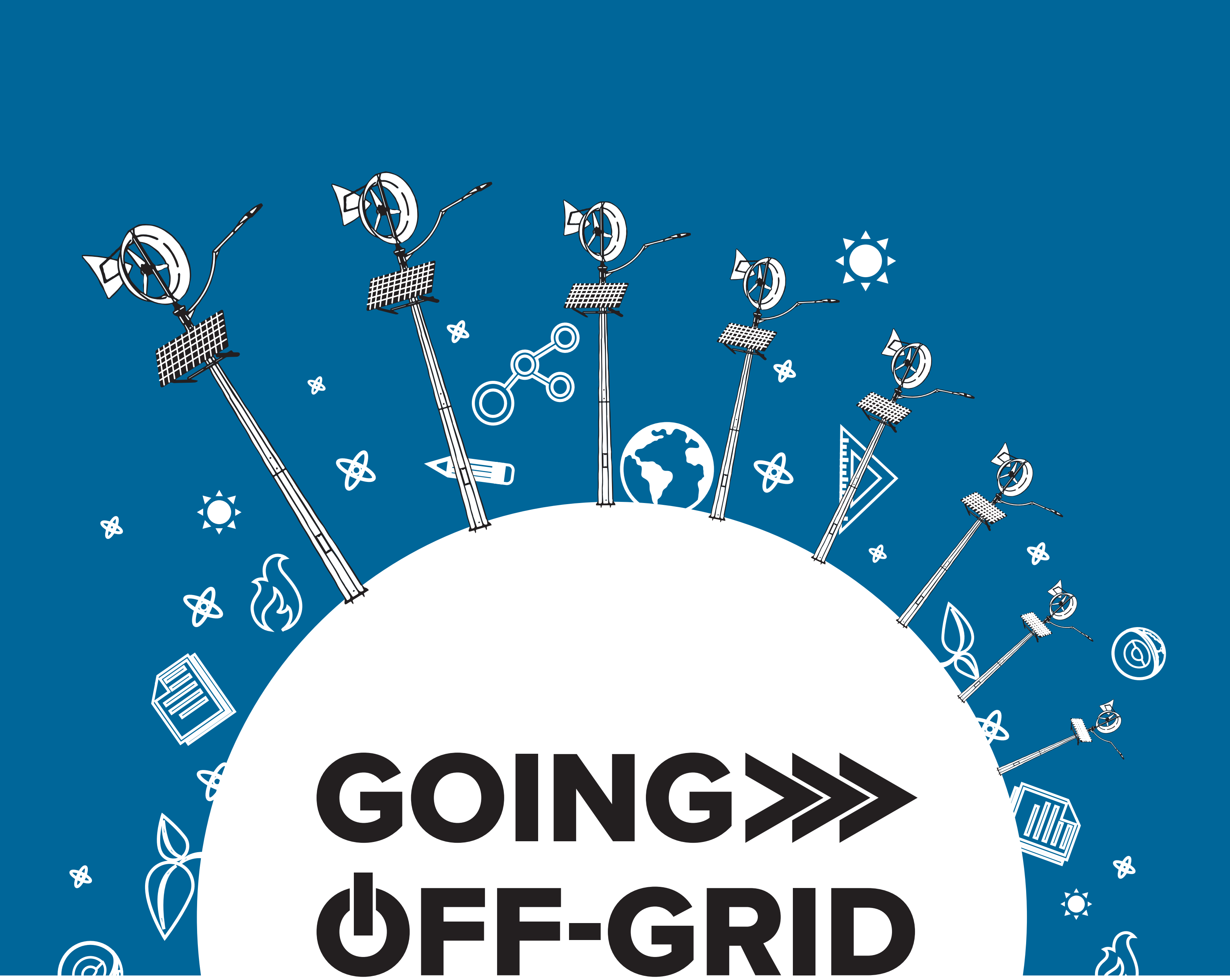


GOING OFF-GRID

SECONDARY GUIDE

ComEd®

NEED
Putting Energy into Education

Teacher Advisory Board

NEED Mission Statement

The mission of The NEED Project is to promote an energy conscious and educated society by creating effective networks of students, educators, business, government and community leaders to design and deliver objective, multi-sided energy education programs.

Permission to Copy

Teacher Advisory Board

In support of NEED, the national Teacher Advisory Board (TAB) is dedicated to developing and promoting standards-based energy curriculum and training.

Energy Data Used in NEED Materials

NEED believes in providing teachers and students with the most recently reported, available, and accurate energy data. Most statistics and data contained within this guide are derived from the U.S. Energy Information Administration. Data is compiled and updated annually where available. Where annual updates are not available, the most current, complete data year available at the time of updates is accessed and printed in NEED materials. To further research energy data, visit the EIA website at www.eia.gov.

NEED
National Energy
Education Development

1.800.875.5029
www.NEED.org

Table of Contents

ComEd®

NEED Putting Energy into Education

Welcome & Kit List

Energy is a very widely used term. But, it's not just a description of how much sugar our students have had today – it's much more! Energy gives us the ability to do work or make change. It moves planes, trains, and automobiles. It bakes cupcakes and freezes ice cream. It plays our favorite songs, powers our computers, and even lights our parking lots! This ComEd-sponsored curriculum and accompanying kit will help reinforce basic energy concepts, and showcase the sources of energy that power the off-grid Aris lighting systems on your school grounds.

Get Ready

- Read through the book and identify activities you will demonstrate for or complete with students.
- Familiarize yourself with the teacher instructions for the activity or activities you have selected. Teacher instructions for each activity will appear first in the book, and any student worksheets will follow, where applicable.
- Make copies of any student worksheets that might be necessary for completing the activity.

Get set

- Gather the materials needed for the activity as listed in the teacher instructions. A list of materials provided is found below. Some additional materials may be needed and will be listed on the teacher instruction sheet.
- Prepare a space to complete the activity or demonstration for the class. Activities may also be set up as stations, if you desire.

GO!

- Have students work through the steps in the experiment with your direction or independently.
- Encourage students to use the student worksheet or student notebooks, where applicable, to record their ideas and data, and answer questions.
- Discuss any analysis and conclusions as a class.

Materials Supplied by ComEd

- 1 Secondary Energy Infobook
- 1 Set of Energy Round Up posters with cards
- 1 Set of Nifty Natural Gas Story prop cards
- 30 Hang tag holders
- 10 Feet of rope
- 25 Ping pong balls
- 1 Small flashlight
- 4 DC microammeters
- 4 Pair of nails (large and small)
- 4 Pair of copper wires (thick and thin)
- 4 Sets of alligator clips
- 4 Deluxe PV cell kits
- 8 Multimeters
- 100 Clear straws
- 30 Milkshake straws
- 30 Stirrer straws
- 1 Box straight pins
- 30 Binder Clips
- 30 Foam Cups
- 15 Paper plates
- 15 Plastic spoons
- 100 Small dowels
- 1 Spool thread
- 4 Hole punches
- 1 Box paper clips
- 1 CFL bulb
- 1 LED bulb
- 1 Incandescent bulb
- 1 Pack 3V LEDs
- 1 Pack 1.5V flashlight bulbs

Aris Wind Off-Grid Remote Power Unit (RPU)

A RENEWABLE LIGHTING SYSTEM

Getting Your School "LIT"

As part of the Community of the Future Initiative, ComEd partnered with Aris Renewable Energy, Chicago Housing Authority, and Chicago Public Schools to install off-grid, remote powered lighting units in the Bronzeville Community to provide safety in underlit/underserved areas, and to educate the community on renewable generation, energy storage, and grid resiliency.

These off-grid, hybrid LED street lights, or RPUs, consist of five key components: a steel pole, an LED lamp, a wind turbine, a solar panel, and an energy storage unit. The wind turbine and solar panels generate electricity to charge the energy storage unit. The LED draws the stored energy to illuminate your school grounds.

These RPUs also collect data in real-time to showcase how much energy is generated, stored, and/or discharged at a certain moment. Your classroom can use this data to make observations and inferences based on a given day.

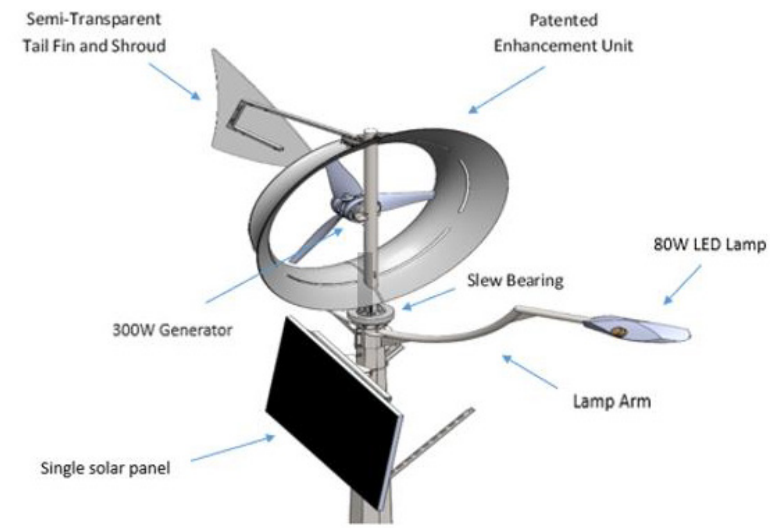


Image Courtesy of Aris.

Specifications

- The lamp is an LED that requires 80 W of power for maximum brightness, but only 45 W when less light is required.
- The wind turbine incorporates a tail fin to orient the turbine based on wind direction. The wind turbine can generate up to 300 W in peak wind conditions.
- The solar panel is equipped with an optimizer that minimizes shading effects and protects the battery. The solar panel can generate up to 320 W.
- The battery can store up to 5 kWh and will avoid total discharge to maintain battery life. The battery is programmable to operate until different depths of discharge are met.

But really, how does it work?

- The battery is charged during the day by solar and wind energy generation (if available).
- If the battery is fully charged, additional energy generation is automatically slowed or stopped.
- The battery is discharged at night, sending its energy to the lamp for lighting the area. The lamp brightness can be reprogrammed. The brighter light desired, the more energy is required to power the lamp.
- If wind is available at night, the turbine will continue to generate electricity to charge the battery.
- For more information, specifics, and diagrams, head to www.ariswind.com, and check out "RPU Streetlight."

Energy Round Up

TEACHER INSTRUCTIONS

Background

This activity will help students begin to think about all the ways in which they might use energy in their day in order to begin thinking the sources of energy we use to power our lives. Students will first complete a quick survey of the room – itemizing ways in which they use energy. *Energy Round Up* will introduce them to the sources of energy that allow each of those items they surveyed to operate.

Objectives

- Students will be able to describe ways in which we use energy in society.
- Students will be able to list and describe the ten energy sources.

Materials

- *Energy Round Up* posters
- *Energy Round Up* cards
- Markerboards and markers (optional)

Time

- 30 minutes

Procedure

1. Prior to class, hang the posters around the room.
2. Hand out the *Energy Use Pre-Survey*. Ask the class to complete in a given amount of time.
3. Review and compile student responses to help students gain insight into all the energy users around them, and all the ways in which they use energy as well.
4. Ask students to read the *Secondary Energy Infobook* introduction to energy. While they read, pass out the cards to the class, making sure that every source is distributed before duplicating sources. Try to ensure that they are evenly distributed as well, for example – if you have 30 students and there are 10 sources, 3 students should receive each source. Instruct the class to keep their cards secret from each other and that during the first phase of the activity, they must not speak or communicate with others.
5. Ask the students to decide if their individual card is representing a renewable or nonrenewable energy source. Explain that the ten posters on the walls around the room each represent one energy source. They must read the ten source posters and try to find the poster that most closely describes their card, without talking or communicating with others. When they find their poster, they should remain beside it. Give the class a signal to begin.
6. If necessary, give the class a hint about the poster color – explain that one color represents renewable and the other nonrenewable. Indicate the colors, as necessary.
7. Once time is up, ask students to find their poster if they haven't yet. Instruct each group to lift the flap on the top of the poster so they can see which source their clues describe. Ensure no one moves or gives away their identity to the rest of the class, even if they are not at the correct spot. Ask each group to pick the three clues that are the most revealing about their source.
8. Once all groups have determined their three clues, have each group share their 3 clues with the class. Each group should record the source for each group, either on paper or on markerboards, as other groups read their clues. See which group can best identify the most sources!

Extensions

- Switch up the game and ask groups to pick the three least revealing clues for more of a challenge.
- Conduct the activity as an assessment, having each individual record their answers and turn it in.
- Have the class make their own posters using the Infobooks. Put students into groups ahead of time using the cards. They must prepare their own group's poster.

Energy Use Pre-Survey

STUDENT WORKSHEET

Using the form below, survey your classroom or other work area. Make a note of the devices using energy, any cold air (or warm air) currents you feel, any mysterious sounds that indicate something is running and not easily identified, and any similar items. The goal is to start paying detailed attention to the way you use energy every day while at school.

ITEMS YOU SEE THAT ARE USING ENERGY	ITEMS YOU HEAR THAT ARE USING ENERGY

ITEMS YOU FEEL THAT ARE USING ENERGY	OTHER NOTES

Forms to Sources of Energy

TEACHER INSTRUCTIONS

Background

This lesson introduces students to the energy forms and connects them to the sources of energy. This activity will help set the stage for understanding energy transformations – a key concept in understanding energy and how it can be used more wisely.

Objectives

- Students will be able to describe different ways in which we use energy in society.
- Students will be able to identify the forms of energy and provide an example of each.
- Students will be able to identify the sources of energy we use the describe the form(s) of energy therein.

Materials

- Calculators (optional)

Time

- 15-20 minutes

✔ Procedure

1. Make copies of the student worksheet and masters or prepare digital versions to project as needed.
2. Project the master for the class. Explain that energy is the ability to do work or make change. Energy is either stored or in motion. Explain that scientists classify energy into various forms – kinetic and potential. Go over each of the forms of energy as a class and list examples of different items or scenarios where each form might exist. Explain that energy is constantly changing forms between the forms of energy on the sheet.
3. Provide the student worksheet for the class. Review the energy sources as needed. Explain that each of the energy sources we use to power our lives relies on at least one form of energy on the master – and that energy is transformed in order for us to use the source. Ask students to complete the worksheet. Project and/or discuss the answers.

Forms of Energy

TEACHER MASTER

All forms of energy fall under two categories:

POTENTIAL

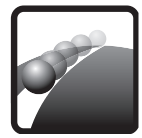
Stored energy and the energy of position (gravitational).

CHEMICAL ENERGY is the energy stored in the bonds between atoms in molecules. Gasoline and a piece of pizza are examples.

NUCLEAR ENERGY is the energy stored in the nucleus or center of an atom – the energy that holds the nucleus together. The energy in the nucleus of a plutonium atom is an example.

ELASTIC ENERGY is energy stored in objects by the application of force. Compressed springs and stretched rubber bands are examples.

GRAVITATIONAL POTENTIAL ENERGY is the energy of place or position. A child at the top of a slide is an example.



KINETIC

The motion of waves, electrons, atoms, molecules, and substances.

RADIANT ENERGY is electromagnetic energy that travels in transverse waves. Light and x-rays are examples.

THERMAL ENERGY or heat is the internal energy in substances – the vibration or movement of atoms and molecules in substances. The heat from a fire is an example.

MOTION ENERGY is the energy of the movement of a substance from one place to another. Wind and moving water are examples.

SOUND ENERGY is the movement of energy through substances in longitudinal waves. Echoes and music are examples.

ELECTRICAL ENERGY is the movement of electrons. Lightning and electricity are examples.

Forms to Sources of Energy

ANSWER KEY

In the United States we use a variety of resources to meet our energy needs. Use the information below to analyze how each energy source is stored and delivered.

1 Using the graphic below, determine how energy is stored or delivered in each of the sources of energy. Remember, if the source of energy must be burned, the energy is stored as chemical energy.

NONRENEWABLE		RENEWABLE	
Petroleum	*CHEMICAL*	Biomass	*CHEMICAL*
Natural Gas	*CHEMICAL*	Hydropower	*MOTION*
Coal	*CHEMICAL*	Wind	*MOTION*
Uranium	*NUCLEAR*	Solar	*RADIANT*
Propane	*CHEMICAL*	Geothermal	*THERMAL*

2 Look at the U.S. Energy Consumption by Source graphic below and calculate the percentage of the nation's energy use that each form of energy provides.

What percentage of the nation's energy is provided by each form of energy?

Chemical *85.00%*

Nuclear *8.61%*

Motion *5.23%*

Radiant *0.79%*

Thermal *0.21%*

What percentage of the nation's energy is provided

by nonrenewables? *88.41%*

by renewables? *11.54%*

U.S. Energy Consumption by Source, 2017

NONRENEWABLE

PETROLEUM 36.99% *
Uses: transportation, manufacturing - includes propane

NATURAL GAS 28.66% *
Uses: heating, manufacturing, electricity - includes propane

COAL 14.15%
Uses: electricity, manufacturing

URANIUM 8.61%
Uses: electricity

PROPANE
Uses: heating, manufacturing

*Propane consumption figures are reported as part of petroleum and natural gas totals.

RENEWABLE

BIOMASS 5.20%
Uses: heating, electricity, transportation

HYDROPOWER 2.83%
Uses: electricity

WIND 2.40%
Uses: electricity

SOLAR 0.79%
Uses: heating, electricity

GEOTHERMAL 0.21%
Uses: heating, electricity

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

Forms and Sources of Energy

STUDENT WORKSHEET

In the United States we use a variety of resources to meet our energy needs. Use the information below to analyze how each energy source is stored and delivered.

1 Using the graphic below, determine how energy is stored or delivered in each of the sources of energy. Remember, if the source of energy must be burned, the energy is stored as chemical energy.

NONRENEWABLE		RENEWABLE	
Petroleum	______________________	Biomass	______________________
Coal	______________________	Hydropower	______________________
Natural Gas	______________________	Wind	______________________
Uranium	______________________	Solar	______________________
Propane	______________________	Geothermal	______________________

2 Look at the U.S. Energy Consumption by Source graphic below and calculate the percentage of the nation's energy use that each form of energy provides.

What percentage of the nation's energy is provided by each form of energy?

Chemical _____

Nuclear _____

Motion _____

Radiant _____

Thermal _____

What percentage of the nation's energy is provided

by nonrenewables? ______

by renewables? ______

U.S. Energy Consumption by Source, 2017

NONRENEWABLE

PETROLEUM 36.99% *
Uses: transportation, manufacturing - includes propane

NATURAL GAS 28.66% *
Uses: heating, manufacturing, electricity - includes propane

COAL 14.15%
Uses: electricity, manufacturing

URANIUM 8.61%
Uses: electricity

PROPANE
Uses: heating, manufacturing

*Propane consumption figures are reported as part of petroleum and natural gas totals.

RENEWABLE

BIOMASS 5.20%
Uses: heating, electricity, transportation

HYDROPOWER 2.83%
Uses: electricity

WIND 2.40%
Uses: electricity

SOLAR 0.79%
Uses: heating, electricity

GEOTHERMAL 0.21%
Uses: heating, electricity

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

Nifty Natural Gas

TEACHER INSTRUCTIONS

Background

When students think of energy, they most often are thinking of electricity; however, a significant proportion of our total energy is supplied by natural gas, and as more natural gas is unlocked from shale deposits, that proportion will continue to increase. The purpose of this activity is to help students understand how natural gas is used in the energy industry and how we can use it as consumers. Students will also identify the energy transformations of natural gas from formation to end use.

Objective

- Students will be able to explain the energy transformations or flows involved with natural gas, from production to use.

Materials

- Art supplies or prop cards

Time

- 40-60 minutes

✔Procedure

1. Make a copy of *A Nifty Natural Gas Story Pantomime* for each student.
2. Provide art supplies for students to assemble their props, or gather the suggested items or reasonable substitutes as shown on the handout. A sample set of prop cards is included in your kit.
3. Prepare copies of the masters to project.
4. Review the forms of energy with the class. Project the master to add to class discussion.
5. Explain and/or review energy transformations using the master as a visual. Discuss the forms of energy in each part of the transformation.
6. Explain to the class that energy transformations allow us to use our energy sources for electricity, to power vehicles, and to heat/cool our homes.
7. Assign students to a specific role on the pantomime sheet.
8. Discuss how natural gas is produced, processed, transported, and used.
9. Have each student assemble his/her props, or provide each student with a suggested prop.
10. Review or introduce any new vocabulary as needed. Project the story. Act out the story from beginning to end. Extra students may help read the story aloud.
11. Substitute in different students or props as necessary.
12. Ask students to write an essay explaining the energy flow involved to produce electricity from natural gas.

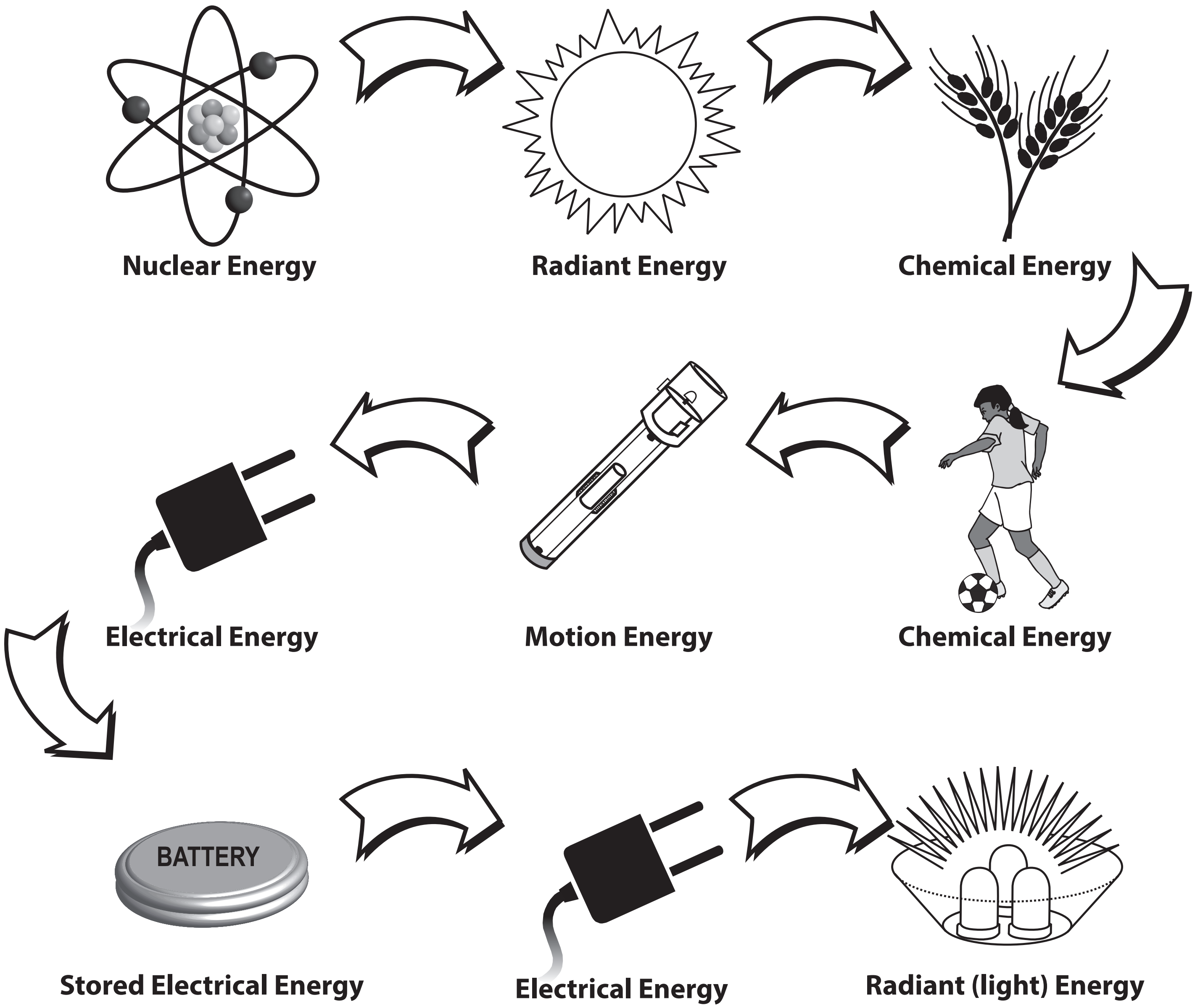
Extension

- Have students substitute different energy sources into the energy flow, creating a new story, props, and outcome for each.

Energy Transformations

HAND GENERATED FLASHLIGHT

TEACHER MASTER



A Nifty Natural Gas Pantomime

Students will demonstrate the flow of energy to heat homes using props. Depending on the audience, signs with the different forms of energy can be used by the students to identify the energy transformations. This activity with different props can also be used to demonstrate other energy flows, like coal to electricity, biodiesel, ethanol, etc.

Sun – Nuclear Energy		Nuclear fusion in the sun produces vast amounts of energy.
	Prop & Action	Yellow ball
Radiant Energy		The sun's radiant energy is transferred to Earth by electromagnetic waves.
	Prop & Action	Long pieces of yellow ribbon; students wave the ribbon in the air
Chemical Energy		Radiant energy is absorbed by tiny green plants in the ocean and changed to chemical energy by photosynthesis.
	Prop & Action	Artificial plants or paper "seaweed"; students move up from the floor and "float" around
Storing Chemical Energy		Tiny animals in the ocean ate the plants and stored their chemical energy.
	Prop & Action	Sock puppets; sock puppet animals "eat" the plants
Natural Gas Formation		The tiny plants and animals died. Over millions and millions of years, they were covered by many layers of dirt and rock. The high pressure changed them into natural gas.
	Prop & Action	Large pieces of brown and black paper and cardboard (several different types and colors); plants and sock puppets are dropped to the floor and the layers of "sediment" are stacked on top of them.
Natural Gas Exploration and Production		A well is drilled into the ground to locate natural gas. The gas is brought out of the ground through the well.
	Prop & Action	Long, hollow cardboard tube, or a rolled-up piece of paper; hold the tube vertically with hands over the head, and push the tube downward to the floor. Use one hand to wave fingers over the top of the tube in a wiggling motion to indicate the flowing of natural gas.
Separation, Dehydration, and Compression		The raw natural gas from the ground is separated from impurities and water, and compressed to high pressure.
	Prop & Action	Plastic mixing bowl or bottle; student uses hand to simulate separating the gas from the impurities, and another student pushes both hands together in a compressing motion to load the "gas" into the "pipeline"
Processing		At the processing facility, a chemical called mercaptan is added to the gas to make it smell like rotten eggs.
	Prop & Action	One long piece of garden hose or other tubing, and one eye dropper; one student holds the tubing from the separator to the processing facility, and one student holds the end of the tubing in one hand and the dropper in the other. The dropper is used to simulate adding mercaptan to the gas
Distribution		The processed gas is transported by pipeline to businesses and homes.
	Prop & Action	Another long piece of garden hose or other tubing; student holds it between the processing facility and the end use location
End Use – Thermal Energy		In our homes, natural gas is burned to heat water and keep us warm in cold weather.
	Prop & Action	Small lighter; student (or adult) lights the lighter and other students hold their hands up to the flame to indicate they are being warmed by the fire.

A Nifty Natural Gas Story

Hundreds of millions of years ago, long before the dinosaurs roamed, most of the Earth was covered with vast, deep oceans. Tiny plants and animals lived in these oceans.

The sun's radiant energy was changed into chemical energy by the plants, which helped them grow. The animals ate the plants, and both the plants and animals stored the sun's energy in their bodies as chemical energy.

When they died, they sank to the ocean floor. As more and more plants and animals died, they sank and made a thick layer deep under the water.

Over time, more layers of rock, sand, and other dead plants and animals built up. As the layers built up, they pressed down hard on the layers beneath.

As the layers of rock built up, the deepest layers got hot. They were under very high pressure with all that weight on top of them.

Eventually, those dead plants and animals under all those layers of rock changed. Now they weren't plants or animals. Now they were special molecules called hydrocarbons, with only hydrogen and carbon in them.

The hydrocarbons became trapped in tiny holes in the rocks. Then they waited.

And waited.

And waited some more - millions of years!

Many years ago, people began to notice bubbles coming out of the ground beneath ponds and lakes. They discovered that the bubbles were flammable – they could fuel a fire. The people used bamboo and other hollow plant stems to carry the bubbling gas to their villages.

Today, geologists search for the layers of rock that contain the hydrocarbons. They use a lot of special equipment and computers to find natural gas. Then they drill an exploratory well. Six times out of ten, they are successful!

The natural gas is pumped out of the ground at the well. It is separated from any liquids and water that might be mixed with it, and compressed into high pressure gas pipelines. The gas moves to the processing facility.

Natural gas has no odor, so at the final processing facility, a chemical called mercaptan is added. Mercaptan smells like rotten eggs! That is what you smell if natural gas is leaking.

After processing, electric power plants might use natural gas to generate electricity for homes, businesses, and schools. Most homes also use natural gas to heat water and stay warm in cold weather.

Natural gas produces less air pollution than other fossil fuels when it is burned. Because it is flammable, it is important to use it safely. If you ever smell natural gas, leave the area immediately and then call 911.

All of those tiny plants and animals millions of years ago are now providing us a clean energy source that is easy to use. Do you think they would be happy to know so many people rely on them?

Understanding an Electricity Bill

TEACHER INSTRUCTIONS

Background

This quick activity aims to help students become familiar with how utilities are measured and billed. Students will analyze the bill like it is a chart or graph, looking for important items that may relate to how much energy they use in a billing cycle.

Objective

- Students will be able to read and interpret the information on an electricity bill.

Materials

- Calculators (optional)
- Additional examples of utility bills (optional)

Time

- 15-20 minutes

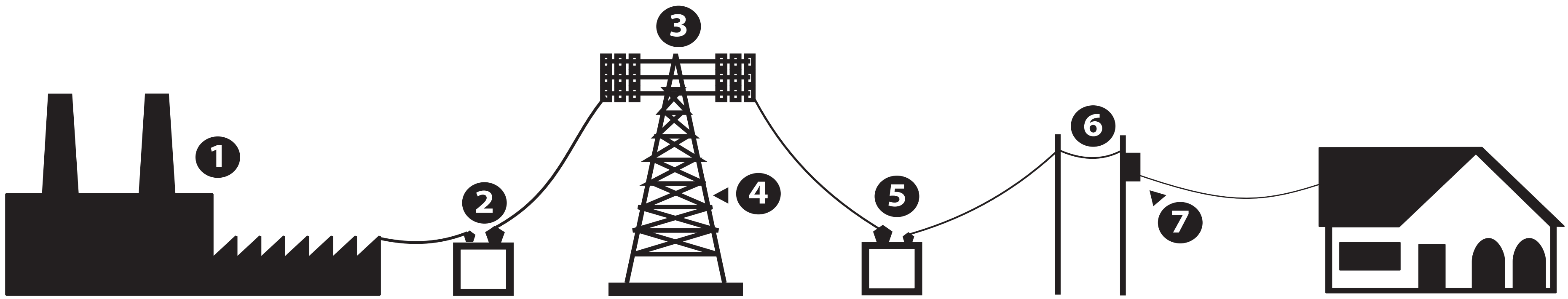
✔ Procedure

1. Prepare a copy of the master to project.
2. Make copies of the sample bill and explanation for each student or make a digital copy for projection and discussion.
3. Explain how electricity is transported. Direct students to the *Secondary Energy Infobook* section on electricity and/or project the master and explain what is happening at each step. Remind students that power is generated to meet the customer's needs. It is then transported to them and they are billed based on how much they actually use.
4. Explain the sample school electric utility bill. If available, distribute or project a copy of your school's actual utility bill for comparison.

Transporting Electricity

TEACHER MASTER

Explain what each of the components numbered below does to get electricity from the generator to the consumer.



Sample School Electric Bill

Nov 27, 2018 1

Customer Bill
ABC Elementary School
Anytown, USA

Your Electric Company

Billing and Payment Summary

Account # 000-1234 2 **Due Date: Jan 02, 2018** 3
Total Amount Due: $ 7,462.61 4

To avoid a Late Payment Charge of 1.5% please pay by Jan 02, 2019.

Previous Amount Due:	$ 8,152.93
Payments as of Nov 27:	$ 8,152.93

Meter and Usage **Usage History**

Current Billing Days: 34

Billable Usage

Schedule 130	*10/23 - 11/26*	12
Total kWh	12192	
Dist Demand	61.0	10
Demand	57.0	
Schedule 130	*10/23 - 11/26*	
Total kWh	69888	
Dist Demand	272.0	
Demand	259.0	10

Measured Usage 5

Meter: 000-1234	*0/23 - 11/26*	
Current Reading	4147	
Previous Reading	4020	
Total kWh	12192	6
Current Reading	.60	
Demand	57.60	11
Multiplier: 96		
Meter: 111-4567	*0/23 - 11/26*	
Current Reading	51746	
Previous Reading	51382	
Total kWh	69888	6
Current Reading	1.35	
Demand	259.20	11
Multiplier: 192		

Explanation of Bill Detail

Your Electric Company		**1-800-123-4567**	
Previous Balance	**8,152.93**		
Payment Received	**8,152.93**		
BALANCE FORWARD		**0**	
Non-Residential Service (Schedule 130)	***10/23 - 11/26***		
Distribution Service			
Basic Customer Charge		**86.52**	
Distribution Demand		**206.29**	
13 **Electricity Supply Service (ESS)**			
ESS Adjustment Charge		**83.93 CR**	
Electricity Supply kWh		**214.94**	
ESS Demand Charge		**558.85**	7
Fuel Charge		**353.81**	
Sales and Use Surcharge		**2.68**	8
Non-Residential Service (Schedule 130)	***10/23 - 11/26***		
14 **Distribution Service**			
Basic Customer Charge		**86.52**	
Distribution Demand		**919.87**	
Electricity Supply Service (ESS)			
ESS Adjustment Charge		**374.243 CR**	
Electricity Supply kWh		**909.41**	
ESS Demand Charge		**2,539.36**	7
Fuel Charge		**2,058.15**	
Sales and Use Surcharge		**13.38**	8
TOTAL CURRENT CHARGES		**7,463.61**	9
TOTAL ACCOUNT BALANCE		**7,463.61**	4

For service emergencies and power outages, call 1-800-123-4567.

Mailed on Nov 28, 2018

Please detach and return this payment coupon with your check made payable to Your Electric Company.

Payment Coupon

Bill Date Nov 27, 2018 1

Please Pay by 01/02/2019 3
$ 7,463.54 4

Amount Enclosed

Account # 000-1234 2

Send payment to:

ABC Elementary School
123 Main Street
Anytown, USA 98765

Your Electric Company
PO BOX 123456
Anytown, USA 98765

01166005000 000000009368 6868686 0001234 11272007

Sample School Electric Bill

EXPLANATION AND DISCUSSION

Explanation

1. Bill mailing date
2. Customer account number
3. Payment due date
4. Total amount due
5. Meter readings by date in kilowatt-hours (note that there are two meters on this bill)
6. Actual kilowatt-hours consumed
7. Cost of the electricity consumed
8. Sales and use surcharge
9. Total current charges
10. Demand. This is a measurement of the rate at which electricity is used. The monthly demand is based on the 15 minutes during a billing period with the highest average kilowatt use. Demand charges are designed to collect some of the generation and transmission-related costs necessary to serve a particular group or class of customers.
11. Actual demand for the meter
12. Schedule 130. A rate class that determines how much is paid per kWh of usage and kW demand
13. Electricity supply service. Customers are billed for the electricity supply and the delivery of the electricity. The supply charge reflects the cost of generating the electricity at the power plant.
14. Distribution service. The delivery charge reflects the cost of delivering the electricity from the power plant to the customer.

Discussion

The appearance of utility bills will be different from one utility to the next, but they typically contain the same information. The rate that a school or other commercial building pays for electricity is determined by measuring two items: the electrical energy usage, in kilowatt-hours, and the electrical energy demand, measured in kilowatts.

The demand is the maximum amount of power that the building needed within a time frame. The higher the total amount of kilowatts being used at any given time by a building, the higher this charge is. Demand can be reduced by rescheduling when high energy devices are running, or scheduling them such that their use is spread out evenly throughout the day. For example, vacuum cleaners or other appliances with high energy motors can be run after school is over, when other devices are turned off. Professional energy managers can make recommendations about this scheduling, or some other changes that can help a building's occupants reduce the demand portion of their electric bill.

The energy use portion is how much electrical energy, in kilowatt-hours, is used in total during the billing period. The more devices turned on and running, the higher the energy use charge is. This portion of the utility bill can be reduced by turning off unnecessary items or installing more efficient equipment. For example, computer monitors in a school computer lab can be turned off at the end of the school day, or ENERGY STAR®appliances can be used in place of older, less efficient models.

Ask your teacher, principal, or building manager for a copy of the school's electric bill, and identify as many of the above items on it as you can. If you have more than one building in your school district, see if you can get bills for other buildings to compare. Talk about ways you as students can help reduce both the demand as well as the energy use portions of your school's utility costs.

Baseload Balance

TEACHER INSTRUCTIONS

Background

Most students don't give electric power much thought until the power goes out. Electricity plays a giant role in our day-to-day lives. This activity demonstrates how electricity supply is transmitted on the electric grid to consumers. It also encourages students to explore the differences between baseload and peak demand power, and how power companies maintain supply to ensure customers have power as they need it.

Students will be introduced to the economics of electricity generation and supply and be able to see first-hand the financial challenges utilities must overcome to be able to provide the power demanded by consumers at the lowest cost. Figures, costs, and sources used in this activity are roughly based on current industry uses and costs, but have been made into round figures for ease of implementation. Students will first play a game with a game board and pieces. This activity is then followed by a simulation where students assume roles as "loads" or "generation". You may decide to change the order of the activity or eliminate a part of the activity to meet the needs of your students.

✪Objectives

- Students will be able to differentiate between baseload and peak demand power.
- Students will be able to explain the purpose of using a variety of sources to meet base and peak load power demand.
- Students will be able to describe the challenges of using certain sources to meet base and peak load power demand.

Materials

- Scissors and tape for each student or small group
- Hang tag holders
- Rope
- Colored paper
- Individual marker boards with erasers and markers

Time

- 30-45 minutes

Vocabulary *SPECIFIC TO THE GAME*

- Baseload
- Generation
- Load
- Transmission
- Peak demand
- Megawatt

Preparation

- Familiarize yourself with the activity instructions and student background information before facilitating the game with students. Decide which version of the game you will use, if only using one part of the activity.
- Make a copy of the *Cheat Sheet* for yourself to have handy when going over the game and during game play with students.
- Copy the hang tags and cut them apart. Attach the tags to three colors of paper or color the cards so that the generation, the transmission, and the load cards are each a different color. Laminate, if desired, for future use.
- Make a copy of the *Incident Cards*. Cut the cards apart and fold on the dotted line. Laminate, if desired, for future use.
- Make a copy of the *Game Board* and *Game Pieces* for each student or small group of students. Laminate the board for future use, if desired.
- Make a copy of the background information for each student.
- Prepare a copy of the *Generation Parameters* master to project for discussion.

CONTINUED ON NEXT PAGE

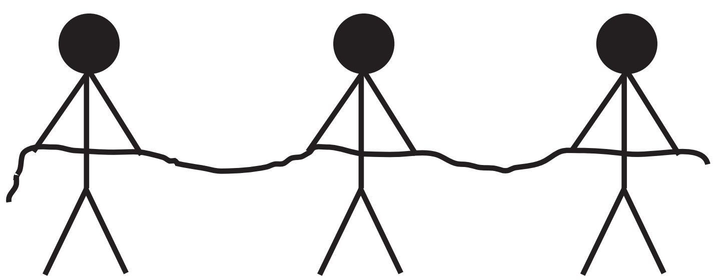
- Designate an area of the room to be the Regional Transmission Organization (RTO). On one side of this area will be the generation group, and the other side will be the load group. Each side should have its own marker board, eraser, and marker.
- Decide if a student will be the RTO leader, or if the teacher or another adult will assume this role. Having a student assume this position will create a more student-centered activity. Depending on the ability of the students in your group, using a student for this role may require more monitoring and time than if a teacher is in charge.
- Instruct all students to read the *Baseload Balance Student Information* the night before playing as a homework assignment.

Discussion Questions

1. What is the peak demand time? When is the least amount of power needed?
2. What was the average cost per megawatt-hour during daylight hours?
3. What was the average cost per megawatt-hour over the entire 24-hour period?
4. Everyone needed to use most of the same baseload generation. However, there were options for some of the generation and options to meet peak demand. Why did you choose your particular sources?
5. How would knowledge of historical data and weather forecasts help in making decisions about which sources to use?

✔ Procedure

1. Assign each student a role that corresponds to each hang tag. If your class does not have enough students for each tag, the baseload tags can be tied to the rope because they are always in operation. A list of the roles can also be found on page 23. The Transmission roles are best assigned to students who are able to think quickly on their feet and have good math skills.
2. Allow time for students to research their roles and re-read the background information. Students should be familiar with the vocabulary and information on their hang tag, including generating capacity, energy source, and power demand. Depending on the level of your students, you may choose to have them skip the section of the background information that discusses regional transmission organizations and independent system operators.
3. Project the *Generation Parameters* master for the class. Discuss the relative cost for each source and plant type as well as the suggested reasoning for the cost of each.
4. The activity begins with the transmission organization students gathering in the Regional Transmission Organization area, each holding onto the rope or string. The student on each end should have plenty of available rope or string onto which the generation students and load students will attach. These students will decide which peak load providers (plants) will be brought online to meet increasing demand as the activity progresses. They will also help the RTO by tabulating the current load or generation on their side of the line. They will display it on their marker board and update it as the activity progresses.



5. In the generation group, the residential baseload, commercial baseload, heavy industry baseload, and all baseload generation students all hold ends of the rope on their respective sides. They will be holding onto the rope during the entire activity because as baseload power or generation, they are providing or using power all the time.
6. At the appropriate time indicated on each hang tag, each load student will join the grid, increasing the load demand. Residential demand comes up (online) at about 7:00 a.m. as people begin to wake. Demand continues to rise as more residential, commercial, and industry come on the grid, pulling electricity or creating another load.
7. The transmission organization students will need to balance the generation against the load while using the cheapest sources available for the longest amount of time. They will choose the best generation students to come online to balance the load students. The RTO can monitor or assist the transmission group by announcing the time and reminding each load or role when to join on.

CONTINUED ON NEXT PAGE

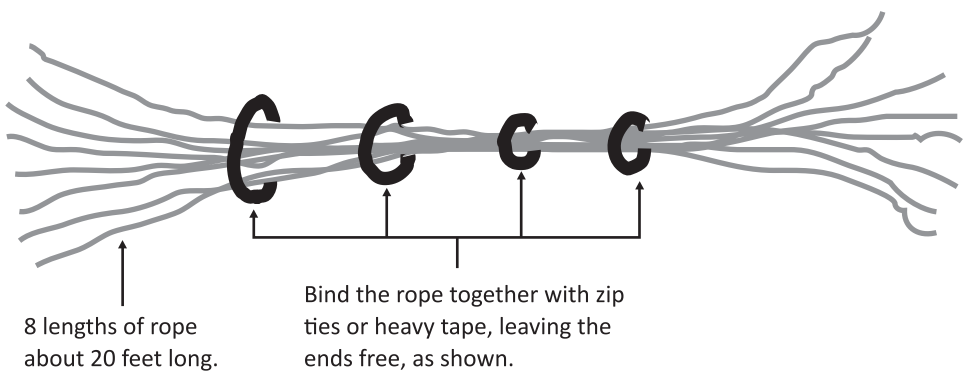
8. If time allows after going through the activity once (one complete 24-hour period), reset the activity to early morning and run through a second time. Choose one or more of the three *Incident Cards* to introduce to the balance. You may also wish to reassign students to different roles, depending on their command of the activity in the first round.

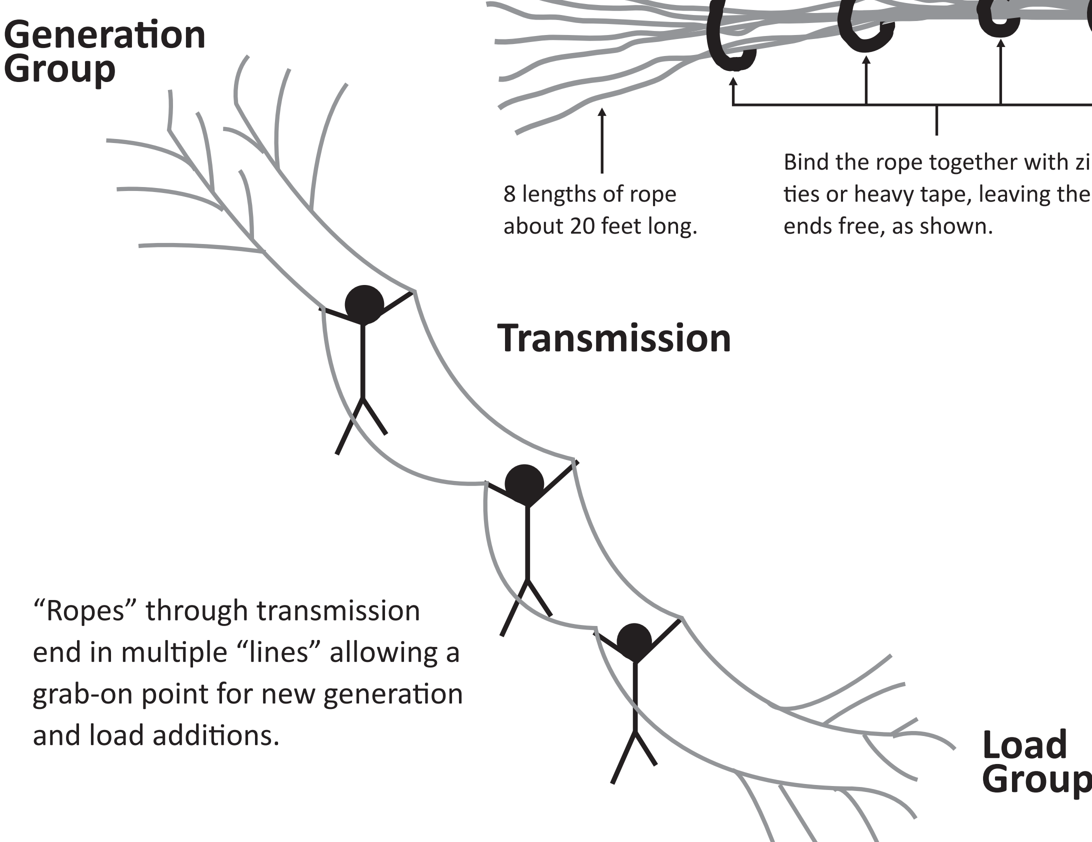
Student Roles for Ending Activity

- Baseload demand – three students
- Peak load demand – eight students
- Baseload generation – six students
- Peak load generation – seven students
- Transmission – three to five students
- RTO – one to three students or a teacher

Extensions

- RTOs usually require generation to be 15 percent above demand. Play the game again accounting for the prescribed demand plus the additional 15 percent, (you may need to add/duplicate a few generation cards). Hold a class discussion about why this extra generation is required.
- Have students brainstorm other scenarios that could fit onto an incident card, and test out those scenarios.
- Students could write a persuasive letter in support of a certain type of power plant after playing the game. Letters should include information gleaned about the plant's advantages and disadvantages, as well as the feasibility for use in generation of electricity at the lowest cost.
- The transmission of power on the grid during this game could also be illustrated with power "lines" made of rope. These ropes would represent the low-voltage and high-voltage lines that carry electricity. Make two bundles of rope, 8 pieces in each. Fasten the bundles of rope together with zip ties or duct tape, leaving several feet of loose rope on each end (see diagram on next page). As generation and loads are added, each student can hold onto a different end of the rope to more accurately demonstrate the distribution of power (see diagram on next page).





Baseload Balance

STUDENT INFORMATION

Introduction

Four kinds of power plants produce most of the electricity in the United States: coal, natural gas, nuclear, and hydropower. Natural gas plants generate a little more than 32 percent of the electricity we use. Coal plants generate about 30 percent of the electricity we use. There are also wind, geothermal, waste-to-energy, solar, and petroleum power plants, which together generate about ten percent of the electricity produced in the United States. All of this electricity is transmitted to customers, or loads, via the network of transmission lines we call the grid.

Fossil Fuel Power Plants

Fossil fuel plants burn coal, natural gas, or petroleum to produce electricity. These energy sources are called fossil fuels because they were formed from the remains of ancient sea plants and animals. Most of our electricity comes from fossil fuel plants in the form of coal and natural gas.

Power plants burn the fossil fuels and use the heat to boil water into steam. The steam is channeled through a pipe at high pressure to spin a turbine generator to make electricity. Fossil fuel power plants can produce emissions that pollute the air and contribute to global climate change. The amount and type of emissions can vary based upon the type of fossil fuel and technologies used within the plant.

Fossil fuel plants are sometimes called thermal power plants because they use heat energy to make electricity. (*Therme* is the Greek word for heat.) Coal is used by many power plants because it is inexpensive and abundant in the United States.

There are many other uses for petroleum and natural gas, but the main use of coal is to produce electricity. Over 90 percent of the coal mined in the United States is sent to power plants to make electricity.

Nuclear Power Plants

Nuclear power plants are called thermal power plants, too. They produce electricity in much the same way as fossil fuel plants, except that the fuel they use is uranium, which isn't burned. Uranium is a mineral found in rocks underground. Uranium atoms are split to make smaller atoms in a process called fission that produces enormous amounts of thermal energy. The thermal energy is used to turn water into steam, which drives a turbine generator.

Nuclear power plants do not produce carbon dioxide emissions, but their waste is radioactive. Nuclear waste must be stored carefully to prevent contamination of people and the environment.

Hydropower Plants

Hydropower plants use the energy in moving water to generate electricity. Fast-moving water is used to spin the blades of a turbine generator. Hydropower is called a renewable energy source because it is renewed by rainfall.

Waste-to-Energy (Biomass) Plants

Waste-to-energy facilities are thermal power plants that burn garbage and other waste to produce electricity. The heat from the incinerator creates steam in a boiler that drives a turbine generator. Facilities monitor and scrub their emissions and recycle ash to be environmentally friendly.

Cost of Electricity

How much does it cost to make electricity? Cost depends on several factors.

- **Fuel Cost**

The major cost of generating electricity is the cost of the fuel. Many energy sources can be used. There are also other factors that tie into the cost of a fuel, including production cost, manufacturing or refining costs, cost of transporting the fuel, and more. Hydropower is the cheapest energy source while solar cells are typically the most expensive way to generate power.

- **Building Cost**

Another factor is the cost of building the power plant itself. A plant may be very expensive to build, but the low cost of the fuel can make the electricity economical to produce. Nuclear power plants, for example, are very expensive to build, but their fuel—uranium—is inexpensive. Coal-fired plants, on the other hand, are cheaper to build, but the fuel (coal) is more expensive than uranium.

- **Efficiency**

When figuring cost, you must also consider a plant's efficiency. Efficiency is the amount of useful energy you get out of a system. A totally efficient machine would change all the energy put in it into useful work. Changing one form of energy into another always involves a loss of usable energy. Efficiency of a power plant does not take into account the energy lost in production or transportation, only the energy lost in the generation of electricity.

Combined Cycle vs. Simple Cycle

In the most simple of thermal power plants, a fuel is burned, and water is heated to form high-pressure steam. That steam is used to turn a single turbine. Thermal power plants running in this manner are about 35 percent efficient, meaning 35 percent of the energy in the fuel is actually transformed into useable electrical energy. The other 65 percent is "lost" to the surrounding environment as thermal energy.

Combined cycle power plants add a second turbine in the cycle, increasing the efficiency of the power plant to as much as 60 percent. By doing this, some of the energy that was being wasted to the environment is now being used to generate useful electricity.

In general, today's power plants use three units of fuel to produce one unit of electricity. Most of the lost energy is waste heat. You can see this waste heat in the great clouds of steam pouring out of giant cooling towers on some power plants. For example, a typical coal plant burns about 4,500 tons of coal each day. The chemical energy in about two-thirds of the coal (3,000 tons) is lost as it is converted first to thermal energy, and then to motion energy, and finally into electrical energy. This degree of efficiency is mirrored in most types of power plants. Thermal power plants typically have between a 30-40% efficiency rating. Wind is usually around the same range, with solar often falling below the 30% mark. The most efficient plant is a hydropower plant, which can operate with an efficiency of up to 95%.

Meeting Demand

We don't use electricity at the same rate at all times during the day. There is a certain amount of power that we need all the time called baseload power. It is the minimum amount of electricity that is needed 24 hours a day, 7 days a week, and is provided by a power company.

However, during the day at different times, and depending on the weather, the amount of power that we use increases by different amounts. We use more power during the week than on the weekends because it is needed for offices and schools. We use more electricity during the summer than the winter because we need to keep our buildings cool. An increase in demand during specific times of the day or year is called peak demand. This peak demand represents the additional power above baseload power that a power company must be able to produce when needed.

Power plants can be used to meet baseload power or peak demand, or both. Some power plants require a lot of time to be brought online – operating and producing power at full capacity. Others can be brought online and shut down fairly quickly.

Coal and nuclear power plants are slow, requiring 24 hours or more to reach full generating capacity, so they are used for baseload power generation. Natural gas is increasing in use for baseload generation because it is widely available, low in cost, and a clean-burning fuel.

Wind, hydropower, and solar can all be used to meet baseload capacity when the energy source is available. Wind is often best at night and drops down in its production just as the sun is rising. Solar power is not available at night, and is greatly diminished on cloudy days. Hydropower can produce electricity as long as there is enough water flow, which can be decreased in times of drought.

To meet peak demand, energy sources other than coal and uranium must be used. Natural gas is a good nonrenewable source to meet peak demand because it requires only 30 minutes to go from total shutdown to full capacity. Many hydropower stations have additional capacity using pumped storage. Some electricity is used to pump water into a storage tank or reservoir, where it can be released at a later time to generate additional electricity as needed. Pumped storage hydropower can be brought fully online in as little as five minutes.

Some power plants, because of regulations or agreements with utilities, suppliers, etc., do not run at full capacity or year-round. These power plants may produce as little as 50 percent of maximum generating capacity, but can increase their output if demand rises, supply from another source is suddenly reduced, or an emergency occurs.

Making Decisions

Someone needs to decide when, which, and how many additional generating locations need to be brought online when demand for electricity increases. This is the job of the Regional Transmission Organization (RTO) or Independent System Organization (ISO). ISOs and RTOs work together with generation facilities and transmission systems across many locations, matching generation to the load immediately so that supply and demand for electricity are balanced. The grid operators predict load and schedule generation to make sure that enough generation and back-up power are available in case demand rises or a power plant or power line is lost.

Transmission Organizations

Besides making decisions about generation, RTOs and ISOs also manage markets for wholesale electricity. Participants can buy and sell electricity from a day early to immediately as needed. These markets give electricity suppliers more options for meeting consumer needs for power at the lowest possible cost.

Ten RTOs operate bulk electric power systems across much of North America. More than half of the electricity produced is managed by RTOs, with the rest under the jurisdiction of individual utilities or utility holding companies.

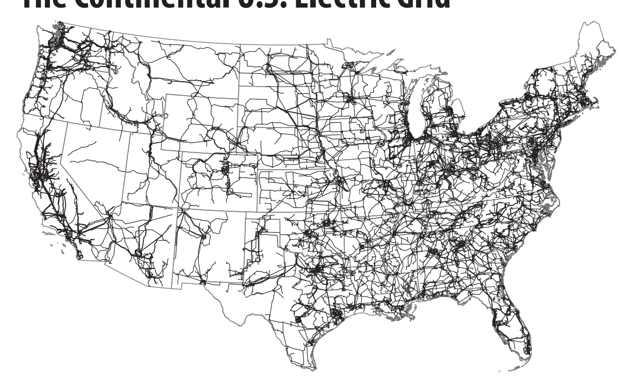
In the 1990s, the Federal Energy Regulatory Commission introduced a policy designed to increase competitive generation by requiring open access to transmission. Northeastern RTOs developed out of coordinated utility operations already in place. RTOs in other locations grew to meet new policies providing for open transmission access.

Members of RTOs include the following:

- Independent power generators
- Transmission companies
- Load-serving entities
- Integrated utilities that combine generation, transmission, and distribution functions
- Other entities such as power marketers and energy traders

RTOs monitor power supply, demand, and other factors such as weather and historical data. This information is input into complex software that optimizes for the best combination of generation and load. They then post large amounts of price data for thousands of locations on the system at time intervals as short as five minutes.

The Continental U.S. Electric Grid



Data: Energy Information Administration

Baseload Balance

GENERATION PARAMETERS

Fuel	Capacity	Type of Generation	Time Required for Full Capacity	Cost per Megawatt-hour
Coal	40 MW	Baseload	24 hours	$60
Nuclear (Uranium)	50 MW	Baseload	24 hours +	$30
Natural Gas Combined Cycle (NGCC)	20 MW	Baseload	30 minutes +	$30
Wind	5 MW	Baseload	Immediate when wind speed is sufficient; primarily at night	$40
Solar	5 MW	Baseload	Immediate when solar intensity is sufficient; only during day	$180
Hydropower	5 MW	Baseload	5 minutes	$30
Waste-to-Energy (Biomass)	10 MW	Baseload	5 minutes	$60
Hyrdropower & Pumped Storage	5-10 MW each site	Peak load	5 minutes	$50-60
Natural Gas Simple Cycle (NGSC)	5-10 MW each site	Peak load	5 minutes	$90-$600

Baseload Balance Hang Tag Template

Generation
Baseload
Nuclear
50 MW
$30 / MW-hour

Generation
Baseload
Coal
40 MW
$60 / MW-hour

Generation
Baseload
Natural Gas CC
20 MW
$30 / MW-hour

Generation
Baseload
Hydro
5 MW
$30 / MW-hour

Generation
Baseload
Wind
5 MW
$40 / MW-hour

Generation
Baseload
Solar
5 MW
$180 / MW-hour

Generation

Baseload

Waste-to-Energy (Biomass)

10 MW

$60 / MW-hour

Generation

Peak Load

Natural Gas SC

10 MW

$90 / MW-hour

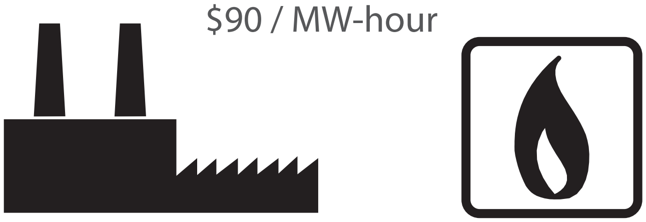
Generation

Peak Load

Natural Gas SC

5 MW

$90 / MW-hour



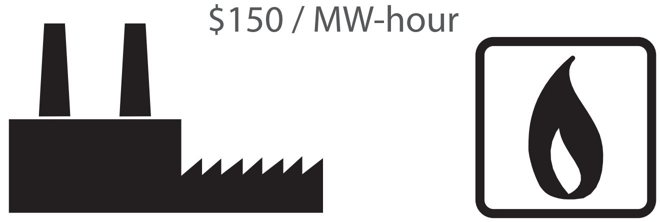
Generation

Peak Load

Natural Gas SC

10 MW

$150 / MW-hour



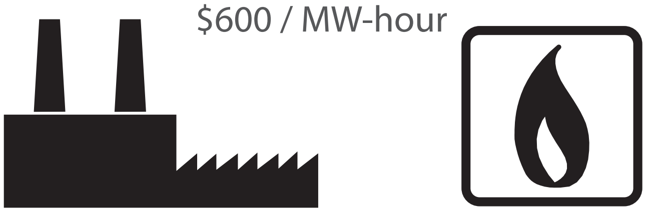
Generation

Peak Load

Natural Gas SC

5 MW

$600 / MW-hour



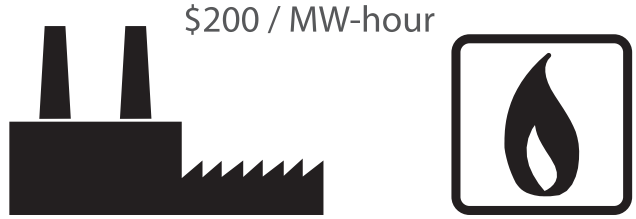
Generation

Peak Load

Natural Gas SC

5 MW

$200 / MW-hour



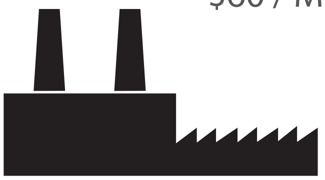
Generation

Peak Load

Hydro (pumped storage)

10 MW

$60 / MW-hour



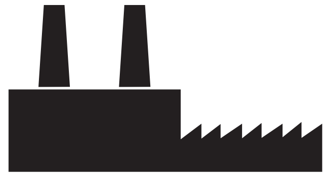
Generation

Peak Load

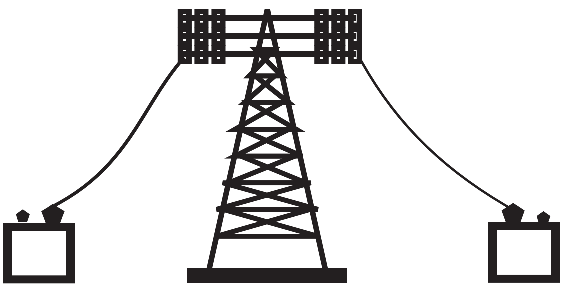
Hydro

5 MW

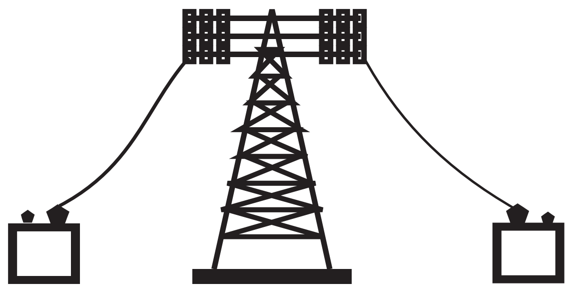
$50 / MW-hour



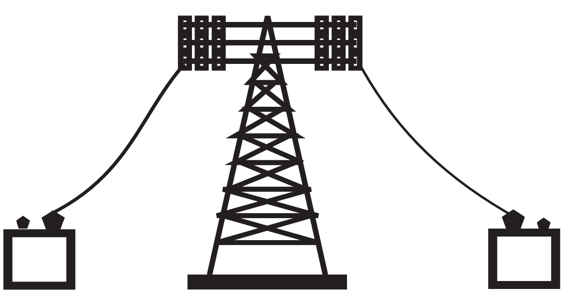
Transmission



Transmission



Transmission



Load

Commercial

20 MW

Baseload

Load
Heavy Industry
60 MW
Baseload

Load
Residential
35 MW
Baseload

Load
Residential
5 MW
7:00 am – 12:00 am

Load
Residential
10 MW
8:00 am –11:00 pm

Load
Commercial
5 MW
9:00 am – 9:00 pm

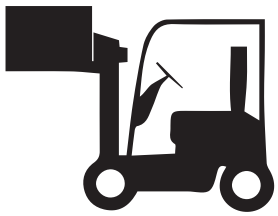
Load
Commercial
5 MW
5:00 pm – 11:00 pm

Load

Light Industry

5 MW

8:00 am – 9:00 pm



Load

Light Industry

5 MW

9:00 am – 8:00 pm

Load

Residential

10 MW

3:00 pm – 1:00 am

Load

Light Industry

5 MW

10:00 am – 8:00 pm

Regional Transmission Organization

Baseload Balance

INCIDENT CARDS

INCIDENT	At 3:00 p.m. heavy cloud cover moves over the region taking out your solar generation. If you can't provide enough power to meet the load, RTO must choose who will lose power and be in blackout. How could a blackout have been avoided?
INCIDENT	At 2:00 p.m. a baseload coal unit trips and you lose 10 MWs of baseload coal. If you can't provide enough power to meet the load, RTO must choose who will lose power and be in blackout. How could a blackout have been avoided?
INCIDENT	At 5:00 p.m. a derecho hits, damaging power lines. You lose half your commercial and residential load. You must balance your load with generation. Could this have been predicted?

Baseload Balance

CHEAT SHEET

	HANG TAGS
3	Baseload Demand
8	Peak Load Demand
6	Baseload Generation
7	Peak Load Generation
3 - 5	Transmission
1 - 3	RTO (Regional Transmission Organization)
28 - 32	**TOTAL**

LOADS

	BASELOAD DEMAND
Residential	35 MW
Heavy Industry	60 MW
Commercial	20 MW
TOTAL	**115 MW**

	PEAK LOAD/DEMAND
7:00 a.m. - 12:00 a.m.	5 MW Residential
8:00 a.m. - 9:00 p.m.	5 MW Light Industry
8:00 a.m. - 11:00 p.m.	10 MW Residential
9:00 a.m. - 8:00 p.m.	5 MW Light Industry
9:00 a.m. - 9:00 p.m.	10 MW Commercial
10:00 a.m. - 8:00 p.m.	5 MW Light Industry
3:00 p.m. - 1:00 a.m.	10 MW Residential
5:00 p.m. - 11:00 p.m.	5 MW Commercial

GENERATORS

AVAILABLE GENERATION

BASELOAD GENERATION		
Coal Baseload	40 MW	$60/MW
Natural Gas Baseload	20 MW	$30/MW
Nuclear Baseload	50 MW	$30/MW
Hydropower Baseload	5 MW	$30/MW
Solar Baseload	5 MW	$180/MW
Wind Baseload	5 MW	$40/MW
Waste-to-Energy Baseload	10 MW	$60/MW

PEAK GENERATION			
Hydropower Pumped	10 MW	$60/MW	5 MIN
Natural Gas Simple Cycle	10 MW	$90/MW	30 MIN
Natural Gas Simple Cycle	5 MW	$90/MW	30 MIN
Natural Gas Simple Cycle	10 MW	$150/MW	30 MIN
Natural Gas Simple Cycle	5 MW	$200/MW	30 MIN
Natural Gas Simple Cycle	5 MW	$600/MW	30 MIN
Hydropwer Peak	5 MW	$50/MW	5 MIN

	TOTAL ONLINE
TOTAL BASELOAD DEMAND	115 MW

PEAK LOAD COMING ONLINE		TOTAL ONLINE
7:00 a.m. - 12:00 a.m.	5 MW	120 MW
8:00 a.m. - 9:00 p.m.	5 MW	125 MW
8:00 a.m. - 11:00 p.m.	10 MW	135 MW
9:00 a.m. - 8:00 p.m.	5 MW	140 MW
9:00 a.m. - 9:00 p.m.	10 MW	150 MW
10:00 a.m. - 8:00 p.m.	5 MW	155 MW
3:00 p.m. - 1:00 a.m.	10 MW	165 MW
5:00 p.m. - 11:00 p.m.	5 MW	170 MW

PEAK LOAD GOING OFFLINE		TOTAL ONLINE
8:00 p.m.	Lose 10 MW (2 Tags)	160 MW
9:00 p.m.	Lose 15 MW (2 Tags)	145 MW
11:00 p.m.	Lose 15 MW (2 Tags)	130 MW
12:00 a.m.	Lose 5 MW (1 Tags)	125 MW
1:00 a.m.	Lose 10 MW (1 Tags)	115 MW

AC/DC Party

TEACHER INSTRUCTIONS

Background

There are two main types of current in which electricity flows. Electrons can flow as direct current, (DC), where a continuous stream of charges move in one direction from one point to another. Electrons can also flow as alternating current, (AC), as a stream of charges that reverses its direction. Direct current is easily demonstrated using a battery. When you connect a wire to the positive and negative ends of the battery, electrons flow and produce a current traveling in one direction. DC power is generated or used in several systems – anything battery powered, solar panels, small wind turbines in your classroom, even hydrogen fuel cells. Alternating current is being used all over your school and home – lights, appliances, and computers all use it. In alternating current, charges move in one direction for a short time and then reverse their direction. This happens regularly and frequently, or at a certain frequency that we measure in Hertz (Hz). AC power in the U.S. switches direction at a frequency of 60 times per second, or 60 Hz, and is generated from generators at a power plant. If you need to take AC power to DC in order to operate a device, or vice versa, you'll need a device called an inverter switch over the type of current.

AC has been used all over the world for many years because it allows for voltage to be increased or decreased easily (stepped up or down), and when the voltage is higher, the transmission of electrons from point to point is more efficient. DC can not be altered easily, and power needs to come directly from its source or too much voltage is lost – maybe only a mile! High voltage DC is in the works in many places, but most power plants and transmission grids are set up to generate and operate on AC.

The Aris RPU system, however, is almost entirely DC! Since the electricity generated from the solar panel doesn't need to travel far, and works to charge the battery, it can stay as DC. The Lamp is a DC LED which means no inverters or special technology are required to store or transmit the electrons. The wind turbine on this unit does produce AC, but has a special control unit that switches power from AC to DC to charge the battery or power the lamp.

Objectives

- Students will be able to compare and contrast alternating current (AC) with direct current (DC).
- Students will be able to explain why AC or DC might be used in certain scenarios.

Materials

- 3-5 Balloons or beach balls
- Masking tape

Time

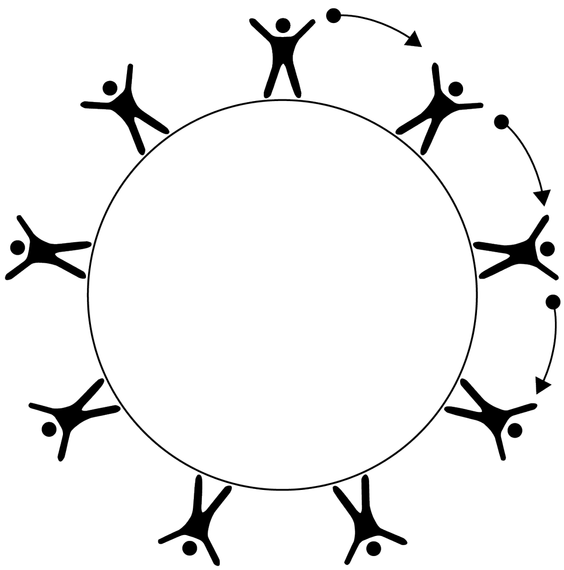
- 20-30 minutes

Procedure

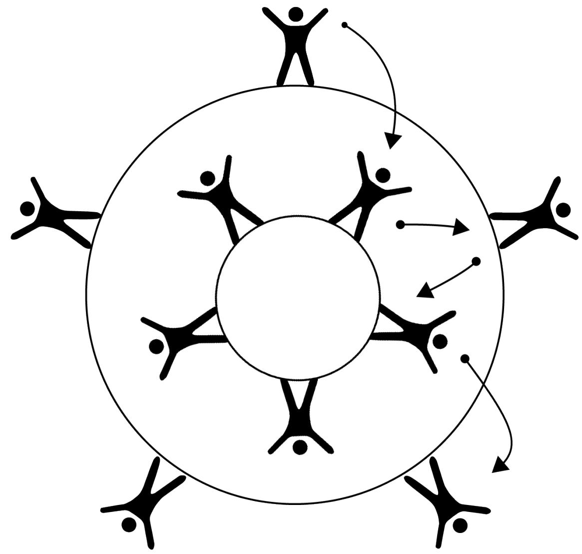
1. Blow up and tie a few balloons or beach balls
2. Mark loops on the floor to match the diagram on the next page.
3. For an introduction, have students read the *Secondary Energy Infobook* section on the history of electricity to establish some base knowledge on AC versus DC. For additional background, perhaps direct students to https://www.energy.gov/articles/war-currents-ac-vs-dc-power and share the background information above.
4. Explain that you will be doing a quick demonstration with the class as a way to show the difference between alternating current and direct current, and why one might be used over another.
5. Ask a few students to place themselves evenly around the DC loop. Start one student off with a ball/balloon and ask them to pass it to the next person in the circle. Keep adding balloons/balls until you can't any longer, making sure the objects keep moving around the circle (circuit) in a constant direction. Explain that you are modeling how direct current moves through a circuit.
6. Now ask students to space themselves out evenly on both of the AC loops. Start one student off with a ball/balloon. Instruct them to bump or pass it in towards the next closest person, (clockwise) on the inner loop. The inner loop person must then direct it back out, to the next person in line on the outer loop. Students must go outer, inner, outer, inner, without skipping a person, in the same general direction. Explain that you are modeling how alternating current moves, constantly oscillating or switching directions.
7. Ask students what the ojects (balls/balloons) representAsk students what limits they might think a DC system would have if you kept adding objects? In truth, a DC system can't increase voltage as easily without too much friction in the transmission lines for transporting long distances. Why would the AC system be easier to add objects to?
8. Discuss any further advantages and disadvantages you might see with DC or AC.
9. Explain that the Aris system is mostly DC. Discuss as a class why this works well for the lighting system.

CONTINUED ON NEXT PAGE

Direct Current (DC)



Alternating Current (AC)



Extension

- Set up an AC "line" with students above and below it. The line represents your axis. Explain or show that the balloon/ball alternating and moving up and down over the line to each person mimics the sine curve showcasing the frequency of the alternating current in Hertz (Hz). Ask students what they might need to do to make their human graph depict a higher or lower frequency.
- Add a load to your loops/circuits. Use a different color ball/balloon for the electrons brought into and out of the load. Students should exchange their electrons when it goes through the load.

Build a Battery

TEACHER INSTRUCTIONS

Background

A battery is also called an electrochemical cell, or something that uses chemicals to generate an electric current. In this activity, students will learn what is necessary for a functioning electrochemical cell and will keep and build one that produces that greatest amount of current using the materials provided.

Objectives

- Students will be able to explain the basic components of an electrochemical cell.
- Students will be able to explain how to produce electricity using a battery.

Materials

- Beakers (one per student group)
- Alligator clips (two per student group)
- Microammeters (one per test station)
- Water
- Salt
- Lemon juice
- Other slightly acidic fluids (vinegar, sodas, hydrogen peroxide, etc.)
- Assorted fresh fruits and vegetables
- Wires or pieces of assorted metals
- Pennies
- Nickles
- Construction paper

Time

- 45-90 minutes

✔ Procedure

- Gather materials you will use for the demonstration and student design challenge.
- Set up stations for students to test their batteries.

Teacher Demonstration:

1. Add water to a beaker until it is about 3/4 full. Dissolve about a teaspoon of salt in the water.
2. Clip a piece of pure copper (wire, metal strip, pre-1982 penny) to one alligator clip. Clip the other end of the alligator clip to the red post on one microammeter.
3. Clip a piece of another metal (iron, zinc) to the other alligator clip and connect this wire to the black post on the microammeter.
4. While students watch, and so they can see the gauge on the microammeter, dip the two pieces of metal barely into the salt water. Slowly immerse them further in the salt water, taking care to not immerse the alligator chips.
5. Ask students to describe what they see.
6. Touch the two pieces of metal together in the salt water. Ask students to describe what happens to the microammeter.
7. Remove the pieces of metal and exchange one of them for a different metal. Repeat steps 4-6.
8. Select a fruit or vegetable.
9. Using a pair of scissors, make two holes in the fruit. Insert the piece of copper in one and another metal in the other. Attach the alligator clips to the pieces of metal and connect to the microammeter. Ask students to describe what they observe on the microammeter.
10. Change the copper in the fruit for a different metal and repeat. If the needle on the microammeter dips below zero, reverse the connection.

CONTINUED ON NEXT PAGE

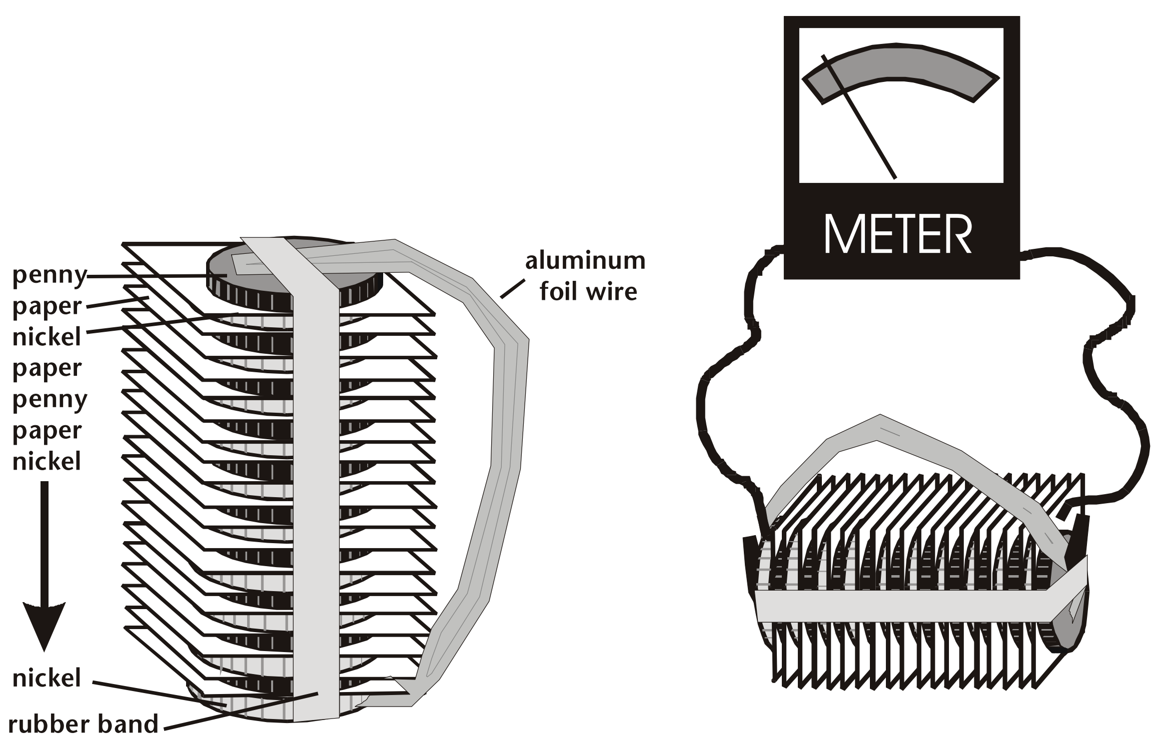
11. Make a stack of pennies, nickels, and construction paper squares soaked in salt water as follows:
    - Place a penny on the table.
    - Place a wet paper square on the penny.
    - Add a nickel, then another piece of wet construction paper.
    - Add a penny and another piece of construction paper.
    - Continue the pattern, using 5 pennies, 9 squares of paper, and ending with the fifth of 5 nickels.
    - Rubber-band the “sandwich” together tightly. Lay it on its side on the table.
    - Touch one alligator clip to one end of the coin battery, and the other to the other end. If the needle dips below zero, reverse the connection.
    - Have students describe what they observe on the microammeter.

Student Design Challenge

1. Explain to students that you want them to design and build a battery with materials you provide. Tell them the goal is to make the strongest current they can with the materials, and any other parameters you determine (such as limits on materials, etc.). Remind students that the design process is to develop a plan, build the design, test the design, then revise the design, repeating as many times as necessary to achieve the design objective or as time allows.
2. Ask students about their observations during the demonstration. Ask students what all three batteries had in common. List these commonalities on the board or somewhere students can access them.
3. Instruct students to begin their design work.
4. Allow students plenty of time to work through the challenge, test their designs, and revise.
5. Keep a running score of the highest current from student batteries.

Extension

- Challenge students to develop a battery strong enough to power a device, such as an LED or small buzzer.



Build a Battery

STUDENT WORKSHEET

Question

What materials will make the best battery?

Hypothesis

Write a sentence or two describing what you will use and how you will build the best battery.

Design Requirements (set by your teacher)

Write down the requirements described by your teacher. What is the goal of the activity? What limits has your teacher set for the activity?

Materials

Your teacher will provide a list of suggested or required materials for this activity.

First Design	Revision #1	Revision #2	Revision #3	Revision #4

Design

Make a diagram of your first design. Label it. Then build it, test it, and revise as necessary. Every time you change your design, make a new diagram. Include a description explaining what you are changing, and why.

First Design	Revision #1	Revision #2	Revision #3	Revision #4

Data

Record your experimental data:

Design	Microammeter Reading
First Design	
Revision #1	
Revision #2	
Revision #3	
Revision #4	
Revision #5	

Conclusion

1. What was the highest microammeter reading you took? ______________________
2. What was the highest microammeter reading in the class? ______________________
3. What materials did the battery with the highest reading have? ______________________
4. What materials do the best batteries use, based on your results and what your classmates did? Use evidence from the activity to explain your answer.

PV Ping Pong

TEACHER INSTRUCTIONS

Background

Solar energy can be used to produce electricity without any chemical reaction. This process, known as the photoelectric effect, allows electrons to be ejected or emitted from the surface of a material when photons of light strike the material. Solar panels, or photovoltaic cells, are the devices we use to collect radiant energy from the sun and turn it directly into electricity to power our homes, schools, and businesses. This process, however, can be somewhat mystifying to students. In this simulation, students will act as the layers of a solar cell within a solar panel, photons of light, and electrons on the move.

✪ Objectives

- Students will be able to describe the photoelectric effect and how a photovoltaic (PV) cell is set up.

Materials

- 20 – 25 Foam or tennis balls
- Flashlight
- Colored tape
- Sticky name tags

Time

- 20-30 minutes

✔ Procedure

1. Set up two lines of tape on the floor for students to stand on. The lines should be facing each other with a few feet between them.
2. Create a circle behind one of the tape lines. This will be the photon home.
3. Project and review the master with the class. If needed, review the *Secondary Energy Infobook* section on solar energy to discuss how a PV cell is set up.
4. Write out name tags for each of the roles. This can also be done by the students once roles are assigned. You may choose to get “fancy” giving name tags or props that resemble roles as well (i.e., N-layers=N, photons=light bulbs, etc.).
5. Assign students to roles.
6. Ask the P-layer students to stand on one line and the N-layer students to stand on the other line so that they are facing each other. Tell them the P-N junction is between them. Have the students on each line hold hands “wiring“ themselves together.
7. The electrical load(s) should stand at the end of two lines. Students on the end of each line should hold hands with the electrical load, forming an open loop from P-layer through electrical load and on to N-layer.
8. Ask the photons to congregate in the photon circle, their “light source”.
9. Give each N-layer student a ball. Tell students these are electrons. P-layer students should have none but should want to receive them.
10. When you signal, have the N-layer students toss their electrons to P-layer students, who will catch them.
11. When you signal, photons must leave the light source circle and tap a P-layer student (student with a ball) on the shoulder. They should then return to the circle and repeat the process.
12. When a P-layer student with a ball feels a tap, he or she should pass their electron down to the next person in line towards the electrical load to start the flow of current (or balls) toward the electrical load student.
13. When the electrical load student receives an electron, he or she should turn on his or her flashlight and yell “WOOO HOO,” and turn it off as they pass the electron to the other side.
14. As electrons come to the N-layer from the load, they should immediately be tossed to the P-layer again.
15. Simulate darkness by having photon students sit in their circle, not moving. P-layer students should stand, holding electrons, ready to receive photons.

PV Ping Pong Simulation and Roles

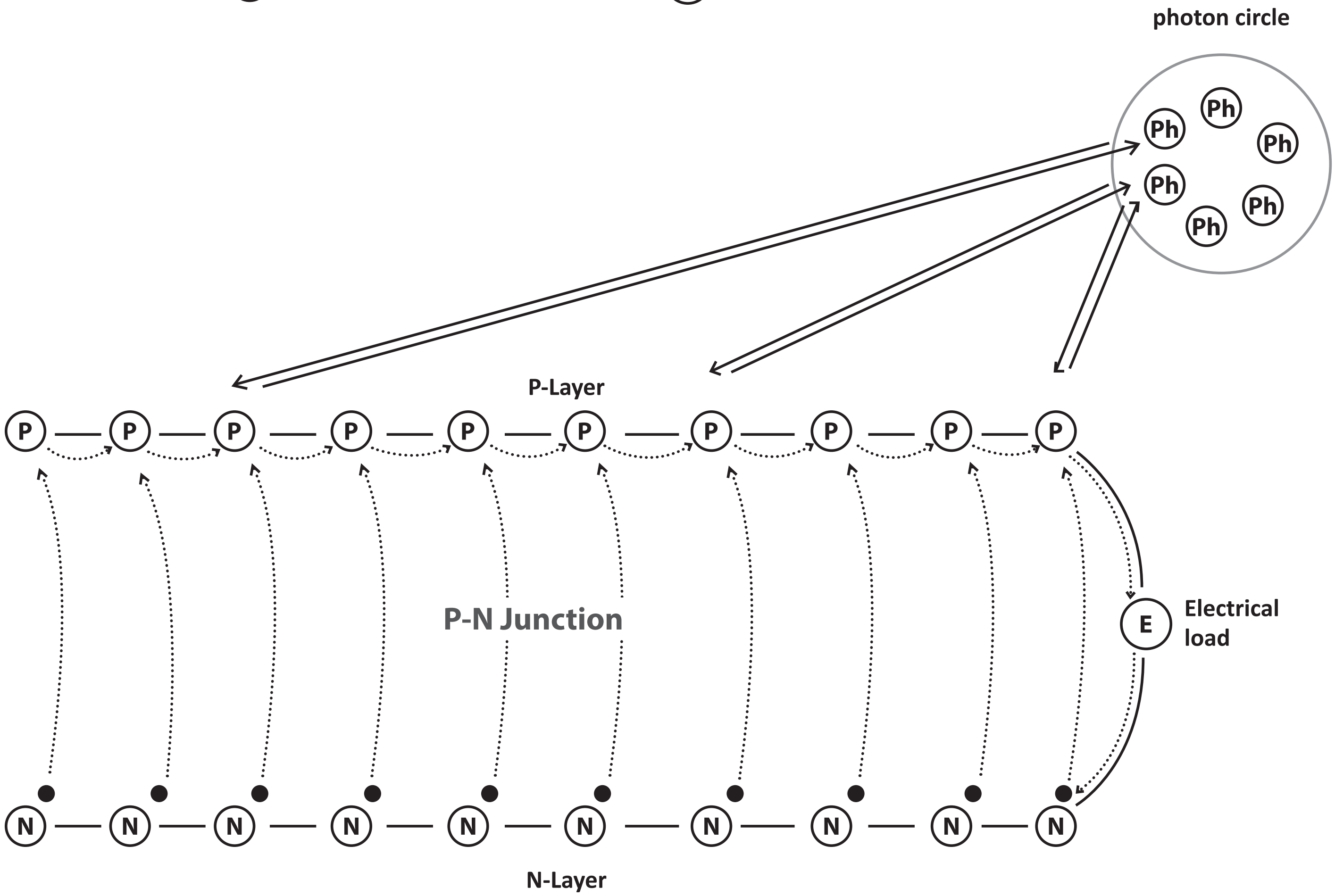
N-layer students – 17 (N)

P- layer students – 17 (P)

Photon students – 10 (Ph)

Electrical load students – 1-2 (E)

● Ball



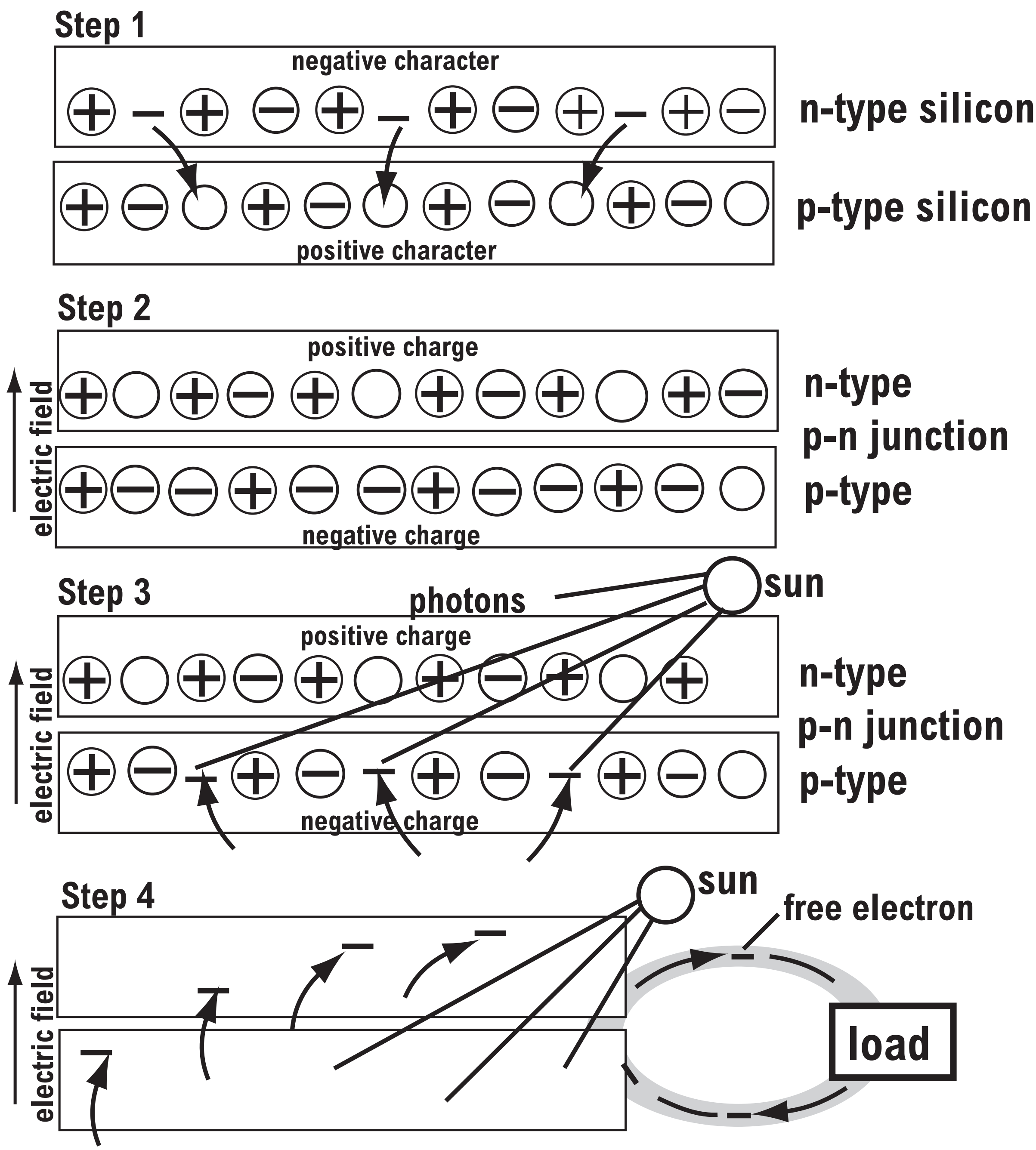
Extensions

- Have students determine how they would extend the simulation to include more solar arrays and devices into the circuitry.
- Have students write a description of how PV cells work.
- Have students design a simulation to showcase how a concentrated solar power (CSP) facility operates.

Photovoltaic Cell

TEACHER MASTER

○	A location that can accept an electron
−	Free electron
⊕	Proton
⊖	Tightly-held electron



PV Cell Explorations

TEACHER INSTRUCTIONS

Background

These activities focus on how solar energy is used to generate electricity through photovoltaics, or solar panels. Students will explore the activities through series wiring at first. For additional challenges, have the students complete all of the explorations found in NEED'S *Exploring Photovoltaics* guide, which explores not only series configurations, but parallel wiring as well.

✪ Objectives

- Students will be able to describe how a PV cell converts radiant energy into electricity.
- Students will be able to calculate power in watts using a PV module and compare several module outputs.

Materials

- PV cell kits
- Alligator clips
- Bright light source or sun
- Multimeters

Time

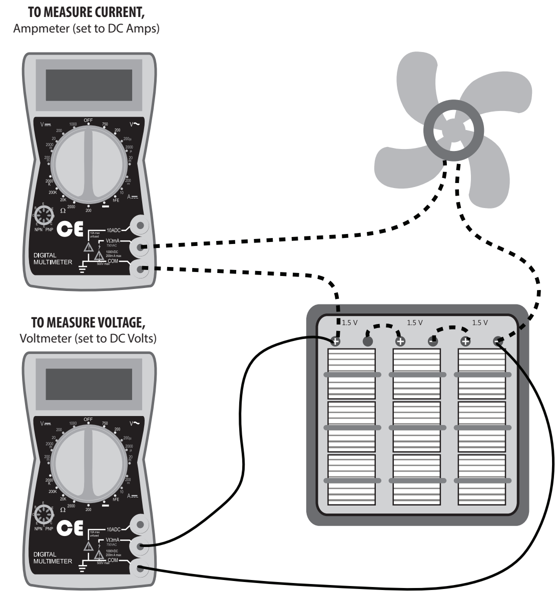
- 30-45 minutes, depending on number of investigations to complete

✔ Procedure

1. Review and discuss a PV cell and its function with the class as needed. Review the difference between series and parallel. Explain that students will be using series wiring for these activities.
2. Set up four centers that each have 4 PV cell kits and 8 multimeters.
3. Preview the student activity pages. Remind students that the diagrams include dashed and solid lines to represent different sets of wiring.
4. Ask students to complete PV Cell Explorations 1-4.
5. Review and discuss activities, results, and challenges as a class.

PV Cell Exploration 1

STUDENT WORKSHEET



Question

How do similar PV modules in an array vary in electrical output? Think about which varies more, current or voltage.

Hypothesis

Develop a hypothesis to address the question.

Materials

- Bright light source
- Alligator clips
- Electrical load (buzzer, motor/fan, or light)
- PV array
- 2 Multimeters

✔Procedure

1. Test each PV module in the array by connecting the electrical load to each cell.
2. With the multimeter, measure the current and voltage of each PV module in the array under identical external conditions.
3. Record the data below and compare.
4. Calculate the power (current x voltage), or wattage of each trial. Record results in the chart below.

Note: Solid and dashed lines in the diagram represent different sets of clips or wires.

Observations

Data

	CURRENT (A)	VOLTAGE (V)	POWER (W)
LEFT PV MODULE			
CENTER PV MODULE			
RIGHT PV MODULE			

Conclusion

Reflections

Were the output currents of the PV modules similar?

Were the output voltages of the PV modules close to one another?

PV Cell Exploration 2

STUDENT WORKSHEET

Question

How does a PV array wired in series affect the electrical output? Think about what will happen to current and voltage output.

Hypothesis

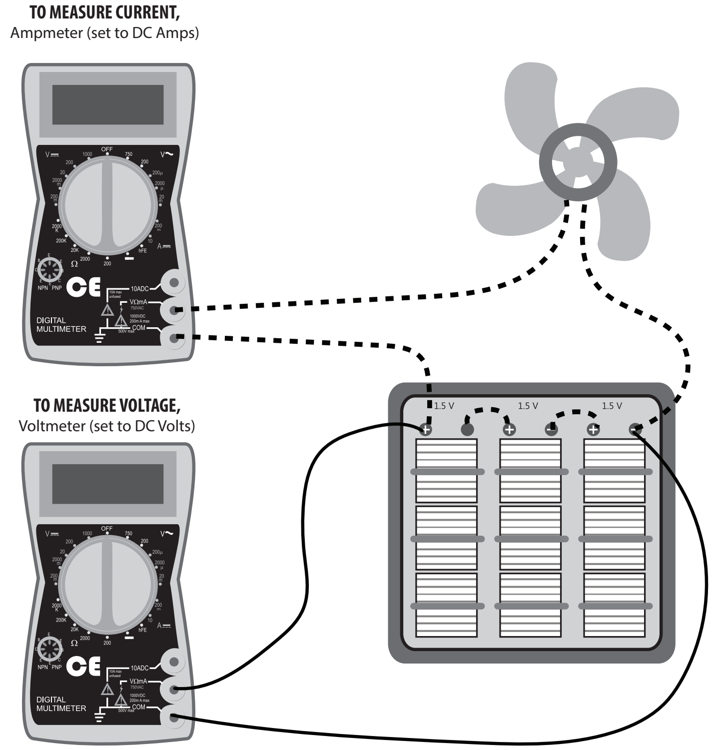
Develop a hypothesis to address the question.

Materials

- PV array
- Electrical load
- 2 Multimeters
- Alligator clips

Procedure

1. Attach the multimeter to the PV array wired in series with an electrical load. See diagram to the right.
2. Measure the current and voltage. Record data in the chart below.
3. Calculate the power (current x voltage), or wattage and record results in the chart below.



Note: Solid and dashed lines in the diagram represent different sets of clips or wires.

Observations

Data

	CURRENT (A)	VOLTAGE (V)	POWER (W)
SERIES			

Conclusion

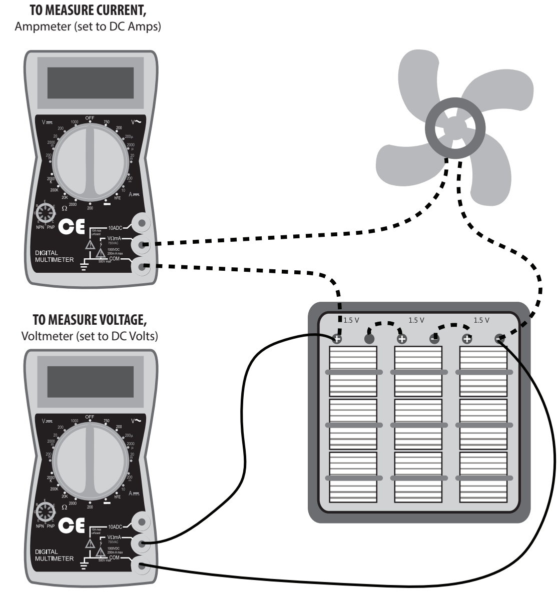
Reflections

How did the current produced in a series circuit compare to the current of an individual PV module?

How did the voltage produced in a series circuit compare to the voltage of an individual PV module?

PV Cell Exploration 3

STUDENT WORKSHEET



Note: Solid and dashed lines in the diagram represent different sets of clips or wires.

Question

How does light intensity affect the electrical output of a PV array wired in series?

Hypothesis

Develop a hypothesis to address the question.

Materials

- 2 Multimeters
- PV array
- Bright light source
- Dim light source
- Electrical load
- Alligator clips

✔Procedure

1. Attach the multimeter to the PV array wired in series with an electrical load.
2. Place the PV array under the bright light source.
3. Measure the current and voltage produced by the PV array.
4. Record data in the chart below.
5. Place the PV array under the dim light source.
6. Measure the current and voltage produced by the PV array.
7. Record data in the chart below.
8. Calculate the power (current x voltage), or wattage of each trial. Record results in the chart below.

Note

When comparing light output of different sources (e.g., bulbs), lumens should be used to compare light intensity rather than watts, which compare power consumption.

Observations

Data

	CURRENT (A)	VOLTAGE (V)	POWER (W)
BRIGHT LIGHT			
DIM LIGHT			

Conclusion

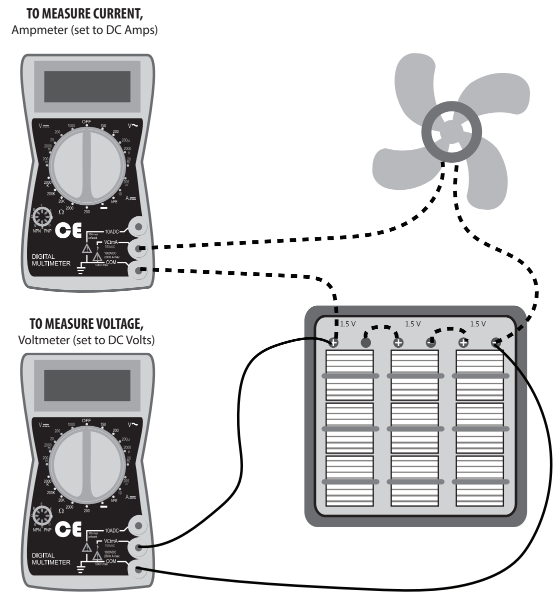
Reflections

What differences did you observe in the variables of the two light intensities?

How does light intensity affect the output of the PV array?

PV Cell Exploration 4

STUDENT WORKSHEET



Question

How does the angle of a PV array (wired in series) relative to the light source affect the electrical output?

Hypothesis

Develop a hypothesis to address the question.

Materials

- PV array
- Bright light source
- Electrical load
- 2 Multimeters
- Alligator clips
- Protractor

Note: Solid and dashed lines in the diagram represent different sets of clips or wires.

✔ Procedure

1. Attach the multimeter to the PV array wired in series with an electrical load.
2. Measure current and voltage when the PV module is at an angle of 90° relative to the light. Record data in the chart.
3. Using the protractor to adjust the angle, measure current and voltage when the PV module is at an angle of 75° relative to the light. Record data in the chart.
4. Using the protractor, measure current and voltage when the PV module is at an angle of 60°, 45°, 30°, and 15° relative to the light. Record data in the chart.
5. Calculate the power (current x voltage), or wattage of each trial. Record results in the chart.
6. Graph your experimental results, wattage (y) vs. degrees (x).

Data

DEGREES	CURRENT (A)	VOLTAGE (V)	POWER (W)
90 °			
75°			
60°			
45°			
30°			
15°			

Conclusion

Reflections

From the graph of your data, what is the relationship between the angle of a PV array to wattage produced?

Your Solar-Powered Cabin

TEACHER INSTRUCTIONS

Background

This activity asks students to focus on the real-world challenges of implementing solar on a smaller scale to power an off-grid home. Students will be asked to design and plan for a system that will power a real-life scenario home while meeting the needs of the lawyers in order to collect their payment (inheritance).

Objectives

- Students will be able to describe how a PV cell converts radiant energy into electricity.
- Students will be able to calculate the cost benefit of employing solar technologies.

Materials

- Calculators (optional)

Time

- 30-45 minutes, depending on depth of desired project outcome

✔ Procedure

1. Download and/or project a U.S. Solar Resource Map from the National Renewable Energy Laboratory website at www.nrel.gov/gis/solar.html.
2. Have the students analyze their electricity usage and peak sun hours to determine whether or not solar energy can meet their demands. Students should use their own electric bill to determine their family's electricity usage. If they do not have access to an electricity bill, students can use the national average of approximately 900 kWh per month.
3. Ask students to design a plan for their cabin using the student worksheet and any additional research and calculations they might need to do.

Your Solar-Powered Cabin

STUDENT WORKSHEET

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 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 PV modules that you will use along with their ratings;
- a schematic diagram of your system design; and
- a spreadsheet detailing your budget and sources for parts.

Have fun!

Extension

- When you finish your plan, design a battery system to store the electrical energy generated for use at night or during storms.

Solar-Powered Cabin

STUDENT WORKSHEET

Description of Modules:

Diagram of Design:

Budget Information:

Wind Can Do Work Challenge

TEACHER INSTRUCTIONS

Background

Before wind energy was used to generate electricity, it was used to do physical labor. Goods and people were transported using wind power. Old windmills ground grain into flour and wind power was used to pump water for livestock and farming. This challenge focuses on using wind energy to do physical work by lifting paper clips.

This activity is based on *Wind Can Do Work*, an activity found in NEED's wind curriculum guides. You can construct towers based on this design, using cups and straws and a blade template, or you can have students come up with their own design completely from scratch. Essential materials include string or thread and paper clips. Additional materials can be provided based on what is available. A list below provides some inspiration. It is often fun to provide detractor materials, or materials that may not appear to be useful, as students can work through the challenge and refine their design.

Objective

- Students will be able to describe how wind can do work.

Materials Needed

- Scissors
- Tape (various)
- Paper clips
- String, thread, or fishing line
- Fan(s)
- Stopwatch or timer
- Rulers
- Protractors

Materials Suggested

- Cups of various sizes and types
- Dowel rods of assorted widths
- Paper
- Cardboard (corrugated boxes or cereal boxes)
- Corrugated plastic (yard signs)
- Popsicle sticks
- Recycled materials, such as water bottles, old CDs, etc.
- Hole punches
- Straws and stirrers of various sizes

Time

- 30-60 minutes

Design Parameters

- Wind turbines, from the bottom of the base to the highest point of the blades in their highest position, can be no more than 25 centimeters.
- All turbines must have no fewer than 3 and no more than 5 blades.
- The turbine must be able to turn on its own when the fan is turned on. No hands-on assistance to overcome inertia is permitted.
- Paper clips must be lifted at least 15 centimeters. This means the lifting mechanism must be able to clear a little more than 15 centimeters.

Testing Parameters

1. Use a fan on medium speed. (If a high velocity fan is used, it may be necessary to start at low speed.)
2. Count the number of paper clips the turbine can lift in a two-minute period. Clips must have completely left the ground or table and have been lifted completely to the top of the lifting mechanism.
3. Paper clips that fall while being lifted do not count.

Teachers' Cheats

These are some things that you will know that your students will not know, that can help you spur the students' creativity and thinking:

- Blades should be inserted in the hub at an angle. Flat blades will not spin consistently.
- If a paper pinwheel turbine is used, it may need to be secured in front of and behind the turbine to keep it from blowing backward on the rotor. This can save many minutes of frustration for your students.
- Provide protractors and rulers so students can evenly space their blades on their rotor assembly.
- Gears are excellent maximizers of efficiency as are pulleys. Building toys have parts that can be used this way.
- Power equals work done divided by the time taken to do the work. Students do not have to lift all their paper clips all at once. They can remove paper clips that have been lifted the full distance, lower the lifting mechanism, and continue.

Comparing Light Bulbs

TEACHER INSTRUCTIONS

Background

Lighting used to be simple. We would buy bulbs based on their wattage, and schools and offices used long fluorescent tubes for light. That was that. Then in 2007, The Energy Independence and Security Act was passed, changing lighting for many, and mandating better efficiency in lighting options. Now, we have a variety of lighting choices, which can be confusing. This lesson helps students understand the types of lighting available for purchase, and those that may still be in homes, allowing students to compare how they work, their efficiency, and their cost to use.

✪ Objectives

- Students will be able to describe how different light bulb types produce light.
- Students will be able to compare and contrast light bulb types for efficiency and cost.

Materials

- Incandescent bulb
- CFL bulb
- LED bulb
- Calculators (optional)

Time

- 15-20 minutes

✔ Procedure

1. Prepare a copy of the activity and answer keys to project or make copies as needed.
2. Ask the class what kinds of light bulbs they see in their homes. Help them to identify the lighting they might use indoors and outdoors, and use the classroom to serve as a model, where needed. Ask students to predict how many light bulbs they have in their home.
3. Have students read the *Secondary Energy Infobook* about lighting.
4. Preview the activity and ask students to complete individually or complete as a class. Discuss which lighting type works best while saving money.

Comparing Light Bulbs

ANSWER KEY

Step		COST OF BULB	INCANDESCENT BULB	HALOGEN	COMPACT FLUORESCENT (CFL)	LIGHT EMITTING DIODE (LED)
		Life of bulb (how long it will light)	1,000 hours	3,000 hours	10,000 hours	25,000 hours
1		Number of bulbs to get 25,000 hours	25 bulbs	8.3 bulbs	2.5 bulbs	1 bulb
	x	Price per bulb	$0.50	$1.50	$1.50	$1.33
2	=	Cost of bulbs for 25,000 hours of light	$12.50	$12.45	$3.75	$1.33
		COST OF ELECTRICITY	**INCANDESCENT BULB**	**HALOGEN**	**COMPACT FLUORESCENT (CFL)**	**LIGHT EMITTING DIODE (LED)**
		Total Hours	25,000 hours	25,000 hours	25,000 hours	25,000 hours
	x	Wattage	60 watts = 0.060 kW	43 watts = 0.043 kW	13 watts = 0.013 kW	12 watts = 0.012 kW
3	=	Total kWh consumption	1,500 kWh	1,075 kWh	325 kWh	300 kWh
	x	Price of electricity per kWh	$0.129	$0.129	$0.129	$0.129
4	=	Cost of Electricity	$193.35	$138.57	$41.89	$38.67
		LIFE CYCLE COST	**INCANDESCENT BULB**	**HALOGEN**	**COMPACT FLUORESCENT (CFL)**	**LIGHT EMITTING DIODE (LED)**
5		Cost of bulbs	$12.50	$12.45	$3.75	$1.33
6	+	Cost of electricity	$193.35	$138.57	$41.89	$38.67
7	=	Life cycle cost	$205.85	$151.02	$45.64	$40.00

Comparing Light Bulbs

STUDENT WORKSHEET

The graphic below shows four light bulbs that produce the same amount of light. You might use bulbs like these as a bright overhead light. One bulb is an incandescent light bulb (IL), one is a halogen, one is a compact fluorescent light (CFL), and another is a light emitting diode (LED). Which one is the better bargain? Let's do the math and compare the four light bulbs using the residential cost of electricity at $0.129 /kWh.

1. Determine how many bulbs you will need to produce 25,000 hours of light by dividing 25,000 by the number of hours each bulb produces light.
2. Multiply the number of bulbs you will need to produce 25,000 hours of light by the price of each bulb. The cost of each bulb has been given to you in the chart below.
3. Multiply the wattage of the bulbs (using the kW number given) by 25,000 hours to determine kilowatt-hours (kWh) consumed.
4. Multiply the number of kilowatt-hours by the cost per kilowatt-hour to determine the cost of electricity to produce 25,000 hours of light.
5. Add the cost of the bulbs plus the cost of electricity to determine the life cycle cost for each bulb. Which one is the better bargain?
6. Compare the environmental impact of using each type of bulb. Multiply the total kWh consumption by the average amount of carbon dioxide produced by a power plant. This will give you the pounds of carbon dioxide produced over the life of each bulb. Which one has the least environmental impact?

All bulbs provide about 850 lumens of light.

	COST OF BULB	INCANDESCENT BULB	HALOGEN	COMPACT FLUORESCENT (CFL)	LIGHT EMITTING DIODE (LED)
	Life of bulb (how long it will light)	1,000 hours	3,000 hours	10,000 hours	25,000 hours
	Number of bulbs to get 25,000 hours				
x	Price per bulb	$0.50	$1.50	$1.50	$1.33
=	**Cost of bulbs for 25,000 hours of light**				
	COST OF ELECTRICITY	**INCANDESCENT BULB**	**HALOGEN**	**COMPACT FLUORESCENT (CFL)**	**LIGHT EMITTING DIODE (LED)**
	Total Hours	25,000 hours	25,000 hours	25,000 hours	25,000 hours
x	Wattage	60 watts = 0.060 kW	43 watts = 0.043 kW	13 watts = 0.013 kW	12 watts = 0.012 kW
=	Total kWh consumption				
x	Price of electricity per kWh	$0.129	$0.129	$0.129	$0.129
=	**Cost of Electricity**				
	LIFE CYCLE COST	**INCANDESCENT BULB**	**HALOGEN**	**COMPACT FLUORESCENT (CFL)**	**LIGHT EMITTING DIODE (LED)**
	Cost of bulbs				
+	Cost of electricity				
=	**Life cycle cost**				
	ENVIRONMENTAL IMPACT	**INCANDESCENT BULB**	**HALOGEN**	**COMPACT FLUORESCENT (CFL)**	**LIGHT EMITTING DIODE (LED)**
	Total kWh consumption				
x	Pounds (lbs) of carbon dioxide per kWh	1.6 lb/kWh	1.6 lb/kWh	1.6 lb/kWh	1.6 lb/kWh
=	**Pounds of carbon dioxide produced**				

Light a Bulb Challenge

TEACHER INSTRUCTIONS

Background

Most kids know how to connect a battery, in a battery holder, to a light bulb in a socket and light the bulb. However, do they know which part(s) of the battery and bulb are actively involved in completing the circuit? Understanding conductors, insulators, and open and closed circuits are standards across the country, and this activity can help your students understand what, exactly, is making them work.

This activity is based loosely on the circuits activities found in NEED's *ElectroWorks* unit, but is more open-ended than the prescribed activities. The challenge asks students to be able to complete an electrical circuit given some basic materials and little else.

Objectives

- Students will be able to describe how loads and circuits must be wired.
- Students will be able to describe how different load draws can require different circuit configurations and/or power supply.

Materials Needed

- Small light bulbs
- D-cell batteries

Materials Suggested

- Alligator clips
- Aluminum foil strips
- Paper clips
- Other conducting materials
- Objects to test for conductance
- Tape (masking, electrical, etc.)

Time

- 10-30 minutes

Design Parameters

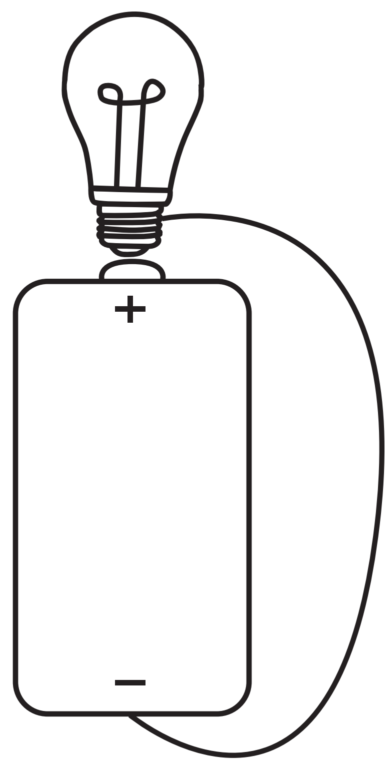
- Provided with a battery and a small light bulb, find materials and use them to light the bulb with the battery.
- Students may not use things like Snap Circuits or building toys with electronics built-in.
- Designs may not include pre-manufactured circuit boards, battery holders, light bulb sockets, etc.
- Designs may be held together with tape, but should not be soldered together.

Testing Parameter

There is only one parameter for this challenge: If the light bulb lights, the design is successful.

Teachers' Cheats

- D-cell batteries are the most cost-effective cells to use for this activity. AA or AAA batteries are the same voltage as D-cell, but produce less current and if short-circuited will run out of power faster.
- Batteries connected to bulbs with thin wires will heat the wires very quickly. Also, connection points on the battery and bulb may get hot, so students should always tape them in place rather than holding connections together with their fingers.
- The simplest circuit can be constructed with one battery, one light bulb, and one wire or strip, as shown.



Extensions and Enrichment

- Substitute the small incandescent bulbs for LEDs. You can get LEDs from failed strings of holiday lights. Note: LEDs only work in one direction, so if it does not work as connected, reverse the connection.
- Give students more than one battery, have them connect the batteries in series (positive to negative), and compare the brightness of the bulb.
- Give students some random objects to insert in their light bulb circuits. Have students classify them as a conductor or insulator based on their results.

Analyzing Data

TEACHER INSTRUCTIONS

Background

In this activity, students will begin to explore the data gathered by the Aris lighting RPU to understand how it works to generate electricity and store energy to power the lamp. Students will first become familiar with the user interface screenshots and learn to draw conclusions from the items they see compared to daily weather information, etc. As students become more familiar, you may have them look at the data each week from their school, compare it to the other sites, and identify patterns and variables that might affect each site's lighting.

Objectives

- Students will be able to read, synthesize, and analyze the data and graphics on the Aris RPU data sheets.
- Students will be able to describe basic variables that affect solar panel and wind turbine performance (wind speed, weather patterns, etc.).
- Students will be able to compare and contrast different Aris systems.

Materials

- Internet access
- Calculators (optional)
- Aris shared data file: https://ariswind.sharefile.com/share/getinfo/scab599c491945519

Time

- 30 minutes, plus ongoing time for continued data analysis

✔ Procedure

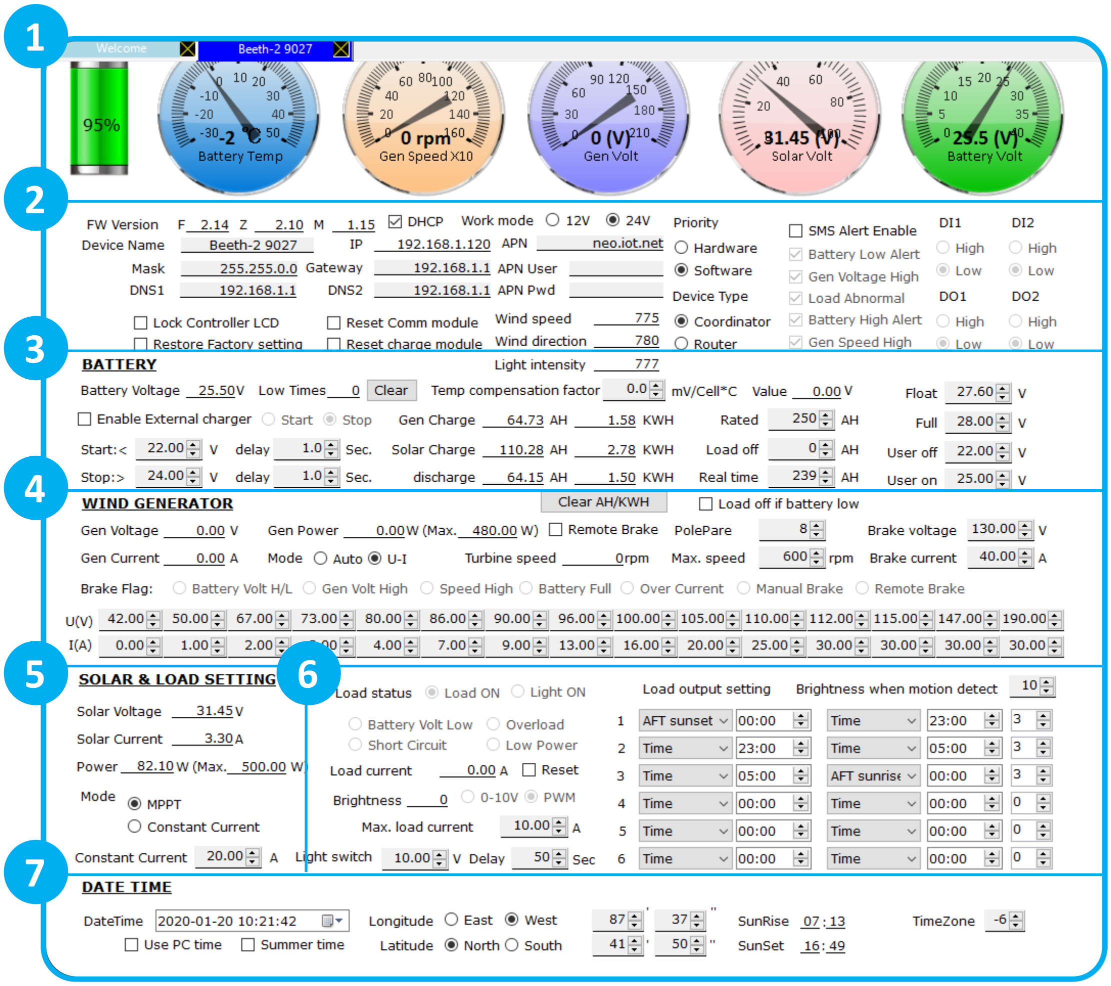
1. Visit the Aris shared file to preview data from each school site as needed. Review the master of the user interface screenshot and identify all the parts listed on the key.
2. Prepare a digital copy of the master to project and/or copies of the student worksheet and master to distribute. Or, visit the link for the shared files and project a more recent version of the data from your school in color. It may also be helpful to prepare a copy of the Aris system overview on page 5 for display.
3. Explain to the class that data is often reported in charts, tables, and graphs.
4. Show or describe the Aris system to your students.
5. Show and explain the data displayed by the Aris user interface. Describe the various dials and sections of the screen, specifically pointing out the time in the bottom (military time), and the presence of solar generation and wind generation on the dials at the top. It may make sense to also pull up a local weather report for that time of day to verify weather conditions (relative sun/clouds, wind speed, etc.). Ask the students to write two sentences summarizing the information in the top line (dials) of the screenshot.
6. Be sure to also point out the battery's instantaneous voltage in comparison to the "full" voltage, and on the battery diagram at the top. Ask students to verify the battery charge calculation if calculating percentages is in their math skills arsenal.
7. Ask students basic questions about the data and the display. For example, why might it be important to know the sunrise and sunset times? Why might the system report on the speed of the generator AND the volts produced? Why might the lamp have different brightness settings? Why might there be volts produced but no current?
8. Show the students the shared data from the other schools. Have the students compare the conditions and associated generation and charging between the various locations and begin to look for similarities and differences over time. What variables might account for the differences between the school sites? Ask students what kind of conditions might need to be in place to drain the battery?

Extension

- Provide your students a screenshot, and focusing simply on the top line (dials), have the students reverse-engineer the day's weather conditions at the time data was pulled.
- Ask the class to calculate the power for each source, solar and wind. How do their calculations compare to the interface? Ask them to develop an explanation for any differences.

Analyzing Data

TEACHER MASTER & KEY



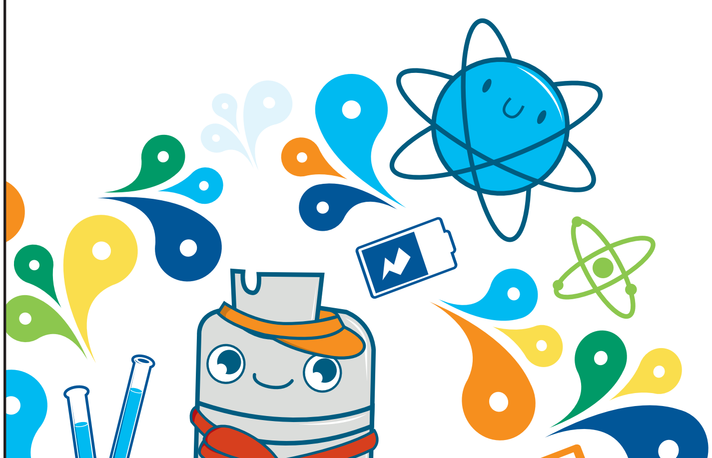
✔ Key

1. **Data Dashboard** – This area shows the most relevant data for students, including current battery charge (%), battery temperature, wind turbine speed, wind turbine generation (V), solar panel generation (V), and battery charge (V).
2. **RPU Information** – This area shows general information for the installers and programmers, including the device's name, current programmed settings, and server information for data collection.
3. **Battery** – This area contains information pertaining to the battery. It will show the battery's current voltage, which should match the reading on the green dial, as well as what full capacity would be when fully charged. It also indicates how many kWh are generated by the wind turbine and solar panel to charge the battery, as well as how much power is discharged.
4. **Wind Generator** – This section showcases how much energy is generated by the wind turbine and its current speed, which should match the purple dial at the top. It also shows the speeds and currents at which a break is applied to slow/stop the generator.
5. **Solar Panel** – This area shows the solar generation from the solar panel.
6. **Load Settings** – This area gives information about the lamp and its settings. It will showcase the times the lamp is set to be on, and at which brightness. The brighter the light, the more power it will consume. It will also show if the battery should be low for any reason.
7. **Date and Time** – This section shows the date and time (military time) at which the reading was pulled. It also shows the latitude and longitude coordinates of the RPU, and at what time sunrise and sunset occurred.

YOUTH ENERGY CONFERENCE AND AWARDS

The NEED Youth Energy Conference and Awards gives students more opportunities to learn about energy and to explore energy in STEM (science, technology, engineering, and math). The annual June conference has students from across the country working in groups on an Energy Challenge designed to stretch their minds and energy knowledge. The conference culminates with the Youth Awards Ceremony recognizing student work throughout the year and during the conference.

For More Info:
www.NEED.org/event/youth-energy-conference-and-awards/



YOUTH AWARDS PROGRAM FOR ENERGY ACHIEVEMENT

All NEED schools have outstanding classroom-based programs in which students learn about energy. Does your school have student leaders who extend these activities into their communities? To recognize outstanding achievement and reward student leadership, The NEED Project conducts the National Youth Awards Program for Energy Achievement.

Share Your Energy Outreach with The NEED Network!
This program combines academic competition with recognition to acknowledge everyone involved in NEED during the year—and to recognize those who achieve excellence in energy education in their schools and communities.

What's involved?

Students and teachers set goals and objectives and keep a record of their activities. Students create a digital project to submit for judging. In April, digital projects are uploaded to the online submission site.

Want more info?

Check out **www.NEED.org/need-students/youth-awards/** for more application and program information, previous winners, and photos of past events.

Awesome Extras!

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

This page is available at www.NEED.org/educators/awesome-extras/.