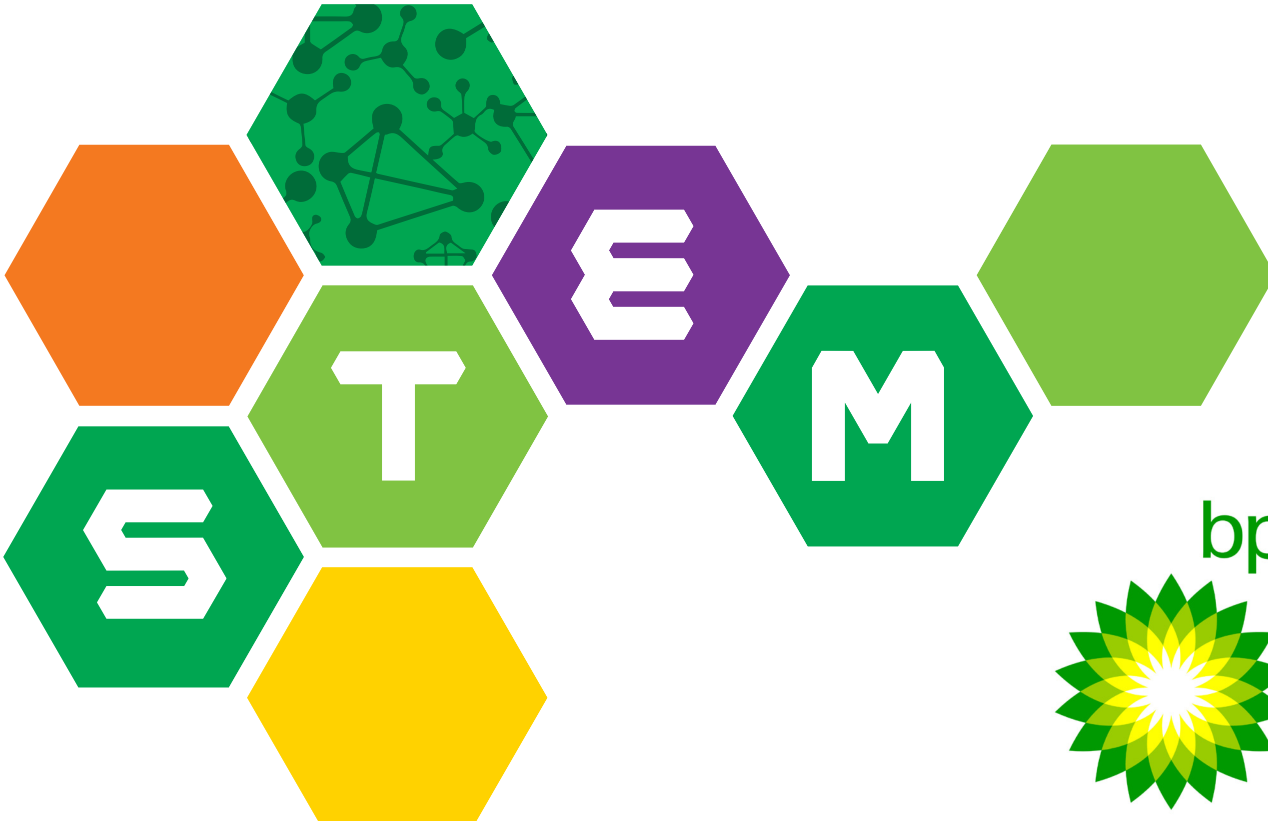
STUDENT GUIDE

HIGH SCHOOL ENERGY EXPERIMENTS

SECONDARY

NEED
National Energy Education Development



SEEKING INNOVATORS
ARE YOU READY TO ENERGIZE THE WORLD?

Science, technology, engineering, and mathematics (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.

To meet these challenges, we strive to help students discover how STEM shapes the world around them so that they understand its importance and pursue careers in these fields.

The information and activities in this booklet will help you understand the critical role STEM plays in the energy industry. Have fun exploring the world of energy, and we hope you learn some interesting new things along the way.

Be sure to check out more hands-on activities and STEM resources at bp.com/STEMresources.

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Introduction and Instructions

Science, Technology, Engineering, and Math are for everyone. They are also lots of fun! Energy is the ability to do work, or make some change. STEM and Energy are very connected! The activities in this booklet aim to help you experiment with energy – doing work and making changes – while practicing and perfecting your STEM process skills.

Get Ready

- Start by picking an activity that sounds interesting and meets your grade level.
- If the activity is designed for younger students, try it out and work with a friend in a younger grade or a sibling. Show them that STEM explorations are fun!
- Read through the entire activity.
- Read through the Safety for STEM Checklist, and check off any items you will have to be careful to do.

Get set

- Clear a work space for yourself. It may be necessary to place newspaper or a table cloth down to protect floors, tables, or counters.
- Gather the materials on the supply list for your activity.
- Find your safety glasses!
- Re-read the activity procedure to make sure you're prepared and can complete all of the steps safely.
- Write or create a hypothesis for what you think may happen.

GO!

- Put on your safety glasses!
- Follow the steps in the experiment.
- Record what you see happening. Take pictures and video. Write down notes. Draw pictures.
- Answer the analysis and conclusion prompts.
- Was your hypothesis correct? Re-test the experiment. Try to design a test to answer any additional questions you might have.
- Clean up your materials.
- Pick a new activity to try!

STEM Challenges

At the end of your booklet are two STEM Challenges. Now that you've explored STEM and energy in a hands-on, guided way, let's challenge ourselves to think beyond the instructions to solve a problem. This challenge will provide you a problem to solve and list of materials to use, but no instructions. Solve the problem however you can. Design something to make it happen, test it out, and re-design it until it works! And, don't forget to have a good time!

Safety For STEM Checklist

Eye Safety

- ☐ Always wear safety glasses when performing experiments.

Fire Safety

- ☐ Do not heat any substance or piece of equipment unless specifically instructed to do so.
- ☐ Be careful of loose clothing. Do not reach across or over a flame.
- ☐ Keep long hair pulled back and secured.
- ☐ Do not heat any substance in a closed container.
- ☐ Always use tongs or protective gloves when handling hot objects. Do not touch hot objects with your hands.
- ☐ Keep all lab equipment, chemicals, papers, and personal items away from the flame.
- ☐ Extinguish the flame as soon as you are finished with the experiment and move it away from the immediate work area.

Heat Safety

- ☐ Always use tongs or protective gloves when handling hot objects and substances.
- ☐ Keep hot objects away from the edge of the experiment surface––in a place where no one will accidentally come into contact with them.
- ☐ Remember that many objects will remain hot for a long time after the heat source is removed or turned off.

Glass Safety

- ☐ Never use a piece of glass equipment that appears to be cracked or broken.
- ☐ Handle glass equipment carefully. If a piece of glassware breaks, do not attempt to clean it up yourself. Inform an adult.
- ☐ Glass equipment can become very hot. Use tongs or gloves if glass has been heated.
- ☐ Clean glass equipment carefully before packing it away.

Chemical Safety

- ☐ Do not smell, touch, or taste liquids unless instructed to do so.
- ☐ Keep liquid containers closed except when using them.
- ☐ Do not mix any materials without specific instructions.
- ☐ Do not shake or heat liquids or solids without specific instructions.
- ☐ Dispose of used lab materials as instructed. Do not pour chemicals back into a container without specific instructions to do so.
- ☐ If a liquid or solid accidentally touches your skin, immediately wash the area with water and inform an adult.
- ☐ Keep long hair pulled back and secured.
- ☐ Be careful of loose clothing.

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, 2017

	2016	2017
World Population	7,442,136,000	7,530,360,000
U.S. Population	323,127,573	325,147,000
World Energy Production	564.769*	
U.S. Energy Production	84.226 Q	88.261 Q
• Renewables	10.181 Q	11.301 Q
• Nonrenewables	74.045 Q	76.960 Q
World Energy Consumption	579.544 Q*	
U.S. Energy Consumption	97.410 Q	97.809 Q
• Renewables	10.113 Q	11.181 Q
• Nonrenewables	87.111 Q	84.464 Q

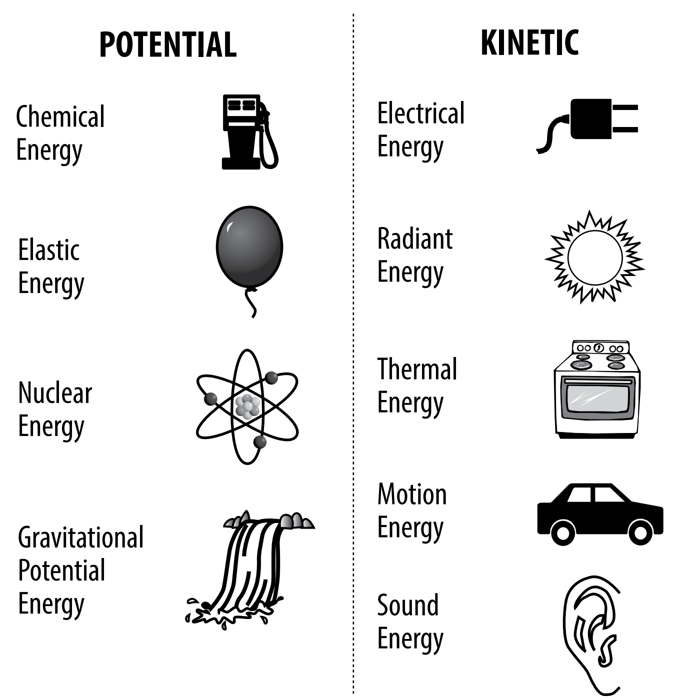
Q = Quad (1015 Btu), see Measuring Energy on page 8.

* 2017 world energy figures not available at time of print.

Data: Energy Information Administration

**Totals may not equal sum of parts due to rounding of figures by EIA.

Forms of Energy



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** or mechanical energy is the movement of objects and substances from one place to another. According to N**ewton'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.

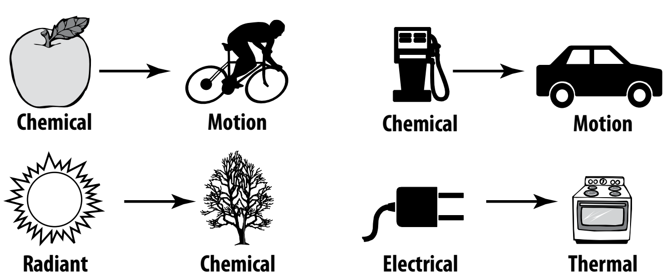
Conservation of Energy

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.

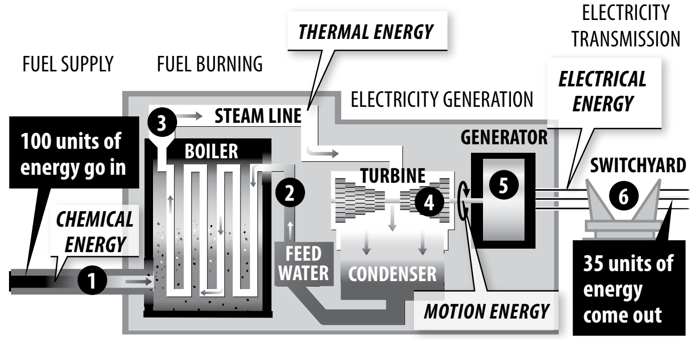
In fact, most energy transformations are not very efficient. The human body is no exception. Your body is like a machine, and the fuel for your "machine" is food. Food gives us the energy to move, breathe, and think. Your body is very inefficient at converting food into useful work. Most of the energy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

A traditional incandescent light bulb isn't efficient either. This type of light bulb converts only 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. Their inefficiency is also why these bulbs are no longer sold for use in homes, and why many consumers use LEDs and CFLs for lighting.

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

Most thermal power plants are about 35 percent efficient. Of the 100 units of energy that go into a plant, 65 units are lost as one form of energy is converted to other forms. The remaining 35 units of energy leave the plant to do usable work.



How a Thermal Power Plant Works

1. Fuel is fed into a boiler, where it is burned (except for uranium which is fissioned, not 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 a ring of magnets inside coils of copper wire. 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.

Measuring Energy

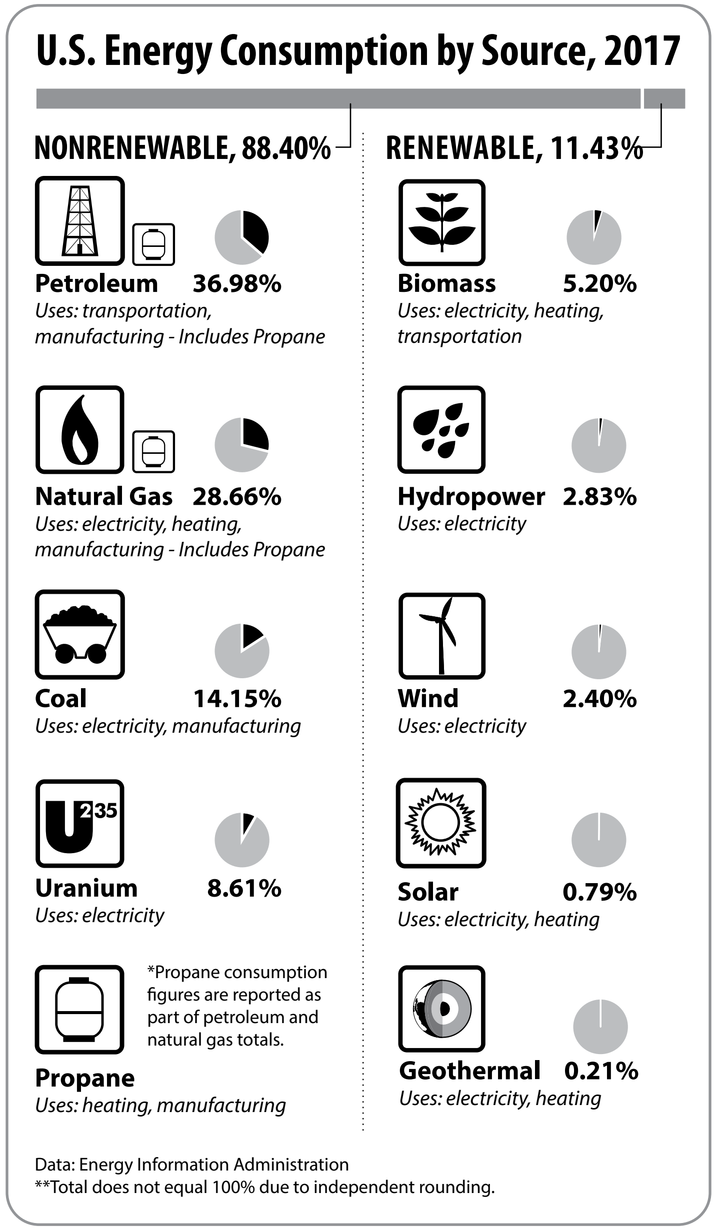
"You can't compare apples and oranges," the old saying goes. That holds true for energy sources. We buy gasoline in gallons, wood in cords, and natural gas in cubic feet. How can we compare them? With **British thermal units (Btu)**, that's how. The energy contained in gasoline, wood, or other energy 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 823,586 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 3.73 days. In 2007, the U.S. consumed 101.296 quads of energy, an all-time high.

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, natural gas is the number one fuel for generating electricity.



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 smart phone as 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 a little more than seven gallons of gasoline. That's every person, every day. Over a course of one year, the sum of this energy is equal to a little more than 2,500 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, electric power,** 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 often 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 10.64 percent of the primary energy supply in 2017, with a total of 10.405 quads. The residential sector consumed 6.017 quads and the commercial sector consumed 4.388 quads.

▪ Industrial

The industrial sector includes manufacturing, construction, mining, farming, fishing, and forestry. This sector consumed 21.113 quads of energy in 2017, which accounted for 22.61 percent of total consumption.

▪ Electric Power

The electric power sector includes electricity generation facilities and power plants. All of the other sectors consume electricity generated by the electric power sector. The electric power sector consumed 38.08 percent of the total energy supply in 2017, more than any of the other sectors, with a total of 37.241 quads.

▪ Transportation

The transportation sector refers to energy consumption by cars, buses, trucks, trains, ships, and airplanes. In 2017, the U.S. consumed 28.121 quads of energy for transportation, which accounted for 28.75 percent of total consumption. 92.05 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.

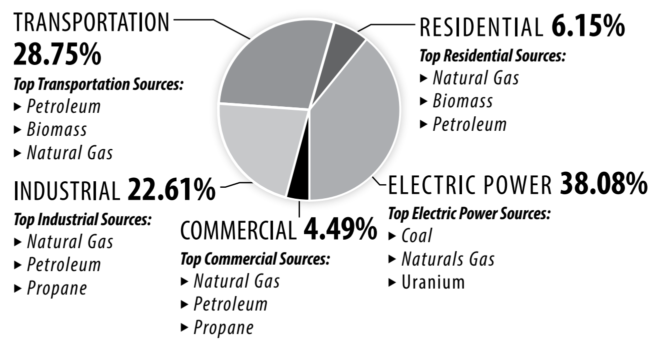
We don't want to simplify energy demand too much. The price of energy is not the only factor in the equation. Other factors that affect how much energy we use include the public's concern for the environment and new technologies that can improve the efficiency and performance of automobiles and appliances.

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 2017, 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 53 percent and the nation's **gross domestic product** was 2.947 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, 2017



The residential, commercial, and industrial sectors use electricity. This graph depicts their energy source consumption outside of electricity.

Data: Energy Information Administration

*Total does not equal 100% due to independent rounding.

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 50% 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.

Make A Magnet

Grade Levels: 7-11

Background

In nature, only three metals can be magnetic: iron, nickel, and cobalt. Common nails are usually made of iron and are coated in zinc to deter corrosion. These metals may not be magnetic to start, but can be magnetized when exposed to a magnetic field. Compasses can be used to show a material is magnetic, as its needle is a magnet. If the needle moves near a magnetized object, the object must be a magnet.

Question

Can electric current make a nail into a magnet?

Possible Hypothesis

Electric current can/cannot be used to make a nail into a magnet.

Materials

- 1 9-volt battery
- 1 Alligator clip
- 1 Nail
- 1 Compass

✔ Procedure

1. Take the nail and hold it next to the compass. Move the nail around over the compass and observe theinteraction.
2. Connect one end of the alligator clip to the negative terminal of the 9-volt battery.
3. Wrap the wire of the alligator clip around the nail, starting at the flat end or head of the nail, and movingtowards the pointed end. Leave enough wire to reconnect the battery.
4. Connect the other alligator clip to the positive terminal of the 9-volt battery.
5. Hold the pointed end of the nail near the compass. Observe the interaction.
6. Hold the flat end or head of the nail near the compass. Observe the interaction.
7. Unwrap the wire from the nail. Hold it near the compass. Observe the interaction.

⁂ Analysis and Conclusions

Was the nail magnetized to start? What allowed it to develop a magnetic property? Could the nail keep its magnetism? How could you remove the magnetic property from the nail? Why would we want magnetized metals?

Balloon Rocket

Grade Levels: 8-11

Safety Concern

This activity requires the use of a balloon. Many balloons are made of latex. If you have a latex allergy, do not handle balloons.

Background

Inflating a balloon stretches the rubber. When the rubber is stretched, it stores elastic energy, and the balloon pushes back against the air inside the balloon. As long as the balloon stem is held shut, the air inside pushes back with equal pressure against the walls of the balloon. However, when the balloon is released, the elastic energy of the balloon pushes the air out. Because of Newton's Third Law of Motion, when the air moves out of the balloon, the balloon moves forward in the air.

Question

Can elastic energy do work?

What energy transformations are involved with balloon rockets?

Possible Hypotheses

Elastic energy can/can not be turned into useful energy for work.

The balloon will transform ____________________ energy to _____________________ energy as it is rocketed down the string.

Materials

- Balloons
- Drinking straws
- String
- Tape
- Meter stick
- Scissors

✔ Procedure

1. Tear one or two strips of tape that are about 10 cm long.
2. Cut a 5 cm length of the drinking straw.
3. Inflate the balloon almost as far as possible. Take care not to overinflate the balloon.
4. While holding the balloon stem pinched shut, work with a partner to tape the straw to the top of the balloon such that it runs parallel to the long axis of the balloon stem.
5. Thread 5-10 m of string through the straw.
6. Working with a partner, hold the string very taut between you, and push the balloon all the way to the end of the string as shown.
7. Release the balloon and allow it to travel along the string until it stops on its own.
8. Observe, re-engineer your set-up, and re-test.

Analysis and Conclusions

When did the balloon travel the fastest? What happened when the balloon was deflated? How does the balloon transform energy? How can you tell work is done? What items did you need to change in your set-up to produce a better rocket?

Sailing with the Wind

Grade Levels: 7-10

Background

Wind has been helping us move people and objects for centuries. There are many designs for a good sailboat, but all must use a sail. The size, shape, and location of the sail depends on the design of the boat.

Question

How can the wind be captured to move an object from one place to another?

Possible Hypothesis

A boat must use a sail to catch the wind. The best materials for the boat are ______________________________________. The best location for the sail is ____.

Materials

- Empty plastic bottle
- Wooden blocks, discs, or boards
- Foam blocks, balls, or pieces
- Paper
- Straws
- Clay
- Tape
- Scissors
- Sink, aquarium, or tub of water

✔ Procedure

1. Make a sailboat to attempt to capture the energy in the wind! Below is a picture of one way to make a sailboat. Use any of the materials listed and your imagination to design a sailboat that you think can capture the wind and move the furthest. The sail can be any shape or size and placed anywhere on the foam, plastic, or wood.
2. Test your design on the water. Make changes to your boat and sail as needed. Retest.

Analysis and Conclusions

What was the best design for your boat and sail? How would your design change to account for changes in wind direction and speed?

STEM CHALLENGE: Light it Up!

Grade Levels: 7-12

Background

A completed circuit allows us to use electricity to power our devices. A circuit must include a power source, wires, and electrical load, like a light bulb. Sometimes circuits have switches you can close, open, connect, or disconnect to make the circuit complete. Certain parts of a power source and bulb must be connected in the correct way to ensure that a bulb in a circuit will light.

STEM Challenge Prompt:

Build a circuit that allows you to light up your bulb.

- Use any combination of the materials on the list.
- Hold your design together with tape, if necessary.
- Use ONLY the types of batteries listed.
- Designs may not include pre-formed circuit boards, snap circuits, battery holders, or electronic toys.

Question

- What will be the best design for my light bulb circuit?

Materials

- AAA Batteries
- AA Batteries
- C Batteries
- D Batteries
- Flashlight bulbs
- Single LEDs (*note the voltage)
- Alligator clips
- Foil
- Tape (masking, electrical)
- Paper clips

Possible Hypothesis and Design

Results

Redesign Notes

STEM CHALLENGE: Build an Energy Efficient House

Grade Levels: 7-12

Background

Sustainable building design is becoming more and more prevalent in architecture and construction. Obtaining an ENERGY STAR®, LEED,or other efficiency certification status is becoming more important to companies wishing to reduce their carbon footprints and promote a more sustainable way of living.

STEM Challenge Prompt:

Construct a house from cardboard that is able to stay the coolest inside the house, compared to the classroom temperature.

- Use any combination of the materials on the list.
- The house must provide at least 1,800 ft2 of living space (1 inch = 1 ft). Garages, basements, and attics are not included in living space.
- Frames (walls), ceilings, floors, corners, and joints must be constructed from cardboard. Exterior walls and floors may be insulated. Interior walls may not.
- Houses must include 2 doors that open and close. Houses must also include 4 windows. Windows do not need to open.
- No insulation may be exposed.

Question

- What will be the best design for my energy efficient house?

Materials

- Cardboard boxes
- Plywood or wood scraps
- Poster board
- Transparency film
- Plastic wrap
- Foil
- Paper
- Foam board
- Glue
- Tape
- Foam batting
- Bubble wrap
- Shredded paper

Possible Hypothesis and Design

✔ Testing Steps

1. Fill a zip-close sandwich bag with ice and seal. Put this bag inside another bag and seal. Place the bags on the ground floor of the house.
2. Record the temperature of the classroom.
3. After ten minutes, record the temperature in both the lower level as well as the upper level, if appropriate, of the house. If an attic is present, record the temperature of this space.
4. Houses that are the coolest compared to the classroom temperature have the best design for minimizing thermal energy transfer.

Results

⁂ Redesign Notes

STEM CHALLENGE: Design a Solar-Powered Cabin

Grade Levels: 9-12

Background

Your crazy old Uncle Ed has just willed you a cabin that he has on a river near Page, AZ. The only problem is that the cabin has no electricity. Uncle Ed believes in hard work and he's specified one condition—if you are to take possession of this prime parcel, you must plan and install a PV system to support the following his specifications. A typical solar module is usually 350 – 365 watts.

STEM Challenge Prompt:

In order to collect your inheritance, you must design and plan for the installation of a PV system to support the following four specifications:

- A light for the kitchen (LED, 12 volts at 15 watts);
- A power supply for charging your laptop (12 volts at 90 watts).;
- An electric pump for the well (12 volts at 100 watts intermittent); and
- A refrigerator (12 volts at 50 watts intermittent).

Before you can collect your inheritance, Uncle Ed's lawyer will need to see:

- A description of the DC and AC power supply requirements;
- A description of the PV modules that you will use along with their ratings;
- Diagram or schematic depicting the design of the cabin, the PV system, and any additional
- Components.
- A spreadsheet detailing your budget and sources for parts.

Question

- What will be the best design for the solar-powered cabin?

Materials

- Internet access
- Drawing supplies or digital drawing software program
- Spreadsheet software or program
- Calculator

✔ Extensions

- Consider how you would include energy storage into your design.
- Create a physical model of the cabin, system, and surroundings, using architectural modeling scale.

Research and Design Questions

Hypothesis and Design

STEM CHALLENGE: Build a Floating, Offshore Wind Turbine

Grade Levels: 7-12

Background

Wind turbines operate on land and on the water. Offshore wind turbines are in use all over the world and are emerging as a great resource for U.S. coastlines. The first offshore wind farm in the U.S. is located off the coast of Rhode Island. There are quite a few challenges to consider when placing, constructing, and harnessing energy from an offshore wind turbine.

STEM Challenge Prompt:

Design and build a basic model of a wind turbine. The model can be made out of recycled materials and found objects. Your model must meet the following design specifications:

- When placed in a tub of water, the model must float for 2 minutes. The platform must be above the water's surface.
- Your design must have an anchor or mooring to keep it in place.
- The designed turbine blades/arms must turn in the wind.

Question

- What will be the best design for the offshore turbine

Materials

- Tub with water
- Adhesives
- Various found materials (cardboard, plastic, foam, paper, etc.)

Research and Design Questions

- What will be the best design for my energy efficient house?

- What do I know about wind turbines?

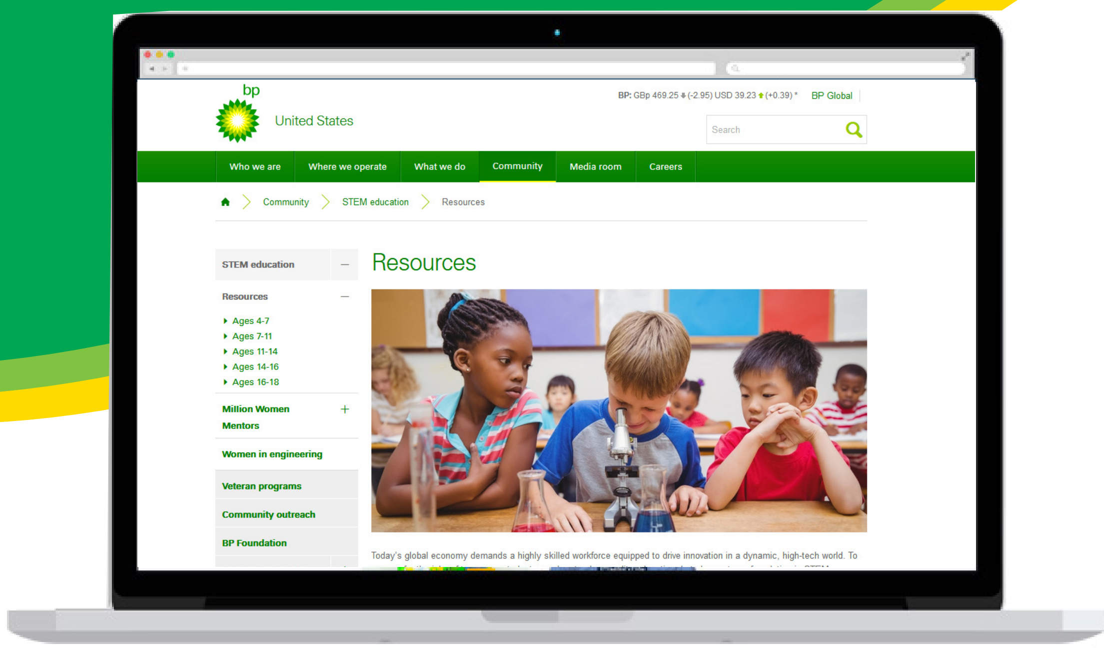
- What do I need to know?

Possible Hypothesis and Design

Results

Redesign Notes

LOOKING FOR MORE ACTIVITIES?



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