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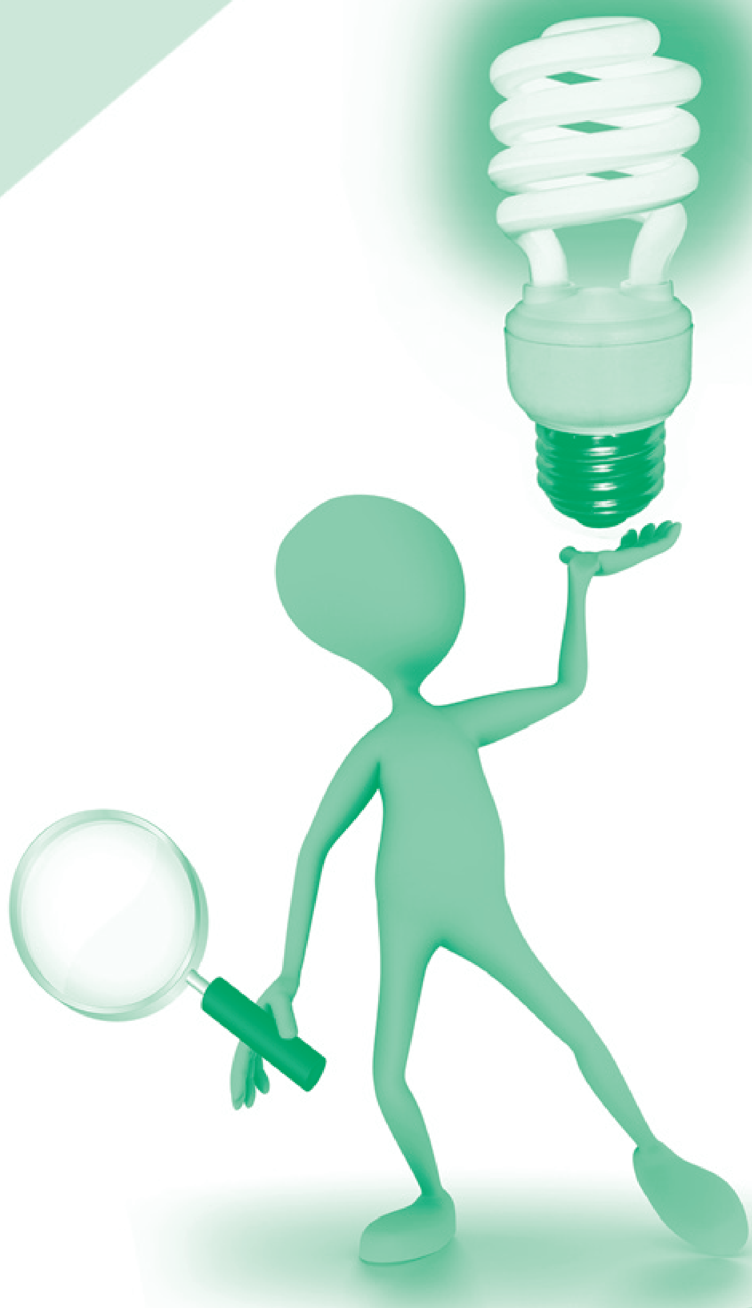
# Energy Investigators



## Student Handbook

# Note to Youth and Parents

*Energy Investigators* is a curriculum developed to help middle-school youth learn about energy conservation and alternative methods of energy generation. Why is this important? The typical U.S. family spends about $1,900 a year on home utility bills (U.S. Department of Energy, 2008). The electricity generated by fossil fuels for a single home puts more carbon dioxide into the air than two average cars each year, and transportation accounts for 67% of all U.S. oil consumption (U.S. Department of Energy, 2008). Much of the energy being used is from nonrenewable natural resources. A large portion of the energy is wasted because people don't understand the energy costs of many of their choices and what to do to reduce their energy use.

Electronic copies of this publication are available at Purdue Extension's Education Store, **www.the-education-store.com**.

The activities in *Energy Investigators* will help youth understand where the energy they use comes from and give them some ways to save money and our natural resources.


## Acknowledgments

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# Contents



## Resources

### Electric Energy on TV

*Indiana Expeditions* series by public television station WFYI:

- Discover how real science impacts our lives every day through video clips.
- "Electrical Energy" (episode 301), **www.wfyi.org/IndianaExpeditions/**

### Learn about Saving Energy

- Energy Star, United States Environmental Protection Agency (US EPA), **www.energystar.gov**
- Energy Savers, **www.energysavers.gov**
- U.S. Department of Energy (DOE), Office of Energy Efficiency and Renewable Energy, **www.eere.energy.gov** (includes a DOE Consumer Guide to Energy Efficiency and Renewable Energy)
- U.S. Department of Energy (DOE), Tips for Energy Savings, **http://www1.eere.energy.gov/consumer/tips/**
- American Council for an Energy-Efficient Economy, **www.aceee.org/consumer/**
- Home Energy information, National Institute of Food and Agriculture (NIFA), **www.eXtension.org** (Choose "Resource Areas," followed by "Energy: Home Energy")
- Purdue Extension Renewable Energy, **www.extension.purdue.edu/renewable-energy**

### Learn about Energy and the Environment

- Carbon Dioxide, **www.epa.gov/climatechange/emissions/co2.html**
- Carbon Footprint, **www.epa.gov/climatechange/emissions/individual.html**
- Geologic Sequestration, **www.epa.gov/climatechange/emissions/co2_geosequest.html**

# Generating Electricity

**Time:** about 20 minutes
**Guiding Question:** Have you ever wondered how electricity is generated (made)?

This experiment shows how the reaction between the metals in two different coins can generate electricity. The two metals react differently in a solution: One has a positive charge and one has a negative charge. Free electrons move in response to the different charges. A difference in the charge between two metals can cause free electrons to detach from atoms and move in a solution. The electron movement, called current, creates electricity. The unit for measuring current is called ampere. Voltage is the force that causes the electrons to move in an electrical circuit. This force is measured in units called volts.

**Tool Kit**
10 pennies
5 nickels
5 dimes
1 T salt
1/4 c. vinegar
1 paper towel
Soap
Small bowl
Small plate (ceramic, plastic or foam)
Scissors
Multimeter that measures 1 volt (An analog multimeter may be purchased for $15-20.)

**Note:** This experiment is modeled after an activity called "A Battery That Makes Cents" found at www.sciencebuddies.org.

## Questions

- Can a stack of pennies and nickels generate voltage?
- Can a stack of pennies and dimes generate voltage?

## Do It

- Mix one tablespoon (1T) salt  and one-quarter cup (¼ c.) vinegar in a bowl
- Cut ten ½-inch squares (½ x ½) from paper towel. The squares should be about the size of the coins.
- Place paper towel squares in the salt and vinegar solution, stir, and set aside.
- Wash the pennies and nickels with soap and water. Rinse and dry.
- Place a piece of dry paper towel on the plate and place a penny on the paper towel. Place a piece of paper towel that was soaked in the solution on top of the penny. Then, build a stack of coins on top of the penny and paper towel, by alternating pennies, paper towel pieces and nickels in the following order: penny, paper towel, nickel, paper towel, penny, paper towel, nickel. Use five pennies, five nickels, and the paper towel squares that were soaked in the solution. Make sure a penny is on the bottom and a nickel is on top.
- Follow the same procedure to build a stack of coins with five pennies, five dimes, and the paper towel squares that were soaked in the solution on another plate.
- Touch the ends of the multimeter to the top (positive lead) and bottom coin (negative lead) in your stack. You may have to press down gently to help make a good connection but be careful or you will topple your stack of coins.
- Measure the voltage produced using the DC (direct current) setting (1-10 volts) to see if your stacks of coins can generate electricity.
- Record the voltage that you measured for each stack. Voltage is a measurement of electricity generated.
- Remove the top penny and nickel from the stack and measure the voltage again.
- Continue to remove coins, two at a time, until you can't measure any voltage. Measure and record the voltage.
- Rinse the coins after you are done or the solution may cause a reaction and discolor the coins.

## Data

| Number of coins: | 10 | 8 | 6 | 4 | 2 |
|---|---|---|---|---|---|
| Electricity Measured: Pennies & Nickels (volts) | | | | | |
| Electricity Measured: Pennies & Dimes (volts) | | | | | |

## Talk It Over

***Share What Happened:***

- How much voltage did the coins produce?
- Did more coins produce more voltage?
- Did the type of coins make a difference in how much electricity was generated?

***Apply:*** What changes could you make to this experiment to learn new information?

***Generalize to Your Life:*** How many things can you list that use electricity?

## Definitions

We use energy to make our work easier. There are three kinds of energy. The actual definition of **energy** is: the ability a physical system has to do work on other physical systems. Energy is always equivalent to the ability to exert pulls or pushes against the basic forces of nature, along a path of a certain length.

The **Law of Conservation of Energy** states that energy cannot be created or destroyed but can be transformed from one kind into another.

- **Kinetic Energy** – the energy a body has by virtue of its motion
- **Potential Energy** – the energy a body has by virtue of its position
- **Rest Energy** – the energy a body has by virtue of its mass

**Conservation of Energy** – energy cannot be created or destroyed but can be transformed from one kind into another.

**Work** is the transfer of energy between systems and is given by the equation:

$$\Delta E = W + Q$$

Where: Δ symbolizes a change in E ~ Energy

The change in energy is equal to the Work (W) done on a system plus the heat (Q) flow into the system.

**Power** is the *rate* that work is done by a force over time. The equation that describes power is:

**Power (P) = Work (W)/time (t) (power = work done/time)**

# Comparing Electricity Options

**Time:** about 20 minutes
**Guiding Question:** What are the costs and benefits of different sources of energy?

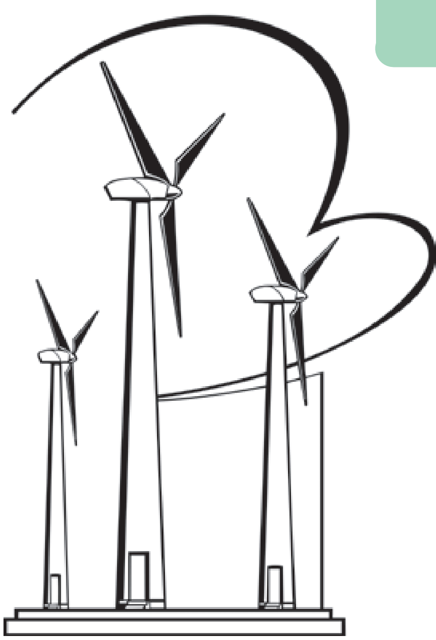
**Tool Kit**
Paper
Pencil
Fuel source chart (optional)

Energy is important to everyone. We use energy to heat and cool our houses and to power all the appliances, electronics, and technology that make life convenient. Electricity places entertainment and information at the tip of our fingers.

There are many different sources of energy for providing electricity and heat in homes, schools, and at work. Each source has costs and benefits. Currently, fossil fuels are the main source used to produce electricity. Since fossil fuels are a nonrenewable resource, we could run out of them one day. Many scientists and citizens are interested in finding renewable energy sources so that we can continue to enjoy the benefits that electricity and heat provide.

**Do It**

- How much general information do you know about energy sources? Estimate your Energy IQ (%).
- Think about each Fuel Type in the Fuel Source Chart and indicate for each: whether Power Availability is constant or variable; if the level of $CO_2$ Emissions is low, medium, or high; and if it is considered Renewable. Guessing is fine.
- List any potential environmental impacts that you know of for each energy source.
- Ask your helper to check the answers in the Fuel Source Chart and calculate your actual Energy IQ (24 correct = 100%). Then discuss the potential environmental impacts.
  (Note: Answers are found in the facilitator's guide.)



## Fuel Source Chart

| Fuel Type | Power Availability | | $CO_2$ Emissions | | | Renewable |
|---|---|---|---|---|---|---|
| | Constant | Variable | Low | Med | High | |
| Coal | | | | | | |
| Natural Gas | | | | | | |
| Nuclear | | | | | | |
| Wind | | | | | | |
| Solar | | | | | | |
| Hydropower (from reservoir) | | | | | | |
| Hydropower (streaming) | | | | | | |
| Geothermal | | | | | | |

## Potential Environmental Impacts

| |
|---|
| Coal- |
| Natural Gas- |
| Nuclear- |
| Wind- |
| Solar- |
| Hydropower (from reservoir)- |
| Hydropower (streaming)- |
| Geothermal- |

### Talk It Over:

***Share What Happened:*** How did your calculated Energy IQ compare with your estimate?

***Apply:*** Why is it important to know about sources of energy, power availability, $CO_2$ emissions, and renewability?

***Generalize to Your Life:*** How might energy legislation made today affect your future?

# Measuring Electricity

**Time:** 15 minutes to one hour (variable – depending on how many electric items are measured)
**Guiding Question:** Where is the power going?

**Tool Kit**
Electricity usage monitor ($ 20-30)
Paper & pencil
Electric bill

When you wake up in the morning you probably turn off your alarm, flip on the bedside lamp, and perhaps unplug your phone from the recharger. Then, you probably take a shower with water that may be heated by electricity. An electric stove and toaster could cook your breakfast. We use electricity in so many ways day and night without even thinking about it that most people don't realize how much they depend on it until they lose power.

Most things that are powered by electricity only use it when they are powered on. But some items draw a little electricity all the time to power clocks or power display lights. Some entertainment equipment, especially televisions and cable or satellite receivers, draw power all the time. This allows viewing guides to be continuously downloaded and instant viewing once they are turned. You can see how much electricity you use by asking your parents to show you the electric bill. But the electric bill won't tell you which appliances and other electric equipment uses the most power. In this activity you will use an electricity usage monitor to account for your electricity use.

Electricity is provided to your home as alternating current, meaning that it changes direction periodically. The change in direction is called the frequency and is measured using the unit Hertz (Hz). Direct current (as in batteries) always flows in one direction. Notice the values of current and frequency while measuring the electric usage of the various devices. These values will fluctuate some but hover around a constant value.

**Do It**

- Make a chart with three columns and space to add rows as needed. Title the columns "Electricity User," "Current (amp)" and "Wattage (watt)." Use the list given or make your own. Include electric appliances, entertainment devices, and other electricity using items in your house. Safety Note: Do not include stoves/ovens or clothes dryers because many of them use 220 volts and these appliances should only be moved by a professional.
- Use your electricity usage monitor to record the current (amps) and electric energy (watts) for each item in your list with your adult helper.
- Measure the voltage (volts) and frequency (Hz) in a few outlets with your adult helper.
- Record how much electricity is used when both on and off for 2-3 Electricity Users with displays that light up when the power is turned off (e.g., a satellite dish or cable for TV).

| Electricity User | Current (amps) | Energy (watts) |
|---|---|---|
| Refrigerator | | |
| TV | | |
| Stereo | | |
| Tuner | | |
| Microwave | | |
| Lamp-1 | | |
| Lamp-2 | | |
| Lamp-3 | | |
| Digital clock/radio | | |
| Satellite dish (on/off) | | |
| Cable receiver (on/off) | | |
| | | |

**Voltage:** approximately ______________ volts (values will vary slightly)

**Frequency:** approximately _____________ Hz (values will vary slightly)

## Talk It Over

***Share What Happened:***

- Which item uses the most electricity?
- Which one uses the least?
- Do any of the Electricity Users continue to use electricity when turned off? If so, why do you think this is so?
- Why do you think the current and frequency values vary from a constant number?

***Apply:***

- How much electricity (total wattage) is being used by the Electricity Users you measured?
- How could you use the data you collected to calculate the total electricity used in your house?
- How could you compare this to what is actually used? (Estimate daily/monthly used and compare to the electric bill.)

***Generalize to Your Life:***

- How can people reduce the amount of electricity they use?
- How can reducing the amount of electricity used help the environment?

## Dig Deeper

- Record the power used (kW) over time (hours) for two to three items. Calculate how much power is used per hour (kW/hour). Multiply this value by 24 to calculate the daily value and then by 30 to calculate a monthly value. What percent of your utility bill does this account for?
- Locate your electricity meter. Read and record the reading each day for a month. Do you use more energy during the weekdays or on the weekend?
- Using your family's electric bill, keep track of how much electricity you use each month and the price paid for each kilowatt. Try and do this for a year. In what month does your family use the most electricity?

# $CO_2$ Production and Absorption

**Time:** about 20 minutes to set up, plus observations over a day or two
**Guiding Question:** Why is carbon staying in the atmosphere?

Carbon dioxide ($CO_2$) occurs in nature. The amount of natural carbon produced is about the same as the amount removed from the atmosphere by oceans and growing plants. Plants use sunlight and water to convert carbon from the atmosphere into sugars though photosynthesis. Plants use these sugars for growth and we depend on plants for oxygen and our food, either directly when we eat plants or indirectly when we eat animals that eat plants or other animals.

Until recently, the carbon cycle was balanced. However, the amount of human-generated $CO_2$ has risen dramatically since the 1700s because of the burning of oil, coal, and gas. At the same time, the amount of growing plants has decreased because of deforestation and other losses. In 2005, global atmospheric concentrations of $CO_2$ were 35% higher than they were before the Industrial Revolution (**www.epa.gov/climatechange/emissions/co2.html**). This is of particular concern because excessive $CO_2$ contributes to climate change by trapping heat in the atmosphere. That's why $CO_2$ is called a greenhouse gas.

### Tool Kit

Large glass container with lid
Small plant
Tea candles
Matches/lighter
Water
Bromothymol blue (BTB) See the Facilitator's Guide for ordering information.
Plastic cup
Timer or watch with second hand
Duct or packing tape*
Optional: Camera
*Note: if you don't have a lid for your glass container, you can use aluminum foil and duct or packing tape to make an air-tight covering.

### Do It

- Put one cup (8 oz.) of water in the plastic cup and add ½ teaspoon (2.5 mL) of BTB. Record the color of the water on your data sheet.
- Place the cup, two tea candles, and small plant in the glass container.
- Place the container on a windowsill or other sunny area.
- Light the candles and cover the container with the lid or foil. Make sure it is air-tight.
- Record how long the candles burn, after you have covered the container.
- Record the color of the water when the candles have burned out.
- Check solution a few times throughout the day. Do not disturb the container.
- Record the time when the water has returned to the color it was when the candles were lit (initial color of the water + BTB). Taking pictures at the start of this experiment may help make the comparison.

**Data Sheet**

Initial color of the water + BTB: ________________________________

Time between container closure and candle burn out: ________________

Color of the water + BTB when the candles burned out: _____________

Time when the water returned to its original color: _______________

## Talk It Over

***Share What Happened:*** How long did it take for the BTB to turn green? How long did it take to turn back to blue? Why are these times different?

***Apply:*** The BTB turned color when $CO_2$ was detected in the container. It should have turned back to the original blue when the $CO_2$ was used by the plant (with water) to make oxygen. How might this reflect what happens on the planet?

***Generalize to Your Life:***

- What can each person do to reduce their carbon footprint? Why is it important?
- What are some other greenhouse gases besides $CO_2$?

# Carbon Sequestration and Storage

**Time:** 10 minutes to set up, but need to collect data 30 and 60 minutes later
**Guiding Question:** How can carbon be removed from the atmosphere?

Carbon dioxide ($CO_2$) is produced by burning of oil, coal, and gas. These fuels are often used in the production of electricity. Scientists are working to reduce the amount of carbon in the atmosphere. One way to reduce it is to capture the carbon before it is released. But this captured carbon must be stored somewhere. Carbon sequestration refers to the process of capturing carbon from the atmosphere and storing it. Geological storage, where captured carbon is injected far into the earth as a means of preventing it from mixing into the atmosphere, may offer a good solution for carbon storage. Geologists have to look for certain places where $CO_2$ can be safely stored. One important feature is a cap stone, which is a layer of rock that prevents a liquid or gas from rising to the surface.

### Tool Kit

- Samples of limestone, sandstone, and shale rocks
- Three plates
- Eyedropper
- Vegetable oil
- Timer or watch with second hand
- Magnifying glass
- Optional: Camera

### Do It

***Preparing Your Rock Samples:***

- Place samples of limestone, sandstone, and shale on a paper plate.
- Identify each rock (write on the paper plate or place the name by each plate.) Choose samples that are similar in size to each other, if possible.
- Position the samples so a flat surface is facing upward, if possible.
- Look carefully at the rocks with and without a magnifying glass. Write down the differences you observe. Can you see any pores or small spaces? Which type of rock do you think will soak up oil the fastest?

***Testing Your Rock Samples:***

- Write down the time you start this experiment (initial time).
- Use an eyedropper to add three drops of oil to each rock sample on each plate
- Place the drops one on top of the other, not spread out over the rock.
- Describe how the rocks look immediately after you place the oil on them.
- Examine the rocks in good light and use the magnifying glass, if desired.
- Examine the rocks again, 30 minutes and 60 minutes after applying the oil.
- Record what you observe.
- Examine the rocks in good light, with and without a magnifying glass.

## Data Sheet

**Limestone**

Observation 1 (initial): ______________________________

Observation 2 (30 minutes): ______________________________

Observation 3 (60 minutes): ______________________________

**Sandstone**

Observation 1 (initial): ______________________________

Observation 2 (30 minutes): ______________________________

Observation 3 (60 minutes): ______________________________

**Shale**

Observation 1 (initial): ______________________________

Observation 2 (30 minutes): ______________________________

Observation 3 (60 minutes): ______________________________

## Talk It Over

***Share What Happened:***

- Which rock(s) soaked up the oil? These rocks are considered permeable to oil.
- What happened if the oil did not soak into the rock?

***Apply:***

- How do you think water movement through rocks might differ from oil movement?
- How do you think $CO_2$ movement through rocks might differ from oil movement?

***Generalize to Your Life:*** Why is understanding rock permeability important when looking for places to store carbon?

## Dig Deeper

Information from the EPA (Environmental Protection Agency) about geologic sequestration: The EPA states, "Carbon dioxide can be captured at stationary sources and injected underground for long-term storage in a process called geologic sequestration." The Intergovernmental Panel on Climate Change (IPCC) identified $CO_2$ capture and geologic sequestration as one of several options (including energy efficiency and renewable energy) that have the potential to reduce climate change mitigation costs and increase flexibility in achieving greenhouse gas emission reductions. The IPCC estimates that there is enough capacity worldwide to permanently store as much as 1,100 gigatons of $CO_2$ underground (for reference, worldwide emissions of $CO_2$ from large stationary sources is approximately 13 gigatons per year) (IPCC, 2005). What states in the United States are better at storing $CO_2$ underground?

Read more at **www.epa.gov/climatechange/emissions/co2_geosequest.html**.

# Notes

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