means something quite different. The Law of Conservation of Energy says energy is neither created nor destroyed.

When we use energy, we do not use it completely—we just change its form. That's really what we mean when we say we are using energy. We change one form of energy into another. A car engine burns gasoline, converting the chemical energy in the gasoline into motion energy that makes the car move. Old-fashioned windmills changed the kinetic energy of the wind into motion energy to grind grain. Solar cells change radiant energy into electrical energy.

Energy can change form, but the total quantity of energy in the universe remains the same. The only exception to this law is when a small amount of matter is converted into energy during nuclear fusion and fission.

Energy Transformations



Efficiency

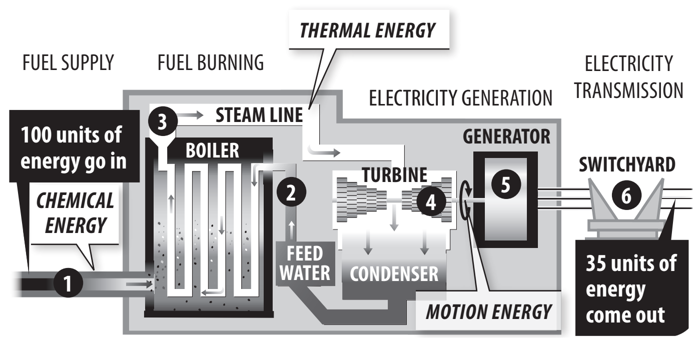
Energy efficiency is the amount of useful energy you can get out of a system. In theory, a 100 percent energy efficient machine would change all of the energy put in it into useful work. Converting one form of energy into another form always involves a loss of usable energy, usually in the form of thermal energy.

In fact, most energy transformations are not very efficient. The human body is no exception. Your body is like a machine, and the fuel for your "machine" is food. Food gives us the energy to move, breathe, and think. Your body is very inefficient at converting food into useful work. Most of the energy in your body is released as thermal energy.

An incandescent light bulb isn't efficient either. This type of light bulb converts ten percent of the electrical energy into light and the rest (90 percent) is converted into thermal energy. That's why these light bulbs are so hot to the touch.

Most electric power plants that use steam to spin turbines are about 35 percent efficient. Thus, it takes three units of fuel to make one unit of electricity. Most of the other energy is lost as waste heat. This heat dissipates into the environment where we can no longer use it as a practical source of energy.

Efficiency of a Thermal Power Plant



How a Thermal Power Plant Works

1. Fuel is fed into a boiler, where it is burned to release thermal energy.
2. Water is piped into the boiler and heated, turning it into steam.
3. The steam travels at high pressure through a steam line.
4. The high pressure steam turns a turbine, which spins a shaft.
5. Inside the generator, the shaft spins coils of copper wire inside a ring of magnets. This creates an electric field, producing electricity.
6. Electricity is sent to a switchyard, where a transformer increases the voltage, allowing it to travel through the electric grid.

Sources of Energy

People have always used energy to do work for them. Thousands of years ago, early humans burned wood to provide light, heat their living spaces, and cook their food. Later, people used the wind to move their boats from place to place. A hundred years ago, people began using falling water to make electricity.

Today, people use more energy than ever from a variety of sources for a multitude of tasks and our lives are undoubtedly better for it. Our homes are comfortable and full of useful and entertaining electrical devices. We communicate instantaneously in many ways. We live longer, healthier lives. We travel the world, or at least see it on television and the internet.

The ten major energy sources we use today are classified into two broad groups—nonrenewable and renewable.

Nonrenewable energy sources include coal, petroleum, natural gas, propane, and uranium. They are used to generate electricity, to heat our homes, to move our cars, and to manufacture products from candy bars to cell phones.

These energy sources are called nonrenewable because they cannot be replenished in a short period of time. Petroleum, a fossil fuel, for example, was formed hundreds of millions of years ago, before dinosaurs existed. It was formed from the remains of ancient sea life, so it cannot be made quickly. We could run out of economically recoverable nonrenewable resources some day.

Renewable energy sources include biomass, geothermal, hydropower, solar, and wind. They are called renewable energy sources because their supplies are replenished in a short time. Day after day, the sun shines, the wind blows, and the rivers flow. We use renewable energy sources mainly to make electricity.

Is electricity a renewable or nonrenewable source of energy? The answer is neither. Electricity is different from the other energy sources because it is a secondary source of energy. That means we have to use another energy source to make it. In the United States, coal is the number one fuel for generating electricity.

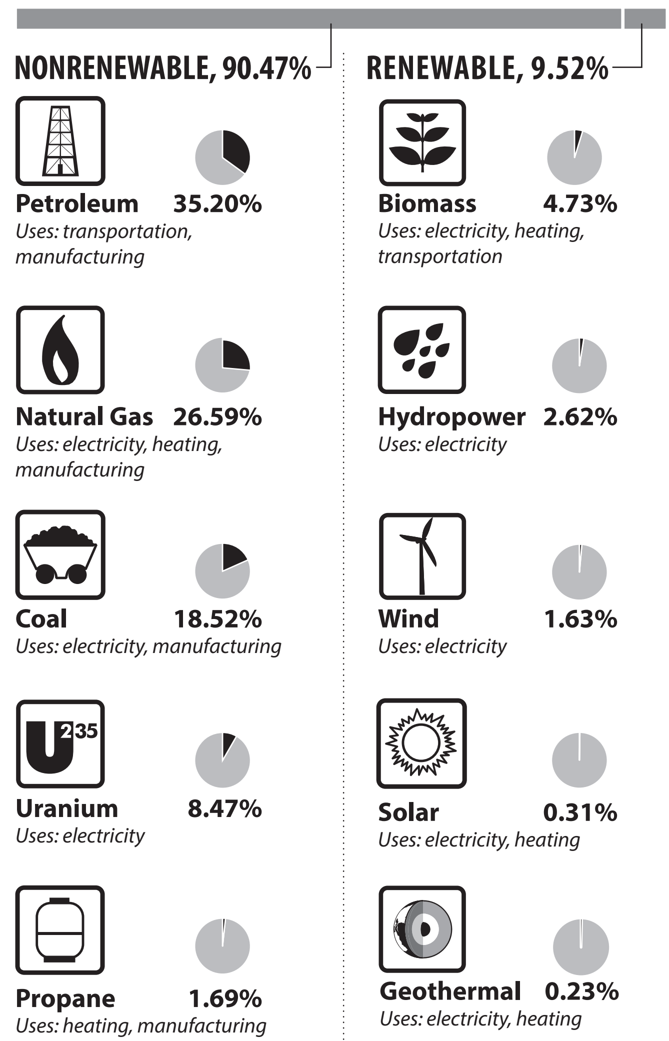
Measuring Energy

"You can't compare apples and oranges," the old saying goes. That holds true for energy sources. We buy gasoline in gallons, wood in cords, and natural gas in cubic feet. How can we compare them? With British thermal units (Btu), that's how. The energy contained in gasoline, wood, or other energy sources can be measured by the amount of heat in Btu it can produce.

One Btu is the amount of thermal energy needed to raise the temperature of one pound of water one degree Fahrenheit. A single Btu is quite small. A wooden kitchen match, if allowed to burn completely, would give off about one Btu of energy. One ounce of gasoline contains almost 1,000 Btu of energy.

Every day the average American uses about 847,000 Btu. We use the term quad (Q) to measure very large quantities of energy. A quad is one quadrillion (1,000,000,000,000,000 or 10^{15}) Btu. The United States uses about one quad of energy approximately every 3.7 days. In 2007, the U.S. consumed 101.296 quads of energy, an all-time high.

U.S. Energy Consumption by Source, 2013



Data: Energy Information Administration
*Total does not equal 100% due to independent rounding.

Energy Use

Imagine how much energy you use every day. You wake up to an electric alarm clock and charge your cell phone. You take a shower with water warmed by a hot water heater using electricity or natural gas.

You listen to music on your MP3 player as you dress. You catch the bus to school. And that's just some of the energy you use to get you through the first part of your day!

Every day, the average American uses about as much energy as is stored in six and a half gallons of gasoline. That's every person, every day. Over a course of one year, the sum of this energy is equal to about 2,400 gallons of gasoline per person. This use of energy is called energy consumption.

Energy Users

The U.S. Department of Energy uses categories to classify energy users—residential, commercial, industrial, and transportation. These categories are called the sectors of the economy.

▪ Residential/Commercial

Residences are people's homes. Commercial buildings include office buildings, hospitals, stores, restaurants, and schools. Residential and commercial energy use are lumped together because homes and businesses use energy in the same ways—for heating, air conditioning, water heating, lighting, and operating appliances.

The residential/commercial sector of the economy consumed 40.21 percent of the total energy supply in 2013, more energy than either of the other sectors, with a total of 39.32 quads. The residential sector consumed 21.27 quads and the commercial sector consumed 18.04 quads.

▪ Industrial

The industrial sector includes manufacturing, construction, mining, farming, fishing, and forestry. This sector consumed 31.20 quads of energy in 2013, which accounted for 31.90 percent of total consumption.

▪ Transportation

The transportation sector refers to energy consumption by cars, buses, trucks, trains, ships, and airplanes. In 2013, the U.S. consumed 27.27 quads of energy for transportation. 92.01 percent of this energy was from petroleum products such as gasoline, diesel, and jet fuel.

Energy Use and Prices

Several decades ago, in 1973, Americans faced a major oil price shock due to an oil embargo. People didn't know how the country would react. How would Americans adjust to skyrocketing energy prices? How would manufacturers and industries respond? We didn't know the answers.

Now we know that Americans tend to use less energy when energy prices are high. We have the statistics to prove it. When energy prices increased sharply in the early 1970s, energy use dropped, creating a gap between actual energy use and how much the experts had thought Americans would be using.

The same thing happened when energy prices shot up again in 1979, 1980, and more recently in 2008—people used less energy. When prices started to drop, energy use began to increase.

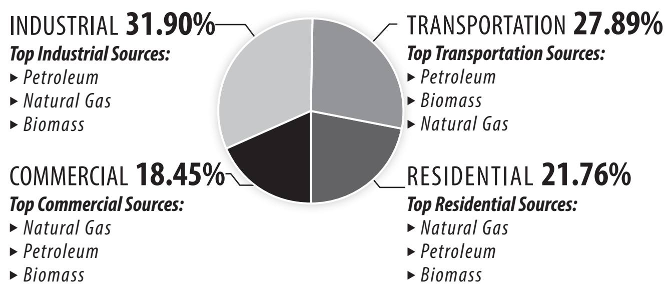
We don't want to simplify energy demand too much. The price of energy is not the only factor in the equation. Other factors that affect how much energy we use include the public's concern for the environment and new technologies that can improve the efficiency and performance of automobiles and appliances.

Most reductions in energy consumption in recent years are the result of improved technologies in industry, vehicles, and appliances. Without these energy conservation and efficiency technologies, we would be using much more energy today.

In 2013, the United States used 29 percent more energy than it did in 1973. That might sound like a lot, but the population has increased by over 49 percent and the nation's gross domestic product was 2.413 times that of 1973.

You may wonder why the 1970s are important—it was so long ago. However, the energy crisis during this decade taught us a valuable lesson. If every person in the United States today consumed energy at the rate we did in the 1970s, we would be using much more energy than we are—perhaps as much as double the amount. Energy efficiency technologies have made a huge impact on overall consumption since the energy crisis of 1973.

U.S. Energy Consumption by Sector, 2013



Data: Energy Information Administration

Acid Rain

Grade Levels: 7-9

Background

An acid is a chemical that has extra hydrogen particles in it. When certain gases mix together with water in our atmosphere, it can create acid rain. Creating pollution can sometimes cause more acid rain to be produced. Is there acid rain all the time? Is it always the same?

Questions

Does precipitation in your area contain acidic emissions from power plants, industries, or vehicle emissions?

Does the acidity of the precipitation change during the year?

Possible Hypotheses

The precipitation does/does not contain acids.

The acidity levels change/do not change during the year.

Materials

- Litmus paper
- Plastic container
- Meter stick

Procedure

1. Place a plastic container outside every day to catch any precipitation that falls.
2. Measure the amount and acidity of the precipitation every day at the same time and record on a calendar.
3. Analyze your data after several months.

Analysis and Conclusion

Is the precipitation in your area acidic? Does the acidity level change, and if so, why? What do you think causes any acidity in the precipitation? Research the power plants, industries, and vehicle emissions in your area.

Clean Air

Grade Levels: 7-10

Background

More than 60% of a school's energy bill is spent on heating, cooling, and ventilating buildings to keep the air safe to breath and the right temperature.

Question

Does indoor or outdoor air have more particulate pollution?

Possible Hypothesis

______________________________ air has more particulate pollution.

Materials

- 15 White index cards
- Petroleum jelly
- Cotton swabs
- Tape
- Magnifying glass

Procedure

1. Label the index cards I-1 to I-7 and O-1 to O-7. Label one card C for control.
2. Smear petroleum jelly on cards I-1, O-1, and C using a cotton swab. Tape cards I-1 and O-1 to the same window, I-1 on the inside and O-1 on the outside. Avoid placing the cards near a door.
3. Place the control card in a closed drawer or inside a cabinet.
4. After 24 hours, take the cards down and repeat the procedure with the cards labeled I-2 and O-2. Make a note of the weather each day, and what you see happening to the petroleum jelly.
5. Do this for a week, replacing the cards each day with the next number. Examine the cards closely and compare them to each other, to previous sets, and to the control.
6. Record your observations, noting any differences.
7. Repeat the experiment in a different location or at a different time of year.

Analysis and Conclusion

How does the inside and outside air compare? How does it compare in different weather, different locations, and in different seasons? What do you think is the main source of particulate pollution in your area? Research and find out.

Corroding Metals

Grade Levels: 4-9

Background

Everything has energy. You eat food because its chemical energy gives you energy to run and talk and play. Chemical energy is also stored within the tiny particles, called atoms, within a material. Those atoms are held together in a bond. If a bond is broken or created, chemical energy is transferred in something called a chemical reaction. Sometimes when materials mix together, chemical reactions occur, and energy is released.

Vocabulary

- corrosion: a slow breakdown of a metal

Questions

What types of metal are susceptible to corrosion?

What kinds of liquid promote corrosion?

Possible Hypotheses

____ will / will not corrode when exposed to ______________________________.

Materials

- Bowls
- Water
- Orange juice
- 2 Pieces of steel wool
- 2 Stainless steel teaspoons
- 2 Pennies
- 2 Squares of aluminum foil

Procedure

1. Fill two bowls – one with water and the other with juice.
2. Put one piece of each of the metal objects in each bowl.
3. Leave the metals in the liquids for a week where they will not be disturbed.
4. After one week, take out the metal samples and examine them. Record your observations.

Analysis and Conclusion

Which liquid caused more corrosion? Which metals were more susceptible to corrosion? Was there a combination of liquid and metal that caused the most corrosion? When can you use metals that corrode and when should you use metals that don't corrode?

Cryogenic Roses

Grade Levels: 4-9

Background

When living things die, they slowly break down or decay over time. This is a chemical reaction where chemical energy is transferred. Adding heat or removing heat can cause a chemical reaction to speed up, or slow down. Heating or cooling a material can also change how quickly its energy is released or absorbed.

Vocabulary

- cryogenic: a material at a very low termperature

Question

Can ice be used to preserve once-living things?

Possible Hypothesis

Ice can/cannot preserve once-living things.

Materials

- 5 Rose buds just beginning to open
- 4 Plastic bowls
- Water
- Freezer

✔ Procedure

1. Fill four plastic bowls with equal amounts of water.
2. Observe the five rose buds and record any differences in the fragrance, texture, appearance, or color.
3. Submerge one rose bud in each bowl of water and put the bowls in the freezer, keeping one rose bud at room temperature for a control. Observe the control daily and record your observations.
4. After one week, allow one rose bud to thaw and observe, comparing it to the control and to the observations made before freezing. Place the thawed rose bud with the control.
5. Repeat this procedure the next week with another frozen rose. Do this weekly until all roses have been thawed and observed.

Analysis and Conclusion

Did ice preserve the roses well? Did the length of freezing have an effect? What happened to the roses once they were thawed? How did the freezing affect the decaying process?

Real World Connection

What practical applications could this technique be used for?

Frozen Salt

Grade Levels: 7-10

Background

Matter comes in three forms: solid, liquid, and gas. Solid water is called ice. It becomes ice through freezing. When ice is melted it becomes liquid. If liquid water is heated, it becomes a gas, or steam. When you change a solid to liquid or liquid to gas, or even a liquid to a solid, energy must be added or removed. Some materials need more energy to freeze or melt than others.

Question

What does salt do to the freezing point of water?

Possible Hypothesis

Adding salt ____ the freezing point of water.

Materials

- 4 8-ounce Plastic cups
- Measuring cup
- Table salt (sodium chloride)
- Freezer
- Thermometer
- Teaspoon

✔ Procedure

1. Fill four cups, each with six ounces of tap water. Add a teaspoon of salt to one cup, two teaspoons to the second, and three teaspoons to the third. Leave the fourth as your control.
2. Place the cups in the freezer. Observe the cups periodically until a thin layer of ice forms on the top of the water, and then record the temperature of each cup.
3. Record your observations.

Analysis and Conclusion

Did adding salt lower the freezing temperature of the water? What was the effect of adding more salt to the water? Can you think of ways that this knowledge can be put to work for you?

Natural and Man-Made Fibers

Grade Levels: 4-9

Background

Our clothes are made out of different materials. "Natural" fibers and fabrics come from plants or animals. For example, cotton is a plant, and silk comes from the cocoons of silkworms. Some fabrics are called "man-made" or "synthetic" because man produces them from chemicals. For example, polyester is made from a petroleum product. Even our fashion choices are related to energy!

Vocabulary

- deteriorate; to become worse, break apart, to decay
- decompose; to rot, to separate into original elements

Question

Do natural fibers decompose faster than man-made fibers?

Possible Hypothesis

Natural fibers will decompose faster/slower than man-made fibers.

Materials

- Old 100% cotton t-shirt (natural)
- Old nylon stocking or tights (synthetic)
- Old wool sock or yarn (natural)
- Old acrylic or polyester sweater (synthetic)
- Plot of soil
- Water
- Glass jar with lid

✔ Procedure

1. Cut three four-inch squares from each material.
2. Bury one square of each material, making sure you mark the spot where they are buried.
3. Put squares of each material in a jar, fill it with water, and put a lid on it. Place the jar inside in a sunny place.
4. Place the third set of squares in a dark place where they will not be disturbed.
5. After one month, remove the samples from the ground, the dark place, and the jar. Examine the squares and record your observations.

Analysis and Conclusion

Which fibers deteriorated? Which environment made the materials deteriorate more quickly? Can you find out why?

Slow Cooker

Grade Levels: 7-10

Background

Over half of the energy that we use in our houses is used for heating and for cooling. We can keep the warm or cool air inside by insulating our homes. Saving energy can also save a family money on their energy bills.

Question

Which natural material works best to insulate a homemade slow cooker?

Possible Hypothesis

The best insulator for a slow cooker is ____.

Materials

- 3 Cardboard boxes of equal size (large enough to hold pan and insulating material)
- 3 Potatoes of equal size
- 3 Identical cooking pans with lids
- Newspaper, cloth, hay, or other insulating materials
- 3 Cooking thermometers
- Water
- Stove

✔ Procedure

1. Place one potato in each pan and cover with the same amount of water. Boil them simultaneously for two minutes over the same amount of heat.
2. Place a layer of one insulating material in the bottom of each box, place the pans inside the boxes, surround the pans with insulating material, and close.
3. After one hour, record the temperature of the interior of the potatoes.

Analysis and Conclusion

Which insulator worked best? Is this an energy efficient way to cook food?

Solar Distillation

Grade Levels: 4-9

Background

Hydropower is considered a renewable energy source because the water on Earth is constantly going through the water cycle because of the sun's energy. Here's another way we may be able to use the sun to make water more useful.

Vocabulary

- distill: to turn something into a gas (vaporization) and then back into a liquid (condensation) to purify it

Questions

Can you distill clean water from muddy water?

Can you distill clean water from salty water?

Possible Hypotheses

You can/cannot make clean water from muddy water.

You can/cannot make clean water from salty water.

Materials

- 2 Large plastic containers
- Clear plastic wrap
- Masking tape
- 2 Small rocks
- 2 Small glasses
- 2 Tablespoons of dirt
- 2 Tablespoons of salt
- Water

✔ Procedure

1. Fill both plastic containers with one inch of water. Mix the dirt into the water in one and the salt into the other.
2. Place one empty glass upright into the middle of each plastic container. Make sure it remains empty.
3. Cover both plastic containers tightly with plastic wrap and seal them with tape. Place a small rock in the middle of the plastic wrap, directly over each glass but not touching it.
4. Place the stills in a sunny place for two hours. Examine any water that forms in the glass. Record your observations.

Analysis and Conclusion

Did the stills make clean water?

Real World Connection

Can you explain how they worked? Can you imagine a situation in which knowledge could save your life? It is estimated that over 1 billion people worldwide drink water that is unhealthy. How could your project help them?

Thermal Energy Put to Work

Grade Levels: 7-10

Background

When air is heated, the molecules move around faster and get further apart (if there is room to spread). The cooler air (with its molecules closer together) starts to sink, pushing the warmer air up. This is where we get the phrase "hot air rises."

Question

Can thermal energy be made to do useful work?

Possible Hypothesis

Thermal energy is/is not useful energy that can be used for work.

Materials

- Plastic 1-liter bottle
- Large balloon
- Freezer
- Bowl of hot (not boiling) water
- Bowl of ice water
- Small rock

✔ Procedure

1. Cool the balloon and the bottle in the freezer for 5 minutes.
2. Fill the bowl with hot, not boiling, water.
3. Put the balloon over the mouth of the bottle, making sure that the air has been squeezed from the balloon. Place the bottle into the hot water.
4. The air inside the bottle should expand and inflate the balloon. After it is inflated, put the bottle in the bowl of ice water and observe it deflate.
5. Design a device to convert this expansion and contraction into usable work, such as lifting a rock. Design a device that circulates hot, then cold, water so that the balloon deflates and inflates without moving the bottle.

Analysis and Conclusion

Were you able to make a device that performed useful work? Can you think of devices that convert thermal energy into motion? Can you think of a way to convert thermal energy into electrical energy?

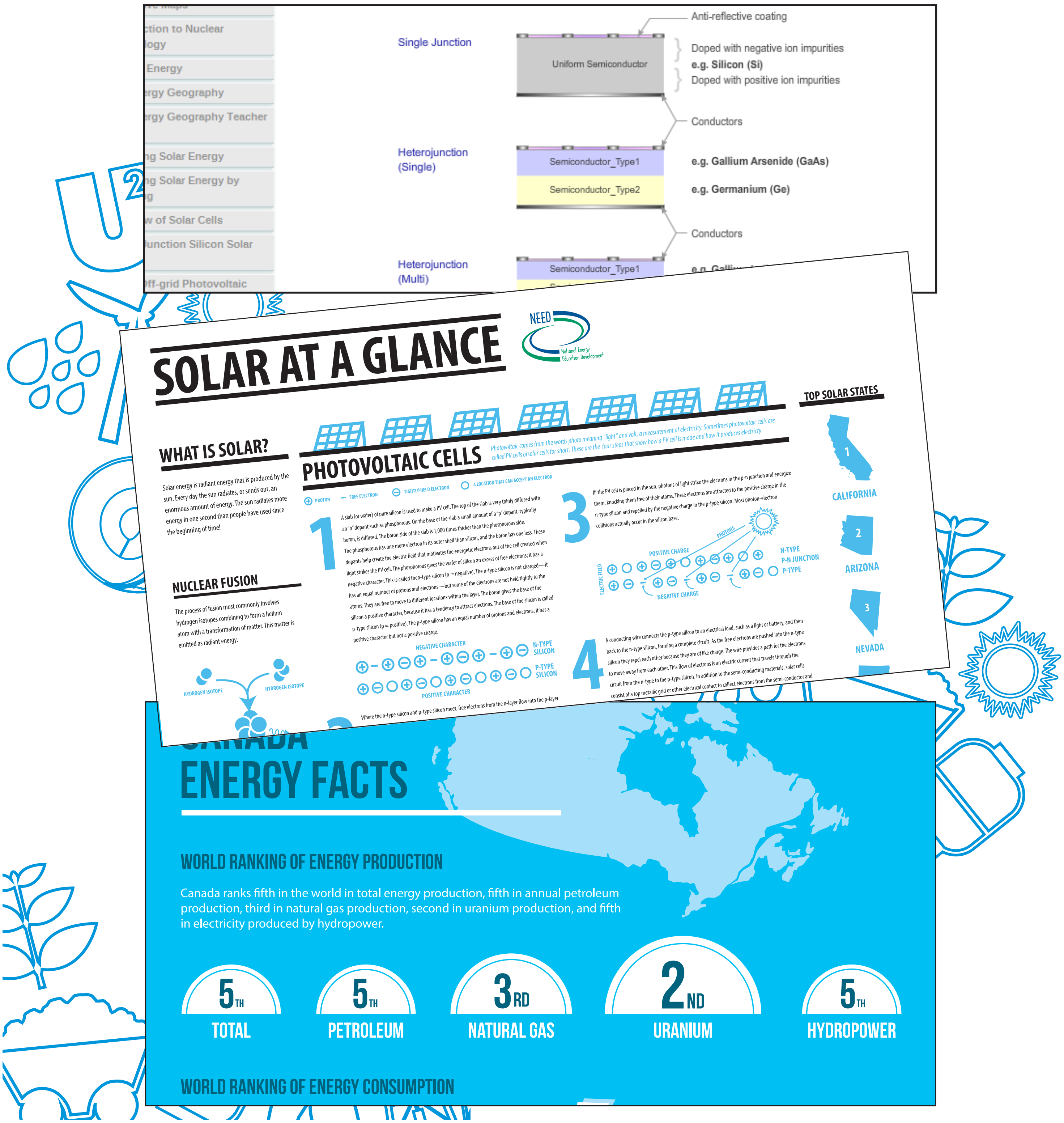
Real World Connection

Research internal combustion engines and turbine generators.

Looking For More Resources?

Our supplemental materials page contains PowerPoints, animations, and other great resources to compliment what you are teaching!

This page is available at www.NEED.org/educators.



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