Exploring Coal

2017-2018

A multi-disciplinary unit that addresses the science behind coal and how it is used for energy and industry. Hands-on, critical thinking, and laboratory exercises expose secondary students to coal formation, coal mining, reclamation of lands, uses of coal, electricity generation, and the advantages and disadvantages of utilizing coal.

Grade Level:

Sec Secondary

Subject Areas:

- Science
- Math
- Social Studies
- Public Speaking
- Careers

NEED
National Energy Education Development Project

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.

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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
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Education Development

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Exploring Coal

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Standards Correlation Information

www.NEED.org/curriculumcorrelations

Next Generation Science Standards

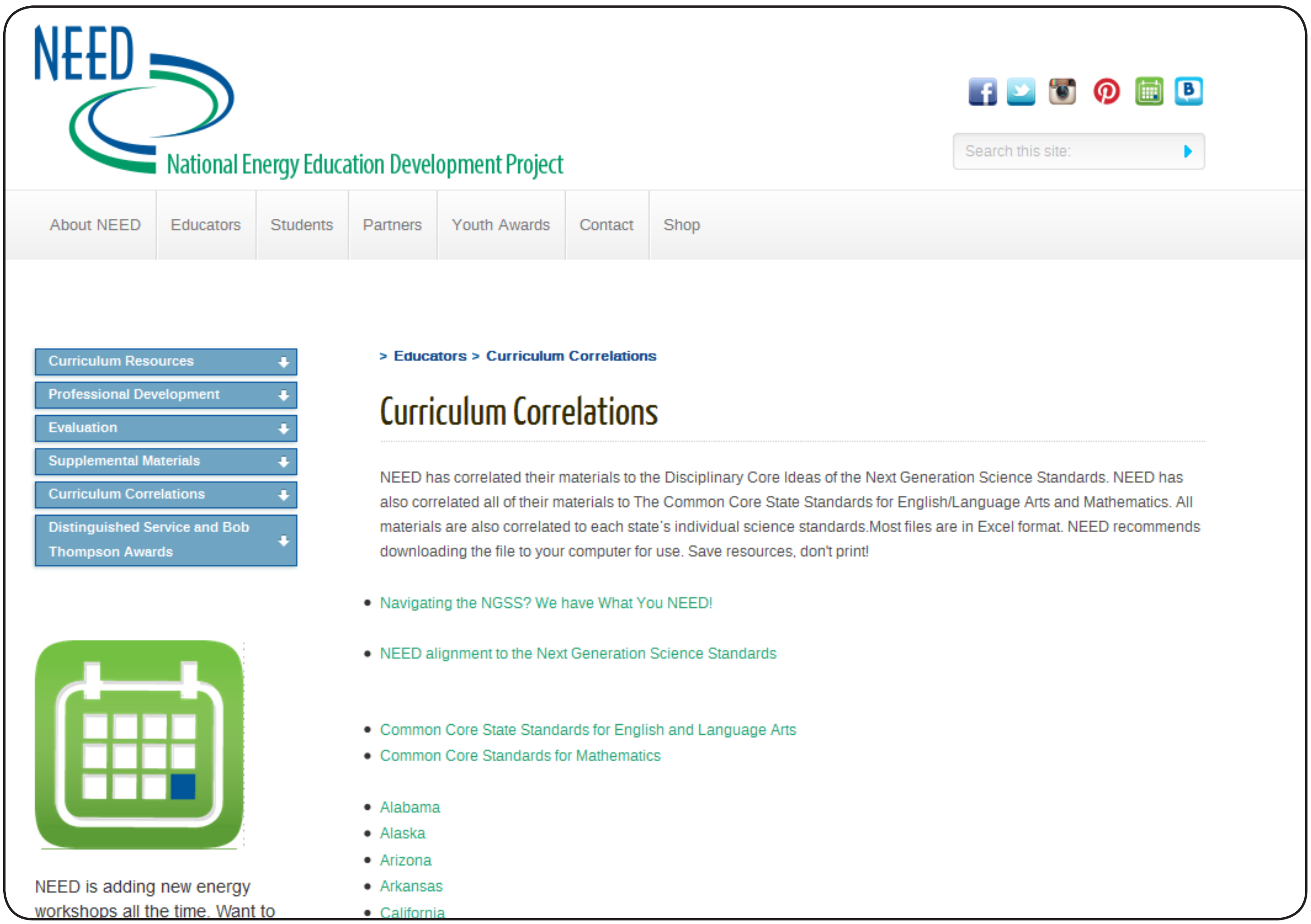
- This guide effectively supports many Next Generation Science Standards. This material can satisfy performance expectations, science and engineering practices, disciplinary core ideas, and cross cutting concepts within your required curriculum. For more details on these correlations, please visit NEED's curriculum correlations website.

Common Core State Standards

- This guide has been correlated to the Common Core State Standards in both language arts and mathematics. These correlations are broken down by grade level and guide title, and can be downloaded as a spreadsheet from the NEED curriculum correlations website.

Individual State Science Standards

- This guide has been correlated to each state's individual science standards. These correlations are broken down by grade level and guide title, and can be downloaded as a spreadsheet from the NEED website.



Exploring Coal Materials

The chart below lists activities that require specific materials other than paper, pencils and computer access. Review the teacher guide beginning on page 7 for a full listing of activities and more information on the types and amounts of materials required. Contact NEED with any questions on materials or how to find materials unfamiliar to you.

ACTIVITY	MATERIALS REQUIRED
Comparing the Types of Coal	▪Samples of peat, lignite, subbituminous, bituminous, and anthracite coal ▪Electronic balances ▪Colored pencils ▪Distilled water ▪Graduated cylinders ▪Scratch plates or fine-grit sand paper
The Properties of Coal	▪Small crucibles with lids ▪Spatulas ▪Coal samples ▪Mortars and pestles ▪Electronic balances ▪Bunsen burners ▪Rings and ring stands ▪Screens or clay triangles ▪Desiccator or drying oven
The Heat Content of Coal	▪Rings and ring stands ▪Bunsen burners ▪Small crucibles ▪Soda can ▪Distilled water ▪Thermometers ▪Dried samples of coal from Activity 3, Part One
Science of Electricity	▪Small round bottles ▪Rubber stoppers with holes ▪Wooden dowels ▪Foam tubes ▪Rectangle magnets (strong) ▪Nails ▪Small spools of magnet wire ▪Push pins ▪Hand operated pencil sharpeners ▪Rulers ▪Permanent markers ▪Sharp scissors ▪Masking tape ▪Fine sandpaper ▪Utility knife (optional) ▪Multimeters ▪Alligator clips
Mining Challenge	▪Wooden toothpicks ▪Plastic toothpicks ▪Large paper clips ▪Napkins or paper towels ▪Play money ▪Chocolate chip cookies
Mine Reclamation	▪Grass seed ▪Potting mix or other soil ▪Aluminum or plastic dishes ▪Small stones and pebbles ▪Twigs ▪Squirt bottles with water ▪Sunny window ledge

ACTIVITY	MATERIALS REQUIRED	
Properties of CO_2	▪Plastic trash bags ▪Dry ice ▪Work gloves ▪Tongs ▪Clear plastic tubs or containers ▪Plastic trays ▪Bottles of bubbles	▪Bottles of water ▪Balloons ▪Pipe cleaners ▪Tealight candles ▪Matches ▪Plastic cups ▪Safety goggles
Enhanced Fuel Recovery Model	▪Clear glass jar with tight lid ▪Water ▪Marbles ▪Pebbles ▪Stones ▪Colored lamp oil or vegetable oil ▪Mason jars with lids ▪24" by ¼" tubing ▪Empty water bottle	▪Dark colored food dye ▪Dry ice or effervescent tablets ▪Assorted rocks, sand, and marbles ▪Drill ▪Safety glasses ▪Tongs ▪Silicon sealant ▪Tissue paper (optional)
Coal in Kentucky	▪Map of home state	
Baseload Balance	▪Tape ▪Scissors ▪String ▪Colored paper ▪Rope	▪Marker boards ▪Erasers ▪Dry-erase markers
Life Cycle of Coal	▪Art supplies ▪Assorted props	

Teacher Guide

Background

Most of our energy consumption comes from petroleum, natural gas, and coal, with coal as the leading energy source for electricity generation. For this reason, it is important for students to identify coal as a valuable energy source. This curriculum unit is designed to help students develop a basic understanding of the formation, composition, acquisition, and use of coal as an energy source. A combination of informational text, research activities, critical thinking, and laboratory exercises provide students with cross-curricular learning experiences as they understand the role coal has played in the development of our society from agrarian to industrial in nature.

Preparation

- Familiarize yourself with the entire teacher guide, informational text, and student activity pages to determine which activities will work best for your classroom.

NOTE: The activities in this unit are organized into four categories: Science, Application, Connection, and Summary. If you determine that you will not have time to conduct every activity, it is recommended that you select at least one activity from each of the four groups to give your students a complete picture of the science, uses, and impacts of coal. See the activity table below for a listing of activities by category.

Science Activities	**Application Activities**
Activity 2 – Comparing the Types of Coal	Activity 6 – Mining Challenge
Activity 3 – The Properties of Coal	Activity 7 – Mine Reclamation
Activity 4 – The Heat Content of Coal	Activity 9 – Enhanced Fuel Recovery Model
Activity 5 – Science of Electricity	Activity 15 – Baseload Balance
Activity 8 – Properties of CO_2	
Connection Activities	**Summarizing Activities**
Activity 10 – Geographical Electric Connections	Activity 1 – Think, Learn, Question
Activity 11 – Electric Bill Analysis	Activity 13 – Analyzing Graphical Information
Activity 12 – Careers in the Coal Industry	Activity 14 – Coal in Kentucky
Activity 16 – Coal Tree Research Activity	Activity 17 – Coal Plant Conundrum
	Activity 18 – Life Cycle of Coal

- Gather materials needed for the activities selected. A list of materials needed for the activities can be found on pages 5-6.
- Prepare a copy of the *Student Informational Text* for each student. The glossary may also be helpful for students. Include a copy of this with the informational text if desired.

Science Notebooks

Throughout this curriculum, science notebooks are referenced. If you currently use science notebooks or journals, you may have your students continue using these. A rubric to guide assessment of student notebooks can be found on page 33.

In addition to science notebooks, student worksheets have been included in the guide. Depending on your students' level of independence and familiarity with the scientific process, you may choose to use these worksheets instead of science notebooks. Or, as appropriate, you may want to make copies of worksheets and have your students glue or tape the copies into their notebooks.

Grade Level

- Secondary, grades 9-12

Time

- Six to twenty class periods, depending on the amount of time available, level of students, and activities selected

Internet Resources

Friends of Coal YouTube channel—https://www.youtube.com/channel/UCgDb3VvixohUZ-CBE9suOwQ

Kentucky Coal Resource Information—http://kgs.uky.edu/kgsmap/kcrim/

Kentucky Geological Survey, University of Kentucky—http://www.uky.edu/KGS/coal/

Science News—https://www.sciencenews.org/

U.S. Department of Energy—http://energy.gov

U.S. Department of Energy News and Blog Page—http://energy.gov/news-blog

U.S. Energy Information Administration

Coal page — http://www.eia.gov/coal/

Natural gas page — http://www.eia.gov/naturalgas/

Electricity page — http://www.eia.gov/electricity/

Activity 1: Think, Learn, Question

✪ Objective

- Students will be able to identify basic knowledge about coal and energy.

Materials

- *Think, Learn, Question* worksheet, page 34

Preparation

- Make one copy of the worksheet for each student and one copy for projection and discussion. Alternatively, students may also copy the master into their science notebooks.

✔ Procedure

1. Explain to students that you will be learning about coal, its formation, its use as an energy source, and the social and environmental implications of its use.
2. Distribute one copy of the worksheet to each student or have students create the organizer in his/her science notebook. Have them fill in the first section with facts they think they already know about coal and energy. Have them also add any initial questions they may have to the bottom portion.
3. Upon completion of the unit, re-distribute the page to each student, or have them open to the page in his/her science notebook. Instruct students to think about what they have learned about coal, and fill in the other two sections.

Activity 2: Comparing the Types of Coal

✪ Objectives

- Students will be able to identify and describe the observable properties of different types of coal.
- Students will be able to compare and differentiate between the different types of coal.

Materials *PER GROUP*

- 1 Sample of each type of coal (lignite, subbituminous, bituminous, anthracite) and a sample of peat
- Electronic balance
- Graduated cylinder
- Scratch plate or piece of fine-grit sandpaper
- Distilled water

NOTE*: *Samples of coal can be obtained by contacting the American Coal Foundation, www.teachcoal.org.

Materials *PER STUDENT*

- Colored pencils
- *Comparing the Types of Coal* worksheet, page 56

Preparation

- Gather all the materials for the activity and set up stations for each lab group.
- Make a copy of the worksheet for each student.

CONTINUED ON NEXT PAGE

✔ Procedure

1. Introduce the activity by explaining or reviewing the physical properties of hardness and density.
2. Show each of the types of coal to the students and identify them.
3. As students are working through the activity, circulate to answer questions or correct misconceptions.
4. After students have finished with the activity, use the conclusion questions as a basis for class discussion and an introduction to the next activity.

Extension

- For a challenge, have students determine their type of coal based on the data they collect, rather than identifying each for the class at the start of the activity.

Activity 3: The Properties of Coal

✪ Objective

- Students will be able to determine the percent moisture by mass and percent ash by mass of a given sample of coal.

Materials *PER GROUP*

- Small crucible with lid
- Spatula
- Coal sample
- Mortar & pestle
- Electronic balance
- Bunsen burner
- Ring and ring stand
- Screen or triangle
- Dried 0.5 gram finely ground sample of coal

Materials *PER STUDENT*

- *The Properties of Coal* worksheets, pages 57-58

Materials *FOR THE CLASS*

- Dessicator or drying oven

Preparation

- Gather all the materials for the activity and set up stations for each lab group.
- Ensure that there is adequate fume hood space for all students to be able to complete Part Two of the activity.
- Make copies of the worksheets for each student.

✔ Procedure

1. Introduce the activity by explaining the concepts of moisture content and ash in relation to coal composition. Refer to the student worksheets and the informational text for background information on both moisture and ash content in coal.
2. As students are working through the activity, circulate to answer questions or correct misconceptions.
3. After students have finished with the activity, use the conclusion questions as a basis for class discussion and an introduction to Activity 4.

Activity 4: The Heat Content of Coal

✪ Objective

- Students will be able to describe the heat content of a sample of coal quantitatively and qualitatively as it compares to another hydrocarbon fuel source such as acetylene or methane.

Materials *PER GROUP*

- 2 Rings
- Ring stand
- Bunsen burner
- Small crucible
- Soda can
- 150 mL of Distilled water
- Thermometer
- 2 Gram dried sample of coal (from Activity 3, Part One)

Materials *PER STUDENT*

- *Heat Content of Coal* worksheets, pages 59-60

Preparation

- Gather all the materials for the activity and set up stations for each lab group.
- Ensure that there is adequate fume hood space for all students to be able to complete the activity.
- Make copies of the worksheets for each student.

✔ Procedure

1. Introduce the activity by explaining the heat content in different types of coal. Refer to the student worksheets and the informational text for background information on heat content in coal.
2. As students are working through the activity, circulate to answer questions or correct misconceptions.
3. After students have finished with the activity, use the conclusion questions as a basis for discussion.

Activity 5: Science of Electricity

Objective

- Students will be able to explain how electricity is generated.

Materials *FOR EACH GROUP*

- 1 Small round bottle
- 4 Strong rectangle magnets
- 1 12″ x ¼″ Wooden dowel
- 1 Rubber stopper with ¼″ center hole
- Foam tube
- Spool of magnet wire
- Masking tape
- Permanent marker
- 1 Small nail
- 1 Large nail
- Fine sandpaper
- Multimeter
- Alligator clips
- Sharp scissors
- Ruler
- Hand operated pencil sharpener
- Push pin
- *Science of Electricity Model* instructions, pages 61-63
- *Science of Electricity Model* worksheet, page 64

Preparation

- Gather materials for the activity.
- Make copies of the instructions and the worksheet for students.
- Pre-assemble the model to help students troubleshoot potential assembly issues.

Procedure

1. As a class, review how electricity is generated from previous reading.
2. Assign students to work in groups of four. Using the *Science of Electricity Model* instructions, students should work together to build their own generator. See page 63 for troubleshooting tips for the turbines.
3. After students have tested their generators by spinning them by hand, have them think about other ways that could be used to turn the dowel that would be easier and more consistent.

OPTIONAL: The *Science of Electricity Model* can be constructed ahead of time and used as a demonstration. Students can then be challenged to improve upon the demonstration model.

Extensions

- Provide your students extra time and materials to optimize or improve the design of their generators by using less materials and/or generating more electricity.
- Provide students with extra time and materials to add to their generator, creating a turbine to produce electricity from another source, other than the motion energy of their hands.

Activity 6: Mining Challenge

✪Objective

- Students will be able to describe the process and challenges of mining.

Materials

- 1 Box of wooden toothpicks
- 1 Box of plastic toothpicks
- 20-30 Large paper clips
- Napkins or paper towels
- Play money*
- Chocolate chip cookies**
- *Mining Challenge* worksheets, pages 65-67

***NOTES*:**

*Each team of students will need $105 in play money in varied increments. Extra cash will be needed for the banker.

**A variety of textures of chocolate chip cookies helps to make this activity more authentic. Using a mixture of soft/chewy, hard, large chunk, etc., cookies is suggested. If desired, have enough cookies on hand to complete the activity and extra on-hand for eating. Be sure the cookies used will be safe for students with allergies.

Preparation

- Split the class into teams of 3-5 students.
- Separate the play money for each team so that each group has varied denominations adding up to $105.
- Select 3 students or helpers to serve as the banker, equipment salesman, and realtor.
- Set up work stations or areas where teams can purchase materials and do their mining.
- Make copies of the worksheets for each student.

✔Procedure

1. Pass out the student worksheets for the activity.
2. Preview the rules of the activity and the steps each group will need to follow. Depending on the level of your students, you may choose to have a sample page completed ahead of time to project so students can work through the process and see the calculations they will make.
3. Help teams pick their jobs or roles and determine how many mine sites and tools they want to purchase. Depending on the time available and level of your students, you may recommend that each team only purchase one mine site. If students purchase more, but they will also need extra grid space. If allowing teams to purchase more than one mine (cookie), you may consider giving teams more than the prescribed amount of play money.
4. Hand out cookies as students visit the realtor to purchase their mines. Instruct the teams that these cookies are just for mining and that they should not be eaten until AFTER the activity. Make sure each team maps out their mine on their grid.
5. Direct the teams to begin mining. Keep time for the 1-minute shifts and moderate as teams are determining their earnings and/or buying supplies. Give the signal for when teams should start each shift. Make sure teams are mining only the number of shifts they have selected to mine. You may choose to pre-determine the number of shifts each team will have to do their mining.
6. As teams finish their shifts, remind them to begin the reclamation process. Assist mineral engineers in assessesing fines to their teams.
7. Direct the teams to help their accountant tally up their final balances.
8. Discuss the profits and losses each team faced. Ask students why they might have had losses despite mining plenty of coal. What challenges did they face during mining? What challenges did they face during reclamation?
9. Allow students to eat cookies, if appropriate.

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General Rules of the Challenge:

1. Each team tries to mine the most coal (chocolate chips) from their mine (cookie).
2. Each team member has a job and must keep that job throughout the game.
3. Cookies must be mined with only the tools purchased – NO hands!
4. Teams must mine in 1-minute shifts. No mining should take place between the timed shifts.
5. After each team finishes their shift allotment, they must reclaim the land using their original outline map.
6. Teams should tally up their total costs and earnings to determine net profit/loss.

Jobs:

Banker: Handles all money, gives each team their initial investment. Makes change, collects payroll, and pays out after each shift.

Equipment Salesman: Sells teams their tools before mining and during shifts.

Realtor: Sells teams their mine, hands out cookies.

Mineral Engineer: Purchases mine land from realtor. Determines which tools will be used and purchased. Outlines/maps out their mine land on the grid. Oversees reclamation.

Accountant: Tracks the expenditures and income of the team. Completes the worksheet table and calculates the final balance. Determines how much coal is mined in each shift. Goes to the banker to seek pay.

Miners: Responsible for mining the coal and reclaiming the land.

Finances:

- Each team receives $105 as an initial investment.
- Each mine site (cookie) costs $20.
- Tools have varying costs: wooden toothpick $1, plastic toothpick $2, and paper clip $3.
- Each team must pay EACH miner $15 for each minute-long shift they work. Money will be deposited in the bank until "pay day". This can be paid up-front to the bank or after each round.
- For every ton (square) of coal, teams earn $5 (square must be at least half-full).
- After reclamation, any land outside the original outline of the mine will be assessed a $1 fine for each square.

Activity 7: Mine Reclamation

✪Objective

- Students will be able to explain the principles, process, and challenges of mine reclamation.

Materials *PER STUDENT OR GROUP*

- Aluminum or plastic dish
- Potting mix or other soil
- Small stones and pebbles
- Twigs
- Grass seed
- Squirt bottle with water
- Sunny window ledge (to allow grass seed to grow)
- *Mine Reclamation* worksheets, pages 68-69

Preparation

- Gather materials needed and set up stations for groups to assemble their reclamation site.
- Make copies of the worksheets for each student.
- Secure enough sunny space (outdoors if the weather is warm enough) for trays of seeded soil to sprout and grow.

✔Procedure

1. Introduce the activity, explaining how it models a very important concept of mining today. Refer to the student informational text for more information on reclamation.
2. Discuss the benefits and limitations of models in general, and this one in particular.
3. Circulate and supervise as students complete the activity. It may be helpful to have a broom and dustpan handy for spills.
4. Direct students as to where they should place their trays of soil and seed to allow them to sprout and grow.
5. Monitor the moisture level of the seeded trays to make sure the grass won't die.

Extension

- If one is close enough to your location, take students to a working mine and/or reclaimed mine site. Discuss the similarities between the locations you visit and the models you worked with in class in Activity 6 and 7.

Activity 8: Properties of CO_2

✪ Objective

- Students will be able to identify and describe the properties of carbon dioxide.

Materials

- Plastic trash bags
- 5-10 lbs. of Dry ice (keep in foam cooler until ready to use)
- Work gloves
- Tongs
- Large, clear containers or tubs
- Plastic trays
- Bottles of bubbles
- Bottles of water
- Balloons
- Pipe cleaners
- Tea light candles
- Matches
- Plastic cups
- Safety glasses
- *Properties of CO_2*, page 70

Preparation

- Make copies of the worksheet for students.
- You may conduct this activity as a demonstration, or gather enough containers, gloves, and tongs to allow small groups to work with the dry ice directly.
- Cover work surfaces with the plastic trash bags.

✔ Procedure

1. Review the safety instructions for working with dry ice with the class. For examples of these, check out NEED's *Exploring Climate Change* guide.
2. Place some dry ice on a plastic tray, place the tray of dry ice in the large container.
3. Explain that carbon dioxide (CO_2) is usually found in its gaseous form. However, it also can be found in a solid form and liquid form. Dry ice is frozen CO_2, or CO_2 in solid form.
4. Ask students, "What happens when frozen water warms up?" (It melts and turns into a liquid.) Next ask, "What do you think happens when frozen CO_2 warms up?" Have students record their predictions in their science notebooks. Have students observe the dry ice for a few minutes. Students should record observations using pictures and words in their science notebooks. Ask students to explain what they are seeing. Discuss that CO_2 does not exist as a liquid at standard atmospheric pressure. As frozen CO_2 thaws, or sublimes, it transforms directly into a gas. CO_2 exists as a liquid only under great pressure.
5. Pour water onto the dry ice until CO_2 gas fills the container. Blow bubbles into the large container. Have students record their observations on the *Properties of CO_2* worksheet, and explain what is happening. After students have had time to write down their own thoughts, explain that CO_2 is more dense than air. Since the bubbles are filled with air, they float on top of the CO_2 gas collected in the container.
6. Light a tea light candle. Using the plastic cup, collect some CO_2 gas from the dry ice container and pour it over the tea light. Using the *Properties of CO_2* worksheet, students should record what happens and explain what they saw. Explain that CO_2 displaces lighter oxygen. The CO_2 is heavier than air and pushes the oxygen away. The fire needs oxygen to continue burning so the fire is extinguished. This is why CO_2 is used in fire extinguishers.
7. Drop an ice cube sized piece of dry ice into a bottle of water. Place a balloon over the mouth of the water bottle. Use a pipe cleaner as a twist tie around the balloon, if needed. Students should record observations on their *Properties of CO_2* worksheets and explain what happened.

Activity 9: Enhanced Fuel Recovery Model

✪ Objective

- Students will be able to describe how carbon dioxide can be used to retrieve additional oil from a reservoir.

Materials *FOR DEMONSTRATION*

- Clear glass jar with tight lid
- Water
- Marbles
- Pebbles
- Stones
- 150 mL Colored lamp oil or vegetable oil

Materials *FOR THE CLASS*

- *Enhanced Fuel Recovery Model* worksheet, page 71 or 72
- Safety glasses

Materials *OPTION A: PER GROUP*

- 2 Mason jars with lids
- 2 Pieces of 24” by ¼” tubing
- 150 mL Vegetable oil or lamp oil
- 350 mL Water
- 1 Empty water bottle
- 1 Dark colored food dye
- 1 Piece of dry ice, about the size of an ice cube
- Assorted rocks, sand, and marbles
- Drill
- Tongs
- Silicon sealant
- Tape

Materials *OPTION B: PER GROUP*

- 2 Mason jars with lids
- 2 Pieces of 24” by ¼” tubing
- 150 mL Vegetable oil or lamp oil
- 350 mL Water
- 1 Empty water bottle
- 1 Dark colored food dye
- 6 Effervescent tablets
- Assorted rocks, sand, and marbles
- Drill
- Tongs
- Silicon sealant
- Piece of tissue paper
- Tape

Preparation *FOR THE DEMONSTRATION*

- Fill the jar with marbles, stones, and pebbles.
- Add 150 mL of lamp oil or vegetable oil. This represents crude oil.
- Fill the rest of the jar with water.
- Put the lid on and secure tightly.

Preparation *FOR THE STUDENT LAB*

- Drill ¼” holes in the lids to the mason jars. Each small group will need one jar with two holes in the lid, and one jar with one hole in the lid.
- Choose option A or B to complete the activity based on your preference and access to the materials. Option A calls for a piece of dry ice to generate carbon dioxide to force liquids from the reservoir containing the sand, pebbles, marbles, water, and oil. If dry ice is not available, effervescent tablets can be substituted in option B.
- If selecting option A, review safety instructions for dry ice as a class prior to beginning the activity.
- Make a copy of the applicable worksheet for each student.

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✔ Procedure

1. Show the class the demonstration jar you have made. Tell the students that this is a model of an oil reservoir, magnified many times over.
2. Oil (the colored oil) is trapped within the pore space of rocks.
3. Gently shake the jar and show students how the oil is trapped among the rocks. Pass the jar around to the class. Explain that there are many places in North America where oil and natural gas are trapped due to geology or other reasons.
4. Review Carbon Capture, Utilization, and Storage in the *Student Informational Text*. Explain to students that they are going to build their own model of an enhanced fuel recovery system like those used for oil recovery at a reservoir.
5. Divide students into small groups. Pass out the *Enhanced Fuel Recovery Model* worksheets for the option you selected and go over the assignment. Remind students of the safety rules for handling dry ice, if necessary. Circulate around the room and assist students as needed.

NOTE: *This is a model of the enhanced fuel recovery process. Students are using CO_2 in gas form to pump out the oil in their model reservoir. In actual practice, CO_2 is pressurized and injected into the reservoir as a liquid. Geologic pressure keeps the CO_2 in liquid form.*

Extension

- What other materials could you use to retrieve the oil from your reservoir? Design and test your experiment.

Activity 10: Geographical Electric Connections

✪ Objective

- Students will be able to describe the energy sources used to generate electricity in their state.

Materials

- *Electric Connections* worksheets, pages 73-76
- Computer and internet access

Preparation

- Make copies of the worksheets for each student.
- Select the state(s) your student will research for comparison ahead of time. If desired, assign a different state to each student in the class to facilitate a richer discussion.

✔ Procedure

1. Lead students through *Electric Connections* as a group for the U.S.
2. Allow time for students to use computers to access the EIA website and answer the questions on the geographical activity page.
3. When students have finished working, bring them back together as a group and discuss the results of the activity.

Extension

- Use a map of your state and other states, and compare the location of power plants and other infrastructure to the locations of major highways, railroads, and population centers.

☑ Electric Connections Answer Key

Biomass - 6	Hydropower - 4	Propane - 10	Wind - 5
Coal - 1	Natural Gas - 2	Solar - 7	
Geothermal - 9	Petroleum - 8	Uranium - 3	

Activity 11: Electric Bill Analysis

✪Objective

- Students will be able to describe how electricity and natural gas are measured and how their costs are calculated.

Materials

- *Sample Bill Explanation Key,* page 77
- *Sample School Electric Bill,* page 78
- *Sample School Natural Gas Bill,* page 79

Preparation

- Make copies of the worksheets for each student.
- If desired, obtain a copy of your school's actual utility bills from the business office of your school district.

✔Procedure

1. Discuss the utilities that your school uses. As a class, create a list of all of the items in the classroom that use electricity. Explain to students that schools pay a good amount of money in utility costs each month to keep the building at a comfortable temperature and to provide power for devices, warm water for cooking and in the restrooms, etc.
2. Discuss how electricity and natural gas are measured and monitored, and review the following terms with the class: therm, Ccf, and kilowatt-hour. Define any terms that are unfamiliar to students.
3. Explain that one way to monitor energy use is by reading utility bills. Have the students review the *Sample Bill Explanation Key* and sample school utility bills.
4. Discuss as a class the amount of energy used by the school during the billing period. Discuss how these bills might vary at other times of the year. Discuss what sources students think provide the energy for their school to run.

Activity 12: Careers in the Coal Industry

Objectives

- Students will be able to describe the careers available in the coal industry.
- Students will be able to construct a résumé.

Materials

- Computer and printer access
- Internet and/or library access
- University or career center input (optional)
- *Careers in the Coal Industry* worksheet, page 80
- *Résumé Template*, page 81

Preparation

- Consult with local universities or technical educational centers in your area to see which careers in the coal industry are most important locally.
- Coordinate with a librarian to make sure your students have access to appropriate resources and use appropriate search tools to conduct their research.
- Prepare a copy of the worksheet and template for each student or copies to project for the class.

Procedure

1. Introduce the activity, explaining the different levels and types of educational requirements.
2. Be prepared to offer alternative key words to students as they look for occupations. Students sometimes have a difficult time constructing a search to get the desired information.
3. Review the résumé template as a class and discuss the important features. Explain to the class that they may provide a printed version like the template or submit a digital copy, depending on your preference.

Extensions

- Ask a guidance counselor or career counselor to speak to your students about preparing for careers in the coal industry and résumé writing.
- Invite coal industry employees into your classroom to discuss their own career paths and their current job responsibilities.

Activity 13: Analyzing Graphical Information

Objective

- Students will be able to interpret information presented on a variety of graphical representations.

Materials

- *Analyzing Graphical Information* worksheets, pages 82-83
- *U.S. Coal Flow, 2015* master, page 35
- Internet access (optional)

Preparation

- Make copies of the worksheets for each student.
- Prepare a copy of the coal flow master to project.
- Familiarize yourself with the mathematics of the coal flow portion of the activity before discussing with your students.

Procedure

1. Introduce the activity, describing the different types of graphs and the type of data each is used to represent.
2. Have students work through the first part of the activity individually.
3. Project the coal flow master and provide an appropriate amount of assistance to students as they answer the related questions on their worksheets.

Extensions

- Visit the EIA website (www.eia.gov) for additional graphs and charts for your students. There are other energy source flow charts, and an electricity flow graphic that your students can also interpret.
- Have students take the information in one of the graphs they interpreted and represent the data in another way or using a different type of graph.
- Print data specific to your state from the EIA website and have your students represent it graphically. Students will probably come up with several different ways to represent the same data set. Have your students present their graphs to the class and discuss why they chose that format.

Activity 14: Coal in Kentucky

Background

For many years Kentucky has been one of the top coal producing states in the country. Kentucky has access to a lot of coal but does not have the ability to use some of the other resources for electricity generation that other states do. Students will analyze Kentucky maps to put coal formation, production, and use into context.

Objective

- Students will be able to interpret symbols and scale represented on different types of maps.

Materials

- Computer and internet access
- Map of your state
- *Coal in Kentucky* worksheet, page 84

Preparation

- Gather the materials and make a copy of the worksheet for each student.
- Preview the website to be familiar with its use and information given, http://kgs.uky.edu/kgs/map/kcrim/.

✔ Procedure

1. Introduce the activity to students by explaining the map and what it shows. Explain to students that different types of maps provide different types of information.
2. Discuss the differences between eastern and western Kentucky. Discuss with students how these differences are represented on the map.

Activity 15: Baseload Balance

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.

CONTINUED ON NEXT PAGE

Materials

- Scissors and tape for each student or small group
- String
- Rope
- Colored paper
- Individual marker boards with erasers and markers
- *Baseload Balance Student Information*, pages 85-86
- Game board for each student or small group, pages 88-89
- Game pieces for each student or small group, pages 90-91
- *Generation Parameters* master, page 92
- Hang tags, pages 93-97
- *Incident Cards*, page 98
- *Cheat Sheet*, page 99

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.
- 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.

✔ Procedure *FOR INDIVIDUAL / SMALL GROUP PLAY*

1. Distribute a game board and game pieces to each student or small group of students.
2. Explain the game board, and what each section represents. Explain that the x-axis shows the 24 hours of a typical day, and the y-axis shows the amount of electric power in demand.
3. Explain the game pieces by describing each energy source, the amount of power being generated, and the difference between baseload and peak load.
4. Instruct the students to cut the game pieces apart.
5. Students are to “meet demand” by laying their game pieces over the game board, starting first with baseload generation, using it to meet baseload demand. They can make small tape rings to hold their pieces in place on the game board, as needed.

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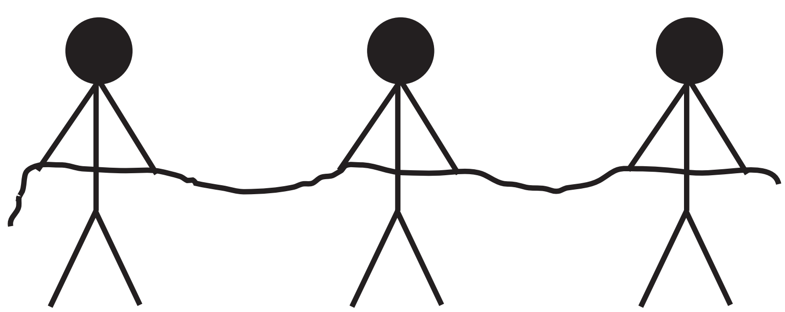
6. To meet peak demand, students should trim their game pieces to cover the peak demand shown on the game board, maintaining the information on each piece (trim the blank areas first).
7. At the bottom of the game board, students can calculate the cost of electric power generation by adding the costs of the generating supply for that hour, if desired. Students can then calculate the average cost per megawatt-hour to generate electricity in that 24-hour period.

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 *FOR SIMULATION ACTIVITY*

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 24. 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.



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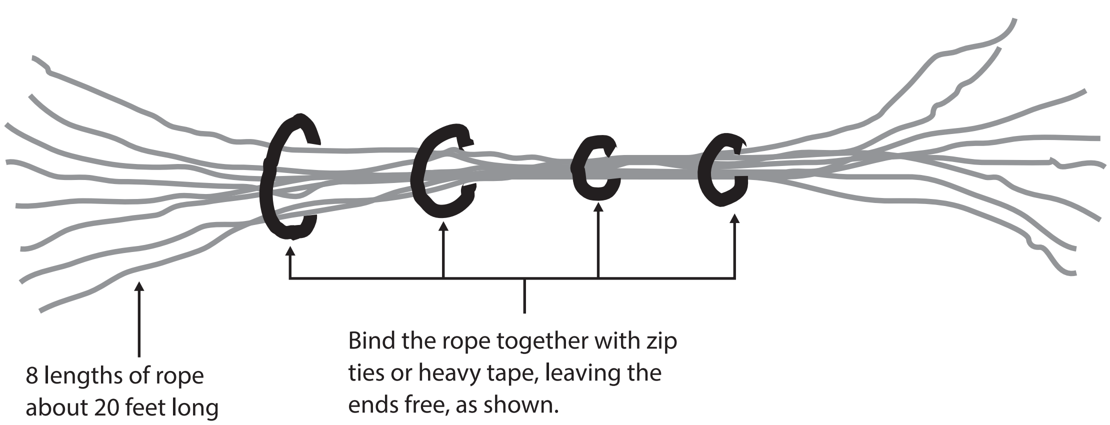
6. At the appropriate time indicated on each hang tag, each load student will join the grid, increasing the load demand. Residential demand comes up (online) at about 7:00 a.m. as people begin to wake. Demand continues to rise as more residential, commercial, and industry come on the grid, pulling electricity 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.
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. 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 below). 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).



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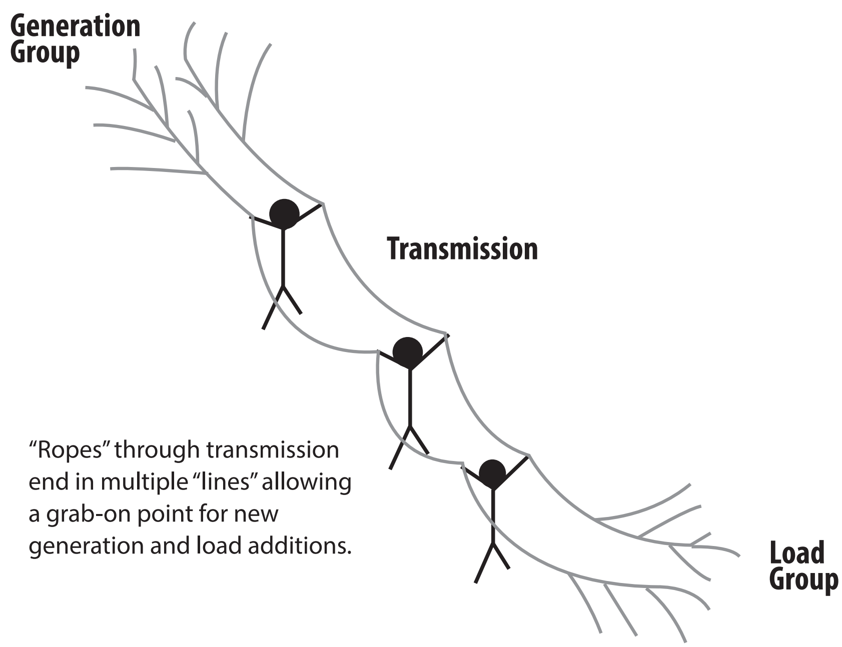


Activity 16: Coal Tree Research Activity

✪Objective

- Students will be able to list products that can be produced from coal.

Materials

- Computer and internet access
- *Coal Tree* master, page 36

Preparation

- Make a copy of the *Coal Tree* master for each student.
- Familiarize yourself with any unfamiliar terms on the graphic.

✔Procedure

1. Explain to students that while coal is used primarily as a fuel to generate electricity, there are many other things for which coal can be used.
2. Discuss each of the major product types listed, and explain that the uses listed at the base of the tree, with the largest "branches," are the most prevalent uses for coal, with the amount of coal used for each decreasing as you move up the tree trunk.
3. Allow students some time to read about the different products and select one. If desired, ensure that each student has selected a different item with no repeated items.
4. Instruct students to research the selected product and how coal is used in its production.
5. Have students report their findings in a short oral report or digital/multimedia format of your choice.

Extension

- Have students write balanced chemical reaction equations for the products they report on. Ask them to identify components such as reaction type, reactants, products, etc., as appropriate within the context of your classroom.

Activity 17: Coal Plant Conundrum

✪ Objectives

- Students will be able to explain how decisions are made regarding power plant fuel type.
- Students will be able to participate in a discussion using a debate format, supporting and defending their viewpoints and reaching a consensus as necessary.

Materials

- Computer and internet access
- *Coal Plant Conundrum* worksheets, pages 100-101
- *Debate Graphic Organizer*, page 102

Preparation

- Familiarize yourself with the activity and the roles listed.
- Decide which role you will assign to each student.
- Make copies of the worksheets for each student.
- Assign students or recruit a group of adults to act as the panelists for WattsUp.

✔ Procedure

1. Introduce the activity and explain that each student will adopt the perspective of the role to which they are assigned. Advise students that they may be asked to take a viewpoint that differs from their own actual opinion.
2. Provide ground rules for the debate and discussion format, or set the rules as a class.
3. Explain that each student will have 3 minutes to present his or her character's point-of-view on the issue.
4. Give a brief introduction to bias in reporting. Instruct students on how to find good information and how to detect overtly biased reporting. Encourage students to consult objective, unbiased sources as much as possible.
5. Give students time to research their viewpoint.
6. Conduct the debate, allowing students to present their viewpoints to the panel. Evaluate each student on his/her presentation. A sample rubric is provided on page 33.
7. After each role has presented their viewpoint, have the panel from WattsUp make their decision.
8. Discuss as a class what factors go into decision making of this type, and how they think their opinions might have shaped the decision of the panel. What were the challenges of presenting their viewpoints?

Extension

- Have students research and locate real-world scenarios similar to this one in your area. Ask students to write an opinion essay or persuasive letter to an official about the topic.

Activity 18: Life Cycle of Coal

Objective

- Students will be able to describe the entire life cycle of the energy in coal, from origin in the sun's core through to end use in a home.

Materials

- Art supplies
- Assorted props
- List of terms for each group (see below)
- *Student Informational Text*, pages 37-51

Preparation

- Assemble a group of possible props for students to use, such as yellow ribbon, plastic or silk plants, plastic tubing, magnets, wire, etc.

Procedure

1. Divide students into four groups. Assign one portion of the activity – formation, mining, electricity generation, or electricity use and transmission – to each group.
2. Allow time for students to do research about their section using the informational text or outside resources.
3. Instruct students to generate a script with motions or actions that fully illustrates and acts out their portion of the life cycle of coal. Provide the list of terms to each group relevant to their section of the activity as shown below.
4. Designate props and supplies available to students to use for this activity, or allow them to create their own. Make suggestions of other items they could bring from home.
5. Allow some time for the groups to work together to develop a uniform, cohesive script and program that incorporates all four stages into one.
6. If your school and/or district allow, have your students perform their script for a group of younger students.

List of Terms

Formation
- anthracite
- bituminous
- lignite
- mire
- nuclear fusion
- peat
- photosynthesis
- pressure
- radiant energy
- sediment
- stagnant

Mining
- banded
- blocky
- conveyor
- mine shaft
- nonbanded
- reclamation
- seam
- surface
- transport(ation)

Electricity Generation
- acid rain
- alternating current
- coils
- conductor
- flue gases
- furnace
- insulator
- magnet
- scrubbers
- steam
- turbine
- voltage

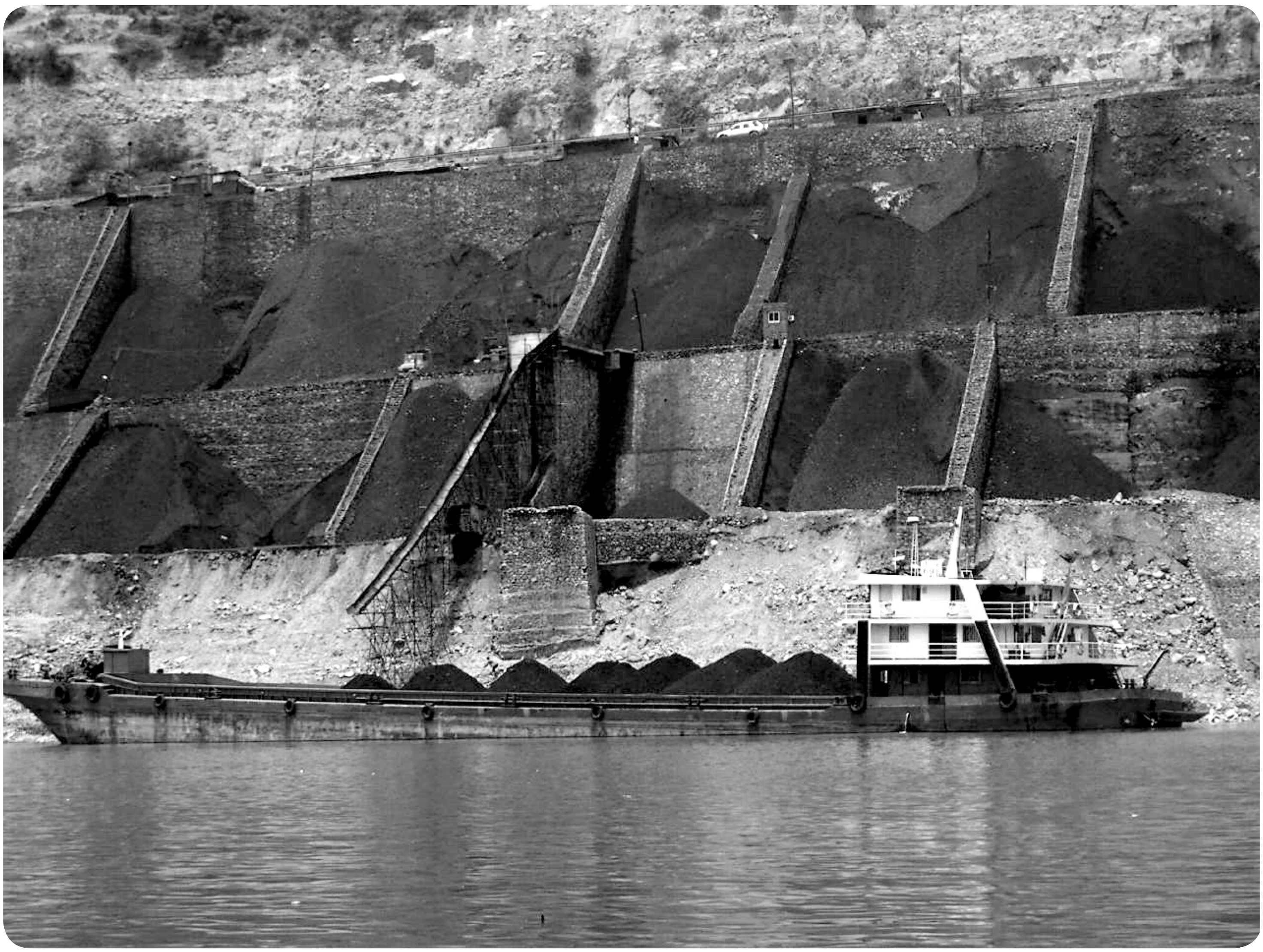
Electricity Use and Transmission
- ampere
- circuit
- electrical panel
- high-voltage line
- meter
- step-down
- step-up
- transformer
- volt
- watt

Extension

- If desired, have students research other uses of coal, such as cement manufacturing and in the steel industry, and prepare a script with props as was done with electricity generation.

☑Evaluation

- Answer keys for selected activities are provided on page 32.
- Evaluate student work on activities using the rubrics provided on page 33.
- Play *Coal Bingo* or *Coal in the Round* as formative assessments. Instructions can be found on pages 29-31.
- Have students complete the *Coal Assessment* on pages 103-104 as a summative assessment. Answers are provided on page 32.
- Evaluate the unit with your students using the *Evaluation Form* on page 115, and return it to NEED.



Coal Hopper with Barge
Photo courtesy of Rob Loftis via wikimedia commons

Coal BINGO Instructions

Get Ready

Duplicate as many *Coal Bingo* sheets (found on page 105) as needed for each person in your group. In addition, decide now if you want to give the winner of your game a prize and what the prize will be.

Get Set

Pass out one *Coal Bingo* sheet to each member of the group.

Go

PART ONE: FILLING IN THE BINGO SHEETS

Give the group the following instructions to create bingo cards:

- This bingo activity is very similar to regular bingo. However, there are a few things you'll need to know to play this game. First, please take a minute to look at your bingo sheet and read the 16 statements at the top of the page. Shortly, you'll be going around the room trying to find 16 people about whom the statements are true so you can write their names in one of the 16 boxes.
- When I give you the signal, you'll get up and ask a person if a statement at the top of your bingo sheet is true for them. If the person gives what you believe is a correct response, write the person's name in the corresponding box on the lower part of the page. For example, if you ask a person question "D" and he or she gives you what you think is a correct response, then go ahead and write the person's name in box D. A correct response is important because later on, if you get bingo, that person will be asked to answer the question correctly in front of the group. If he or she can't answer the question correctly, then you lose bingo. So, if someone gives you an incorrect answer, ask someone else! Don't use your name for one of the boxes or use the same person's name twice.
- Try to fill all 16 boxes in the next 20 minutes. This will increase your chances of winning. After the 20 minutes are up, please sit down and I will begin asking players to stand up and give their names. Are there any questions? You'll now have 20 minutes. Go!
- During the next 20 minutes, move around the room to assist the players. Every five minutes or so tell the players how many minutes are remaining in the game. Give the players a warning when just a minute or two remains. When the 20 minutes are up, stop the players and ask them to be seated.

PART TWO: PLAYING BINGO

Give the class the following instructions to play the game:

- When I point to you, please stand up and in a LOUD and CLEAR voice give us your name. Now, if anyone has the name of the person I call on, put a big "X" in the box with that person's name. When you get four names in a row—across, down, or diagonally—shout "Bingo!" Then I'll ask you to come up front to verify your results.
- Let's start off with you (point to a player in the group). Please stand and give us your name. (Player gives name. Let's say the player's name was "Joe.") Okay, players, if any of you have Joe's name in one of your boxes, go ahead and put an "X" through that box.
- When the first player shouts "Bingo," ask him (or her) to come to the front of the room. Ask him to give his name. Then ask him to tell the group how his bingo run was made, e.g., down from A to M, across from E to H, and so on.

***Coal Bingo* is a great icebreaker for a NEED workshop or conference. As a classroom activity, it also makes a great introduction to an energy unit.**

Preparation

- 5 minutes

Time

- 45 minutes

Bingos are available on several different topics. Check out these resources for more bingo options! All are available for free download at www.NEED.org.

- Biomass Bingo—*Energy Stories and More*
- Change a Light Bingo—*Energy Conservation Contract*
- Energy Bingo—*Energy Games and Icebreakers*
- Energy Efficiency Bingo—*Monitoring and Mentoring* and *Learning and Conserving*
- Hydrogen Bingo—*H_2 Educate*
- Hydropower Bingo—Hydropower guides
- Nuclear Energy Bingo—Nuclear guides
- Oil and Natural Gas Bingo—Oil and Natural Gas guides
- Solar Bingo—Solar guides
- Transportation Bingo—Transportation guides
- Wind Energy Bingo—Wind guides

- Now you need to verify the bingo winner's results. Ask the bingo winner to call out the first person's name on his bingo run. That player then stands and the bingo winner asks him the question which he previously answered during the 20-minute session. For example, if the statement was "can name two renewable sources of energy," the player must now name two sources. If he can answer the question correctly, the bingo winner calls out the next person's name on his bingo run. However, if he does not answer the question correctly, the bingo winner does not have bingo after all and must sit down with the rest of the players. You should continue to point to players until another person yells "Bingo."

COAL BINGO

ANSWERS

A. Knows what type of rock coal is

B. Can explain the purpose of clean coal technology

C. Can name three of the top five coal producing states

D. Knows what is compressed over time to form coal

E. Knows the top two uses of coal

F. Can name two types of coal

G. Can name the country with the most coal reserves

H. Can name one of the two types of coal mining

I. Can name one of the factors leading to the formation of coal

J. Can name one advantage and one disadvantage of using coal

K. Knows how most coal is transported

L. Knows the form of energy stored in coal

M. Has seen a coal mine

N. Has never seen coal

O. Knows the element in coal that contributes to acid rain

P. Knows the greenhouse gas released when coal is burned

A Organic sedimentary	**B** Removes pollutants (sulfur, NOx) before, during, and after burning	**C** Wyoming, West Virginia, Kentucky, Illinois, Pennsylvania	**D** Peat
E Electricity generation Non-CHP(combined heat and power) Industry	**F** Anthracite Bituminous Subbituminous Lignite	**G** United States	**H** Surface mining Deep mining
I Time Heat Pressure Originates with stagnant water / swamp	**J** **Advantage:** energy density, supply, domestic **Disadvantage:** Pollution, greenhouse gases, mine safety	**K** Railroad car	**L** Chemical energy
M Ask for details	**N**	**O** Sulfur	**P** CO_2

Coal in the Round Instructions

Get Ready

- Copy one set of the *Coal in the Round Cards* on pages 106-108 on cardstock and cut into individual cards.
- Have the student informational text or a class set of the *Secondary Energy Infobooks* available for quick reference.

Get Set

- Distribute one card to each student. If you have cards left over, give some students two cards so that all of the cards are distributed.
- Have the students look at their bolded words at the top of the cards. Give them five minutes to review the information about their words using the informational text or *Secondary Energy Infobooks*.

Go

- Choose a student to begin and give the following instructions:
  - Read the question on your card. The student with the correct answer will stand up and read the bolded answer, "I have ______."
  - That student will then read the question on his/her card, and the round will continue until the first student stands up and answers a question, signaling the end of the round.
- If there is a disagreement about the correct answer, have the students listen to the question carefully looking for key words (forms versus sources, for example) and discuss until a consensus is reached about the correct answer.

ANSWER KEY

STARTING WITH ANTHRACITE CLUE:

BITUMINOUS
CHEMICAL ENERGY
CLARAIN
COKE
DURAIN
ELECTRICITY
ENERGY DENSITY
EQUILIBRIUM
FUSAIN
GASIFICATION
HYDROCARBON
LAW OF CONSERVATION OF ENERGY/MATTER
LIGNITE
LONGWALL MINING
MACERALS
METHANE
MOUNTAINTOP REMOVAL
OVERBURDEN
PEAT
RANK
RECLAMATION
ROOM-AND-PILLAR MINING
STAGED COMBUSTION
SUBBITUMINOUS
SURFACE MINING
THERMAL POWER PLANT
TURBINE
UNDERGROUND MINING
VITRAIN

***Coal in the Round* is a quick, entertaining game to reinforce information about energy sources, forms of energy, and general energy information from the *Student Informational Text*.**

Preparation

- 10 minutes

Time

- 20–30 minutes

Alternative Instructions

- Give each student or pair a set of cards.
- Students will put the cards in order, taping or arranging each card so that the answer is directly under the question.
- Have students connect the cards to fit in a circle or have them arrange them in a column.

"In the Rounds" are available on several different topics. Check out these resources for more, fun "In the Round" examples! All are available for free download at www.NEED.org.

- Energy in the Round—*Energy Games and Icebreakers*
- Hydrogen in the Round—*H_2 Educate*
- Conservation in the Round—*Monitoring and Mentoring, Learning and Conserving*
- Oil and Natural Gas Industry in the Round—*Fossil Fuels to Products, Exploring Oil and Natural Gas*
- Uranium in the Round—Nuclear guides
- Solar Energy in the Round—*Energy From the Sun*
- Transportation Fuels in the Round—Transportation guides

Answer Keys

Analyzing Graphical Information, Part 1, page 82

1. Coal production over time, and coal production projections.
2. It shows continuous change over time. Line graphs are used to show change over time.
3. Varies by student, but could include things like the total coal production decreased between 2000 and 2016, or coal is expected to remain about the same in the future, depending on oil and natural gas supplies.
4. Answers will vary by student.

Analyzing Graphical Information, Part 2, page 83

1. 44.1%
2. 920.57 million short tons
3. Anthracite requires the most time to form, and is the oldest. Therefore, not much can be found. One of the only known locations for mining anthracite is in northeastern Pennsylvania.
4. steel making, cement production, etc.

Coal in Kentucky, page 84

1. 10 2. 40 3. 27 4. 17 5. 18 6. Ohio River 7. 20 8. 11

Coal Assessment, pages 103-104

1. lignite, subbituminous, bituminous, anthracite; arrow points from lignite to anthracite
2. banding, hardness, shininess
3. liptinite, vitrinite, inertinite
4. Macroscopic characteristics are determined with the naked eye or a simple hand-held magnifying lens. Microscopic characteristics can only be seen with a microscope.
5. Coal is ground, weighed, and placed in an oven at 100-110 degrees Celsius. After drying, the coal is weighed again.
6. If dried coal is not used, the moisture factors into the total mass of the coal, and does not give an accurate percentage for the ash content. Ash content will be reported lower than it really is.
7. Scrubbers, staged combustion, washing, fluidized bed combustion, gasification
8. Diagrams will vary by student, but should accurately depict a mine shaft, coal seam, and longwall mining and room-and-pillar mining differently.
9. Coke used in steel production; cement production; liquid fuels; carbon-containing chemicals
10. Mercury, sulfur, and nitrogen emissions; particulate matter in emissions; greenhouse gas emissions; culm mitigation; reclamation; acid mine runoff.
11. Coal is burned and the thermal energy boils water into high-pressure steam. The steam turns a turbine, which moves coils of wire within a magnetic field. Electric current is induced in the coils, and the electricity is sent through transmission lines to homes and businesses. The high-pressure steam is cooled and the process starts over again.
12. Reclamation must be planned before a mine is approved and operations begin. After mining is complete, the land is contoured, and overburden and topsoil are replaced. Finally, vegetation is planted and the site is monitored for several years to ensure complete reclamation has occurred and acid runoff is not occurring.
13. Answers will vary by student.

Rubrics for Assessment

Inquiry Explorations Rubric

This is a sample rubric that can be used with inquiry investigations and science notebooks. You may choose to only assess one area at a time, or look at an investigation as a whole. It is suggested that you share this rubric with students and discuss the different components.

	SCIENTIFIC CONCEPTS	SCIENTIFIC INQUIRY	DATA/OBSERVATIONS	CONCLUSIONS
4	Written explanations illustrate accurate and thorough understanding of scientific concepts.	The student independently conducts investigations and designs and carries out his or her own investigations.	Comprehensive data is collected and thorough observations are made. Diagrams, charts, tables, and graphs are used appropriately. Data and observations are presented clearly and neatly with appropriate labels.	The student clearly communicates what was learned and uses strong evidence to support reasoning. The conclusion includes application to real life situations.
3	Written explanations illustrate an accurate understanding of most scientific concepts.	The student follows procedures accurately to conduct given investigations, begins to design his or her own investigations.	Necessary data is collected. Observations are recorded. Diagrams, charts, tables, and graphs are used appropriately most of the time. Data is presented clearly.	The student communicates what was learned and uses some evidence to support reasoning.
2	Written explanations illustrate a limited understanding of scientific concepts.	The student may not conduct an investigation completely, parts of the inquiry process are missing.	Some data is collected. The student may lean more heavily on observations. Diagrams, charts, tables, and graphs may be used inappropriately or have some missing information.	The student communicates what was learned but is missing evidence to support reasoning.
1	Written explanations illustrate an inaccurate understanding of scientific concepts.	The student needs significant support to conduct an investigation.	Data and/or observations are missing or inaccurate.	The conclusion is missing or inaccurate.

Group Work or Culminating Projects Rubric

This rubric may be used or adapted for assessing group work or individual work on projects such as the résumé, *Coal Tree Research Activity*, or *Coal Plant Conundrum*.

	CONTENT	ORGANIZATION	ORIGINALITY	WORKLOAD
4	Project covers the topic in-depth with many details and examples. Subject knowledge is excellent.	Content is very well organized and presented in a logical sequence.	Project shows much original thought. Ideas are creative and inventive.	The workload is divided and shared equally by all members of the group.
3	Project includes essential information about the topic. Subject knowledge is accurate.	Content is organized in a logical sequence.	Project shows some original work. Work shows new ideas and insights.	The workload is divided and shared fairly equally by all group members, but workloads may vary.
2	Project includes essential information about the topic, but there are 1-2 factual errors.	Content is logically organized but may have a few confusing sections.	Project provides essential information, but there is little evidence of original thinking.	The workload is divided, but one person in the group is viewed as not doing a fair share of the work.
1	Project includes minimal information or there are several factual errors.	There is no clear organizational structure, just a compilation of facts.	Project provides some essential information, but no original thought.	The workload is not divided, or it is evident that one person is doing a significant amount of the work.

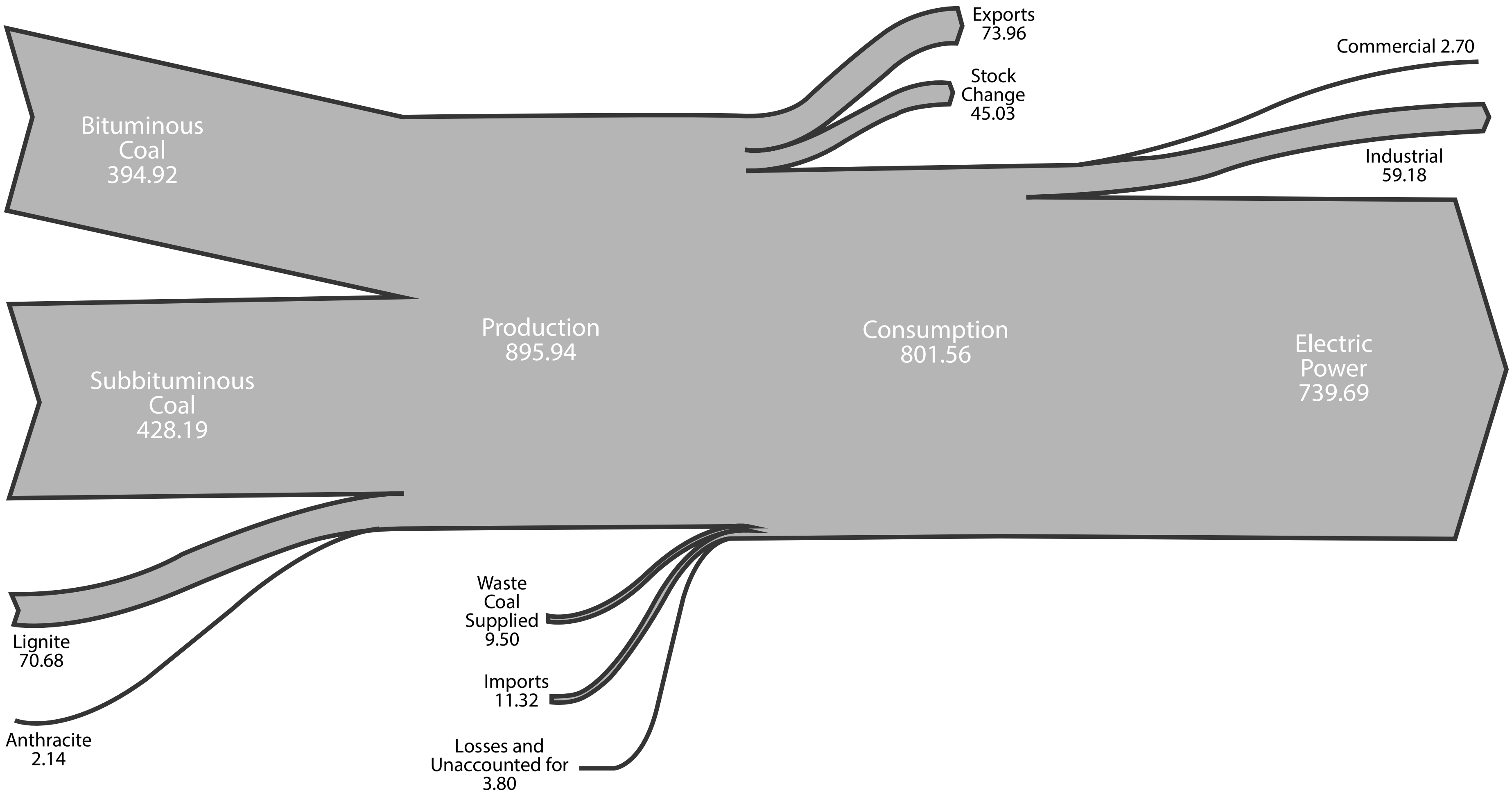
Think, Learn, Question

What Do I Think I Know About Coal?	What Have I Learned About Coal?

What New Questions Do I Have About Coal?

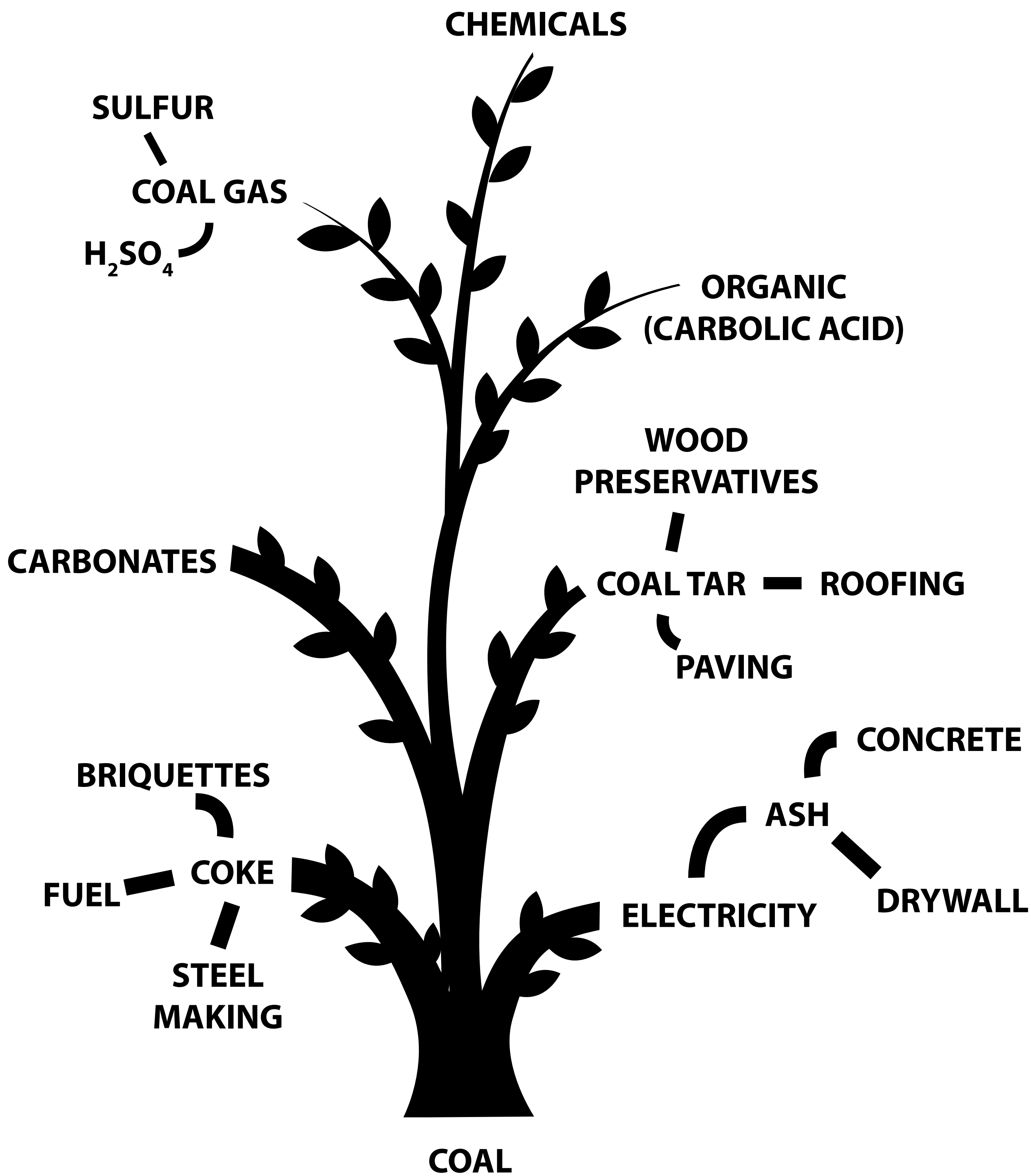
U.S. Coal Flow, 2015

(MILLION SHORT TONS)



*Totals may not equal sum of components due to independent rounding.
Data: U.S. Energy Information Administration, Monthly Energy Review

Coal Tree


CHEMICALS
SULFUR
COAL GAS
H_2SO_4
ORGANIC
(CARBOLIC ACID)
WOOD
PRESERVATIVES
CARBONATES
COAL TAR
ROOFING
PAVING
CONCRETE
BRIQUETTES
ASH
COKE
FUEL
DRYWALL
ELECTRICITY
STEEL
MAKING
COAL

Student Informational Text

What is Energy?

Energy allows us to do the things we do every day. Transportation, cooking, even the functioning of your body are all dependent upon energy. Energy changes forms, can be stored, and is almost always in flux.

Energy is defined as the ability to do work or produce change. Energy can be stored, and we refer to it as potential energy. When it is currently in use, it is called kinetic energy.

Forms of Energy

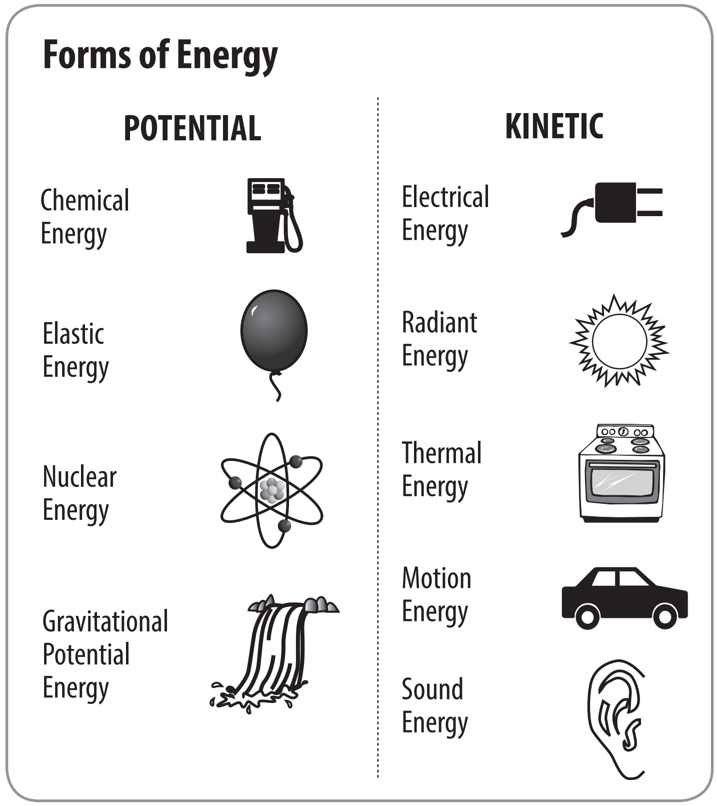
There are many forms of energy but they are all categorized as potential or kinetic energy.

POTENTIAL ENERGY

Stored energy and the energy of position are referred to as **potential energy.**

- **Chemical energy** is stored in the bonds between atoms in molecules. The energy is released when the bonds between molecules are broken. Biomass, petroleum, natural gas, and propane are sources with stored chemical energy.

  During **photosynthesis**, sunlight gives plants the energy they need to build complex chemical compounds. When these compounds are later broken down, the stored chemical energy is released as thermal energy, radiant energy, motion energy, and sound.
- **Elastic energy** is stored in objects by the application of a force. Compressed springs and stretched rubber bands are examples of elastic energy.
- **Nuclear energy** is stored in the nucleus of an atom. The energy that binds the nucleus together can be released when the nuclei are combined or split apart. Nuclear power plants split the nuclei of uranium atoms in a process called **fission**. The sun combines the nuclei of hydrogen isotopes to form helium nuclei in a process called **fusion**. In both fission and fusion, mass is converted into energy according to Einstein's equation, $E=mc^2$.
- **Gravitational potential energy** is the energy of position or place. A rock resting at the top of a hill contains gravitational potential energy because of its position. Hydropower generated from water held in a reservoir behind a dam uses gravitational potential energy to produce electricity.



KINETIC ENERGY

The motion of waves, electrons, atoms, molecules, substances, and objects are all classified as **kinetic energy**.

- **Electrical energy** is the movement of electrons. Everything is made of tiny particles called atoms. Atoms are made of even smaller particles called electrons, protons, and neutrons. Protons and neutrons remain relatively stationary in the atom, but electrons move, and when energized they can move to another location. Those electrons transferring energy in one direction in a wire are called **electricity**. Lightning is another example of electrical energy.
- **Radiant energy** is electromagnetic energy that travels in **transverse** waves. Radiant energy includes visible light, x-rays, gamma rays, and radio waves. **Solar energy** is an example of radiant energy.
- **Thermal energy**, also called heat, is the internal energy causing the atoms and molecules of substances to move and vibrate. The faster molecules and atoms vibrate and move within a substance, the more thermal energy present and the hotter they become. **Geothermal** energy is an example of thermal energy.
- **Motion energy** is the movement of objects and substances from one place to another. According to Newton's Laws of Motion, objects and substances move when an unbalanced force is applied. Energy from wind uses motion energy. Motion energy is often also referred to as mechanical or simply, kinetic energy.
- **Sound energy** is the movement of energy through substances in **longitudinal** waves, also called compression or rarefaction waves. Sound is produced when a force causes an object or substance to vibrate. The energy is transferred through the substance in a wave.

Conservation of Energy

Scientists and parents have different meanings when they discuss energy conservation. Your parents want you to conserve, or use less, energy to keep utility costs low. Scientists, however, know that the amount of energy in the universe remains constant; it is conserved. This is known as the **Law of Conservation of Energy**, and it states that energy is neither created nor destroyed, but merely changing form.

When we use energy, we do not use it completely – we just change its form. That is what we mean when we say we are using energy. We change, or transform, one form of energy into another. When a car engine burns gasoline, it is changing the chemical energy in the gasoline into kinetic energy in the movement of the engine, the wheels of the car, and ultimately the car itself. Much of the energy of the gasoline is also transformed into thermal energy, making the car engine hot.

Energy, like matter, cannot be created or destroyed. If you boil a gallon of water, it does not disappear, it just becomes water vapor in the atmosphere. Likewise, if you burn a few pieces of wood in your fireplace, they do not disappear but instead become water vapor, carbon dioxide, and other gases, plus the ash that remains after the fire goes out. The thermal and radiant energy from burning wood are released when the bonds in the wood itself are broken.

Sometimes, it appears that energy has been created from nothing, or that mass has been lost. This occurs when nuclear energy is being used, and is the result of a small amount of mass in the nucleus of an atom being changed into enormous amounts of energy. This occurs on a very small scale when uranium is fissioned in a nuclear power plant, and on an extremely large scale when hydrogen **isotopes** are fused to form helium in the sun. The mass is not lost, it is simply changed into energy. In fact, scientists now consider the Law of Conservation of Energy and the Law of Conservation of Matter to be one unified principle, the Law of Conservation of Matter/Energy. Einstein's equation, $E=mc^2$, is the mathematical relationship that ties energy and matter together.

Efficiency

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

In fact, most energy transformations are not very efficient. The human body is no exception. Your body is like a machine, and the fuel for your machine is food. Food gives us the energy to move, breathe, and think, but your body is not very efficient at converting food into useful work. A majority of the chemical energy from your food is transformed into thermal energy.

The car engine we discussed earlier is very inefficient. Only about ten percent of the energy in the gasoline is actually transformed into moving the car forward. The other 90 percent of the energy is lost as some sound energy in the noise of the engine and other moving parts, and in thermal energy as the engine, other parts, and tires get hot.

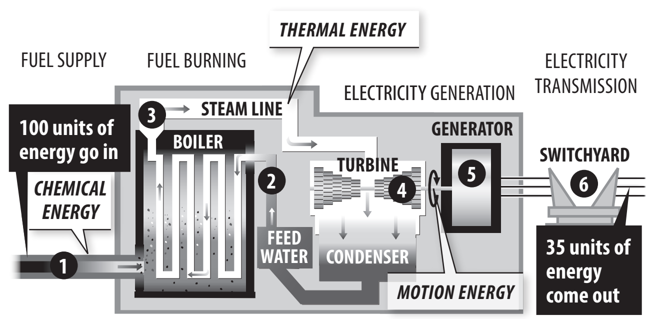
Energy at a Glance, 2015

	2014	2015
World Population	7,178,722,893	7,245,299,845
U.S. Population	318,857,056	321,418,820
World Energy Production	539.5 Q	546.7 Q
U.S. Energy Production	87.398 Q	88.024 Q
• Renewables	9.6923 Q	9.466 Q
• Nonrenewables	77.706 Q	78.558 Q
World Energy Consumption	537.36 Q	542.49 Q
U.S. Energy Consumption	99.868 Q	97.344 Q
• Renewables	9.656 Q	9.450 Q
• Nonrenewables	90.212 Q	87.894 Q

Q = Quad (10^{15} Btu), see Measuring Energy on page 39.

Data: Energy Information Administration

Efficiency of a Thermal Power Plant



How a Thermal Power Plant Works

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

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

Sources of Energy

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

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

We use ten sources to acquire the energy we need. They can be classified into two broad groups – **nonrenewable** and **renewable**.

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

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

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

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

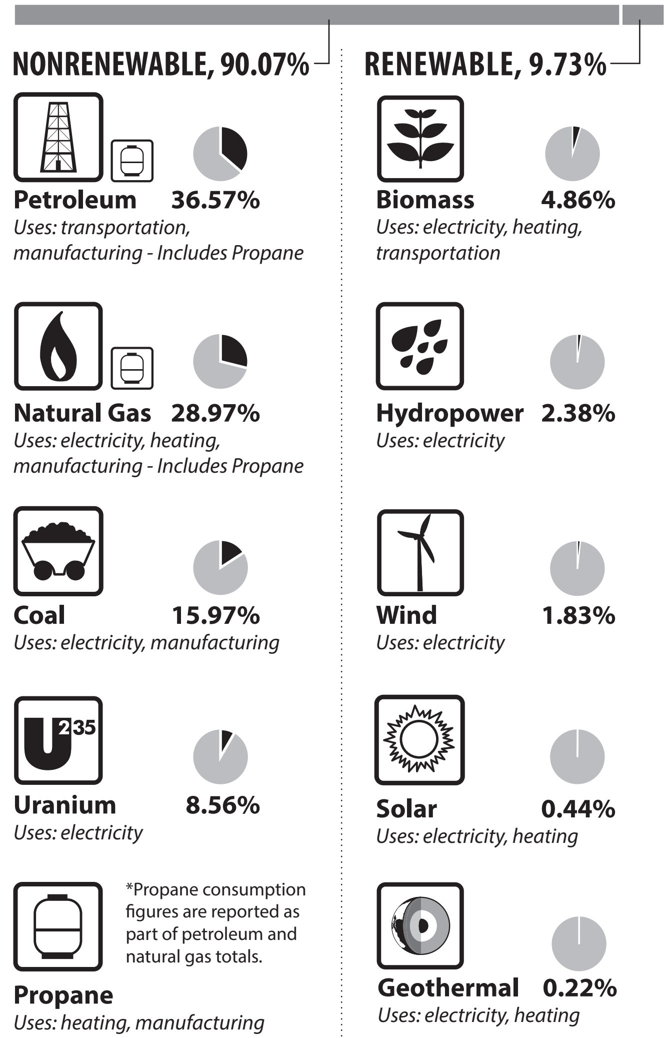
Measuring Energy

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

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

Every day the average American uses about 829,000 Btu. We use the term quad (Q) to measure very large quantities of energy. A quad is one quadrillion (1,000,000,000,000,000 or 10^{15}) Btu. The United States uses about one quad of energy approximately every 3.7 days. In 2007, the U.S. consumed 101.296 quads of energy, an all-time high.

U.S. Energy Consumption by Source, 2015



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

Energy Use

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

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

Every day, the average American uses about as much energy as is stored in seven gallons of gasoline. That's every person, every day. Over a course of one year, the sum of this energy is equal to about 2,500 gallons of gasoline per person. This use of energy is called **energy consumption**.

Energy Users

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

▪ Residential/Commercial

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

The residential/commercial sector of the economy consumed 10.76 percent of the total energy supply in 2015, with a total of 10.48 quads. The residential sector consumed 6.37 quads and the commercial sector consumed 4.11 quads.

▪ Industrial

The industrial sector includes manufacturing, construction, mining, farming, fishing, and forestry. This sector consumed 21.44 quads of energy in 2015, which accounted for 22.02 percent of total consumption.

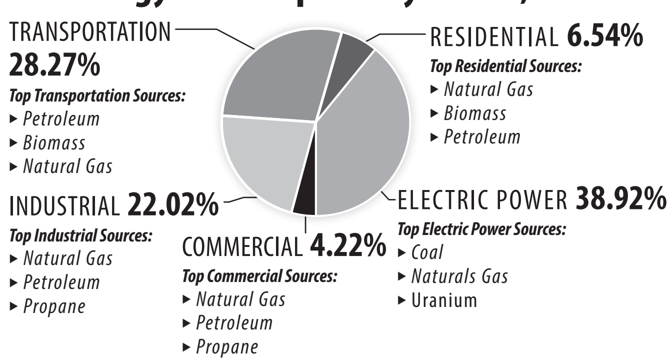
▪ Electric Power

The electric power sector includes electricity generation facilities and power plants. All of the other sectors consume electricity generated by the electric power sector. The electric power sector consumed 38.92 percent of the total energy supply in 2015, more than any of the other sectors, with a total of 37.89 quads.

▪ Transportation

The transportation sector refers to energy consumption by cars, buses, trucks, trains, ships, and airplanes. In 2015, the U.S. consumed 27.52 quads of energy for transportation, which accounted for 28.27 percent of total consumption. 92.44 percent of this energy was from petroleum products such as gasoline, diesel, and jet fuel.

U.S. Energy Consumption by Sector, 2015



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

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

Energy Use and Prices

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

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

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

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

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

In 2015, the United States used 29 percent more energy than it did in 1973. That might sound like a lot, but the population has increased by over 50 percent and the nation's **gross domestic product** was 2.67 times that of 1973.

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

Energy from a Rock

Historically, most of the energy people needed was acquired by burning wood or capturing wind energy; however, coal was also used. Before recorded history began, coal was burned to heat living spaces. The ancient Romans living in England used coal as early as the second and third centuries, and the Hopi in North America used coal to fire clay pottery. However, in the 1700s the English realized that coal was a better source of energy than wood, and coal began to emerge as the preferred energy source.

Coal is a hard, dark, rocky-looking solid found underground that is used primarily to generate electricity. Coal has a much higher energy content than wood when burned and therefore has a higher **energy density** – the amount of energy in a given volume of a substance.

The first commercial coal mine in the United States was opened in 1748 in Richmond, Virginia. Since its rise to prominence, we have been mining massive amounts of coal out of the earth to power steam engines, steam locomotives, **foundries**, and electric power plants. Where wood once supplied most of our energy needs, by the end of the 19th century coal was supplying most of the country's energy. Coal continues to be one of our major energy suppliers today.

A Stinking, Swampy Mess

Coal's origins are unique. While the story behind oil and natural gas stretches back hundreds of millions of years, coal's story begins somewhat more recently. Some coal formed hundreds of millions of years ago, but some may have formed as recently as several hundred thousand years ago.

The ingredients to make a good coal seam are rich plant life, stagnant water, and time. As the Earth changed, areas of land that contained lots of plants were engulfed and eventually consumed by a swamp.

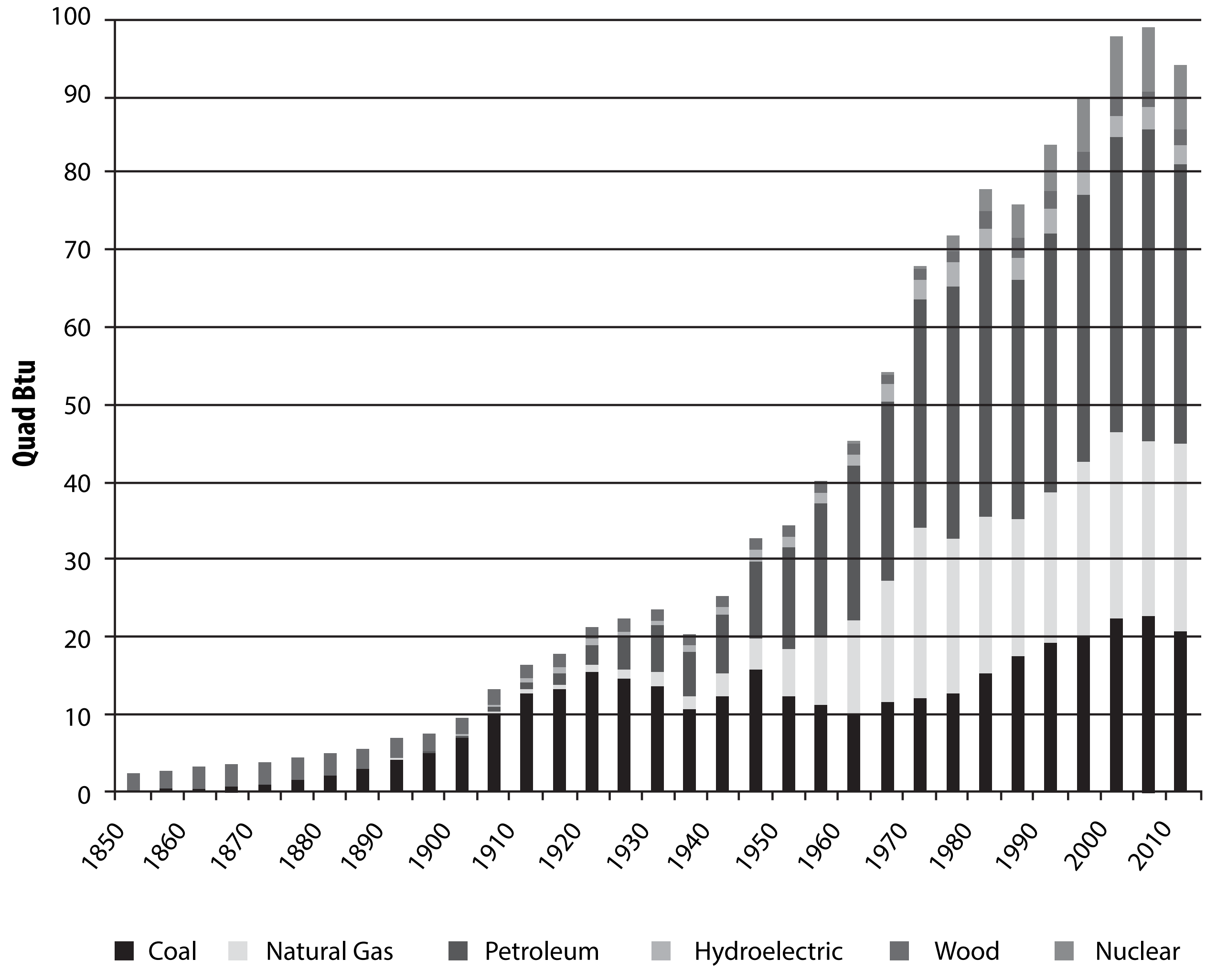
As layers and layers of sediment were added on top of the swamp, the dead trees and other plant matter were covered and subjected to great pressure. The plants and swampy ground changed into **peat**. In some places, the pressure has only been adequate enough to form peat, but not coal.

Increased pressure and time will allow peat to eventually change into coal. The quality of the coal, and its energy content, are dependent upon the amount of pressure put on the coal, as well as the amount of moisture that remains within the coal.

Seams of coal—ranging in thickness from a fraction of an inch to hundreds of feet—may represent hundreds or thousands of years of plant growth. One seam, the seven-foot thick Pittsburgh seam, may represent 2,000 years of rapid plant growth. One acre of this seam contains about 14,000 tons of coal.

Movement of the tectonic plates in the Earth's crust will often push a coal seam up closer to the surface. In some coal-rich areas, coal is visible in a hillside, or where a mountain has been cut to make way for a roadway. The coal that is closer to the Earth's surface is younger than the coal deeper underground, and is the coal that has historically been mined first. As exploration technology and methodology have improved, geologists have been able to locate coal seams that are farther underground and potentially contain higher-quality coal with less moisture.

Historical Energy Consumption by Major Source



Data: Energy Information Administration

The Life Cycle of Coal

Peat is compressed into lignite and moisture is removed.
As temperature and time increase, so does the degree to which the coal is altered, increasing its rank and its energy content.

The Chemistry of Coal

Coal is a word that actually refers to a specific class of altered sediments underground. Examining coal with a simple, hand-held magnifying lens reveals some features that help identify its chemical make-up without having to do any chemistry. These descriptions are called **macroscopic** characteristics, and describing coal in these terms helps identify its classification and quality.

Coal can be **banded** or **non-banded**. Non-banded forms of coal are called either **cannel** or **boghead** coal. Cannel coal is formed from spores that settled to the bottom of the prehistoric **mire** and gets its name from the word "candle." Pencil-shaped pieces of cannel were used as candles in areas where cannel coal is prevalent. Boghead coal is formed from algae. Both cannel and boghead coal are **dull** and **blocky**, breaking into large blocks when mined.

Banded coal ranges from a dull, grainy, tough coal called **durain** to a bright, black, glassy, brittle coal called **vitrain**. **Clarain** is a banded coal that is satiny and brittle but not as shiny as vitrain. **Fusain** runs in thin, sporadic bands, and is dull, resembling charcoal. Dull coals rich in durain are also often referred to as "**splint**" coal. The bright, glassy coals rich in clarain and vitrain break easily along faults, or "**cleats**."

Examining coal with a microscope reveals many organic grains called **macerals**. These grains are classified according to the light they reflect. **Liptinite** is dark gray and contains many saturated or nearly saturated **hydrocarbons**. Coal formed from spores, pollen, cuticle, and plant resin typically contains liptinite. **Vitrinite** is medium to light gray, and is formed from wood, bark, and roots. The highest carbon-containing macerals are called **inertinite**, which are white and are the result of **oxidation** of other macerals. Ancient peat that burned and was buried will contain **fusinite**, a type of inertinite. Inertinites are richer in carbon than either liptinites or vitrinites.

Composition

There are four different classifications of coal, but they all have the same basic composition of primarily carbon, hydrogen, and oxygen, with a very small amount of nitrogen and sulfur. The proportion of carbon, hydrogen, and oxygen will vary somewhat from one grade to another, with the highest quality coal having the highest amount of carbon.

The amount of moisture and ash in coal will also determine how it is classified and used. Coal with a high **moisture content** will not produce as much thermal energy when burned and is a lower quality, or **rank**, coal. **Ash** describes the clay and silt that become bound up in the coal. Unlike petroleum, which is a liquid and can separate from solid sediments, coal is a solid and the clay and silt trapped in coal cannot sink to the bottom, but remain trapped inside it. When the coal burns, ash does not, and it reduces the amount of thermal energy obtainable from the coal. The higher the ash content, the lower the quality of coal.

Type of Coal	AVERAGE COMPOSITIONAL CHARACTERISTICS OF COAL CLASSES				
	Sulfur content (weight percent)	Moisture content (weight percent)	Carbon content (weight percent)	Ash content (weight percent)	Bulk density (g/cm^3)
Lignite	0.4	39	31.4	4.2	0.6-0.9
Bituminous	0.7-4.0	2.2-15.9	44.9-78.2	3.3-11.7	0.6-0.9
Anthracite	0.6-0.8	2.8-16.3	80-85.7	9.7-20.2	0.8-0.9

Data: Engineers Toolbox

Types of Coal

Coal is classified into four main types, depending on the amount of carbon, oxygen, and hydrogen present. The higher the carbon content, the more energy the coal contains.

- **Lignite**

Lignite is the lowest rank of coal, with a **heating value** of 4,000 to 8,300 British thermal units (Btu) per pound. Lignite is crumbly and has high moisture content. Most lignite mined in the United States comes from Texas. Lignite is mainly used to produce electricity. It contains 25 to 35 percent carbon. About eight percent of the coal mined in 2015 was lignite.

- **Subbituminous coal**

Subbituminous coal typically contains less heating value than bituminous coal (8,300 to 13,000 Btu per pound) and more moisture. It contains 35 to 45 percent carbon. 48 percent of the coal mined in 2015 in the U.S. was subbituminous.

- **Bituminous coal**

Bituminous coal was formed by added heat and pressure on lignite. Made of many tiny layers, bituminous coal looks smooth and sometimes shiny. It is the most abundant type of coal found in the United States and has two to three times the heating value of lignite. Bituminous coal contains 11,000 to 15,500 Btu per pound. Bituminous coal is used to generate electricity and is an important fuel for the steel and iron industries. It contains 45 to 86 percent carbon. 44 percent of the coal mined in 2015 was bituminous coal.

- **Anthracite**

Anthracite was created where additional pressure combined with very high temperature inside the Earth. It is deep black and looks almost metallic due to its glossy surface. It is found primarily in the northeastern counties of Pennsylvania. Like bituminous coal, anthracite coal is a big energy producer, containing nearly 15,000 Btu per pound. It contains 86 to 97 percent carbon. Less than one percent of coal mined in 2015 was anthracite.

Combustion Combination

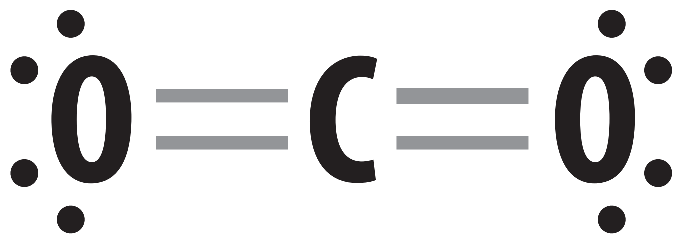
To use the chemical energy stored in the coal, it must be burned. Combining a material in the presence of oxygen that results in thermal energy being released is called **combustion**. During combustion, the **covalent bonds** between the carbon, hydrogen, and oxygen atoms, and often a few nitrogen and sulfur atoms as well, are broken and rearranged to make new compounds.

As you might expect, the different types of coal, with their variations in moisture and carbon content, have differing amounts of energy stored within them, and result in different amounts of thermal energy being released when burned. The oldest coal, anthracite, has the highest energy content, while the youngest coal, lignite, has the lowest.

Under ideal conditions with unlimited oxygen, burning coal produces **carbon dioxide** and water vapor. However, when oxygen supplies are limited, some carbon monoxide is produced. **Carbon monoxide** is dangerous because it is odorless and colorless, and more dense than air. It will bind to hemoglobin in the blood, preventing it from binding oxygen. This can cause hypoxia, where the body is deprived of oxygen. Carbon dioxide is not poisonous in normal concentrations, but increasing carbon dioxide levels in the atmosphere have been linked to global climate change and its ever-increasing effects.

Burning nitrogen results in nitrogen oxides (NOx) that when mixed with water vapor form nitric acid in the atmosphere. Burning sulfur produces sulfur oxides that will form sulfuric and sulfurous acid with water in the atmosphere. In the 1970s and early 1980s, **acid rain** became a significant environmental concern. Heavily forested areas became stressed as the low-pH rain altered the soil **pH**. Monuments and buildings constructed of limestone and marble suffered damage. Limestone and marble contain high amounts of calcium carbonate, which is **basic**. When the **acidic** rain would come into contact with the basic calcium carbonate, carbon dioxide was released and the stone was eroded away at a rapid rate. For this reason, the United States Department of Energy formed a partnership with the Canadian government to reduce the amount of sulfur oxides introduced into the atmosphere by coal combustion. Working with state governments and private companies, the Clean Coal Technology Program was begun in 1985, with the goal to virtually eliminate acid-forming gases from coal combustion products.

The Lewis Structure of Carbon Dioxide



The Lewis Structure of Carbon Monoxide

Just how much energy is in coal? The black coals (anthracite, bituminous, subbituminous) release 22.7 – 27.4 million Btu per metric ton when burned. By comparison, dry wood releases 15.3 million Btu when burned. Uranium ore has the potential to release a whopping 445,000 million Btu!

Cleaner Coal Technology

Coal is the United States' most plentiful fossil fuel, but traditional methods of burning coal produce **emissions** that can reduce air and water quality. Using coal can help the United States achieve domestic energy security if we can develop methods to use coal that won't damage the environment.

The Clean Coal Technology Program is a government and industry funded program that began in 1985 in an effort to resolve U.S. and Canadian concern over acid rain. Clean coal technologies remove sulfur and nitrogen oxides before, during, and after coal is burned, or convert coal to a gas or liquid fuel. Clean coal technologies are also more efficient, using less coal to produce the same amount of electricity. The U.S. has been exploring clean coal technology through its Clean Coal Power Initiative. These projects are costly and challenging.

Sulfur can be removed before combustion by crushing the coal and washing it. Sulfur bound with iron in **pyrite**, which you know as "fool's gold," can be easily removed this way. The coal floats, and the pyrite sinks in water. The sulfur that is chemically bound within the coal itself, though, cannot be removed by physical means. Chemically removing sulfur before combustion is cost-prohibitive, so most power plants have devices that remove the sulfur from the emissions in the smoke stack. All power plants built after 1978 are required to have these **flue gas** desulfurization units, or **scrubbers**, and many older power plants have been retrofit with them to reduce sulfur emissions.

Eliminating NOx from flue gases is more difficult because the atmosphere is almost 80 percent nitrogen and, if heated enough, it will form NOx just as the nitrogen in coal will. The best way to reduce NOx is to not allow it to form in the first place. This is done by controlling the amount of oxygen present in the combustion chamber. Starved for oxygen, the fuel, in this case coal, will burn and the nitrogen will not. Any fuel remaining after this process is sent to a second combustion chamber where oxygen is again controlled. This is called **staged combustion**, because coal is burned in stages rather than all at once. The Clean Coal Technology Program research produced a new type of burner called a low-NOx burner that reduces the amount of NOx by half.

▪ Fluidized Bed Combustor

One technique that cleans coal as it burns is a fluidized bed combustor. In this combustor, crushed coal is mixed with limestone and suspended on jets of air inside a boiler. The coal mixture floats in the boiler much like a boiling liquid. The limestone acts like a sponge by capturing 90 percent of the organic sulfur that is released when the coal is burned. The bubbling motion of the coal also enhances the burning process.

Effects of Climate Change

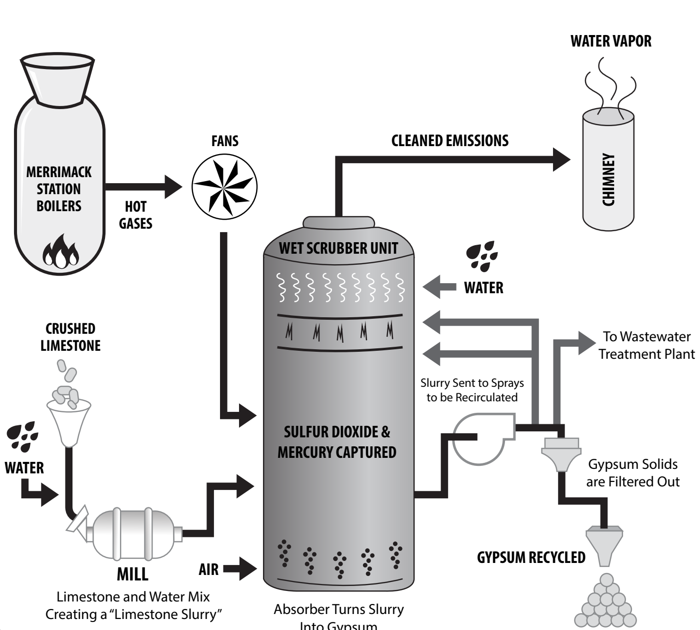
Increases in carbon dioxide concentration in the atmosphere are bringing about changes in the climate and conditions around the Earth. CO_2 is a **greenhouse gas**, and as such it absorbs and traps thermal energy in the atmosphere. The average, or mean temperature at the surface has been increasing since 1880.

Ice in the seas have decreased almost 5% per decade since 1979, and ice that remains year-round on land has been decreasing over 15% per decade since 1979. Some of the ice loss is irreversible and will continue even if global temperatures do not increase further.

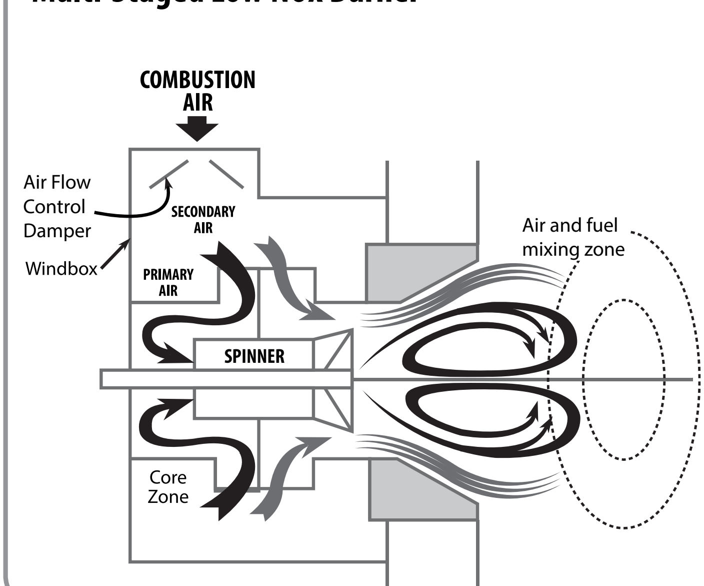
Permafrost, ground that remains frozen year-round, supports **tundra** ecosystems and keeps methane gas trapped beneath its frozen layers. As it thaws, **methane**, a much more potent greenhouse gas than CO_2, is released. The permafrost boundary has moved 50 km north in northern Russia.

The ocean and atmosphere exist in equilibrium. When the concentration of carbon dioxide in the atmosphere increases, the ocean responds by dissolving more to maintain that balance. Dissolving CO_2 decreases the pH of the water, and the pH of the oceans has been decreasing since the Industrial Revolution.

Wet Flue Gas Desulfurization Technology



Multi-Staged Low NOx Burner



Combustion temperatures can be held to 1,500 degrees Fahrenheit, about half that of a conventional boiler. Since this temperature is below the threshold where nitrogen pollutants form, a fluidized bed combustor keeps both sulfur and nitrogen oxides in check.

Coal Gasification

Another clean coal technology bypasses the conventional coal burning process altogether by converting coal into a gas. **Gasification** is simply incomplete combustion, and any nitrogen or sulfur present in the fuel chemically bonds with hydrogen rather than oxygen. This makes it easier and more economical to remove sulfur and nitrogen from the gases emitted. The product of gasification is a mixture of combustible gases called **syngas**.

Gasification offers several advantages over ordinary combustion, but perhaps the most compelling is that any carbon-based solid or liquid fuel can be used – even municipal solid waste. The fuel used to produce syngas has great influence on the type of gasifier selected. There are many styles of coal gasifiers, and they are differentiated by the location of the pulverized coal, steam, and air inlets and the syngas outlet valve. All accomplish the task of turning solid coal fuel into the syngas mixture, and each technology yields a syngas with its own signature mixture composition.

The Chemistry of Coal Gasification

Gasification of coal, or any other carbon-based fuel, is best classified as an incomplete combustion. The first part of gasification is **pyrolysis** and takes place in a high-temperature, oxygen-poor environment. The major chemical reactions in this process are oxidation of carbon, carbon monoxide, and hydrogen, all of which are exothermic reactions. The thermal energy released in these oxidations provides the energy necessary to drive the other reactions in the gasification process.

Combustion reactions of carbon, carbon monoxide, and hydrogen:

$C + ½\,O_2 \rightarrow CO$ $\Delta H = -111$ kJ/mol

$CO + ½\,O_2 \rightarrow CO_2$ $\Delta H = -283$ kJ/mol

$H_2 + ½\,O_2 \rightarrow H_2O$ $\Delta H = -242$ kJ/mol

One important reaction outside of combustion is known as the Water-Gas reaction. This endothermic reversible process combines carbon and water to make carbon monoxide and hydrogen gas. Two other reversible processes are also important in gasification. The first, the Boudouard reaction, is the interaction between carbon and carbon dioxide to form carbon monoxide, and is endothermic. Methanation also occurs in gasification, and is the reversible interaction between carbon and two hydrogen molecules forming methane. Methanation is exothermic.

Water-Gas Reaction

$C + H_2O \leftrightarrow CO + H_2$ $\Delta H = +131$ kJ/mol

Boudouard Reaction

$C + CO_2 \leftrightarrow 2\,CO$ $\Delta H = +172$ kJ/mol

Methanation Reaction

$C + 2\,H_2 \leftrightarrow CH_4$ $\Delta H = -75$ kJ/mol

Water-Gas Shift Reaction

$CO + H_2O \leftrightarrow CO_2 + H_2$ $\Delta H = -41$ kJ/mol

Steam-Methane Reforming Reaction

$CH_4 + H_2O \leftrightarrow CO_2 + 3\,H_2$ $\Delta H = +206$ kJ/mol

One of the major benefits of gasification over complete coal combustion is the ability to control sulfur and nitrogen oxide production. The high temperatures and excess amounts of oxygen in ordinary combustion chambers yield sulfur dioxide and nitrogen oxides, which are problematic emissions and must be removed from flue gases to meet environmental standards. The following chart provides a good comparison of the products of oxygen-poor gasification vs. the products of oxygen-rich combustion.

Element in Fuel	Gasification Product	Combustion Product
Carbon	Carbon Monoxide	Carbon Dioxide
Hydrogen (from hydrocarbon)	Hydrogen Gas Molecules	Water Vapor
Nitrogen	Nitrogen Gas Molecules Ammonia (NH_3)	Nitrogen Oxides (NOx)
Sulfur	Hydrogen Sulfide	Sulfur Dioxide

One of the U.S. Department of Energy funded Clean Coal Power Initiative projects began construction in Mississippi in 2006. The Kemper County Energy Facility was to be a lignite-fired gasification plant, fueled by local lignite in the area. The plant was designed to be an integrated combined-cycle facility that operated on the syngas from the lignite, and natural gas to fuel recovery steam generators. The plant was designed to capture 65 percent of the carbon dioxide that would be emitted, while controlling for other emissions as well. The plant came online in 2016. However, in 2017, after only 200 days of gasification operations, the plant announced it would halt all gasification, due to concerns with the technology. The plant will continue to operate on natural gas alone. It is unknown if gasification will occur again at this plant in the future.

Improving Coal Combustion

Before the Industrial Revolution, wood provided most of society's energy needs. As machines were developed, more energy was needed to power those machines, and a better energy source was used to provide that energy. This is when coal began to play a larger role in the drama of society's energy use.

The first methods of burning coal for energy utilized hand-fed boilers. As you can imagine, this was very labor-intensive and not the best way for maintaining a constant rate of combustion. The fire inside would die down, the fireman would shovel coal, and the fire would flare back up. This is how steam locomotives were run, and it's also how the very first coal-fired electric power plants were powered.

As more power was needed, better methods of feeding coal into the combustion chamber were needed. Furthermore, as boilers were being maintained and cleaned, the maintenance crews were discovering a significant amount of unburned coal in the **bottom ash**. Such an inefficient use of coal led to the development of more efficient methods of coal combustion. Like any chemical reaction, coal combustion can be influenced by the surface area of the coal being burned and the concentration of the reactants present – in this case, coal and oxygen. The following technologies are arranged in a general chronological order, with the oldest being discussed first. As you read about them, you will begin to see how the principles of chemical reaction rates tie into the design of the different combustion technology.

Stoker Fired Coal Combustion is the earliest form of coal combustion and uses a boiler system which controls burning by the method of feeding the coal to the fire. The furnace is fed coal at a steady rate, which allows the fires to burn in suspension and large chunks of coal to fall to the bottom where a grate holds them above a thin bed of burning coal. A stoker fired boiler allows for changes in energy production because increasing the amount of coal added to the furnace results in a direct increase in energy output in response to load needs. This process often does not burn all of the coal; some coal falls in with the ash and is removed as waste.

Pulverized Coal Combustion is the world's most common combustion style for producing electricity. Coal is ground into a fine dust and blown into the furnace with part of the combustion air while additional air is fed through nozzles. In the combustion chamber a fireball is created in the center of the boiler as four burners are positioned in each corner where the air and pulverized coal are injected into the boiler. The combustion temperature is very high (1300 -1700 °C) which allows for a quick response to electricity load demands merely by increasing the feed of fuel. Combustion temperatures this high, however, increase the production of nitrogen oxides.

Cyclone Coal Combustion is a process where the air and pulverized coal mixture swirls in a fashion similar to a tornado, or cyclone. The furnace can be lined with water pipes to increase steam production, which in turn increases the electricity produced as the steam powers a turbine. High powered fans are used to blow air and crushed coal into the cyclone and adding heated combustion air causes the combustion mixture to spin like a cyclone. This spiral motion of the fuel and air improves the complete combustion of the coal but does so at a very high temperature that increases NOx gas output. The temperature is so high that slag and ash from the coal are liquefied like lava and drain to the bottom of the combustion chamber, where it is solidified and collected. This style of combustion has the biggest advantage with regard to ash collection.

Fluidized Bed Combustion offers many benefits over standardized boiler systems because of its lower combustion temperature (840-950 °C). This type of combustion does not produce as much NOx nor does it have the problems associated with melted ash or contaminants in the coal itself. A layer of solid coal and limestone are combined with sand and air supported by a fine mesh, creating a fluidized bed. The limestone is present to help remove sulfur from the combustion emissions. As air is added to the mixture, it behaves similarly to a boiling liquid. As this material is heated to the temperature of coal combustion and the fuel is injected into the boiler, the coal burns rapidly, maintaining a uniform and consistent temperature. Thermal energy transfer is much more effective because tubes can be dispersed through and around the bed to collect and transfer it to turn turbines for electricity production.

Pressurized Fluidized Bed Combustion operates the same as fluidized bed combustion to release the energy from the coal but increases the efficiency of the output. The entire boiler is enclosed to create a pressurized chamber, which produces pressurized gases from the combustion that are used to drive a gas turbine to produce electricity. Heat transfer tubes are still dispersed throughout the bed to heat water to steam, but the addition of a gas turbine increases the efficiency of the entire system.

Integrated Gasification Combined Cycle (IGCC) is one of the newest operational methods by which coal is used to create electricity on a public level. The technology has increased the level of thermal efficiency for electricity to around 60%. IGCC is a two-step process. First, the fuel is gasified and converted into hydrogen and carbon monoxide. This syngas mixture is burned to generate steam and turn a turbine. The thermal energy from the gasification chamber can be used to operate a steam turbine. Gasification is beneficial not only for the improved efficiency in electricity generation, but also because it all but eliminates pollutants from the emissions (see section on Gasification on page 45).

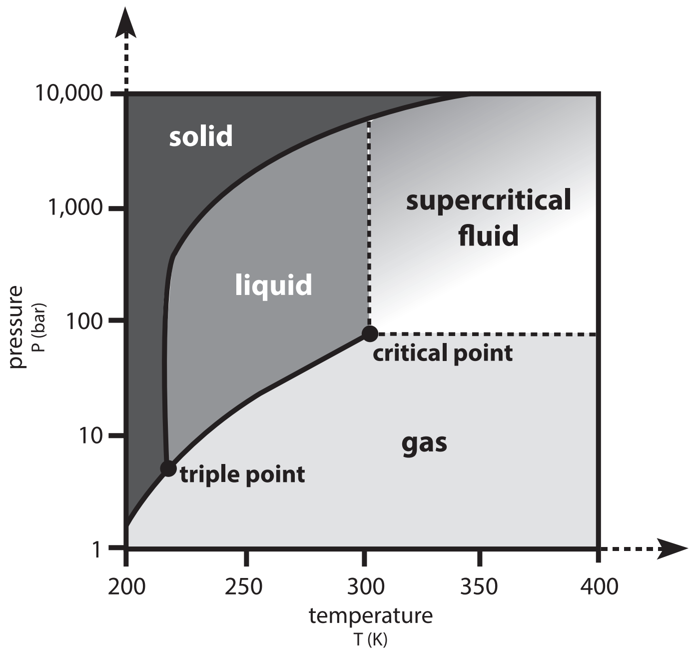
Oxyfuel Combustion uses pure oxygen rather than air for the combustion of coal and other fossil fuels. In this combustion the major byproducts are carbon dioxide and water. This combustion technique increases the concentration of carbon dioxide in the flue gases, which improves the process of carbon sequestration. Plants are built with facilities to remove nitrogen from the air to concentrate the oxygen gas for the combustion process that uses around 15% of the energy produced for air separation. The temperature of oxyfuel combustion is very high so flue gas is recycled back through the boiler to increase gas volume for combustion and control the temperature of the boiler. Oxyfuel combustion is an option for retrofitting older types of power generation plants to meet air standards regarding greenhouse gases.

Polygeneration refers to producing electricity with syngas combined with other technology to co-produce other marketable products such as fertilizer, polymer feed stock, sulfur, and compressed CO_2 for enhanced oil recovery. The boiler system is an IGCC power generation, and a chemical plant is located on the same site. This offers the facility the flexibility to switch from one product to another such as power generation during the day and co-product by night. Polygeneration increases the output of two products at a much higher efficiency than producing the two products in different facilities.

Supercritical CO_2 Power Cycle is a new technology where carbon dioxide is used as the heat transfer medium rather than water/steam in turning a turbine to produce electricity. Carbon dioxide does not exist as a liquid at standard pressures so to reach a liquid state the the compound must be at a pressure of 73 atmospheres and a temperature of 300 Kelvin (27 degrees Celsius).

Carbon dioxide in a supercritical state (sCO_2) gives the compound properties of both a liquid and a gas which enhances its ability to transfer thermal energy. Heat used in phase changes in a steam system is not needed for sCO_2, which increases its thermal stability as a mechanism for heat transfer. sCO_2 is also not as corrosive as water to the parts of a turbine. The sCO_2 power cycle increases power output and efficiency by using a much smaller turbine, and has lower maintenance and operational costs than using water for heat transfer. sCO_2 turbines can be retrofitted to existing electric power plants, thereby increasing significantly their efficiency and power output.

Phase Diagram of CO_2



Carbon Capture, Utilization, and Storage

Research and demonstration projects are underway around the U.S. and the world to capture carbon dioxide from power plants and use it or store it deep underground in geologic formations. Researchers are investigating the best ways to capture carbon dioxide, either before or after coal is combusted. The carbon dioxide will then be compressed, converting the gas to a liquid. It can then be utilized by industry or transported via pipeline to appropriate storage sites. Three different types of locations have been identified as being able to hold carbon dioxide: 1) deep saline formations; 2) oil and gas reservoirs that are near depletion or have been depleted; and 3) unmineable coal seams. The United States Department of Energy sponsors the testing of CCUS projects, and has partnered with industry to deploy these technologies.

Coal Mining

There are two ways to remove coal from the ground—surface and underground mining. **Underground** (or deep) **mining** is used when the coal seam is buried several hundred feet below the surface. In underground mining, workers and machinery go down a vertical shaft or a slanted tunnel called a slope to remove the coal. Mine shafts may sink as deep as 1,000 feet.

One method of underground mining is called **room-and-pillar** mining. With this method, much of the coal must be left behind to support the mine's roofs and walls. Sometimes as much as half the coal is left behind in large column formations to keep the mine from collapsing.

A more efficient and safer underground mining method, called **longwall mining**, uses a specially shielded machine that allows a mined-out area to collapse in a controlled manner. This method is called longwall mining because huge blocks of coal up to several hundred feet wide can be removed.

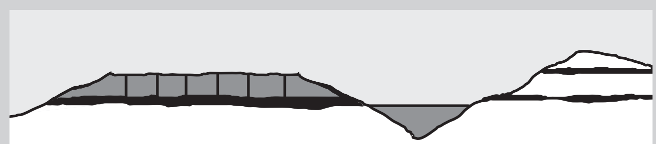
Mountaintop Removal

One method of mining coal that is near the top of a mountain is **mountaintop removal**, or MTR. In this method, the entire top of a mountain is removed in stages, exposing the coal, and the **overburden** is disposed of in valleys next to the mountain.

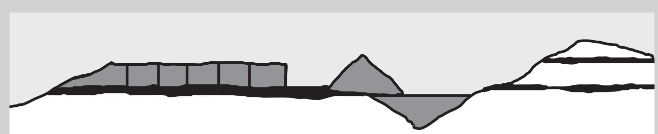
There are five steps in MTR:

1. Removal of overburden
2. Removal of upper seams of coal
3. Excavation of lower layers of coal with draglines
4. Regrading during excavation
5. Final grading and planting with vegetation

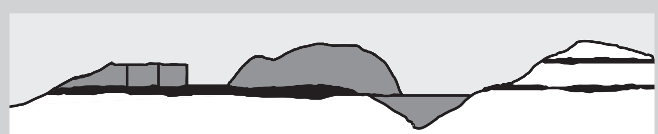
Step 1: Layers of rock and soil above the coal (called overburden) are removed.



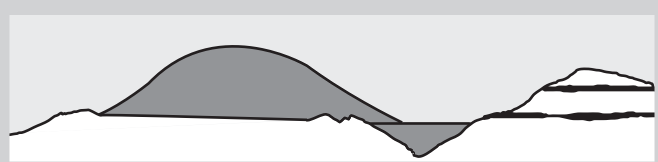
Step 2: The upper seams of coal are removed with spoils placed in an adjacent valley.



Step 3: Draglines excavate lower layers of coal with spoils placed in spoil piles.



Step 4: Regrading begins as coal excavation continues.



Step 5: Once coal removal is complete, final regrading takes place and the area is revegetated.

Surface mining is used when a coal seam is relatively close to the surface, usually within 200 feet. The first step in surface mining is to remove and store the topsoil, then remove rock covering the coal, called the overburden. Workers use a variety of equipment—draglines, power shovels, bulldozers, and front-end loaders—to expose the coal seam for mining. Layers of rock are removed and coal seams are mined until mining is no longer practical or possible.

About two-thirds of the nation's coal is extracted by surface mining. Surface mining is typically much less expensive than underground mining. With new technologies, surface mining productivity has almost doubled since 1973. Underground mining accounts for one-third of U.S. coal mined.

Restoring the Land

Both methods of mining coal affect the surrounding environment. Even underground mines leave behind piles of waste material, called **culm**, that need to be removed before plants can grow in the area. To restore the area as close to its original condition as possible, a mine undergoes **reclamation**. The process of reclamation is subject to many federal and state regulations and agency oversight.

Before a mine is permitted to begin operation, a reclamation plan must be submitted and approved. The mining company must post financial reclamation **bonds** to ensure reclamation will be completed when mining operations have stopped.

After surface mining, the land is contoured and workers replace the overburden, grade it, and cover it with topsoil. Next, the area is fertilized and seeded or planted with native vegetation, crops, or trees. The area is monitored for many years following planting to make sure the process has been successful. This land reclamation is required by law and helps restore the biological balance of the area and prevent erosion. The land can then be used for croplands, wildlife habitats, recreation, or as sites for commercial development.

Underground mining has a less obvious, but equally dramatic, effect on the surrounding land. Runoff from culm at underground mine sites introduces silt and ions to waterways. Some of the ions are heavy metals, which are toxic to many species. Another pollutant is pyrite, or FeS_2, also known as "fool's gold". When exposed to air and moisture, the sulfur in pyrite forms sulfuric acid, which will reduce the pH of the soil and watershed surrounding the mine.

To return the area around an underground mine to its original condition, or better, reclamation in these areas involves mitigating the acid and metal ion runoff and removing or containing the culm to prevent further contamination. Some of the very old, now abandoned coal mines from the late 1800s and early 1900s were never reclaimed properly. Government agencies and environmental groups are going back to these areas for reclamation and restoration, at a cost of dozens of millions of dollars per mine site.

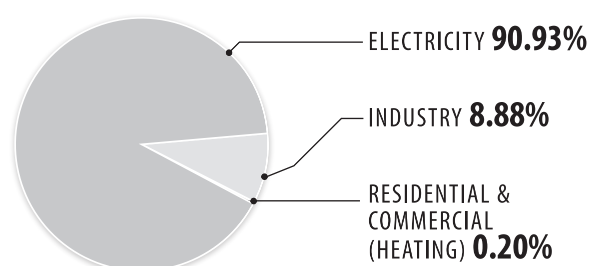
Acid Mine Drainage

Water dissolves nearly anything found in nature; any contaminants on the ground, like salts, metal ions, fertilizers, and acid-forming compounds will be dissolved by rain and melting snow running through a watershed into lakes and rivers. The waste products from a coal mine contain many heavy metals and sulfur, and the precipitation will carry these compounds into the surrounding waterways.

Decreasing the pH of water will increase its ability to dissolve metallic compounds. Rocks affected by acid mine drainage have a reddish appearance because iron ions will precipitate out of the water. The water will be crystal clear because other compounds will remain dissolved.

The health of a waterway system is measured by the number and variety of **macroinvertebrates** inhabiting the water. Most macroinvertebrates are insect larvae, a crucial part of the food web for their respective ecosystems. Decreasing the pH of the water puts great strain on the larvae because they have gills for breathing that are outside their body and exposed to the acidic water. Reducing acid mine drainage is pivotal to maintaining the health of the waterway surrounding the mine area.

U.S. Coal Consumption by Sector, 2015



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

Processing and Transporting Coal

After coal comes out of the ground, it typically goes on a conveyor belt to a preparation plant that is located at the mining site. The plant cleans and processes coal to remove dirt, rock, ash, sulfur, and other impurities, increasing the heating value of the coal.

After the coal is mined and processed, it is ready to go to market. It is very important to consider transportation when comparing coal with other energy sources, because sometimes transporting the coal can cost more than mining it.

Underground pipelines can easily move petroleum and natural gas to market, but that's not so for coal. Huge trains transport almost 70 percent of our coal for at least part of its journey to market.

It is cheaper to transport coal on river barges, but this option is not always geographically available. Coal can also be moved by trucks and conveyors if the coal mine is close by. Ideally, coal-fired power plants are built near coal mines to minimize transportation costs.

Uses of Coal

Coal has four major uses: electricity generation; steel production; cement manufacturing; and liquid fuel production. Most of the coal produced – 90.93 percent in 2015 – is used to generate electricity. However, a majority of steel is produced using coal as a source of carbon. Additionally, as coal use for energy production has recently declined, research labs are discovering more ways to utilize this abundant source of carbon. Nonetheless, Americans still use a large amount of coal. In fact, the U.S. Minerals Education Coalition estimates that every American born will need or use more than 355,000 pounds of coal for the electricity and other coal related products they consume in their lifetime.

▪ Electricity Generation

Electric power generation requires some method of turning coils of wire inside a magnetic field to induce an electric current using a device called a turbine. The method used most commonly to turn a turbine is heating water to produce high-pressure steam. The steam, at pressures 75-100 times atmospheric pressure, turns the turbine and then is cooled and condensed back to liquid water. Nearly 90 percent of the electricity generated in the U.S. is produced in a **thermal power plant**, including coal, natural gas, biomass, geothermal, and nuclear power. Coal accounts for 33.08% of United States electricity generation. It is a major provider of **baseload** electricity requirements because of its energy density, cost, and availability to us in the U.S.

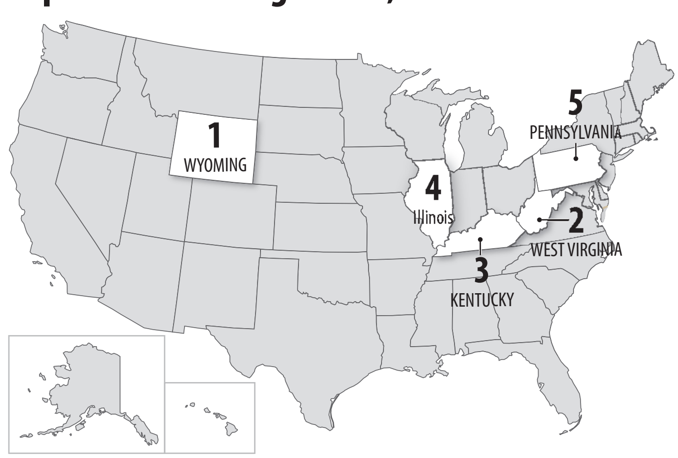
▪ Steel Production

Steel is an alloy of iron and carbon, and is used worldwide for a wide variety of purposes, from ship building, to manufacturing cars, steel cans, and a host of other products. Coal provides the carbon needed to produce steel.

To be used as a carbon source, the coal must be purified into **coke**. It is heated, softens, liquefies, and is resolidified. The result is a hard, porous, black material that is low in phosphorus and sulfur.

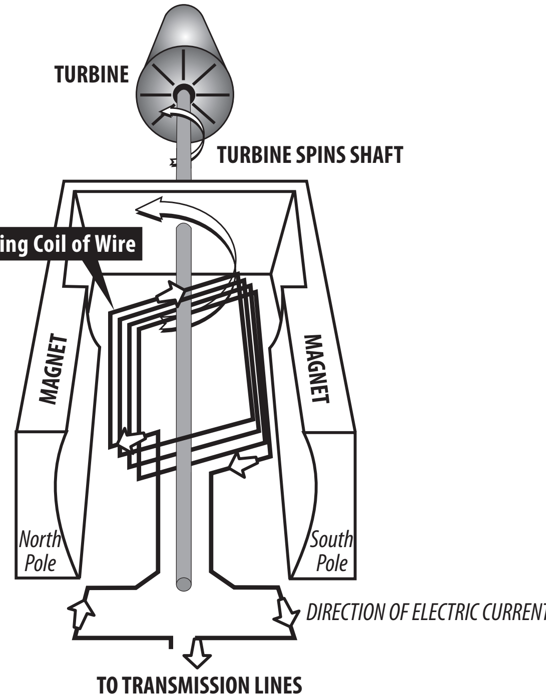
To make steel, iron must first be reduced from iron ore. The ore is heated in a blast furnace with coke and a small amount of limestone that absorbs impurities. Air heated to 1200°C is pumped in, igniting the coke and producing carbon monoxide. The iron in the ore melts and reacts with the carbon monoxide, and the molten iron is removed.

Top Coal Producing States, 2015

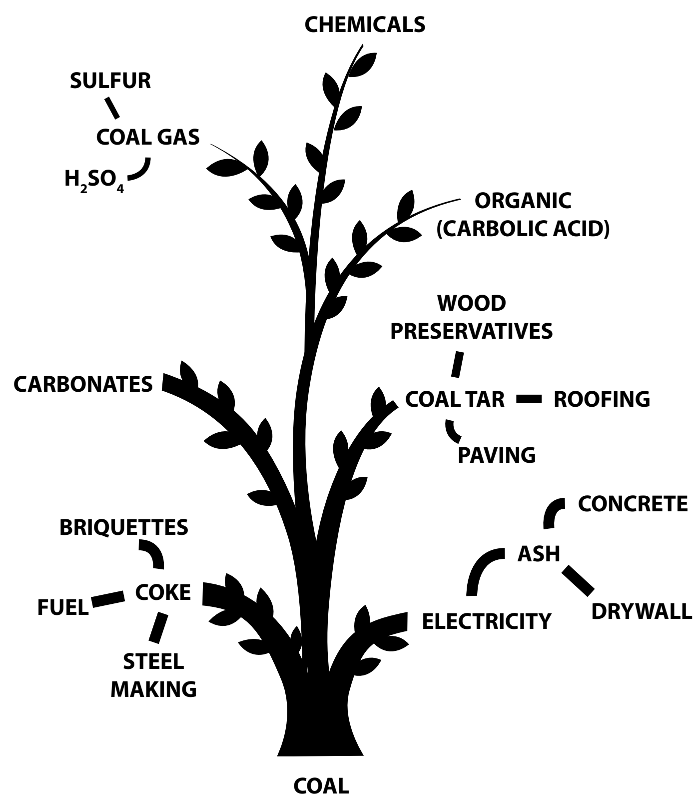


Data: Energy Information Administration

Turbine Generator



Coal Tree

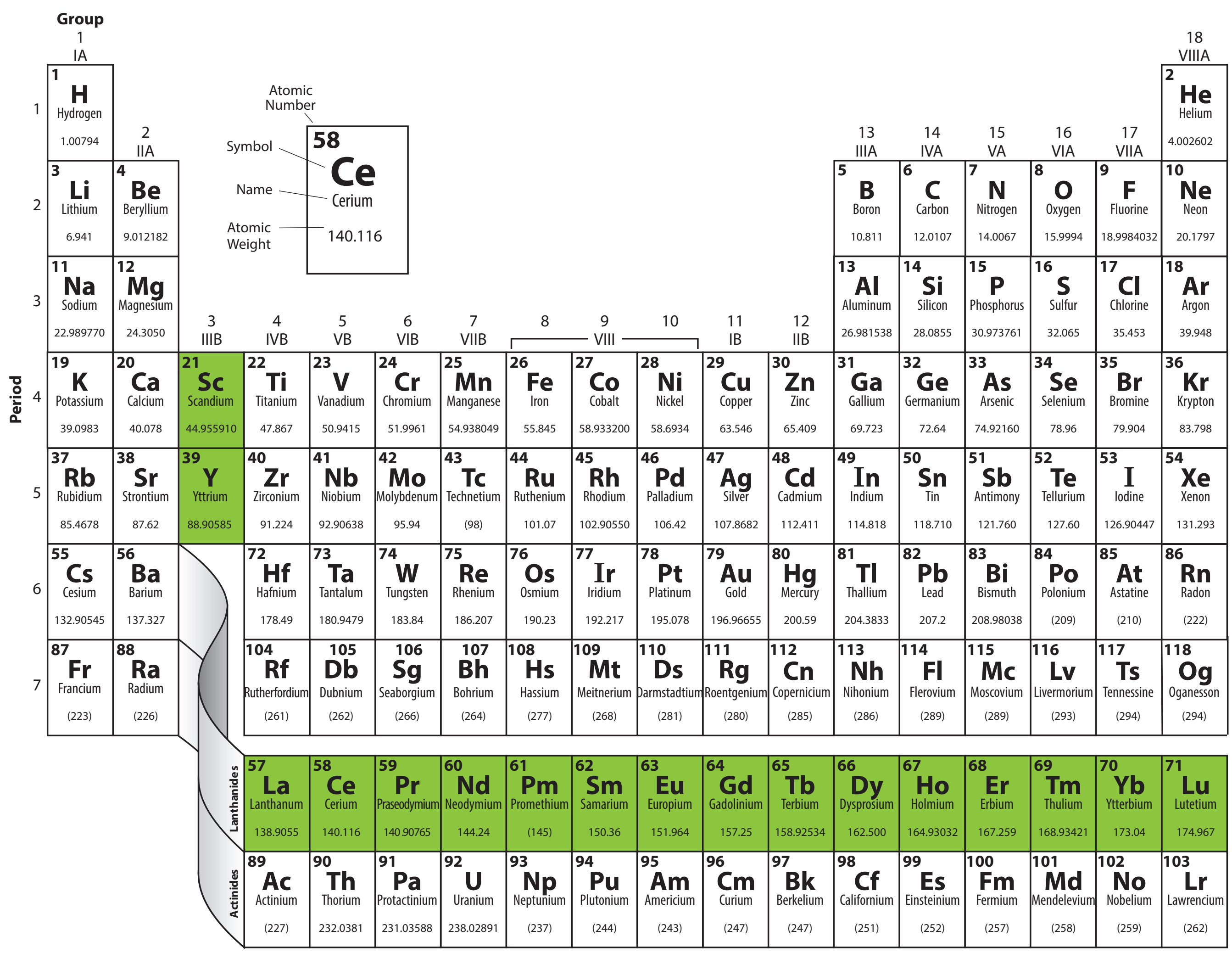


Rare Earth Elements

Their names may only be familiar if you've spent any time studying the periodic table of elements: Scandium, Yttrium, Lanthanum, Cerium, Praseodymium, Neodymium, Promethium, Samarium, Europium, Gadolinium, Terbium, Dysprosium, Holmium, Erbium, Thulium, Ytterbium, and Lutetium. These seventeen elements are in such low concentrations in Earth's crust that they're designated as rare. However, according to the American Chemistry Council they account for $329 billion of economic activity in North America alone, including being a critical part in manufacturing electronic devices such as computers and cell phones. Currently, 85 percent of the rare earth elements, or REEs, being utilized are recovered in China, and only 6 percent are currently being recovered in the United States. The kinds of products that require REEs are also critical to the U.S. military. Finding a domestic source of REEs that is economically viable is a priority.

A study published in early 2016 shows that the United States might have more resources rich in REEs than earlier thought. Researchers at Duke University found that ash from coal mined from the Appalachian region of the United States is very high in its REE concentration. Furthermore, work done at Penn State University showed that the shale immediately above a coal seam also has very high concentrations of REEs. Using appropriate extraction methods on each of these two coal byproducts could mean a billions-of-dollars industry lies literally under our feet. The U.S. Department of Energy plans to invest $20 million in companies who are able to develop a way to extract REEs that makes economic sense.

The Periodic Table of the Elements with Rare Earth Elements Highlighted



To complete the steel-making process, iron is sent to a blast furnace. Oxygen that is 99 percent pure is blown into the blast furnace, increasing the temperature to 1700°C. As a result, impurities oxidize, the scrap melts, and carbon is reduced by 90 percent. The liquid steel is cooled and sent on to other processes.

▪ Cement Manufacturing

One of the most energy-intensive industries is manufacturing cement. Coal is used as an energy source in a high-temperature kiln to produce cement, which is used to build roads, buildings, sidewalks, almost anything man-made requiring a firm foundation. Two hundred kilograms of coal are needed to produce one **tonne** of cement, and 300-400 kg of cement are needed to produce one cubic meter of concrete.

▪ Liquid Fuel Production

Coal can be converted to a liquid fuel in a process called **liquefaction**, or CTL (coal to liquid). The liquid fuel can be used as an alternative to oil. Countries that rely heavily on petroleum imports and also have large domestic coal deposits are best suited to use CTL. South Africa has the only commercial CTL industry currently in operation.

▪ Other Coal Uses

Several years ago, researchers in South Africa were looking for a way to capture the tiny coal particles and coal dust that were wasted in standard coal mining operations. The dust was carried away in water used to rid coal of other contaminants. The research team at Nelson Mandela Metropolitan University, led by Professor Ben Zeelie, mixed the water-coal mixture with algae and discovered that the coal dust would stick to the algae, but the other, noncombustible minerals would not. The algae-coal was compressed into briquettes and marketed as Coalgae®. The briquettes could be used as is just like coal, and had an advantage because they were partly renewable. However, Dr. Zeelie discovered that heating the briquettes to about 500 °C without oxygen present would cause them to turn into a good-quality crude oil. The project is still in research and development stages, but could prove to be a promising way to utilize an abundant resource in a way other than burning it directly.

Coal is rich in carbon, which is what makes it a good energy source. As the demand for coal as an energy source decreases, researchers at the University of Kentucky are looking for more ways to use this carbon-rich resource. The Center for Applied Energy Research is investigating ways to use coal as a source for polymers, carbon fiber, carbon nanotubes, and activated carbon. More work will continue to be done in Kentucky and around the globe to find new uses for this abundant resource as the demand for carbon-based fuels shifts toward more renewable sources that have a lower environmental impact.

Coal Combustion Byproducts

▪ Fly Ash

Fly ash is produced when pulverized coal is burned. It is made up of the particles of unburned substances in coal. The particles are very small – averaging 50 micrometers in size – and are carried along with the hot flue gases out of the boiler. Filtration equipment designed to remove the particles in flue gases capture the fly ash for removal.

The value of fly ash lies in its high concentration of silicon dioxide and aluminum oxide. These materials will not form cement on their own, but when mixed with water and lime, Portland cement, or kiln dust, fly ash forms cement that can be used in a variety of applications. In fact, cement is one of the main uses of fly ash.

There are two classes of fly ash as defined by the American Society for Testing and Materials (ASTM). Class F is produced when anthracite or bituminous coal are burned. The silica and aluminum oxide are glassy in appearance, making 70 percent of the fly ash content by weight. Class C is produced when subbituminous or lignite coal are burned. It is **pozzolanic**, which means when mixed with water it can harden on its own and does not require an additional activator like lime. Class C fly ash is 50 percent silica and aluminum oxide.

Fly ash is used to make traditional concrete and is desirable for this application because the cement in the concrete tends to be stronger. Fly ash can also be used to make cellular or foam concrete, which incorporates a gas into the concrete mixture, making it lighter. In addition to concrete, fly ash can be used as a road bed base and soil conditioner.

▪ Using Flue Gases to Cultivate Algae

As discussed earlier, researchers discovered a way to combine coal dust with algae and change it into crude oil. Dr. Zeelie's research team also developed a way to cultivate algae using the flue gases from burning coal. The carbon dioxide and other gases are piped directly into the cultivation system. The nitrogen oxides (NOx) and carbon dioxide provide the exact nutritional needs of the algae, and the growing algae consume all the NOx and most of the CO_2 in the flue gases. Not all algae species are suitable for this kind of growth, and merely pumping the flue gas into a pond to grow algae is not practical. However, the technique has the potential to change the way we develop and cultivate biofuels in the future.

▪ Magnetite

When coal is first removed from the mine, it is often contaminated with rock and other noncombustible minerals. The coal is separated from the contaminants by density. Water is mixed with magnetite, a mineral high in iron, to achieve a fluid with a density higher than coal but lower than the other minerals. The coal floats on the water-magnetite slurry, while the rock and minerals sink to the bottom.

As iron mining techniques have evolved, the price of magnetite has increased because the techniques for mining domestic sources of iron ore are increasing in price, and magnetite is now being imported from countries where its production costs are lower. Thus the cost of separating the coal from its contaminants has increased significantly. In Kentucky, the cost of using magnetite in this way rose from $9.1 million to $21.5 million over the five years starting in 2004.

Since 1924, it has been well known in the scientific and patent-seeking communities that fly ash contains significant amounts of magnetite. However, recovering the magnetite, which is only about two percent of the mass of fly ash, was too expense to make it worthwhile. It is only recently that recovering magnetite from coal ash has been economically viable. The bottom ash is washed out of the boiler, piled, allowed to drain, and separated by particle size. The magnetite is removed using magnets and other separation techniques, then used by the mine to clean the coal of its contaminants as previously described.

Q&A

NEED GETS TO KNOW INDUSTRY PROFESSIONALS

Kris, Red Bone Mining Company

Kris is assistant superintendent, mine foreman, and engineer with a mining company in West Virginia. He worked part-time for the company while in college and joined them full-time after college.

TELL US A LITTLE ABOUT YOUR JOB AND WHAT YOU DO.

Red Bone Mining Company is a small independent contractor started by my father in 1983. We now have 40 employees and mine about 450,000 tons of coal a year. I'm involved in the day-to-day duties of the management side of operations. This means that even though I have a mining engineering degree, I do just about every job at the company that keeps us moving forward. I get involved in all aspects of mining, production, safety, and everything else connected with the business end, and spend 10 to 20 hours a week in the mine. My work involves constantly checking and rechecking what is being done and what we've just finished, especially to ensure safety and productivity. In one sweep of the eyes, I might be able to take care of 10 things at once.

HOW DID YOU DECIDE TO GO TO WORK IN THIS FIELD?

I started out in engineering school and was interested in both mining and the petroleum and natural gas fields. I chose mining because I had been around the business since I was a little kid and I knew the opportunities possible in this field. One other factor in choosing it was that I am very happy living in this area and wanted to stay here. Because the coal resource is here, I knew my work couldn't be moved as easily as in some other jobs. With some jobs, you can end up moving around the country or even outside the U.S. I knew this couldn't happen in this job.

WHAT TECHNOLOGY HAVE YOU USED THAT HAS HELPED YOU THE MOST IN YOUR WORK?

Unlike a lot of jobs today, you don't need great computer skills to do our work – just a basic understanding of how using a computer and programs like autocad or word processing can be enough. Where technology comes in is with the new technologies that make life better, the peace of mind kinds of things. The equipment we use is vastly improved, making our work better and safer.

WHAT IS A TYPICAL DAY AT WORK LIKE FOR YOU?

Because we have people working around the clock, someone is leaving when you start your day, and then someone else will follow you, so communication, organization and planning are very important. Once I go over what has been done and needs to be done, I have a list of things to do like inspections, making sure everything is operating the way it should be, and so forth, and I work on them.

WHAT IS THE MOST REWARDING PART OF YOUR JOB?

Just being around all the different people and working together as a group. Knowing that what you are doing certainly matters and it takes the group effort to get it done. I really enjoy that type of work environment and the pride of being part of a successful team.

WHAT ADVICE WOULD YOU GIVE TO A YOUNG PERSON WANTING TO WORK IN THIS ASPECT OF THE COAL FIELD?

If you want to be a miner, there is a certain amount of training needed to become an apprentice miner, which is where you'll start, but get other skills that interest you as well. We have hired people with good mechanic skills, wrench-turners who like to work on their cars, or people with welding and fabrication skills, all things you can learn in high school or career and technology programs.

WHAT OTHER COMMENTS DO YOU HAVE FOR STUDENTS?

Coal is the fuel that revolutionized our country and has been our mainstay for electricity generation for a long time. The hard work of coal mining people has made this possible. This field can be as rewarding as you want to make it and it will give you opportunities to go into many different career paths in the industry and make your work as challenging or as easy as you'd like it. Education is important – while some companies hire people with only high school degrees, a college education is a real plus for many jobs. As your education changes, the direction you can take changes.

Q&A NEED GETS TO KNOW INDUSTRY PROFESSIONALS

Kimberly, American Electric Power

Kimberly is a Portfolio Manager II in Fuel Procurement with AEP.

TELL US ABOUT YOUR JOB AND WHAT YOU DO.

My group, Fuel Procurement East, is responsible for purchasing the coal for the power plants in the eastern portion of the AEP system. The job involves working with coal suppliers and our power plants to assure there is an adequate supply of coal at the lowest reasonable cost to generate electricity for our customers.

HOW DID YOU DECIDE TO GO TO WORK IN THIS FIELD?

Having an engineering degree gave me the opportunity to choose from a variety of work when I graduated from college. I knew that I did not want to work in an office immediately, but probably would as I grew in my career. My first job with AEP was as a chemist at the Conesville Power Plant in Ohio. The experience I gained at Conesville and my knowledge of coal led to a job offer in AEP's Fuel, Emissions and Logistics Group (FEL), overseeing the quality of the coal delivered to the system. Being in FEL gave me the opportunity to work with the fuel buyers and to gain a better understanding of their responsibilities. I could see the job was challenging and involved working with a variety of internal and external groups, which was very appealing to me.

WHAT TECHNOLOGY HAVE YOU USED THAT HAS HELPED YOU THE MOST IN YOUR WORK?

Computers are essential tools we use every day. We have programs that help us to balance supply with consumption and track the deliveries from the contracts we manage. We also use our systems to track the quality and characteristics of coal to make sure we meet plant and environmental requirements.

WHAT IS A TYPICAL DAY AT WORK LIKE FOR YOU?

There really is no such thing as a typical day in my job. My day can go from being very quiet to being crazy in a matter of minutes. On a quiet day I would have time to review contract shipments, check plant inventories, talk to coal suppliers and plants and do paperwork for contracts. What makes the job become crazy are all the things that can go wrong at a plant, in transportation, or at a mine, that impact the unloading, consumption, delivery or mining of the coal we need. From the moment something goes wrong until the problem is fixed, I am involved to help find a solution.

WHAT IS THE MOST REWARDING PART OF YOUR JOB?

It is knowing that what I do is very important and integral to the company, and that through my actions and decisions, I can make a difference.

WHAT ADVICE WOULD YOU GIVE TO A YOUNG PERSON WANTING TO WORK IN THIS FIELD?

A college degree is very important and necessary to work in the energy industry since that will get your foot in the door and allow people to see the skills and talents you possess. Also, you have to find a job that fits both your education and your personality. A quiet person who does not like to talk with people would really struggle in a job similar to mine. Find a job that fits you and that you would enjoy. At times, the work can be very challenging, and at other times it can be very dry and tedious. However, in the end, it is very rewarding. Just remember that hard work and being open to opportunities are essential.

Q&A

NEED GETS TO KNOW INDUSTRY PROFESSIONALS

Kyle, American Electric Power

Kyle is an Energy Trader with AEP.

TELL US A LITTLE ABOUT YOUR JOB AND WHAT YOU DO.

I am responsible for managing an electricity-trading portfolio. My portfolio consists of purchases and sales of electricity contracts which are based on the price of electricity at certain times and locations. My goal is to make money by buying low and selling high. At American Electric Power (AEP), we have a robust energy marketing team that brings in business from customers that have come to rely on us for customized solutions for their electricity needs. Part of my job is to provide pricing for these deals and to assume these positions into my portfolio once the deal is done.

HOW DID YOU DECIDE TO GO TO WORK IN THIS FIELD?

Finance, especially investments, interested me the most in college so that is what I pursued. Since joining AEP, I have worked within several groups inside Commercial Operations, finally landing in Trading. I feel that gravitating toward trading was natural given its competitive nature and my background playing sports from childhood through college.

WHAT TECHNOLOGY HAVE YOU USED THAT HAS HELPED YOU THE MOST IN YOUR WORK?

Everything that I do in my job requires the most current information available. At AEP, we have different groups that are responsible for performing various analyses daily and providing that output to the rest of the company. All of this assists in my decision-making process throughout the day. Most of my work is done on the computer screen but there is still a lot to be said about talking to people and getting the deal done through negotiation.

WHAT IS A TYPICAL DAY AT WORK LIKE FOR YOU?

I get into the office early so that I can take my time and get ready for the flurry of activity that is about to start. The market that I trade is dependent on many factors and I need to get caught up to any changes that might have occurred overnight. For example, the weather is a major driver of my business. We employ a group of full-time meteorologists who brief us first thing in the morning on the forecast for the next 15 days. After I get caught up with new information, I canvass the market and try to find opportunities for profit. No day is ever the same.

WHAT IS THE MOST REWARDING PART OF YOUR JOB?

I liken trading to a competition, which makes “winning” the most rewarding part of my job. Success in my job is based on making good decisions. Not every decision you will make will be a good one, of course, but to have success you need many more good ones than bad ones. I find it very rewarding to see an idea make it from conception to fruition. Although it may take a long time and make you second-guess along the way, there is something good to be said about watching your idea succeed.

WHAT ADVICE WOULD YOU GIVE TO A YOUNG PERSON WANTING TO WORK IN THIS ASPECT OF THE COAL INDUSTRY?

A willingness to work hard will be required, beginning now in your formative years. Be patient throughout your schooling and first years on the job, and make the most of every experience. This field requires a love of working with numbers and attention to detail. You will need to be personable and function well in a team environment.

WHAT OTHER COMMENTS DO YOU HAVE FOR STUDENTS?

It is not too early to start thinking seriously about what you want to do in life and what you must do to get there. Explore many different careers and let the ones that interest you be your guide to future study. Always be networking, making new friends and keeping in touch with old, since having a large pool of contacts will benefit you in many aspects of your life.

Gary, American Electric Power

Gary is Manager of IGCC (Integrated Gasification Combined Cycle) & CCS (Carbon Capture and Sequestration) Engineering at AEP.

TELL US A LITTLE ABOUT YOUR JOB AND WHAT YOU DO.

I am a chemical engineer by background, and I work in the engineering section that evaluates new power generation technology. I am the group manager responsible for engineering of new gasification power plants and also of CCS projects and the installation of CCS technology in both existing power plants and in new ones. We work on the engineering equipment and the geology aspects of carbon sequestration (storage). What is especially fascinating about this is that most engineers don't have a lot of experience with geology, so my area of work is becoming very important these days.

HOW DID YOU DECIDE TO GO TO WORK IN THIS FIELD?

At AEP, I established a history of being able to do work that involved integrating new technologies into existing power plants, so when the opportunity to do CCS work came along, it seemed to be a natural fit. I headed in that direction and have been very happy to be working on these important projects. The CCS work at AEP started in the 1990s with limited geological characterization of sites. The company decided to demonstrate the technology in 2006, and that's when I got fully immersed in this work. Beyond technology and more formalized engineering, I am also responsible for public policy work on climate change as it relates to technology, so I guess I am involved in just about all aspects of CCS work, and I really enjoy it.

WHAT TECHNOLOGY HAVE YOU USED THAT HAS HELPED YOU THE MOST IN YOUR WORK?

While computers are obviously a big part of every engineer's life, I find the basic telephone and teleconferencing technologies are absolutely critical to my work. They may not be very high-tech, but they are very important to me to get my job done. Communication is an essential part of what I do. I give many presentations to federal and state policy-makers, university administrators, high school students and others, so I use presentation programs frequently in this work.

WHAT IS A TYPICAL DAY AT WORK LIKE FOR YOU?

I don't think I've ever had a day that I'd call typical. Because we do actual installation of CCS technology, for example, there is frequent interface with field engineers through teleconferences and meetings. Several times a week I am on the phone with our corporate policy people discussing the latest legislative language that is being considered. I spend a lot of time writing and reviewing grant documents. In other words, there are so many different things that need to be done that every day takes me in a different direction.

WHAT IS THE MOST REWARDING PART OF YOUR JOB?

Seeing new technologies go from concept on paper to actually being designed, installed and operational, is absolutely fascinating to me. It is personally rewarding to see a project I'm working on go from concept to completion.

WHAT ADVICE WOULD YOU GIVE TO A YOUNG PERSON WANTING TO WORK IN THIS ASPECT OF THE COAL FIELD?

Be open to challenges and opportunities that come your way, and stretch what you think you would be capable of doing. Make sure you value communications skills. It is one thing to be good at math or science or solving those types of problems, but if you can't communicate those answers to others, it is not useful.

WHAT OTHER COMMENTS DO YOU HAVE FOR STUDENTS?

Looking back at my studies, I never envisioned I'd be doing the kind of work that I am doing today. I knew I liked math and science, so engineering would be a good fit. But it never occurred to me all the ways that engineering is used in the business world. Keep your mind open to opportunities and to make sure you focus on things that interest you since there are so many ways you can take an engineering career. Think about things that catch your interest and look at how you might be able to bend your fascination with science and math toward those things.

Comparing the Types of Coal

Question

What are the differences between the major forms of coal?

Hypothesis

Write a hypothesis identifying what you think the major differences between the coal types are.

Materials

- One sample of each type of coal
- Colored pencils
- Electronic balance
- Graduated cylinder large enough to hold each coal sample
- Distilled water
- Scratch plate (optional) or fine-grit sandpaper

✔Procedure

1. Look at the samples of coal. Make a diagram of each of the pieces you have. Using colored pencils, accurately shade your diagrams to reflect the appearance of each piece.
2. Beneath each drawing, list identifying characteristics such as hardness, luster, odor, chalkiness, etc.
3. If you have a scratch plate, use it to determine the hardness of each coal sample. If you do not have one, rub the samples against the sand paper and rank them in order from softest to hardest.
4. Use a balance to determine the mass of each sample. Record the mass in the data table.
5. Use a graduated cylinder with a known volume of water to determine the volume of each sample. Record the volume in the data table.
6. Calculate the density of each sample. The density is calculated by dividing the mass by the volume. Density is expressed in units of g/cm^3. Record the density in the data table.
7. Dry off each coal sample and return it to its original location. Empty the graduated cylinder, rinse it, and let it dry.

Data and Observations

COAL TYPE	PEAT	LIGNITE	SUBBITUMINOUS	BITUMINOUS	ANTHRACITE
DRAWING					
DESCRIPTION					
MASS (g)					
VOLUME (cm^3)					
DENSITY (g/cm^3)					

Conclusion

1. List the forms of coal in order from softest to hardest. Cite the experimental evidence that supports your ranking.
2. List the forms of coal in order from least dense to most dense. Which forms would float in distilled water? Cite the experimental evidence that supports your answer.
3. Anthracite is the highest rank of coal. Using your experimental data, explain why this is.
4. Lignite is the lowest rank of coal. Using your experimental data, explain why this is.
5. Compare your data to the chart in the informational text on page 42. Explain how your observations and calculations are within the stated range for each type of coal, or if they fall outside the range, give some reasons as to why.

The Properties of Coal

Part One: Moisture Content in Coal

Question

What is the percent moisture of coal?

Hypothesis

Predict the mass by percent moisture in a sample of coal.

Materials

- Small crucible with lid
- Spatula
- Coal sample
- Mortar & pestle
- Drying oven (can use a small electrical cooking oven)
- Desiccator
- Electronic scale

Vocabulary

- desiccant (desiccator)
- volatiles
- moisture content

Procedure

1. Grind 10 grams of a coal sample in the mortar to a fine powder.
2. Measure out a 0.5 gram sample of the ground coal and place in a weighed crucible with a lid.
3. Record the mass of the ground coal sample plus the crucible and lid.
4. Place the crucible containing the sample in a drying oven with the lid on the crucible. Set the temperature at 105 to 110 degrees Celsius for about 8-10 hours or overnight.
5. When the sample is dried, place the crucible and sample in a desiccator until you're ready to take the mass.
6. Record the mass of the dried sample and calculate the mass of water removed from the sample.

Data and Observations

MASS OF EMPTY CRUCIBLE AND LID	g
MASS OF CRUCIBLE, LID, AND COAL SAMPLE, BEFORE DRYING	g
MASS OF CRUCIBLE, LID, AND COAL SAMPLE, AFTER DRYING	g
MASS OF WATER REMOVED FROM COAL SAMPLE	g

Conclusion

1. Calculate the percent moisture based on the weight lost in the experiment.
2. Was your prediction correct? Use your experimental evidence to support your statement.
3. Explain why it is important to use both a lid and the desiccator for this experiment.
4. Based on your evidence and the information provided in the informational text, explain and support what effect the moisture content will have on the energy output of this coal.
5. Give suggestions explaining how the water came to be incorporated in the coal sample. Support your answer with experimental data and information from the text.

Part Two: Ash Content of Coal

Question

What is the percent ash of a coal sample?

Hypothesis

Predict the percent by mass of ash in a coal sample.

Materials

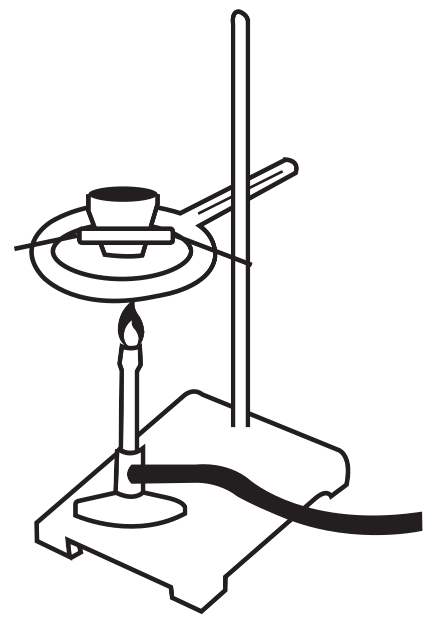
- Crucible with lid
- Electronic balance
- Bunsen burner (alcohol burner)
- Ring and ring stand
- Screen or triangle or desiccator
- Dried 0.5 gram finely ground sample of coal (Use dried samples from Part One)

Vocabulary

- fly ash
- bottom ash
- clinkers
- volatiles
- fixed carbon

✔ Procedure

1. Record the mass of the dried 0.5 gram sample from Part One.
2. In a hood, set up the apparatus shown with a crucible, triangle, ring stand, and burner.
3. Use the burner to heat the dry coal with the lid off for 10 minutes, until all volatiles are gone and a dull, dark, carbon mass is formed (coke).
4. Tilt the crucible and place the flame of the burner or torch directly on the coke, igniting it. Allow it to burn until it is a gray color of ash. This will take an additional 10 minutes to burn completely.
5. Place the ash sample and crucible in a desiccator in the fume hood to cool.
6. When fully cooled, take the mass of the ash and record it in the data table.



Data and Observations

MASS OF CRUCIBLE, LID, AND DRY COAL SAMPLE	g
MASS OF CRUCIBLE, LID, AND ASH AFTER BURNING	g
MASS OF ASH IN COAL	g

Conclusion

1. Calculate percent by mass of the ash in a dried coal sample.
2. Was your prediction correct? Use evidence to support your statement.
3. Based on your evidence and information in the text, explain and support what effect ash content will have on the energy output of the coal.
4. Give examples and support with evidence what determines the ash in your coal sample.
5. Based on the data collected in both Part One and Part Two, and using the chart in the informational text on page 42, identify your coal sample by type.

Extension

- While burning the volatiles off the coal, use tongs and hold a damp pH paper in the fumes and observe the color change on the paper. Explain what your observation might indicate is present in the fumes and use evidence to support what problems might arise from the release of these volatiles.

Heat Content of Coal

Background

Successful combustion of any material requires three things – fuel, oxygen, and an ignition source – known as the fire triangle. Because it is a chemical reaction, the rate at which combustion occurs can be affected by the amount of surface area of a solid reactant or amount of ignition energy present.

Coal is very stable in the Earth's atmosphere despite the large amount of oxygen present. Even if left to sit undisturbed on a shelf, coal will not change much. However, coal is also one of the top three energy sources in the United States, and the energy contained within it is released via combustion. In order to use it as an energy source, some important changes to the way coal is burned must occur.

One way to increase the rate of combustion of coal is to pulverize it to a powder. This serves two purposes. First, pulverizing the coal and washing it removes heavy, rocky sediments that would interfere with the combustion of coal and the amount of thermal energy it releases. Second, crushing it increases the amount of surface area available for the combustion reaction and increases the rate of reaction.

Another way to increase the rate of combustion is to increase the amount of ignition energy available. This is done by dousing the coal with another hydrocarbon fuel source, such as diesel fuel or natural gas, and igniting it. In fact, it is very difficult to ignite coal without using a secondary fuel source to increase the temperature. The energy released by the burning fuel is then enough to initiate the combustion of the coal. Once a coal-fired boiler is ignited, it is kept burning until extinguishing the fire is absolutely necessary.

The extra effort required to ignite coal is why it is used primarily for baseload electricity generation. Keeping a coal power plant burning at a constant rate decreases the need for additional fuel to re-ignite the burner.

Question

Which fuel releases more thermal energy?

Hypothesis

Predict the amount of thermal energy released in a five minute burn of coal and compared to the burning of another fuel.

Caution

Experiment must be done in a hood to avoid inhaling the fumes from the burning of the coal sample.

Materials

- 2 Rings
- Ring stand
- Burner (Bunsen, alcohol, or propane)
- Small crucible
- Soda can
- 150 mL of Distilled water
- Thermometer
- 2 Gram dried sample of coal (from previous activity, Part One)

Vocabulary

- Btu
- calorie
- specific heat (1 kg = 2.2 lbs)

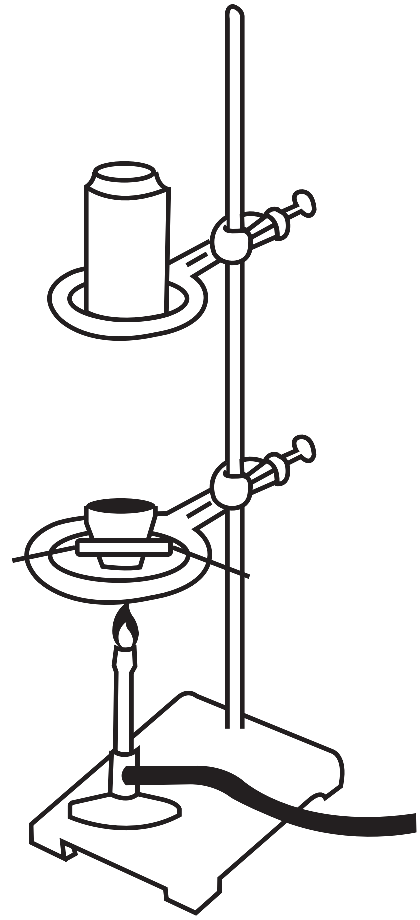
Conversions

- 1 Btu = 255.2 calories
- Specific heat of water = 4.18 J/g °C
- 1 kg = 2.2 lbs

✔ Procedure

***NOTE*:** The first part of the experiment can be done outside the hood.

1. Weigh and record the mass of 50 mL of distilled water. Place the water in an empty soda can.
2. Measure and record the temperature of the water.
3. Set up the apparatus so the can with water is placed on a ring stand just above the flame of your fuel source (do not use coal for this trial run).
4. Light the burner and heat the water for 3 minutes. Record the water temperature at the end of 3 minutes of heating.
5. After the apparatus is cooled, empty the water and move the apparatus inside the fume hood.
6. Weigh and record the mass of 50 mL of distilled water. Add the water to the soda can.
7. Measure and record the initial temperature of the water in the can.
8. Set the can in the apparatus, and place to the side.
9. Measure and record the mass of a dried 2 gram ground sample of coal (use remaining ground coal from *The Properties of Coal* activity).
10. Place the coal in the crucible and begin heating the coal directly with the burner flame until the coal has ignited.
11. Turn off the burner flame and place the burning coal sample in the crucible underneath the filled soda can.
12. Let the burning coal sample heat the water for 3 minutes.
13. Measure and record the water temperature after the 3 minute coal heating.
14. Use the formula *mass x* ΔT of water to determine the amount of calories of heat measured from the burning of the coal and the burning of the burner in a 3 minute interval.



⁂ Conclusion

1. Calculate the amount of energy in calories for both of the respective burns.
2. Use evidence to compare the amount of energy produced with each of the 3 minute burns.
3. Explain how error might occur in this lab.
4. Extrapolate the amount of Btus in a ton of this coal, assuming a 10 minute burn is required for a 2 gram sample.

Science of Electricity Model

✪ Objective

To demonstrate how electricity is generated.

Caution

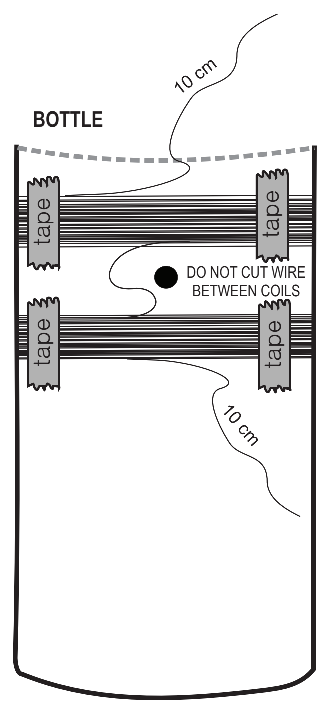
- The magnets used in this model are very strong.
- Use caution with nails and scissors when puncturing the bottle.

Materials

- 1 Small bottle
- 1 Rubber stopper with ¼" hole
- 1 Wooden dowel (12" x ¼")
- 4 Strong rectangle magnets
- 1 Foam tube
- 1 Small nail
- 1 Large nail
- Magnet wire
- Permanent marker
- 1 Pair sharp scissors
- Masking tape
- Fine sandpaper
- 1 Push pin
- 1 Multimeter with alligator clips
- Hand operated pencil sharpener
- Ruler
- Utility knife (optional)

Preparing the Bottle

1. If needed, cut the top off of the bottle so you have a smooth edge and your hand can fit inside. This step may not be necessary. If necessary, a utility knife may be of assistance.
2. Pick a spot at the base of the bottle. (HINT: If the bottle you are using has visible seams, measure along these lines so your holes will be on the opposite sides of the bottle.) Measure 10 centimeters (cm) up from the base and mark this location with a permanent marker.
3. On the exact opposite side of the bottle, measure 10 cm up and mark this location with a permanent marker.
4. Over each mark, poke a hole with a push pin. Do not distort the shape of the bottle as you do this.
   CAUTION: Hold a rubber stopper inside the bottle behind where the hole will be so the push pin, and later the nails, will hit the rubber stopper and not your hand, once it pokes through the bottle.
5. Widen each hole by pushing a nail through it. Continue making the hole bigger by circling the edge of the hole with the side of the nail. (A 9/32 drill bit twisted slowly also works, using a rubber stopper on the end of the bit as a handle.)
6. Sharpen one end of the dowel using a hand operated pencil sharpener (the dowel does not have to sharpen into a fine point). Push the sharpened end of the dowel rod through the first hole. Circle the edge of the hole with the dowel so that the hole is a little bigger than the dowel.
7. Remove the dowel and insert it into the opposite hole. Circle the edge of the hole with the dowel so that the hole is a little bigger than the dowel. An ink pen will also work to enlarge the hole. Be careful not to make the hole too large, however.
8. Insert the dowel through both holes. Hold each end of the dowel and swing the bottle around the dowel. You should have a smooth rotation. Make adjustments as needed. Take the dowel out of the bottle and set aside.
9. With a permanent marker, label one hole "A" and the other hole "B."

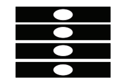


Generator Assembly: Part 1

1. Tear 6 pieces of tape approximately 6 cm long each and set aside.
2. Take the bottle and the magnet wire. Leave a 10 cm tail, and tape the wire to the bottle about 2 cm below hole A. Wrap the wire clockwise 200 times, stacking each wire wrap on top of each other. Keep the wire wrap below the holes, but be careful not to cover the holes, or get too far away from the holes.
3. DO NOT cut the wire. Use two pieces of tape to hold the coil of wire in place; do not cover the holes in the bottle with tape (see diagram).
4. Without cutting the wire, move the wire about 2 cm above the hole to begin the second coil of wraps in a clockwise direction. Tape the wire to secure it in place.

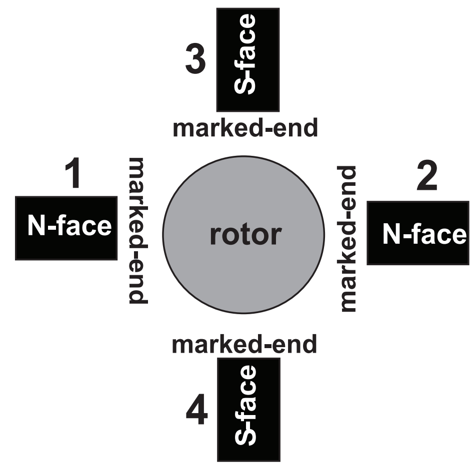
1. Wrap the wire 200 times clockwise, again stacking each wrap on top of each other. Hold the coil in place with tape (see diagram).
2. Unwind 10 cm of wire (for a tail) from the spool and cut the wire.
3. Check your coil wraps. Using your fingers, pinch the individual wire wraps to make sure the wire is close together and close to the holes. Re-tape the coils in place as needed.
4. Using fine sandpaper, remove the enamel coating from 4 cm of the end of each wire tail, leaving bare copper wires. (This step may need to be repeated again when testing the model, or saved for the very end).

Diagram 1



Stacked Magnets End View

Diagram 2

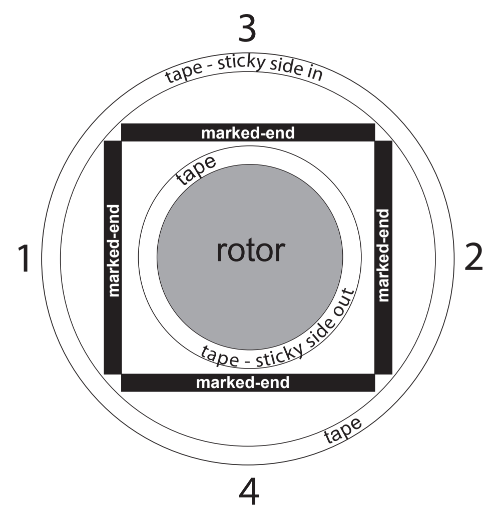


Rotor Assembly

1. Measure 4 cm from the end of the foam tube. Using scissors, carefully score a circle around the tube. Snap the piece from the tube. This piece is now your rotor.
2. On the flat ends of the rotor, measure to find the center point. Mark this location with a permanent marker.
3. Insert the small nail directly through the rotor's center using your mark as a guide.
4. Remove the small nail and insert the bigger nail.
5. Remove the nail and push the dowel through, then remove the dowel and set aside. Do **NOT** enlarge this hole.
6. Stack the four magnets together. While stacked, mark one end (it does not matter which end) of each of the stacked magnets with a permanent marker as shown in Diagram 1.
7. Place the magnets around the foam piece as shown in Diagram 2. Make sure you place the magnets at a distance so they do not snap back together.
8. Wrap a piece of masking tape around the curved surface of the rotor, sticky side out. Tape it down at one spot, if helpful.
9. Lift the marked end of Magnet 1 to a vertical position and attach it to the rotor. Repeat for Magnets 2, 3, and 4.
10. Secure the magnets in place by wrapping another piece of masking tape over the magnets, sticky side in (Diagram 3).

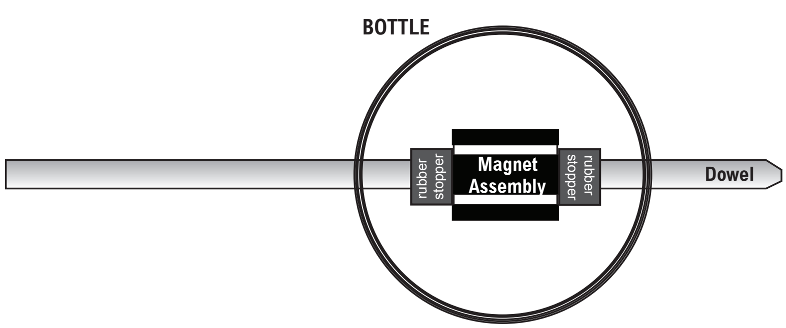
*WARNING: These magnets are <u>**very**</u> strong. Use caution when handling.*

Diagram 3



Generator Assembly: Part 2

1. Slide the sharp end of the dowel through Hole A of the bottle.
2. Inside the bottle, put on a stopper, the rotor, and another stopper. The stoppers should hold the foam rotor in place. If the rotor spins freely on the axis, push the two stoppers closer against the rotor. This is a pressure fit and no glue is needed.
3. Slide the sharp end of the dowel through Hole B until it sticks out about 4 cm from the bottle.
4. Make sure your dowel can spin freely. Adjust the rotor so it is in the middle of the bottle.



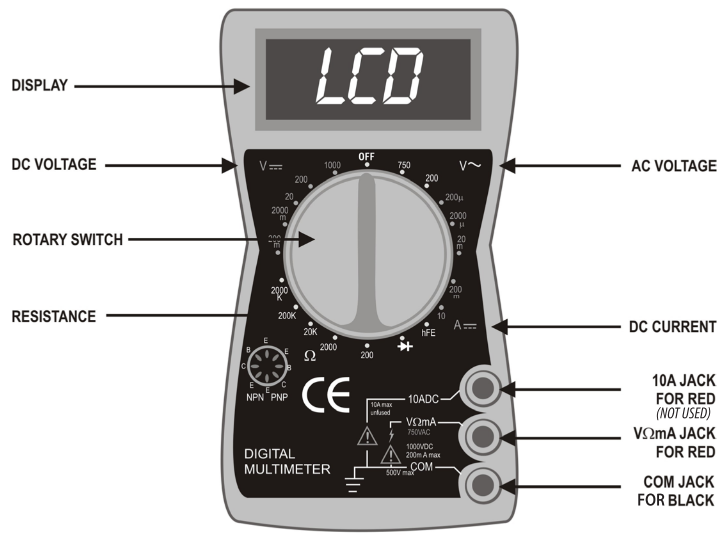
Assembly Notes

- The stoppers can be cut in half so that one stopper is made into two, to allow for more materials. These often slide more easily on the dowel. This must be done using sharp scissors or a utility knife, and can often be dangerous. As this step is not required (the kit supplies you with two stoppers to use), exercise extreme caution.
- If the foam rotor fits snugly on the dowel, put the stoppers on the outside of the bottle to help center the rotor in the bottle. Leave enough space to allow free rotation of the rotor.
- The dowel may be lubricated with lip balm or oil for ease of sliding the stoppers, if necessary.
- If a glue gun is available, magnets can be attached to the rotor on edge or on end to get them closer to the coils of wire. Use the magnet to make an indentation into the foam. Lay down a bead of glue, and attach the magnets. If placing the magnets on end, however, make sure they clear the sides of the bottle for rotation.

Testing the Science of Electricity Model

1. Connect the leads to the multimeter to obtain a DC Voltage reading.
2. Connect one alligator clip to each end of the magnet wire. Connect the other end of the alligator clips to the multimeter probes.
3. Set your multimeter to DC Voltage 200 mV (millivolts). Voltage measures the pressure that pushes electrons through a circuit. You will be measuring millivolts, or thousandths of a volt.
4. Demonstrate to the class, or allow students to test how spinning the dowel rod with the rotor will generate electricity as evidenced by a voltage reading. As appropriate for your class, you may switch the dial between 200 mV and 20 volts. Discuss the difference in readings and the decimal placement.*
5. Optional: Redesign the generator to test different variables including the number of wire wraps, different magnet strengths, and number of magnets.

*Speed of rotation will impact meter readings.



Note: Your multimeter may look different than the one shown. Read the instruction manual included in the multimeter box for safety information and complete operating instructions.

Troubleshooting

If you are unable to get a voltage or current reading, double check the following:

- Did you remove the enamel coating from the ends of the magnet wire?
- Are the magnets oriented correctly?
- The magnet wire should not have been cut as you wrapped 200 wraps below the bottle holes and 200 wraps above the bottle holes. It should be one continuous wire.
- Are you able to spin the dowel freely? Is there too much friction between the dowel and the bottle?
- Is the rotor spinning freely on the dowel? Adjust the rubber stoppers so there is a tight fit, and the rotor does not spin independently.

Notes

- The *Science of Electricity Model* was designed to give students a more tangible understanding of electricity and the components required to generate electricity. The amount of electricity that this model is able to generate is very small.
- The *Science of Electricity Model* has many variables that will affect the output you are able to achieve. When measuring millivolts, you can expect to achieve anywhere from 1 mV to over 35 mV.
- More information about measuring electricity can be found in NEED's *Secondary Energy Infobook*. You may download this guide from www.NEED.org.

Science of Electricity Model

Observe the science of electricity model. Draw and label the parts of the apparatus.

Explain how electricity is generated using appropriate vocabulary.

Mining Challenge

✪Objective

You will work in teams. Each team will become a mining company. Your company wants to mine as much coal (chocolate chips) from your mine (cookie) as possible. Each team will be given a starting investment of $105.00 to purchase land, equipment, and pay their miners. There will be a class banker, equipment salesman, and realtor who sells the land to be mined. A list of costs includes:

Each mine will cost **$20.00** to purchase

Wooden tools will cost **$1.00** each to purchase

Plastic tools will cost **$2.00** each to purchase

Metal tools will cost **$3.00** each to purchase

Each miner must be paid **$15.00** for each shift

Each ton (square) of coal mined is worth **$5.00**

Land outside the original mine after reclamation will cost **$1.00** (per square)

✔Procedure

1. Each team member will assume a role in the company. Read the job descriptions below and write each team member's name on the line next to the job he/she has picked.

The mineral engineer (1 team member) is responsible for purchasing the land to be mined and determining which tools the team will purchase. He/she will also survey the boundaries of the mine, outlining the land boundaries on the grid. When the mining shift ends, he/she will oversee reclamation of the land.

Mineral engineer____

The accountant (1 team member) is responsible for tracking the expenses and income of the company.

Accountant____

The miners (1-3 team members) are responsible for 'mining' the coal and reclaiming the land.

Miner 1 ____

Miner 2 ____

Miner 3 ____

2. Decide how many mines ($20.00 each) your company wants to purchase and what mining supplies you wish to purchase.
3. Determine how many 1-minute shifts your team will use to complete the mining.
4. Mine your land (cookie) during the timed shifts. Remember, you may ONLY use the tools purchased to do your mining – NO HANDS! Try to recover as much coal (chocolate chips) as possible during each shift. At the end of each minute shift, place your coal in the grid to be counted. Each ton will earn you a payout. A square must be at least half-full to count as a ton. Tally up labor costs to pay the miners and take this money to the bank for safe keeping. Your accountant will keep track of your funds earned and paid.

5. Once your team has mined for the number of shifts you selected, you must reclaim your land. Try to piece your cookie together so that the land is as good as, or better than, it was before.
6. The mineral engineer will determine if any land is outside the original mine and fine your team $1.00 for any land leftover outside of the original mine outline.
7. Help your accountant total up your expenses and earnings and complete the final balance.

Data

Name of your company:_______________________ Beginning Balance: $__________________

EXPENSES	QUANTITY	UNIT PRICE	TOTAL
Mine Site		$20.00	
Wooden Toothpick		$1.00	
Plastic Toothpick		$2.00	
Paper Clip		$3.00	
Labor Costs		$15.00 per shift	
Reclamation		$1.00 per square	
TOTAL EXPENSES			**$**

Final Balance

Step 1

Beginning balance $________________

Minus expenses $________________

Current balance $________________

Step 2

Current balance $________________

Plus income from coal $________________

Ending balance $________________

Did your company make a profit or suffer a loss? (+ or -) _______________________

What was your profit/loss amount? $_______________________

Area of Mine Site

Outline your mine (cookie) on the grid below.

Put mined coal (chips) here.

Income from coal: ___________________

$5 per ton (square must be at least half-full to be counted as a ton)

Mine Reclamation

Background

Reclamation regulations require that land be returned to its original state or better after mining operations are completed. Simply pushing the dirt around to fill in holes is not enough to return the area back to its original state. If done improperly, sites can be exposed to erosion, or movement of soil and sediment, leaking of chemicals, or even landslides. This activity will show you how the different parts of reclamation serve to reclaim mine sites for other uses such as recreation, farming, or nature.

Question

What happens at a mine site when mining operations cease?

Materials

- Aluminum or plastic pan, 2-3" deep
- Soil or potting mix
- Squirt bottle with water
- Pebbles and stones
- Twigs
- Grass seed

✔ Procedure

1. Make a mountain of soil in the middle of the pan. Build the soil up but don't pack it down very hard.
2. Using the squirt bottle, gently squirt water on your "mountain" to simulate a gentle rain. Record your observations. Squeeze the bottle again, this time with more force to simulate hard rain, and record your observations.
3. Build your mountain again, and add some pebbles or stones to the mountain.
4. Repeat step 2 on your rocky mountain and record your observations.
5. Build your mountain a third time, and add some twigs to represent trees. Repeat step 2 and record your observations.
6. Build your mountain a fourth time, packing the soil down tightly. Repeat step 2 and record your observations.
7. Break up your tightly packed mountain, then rebuild it. Tightly pack one side only. Sow some grass seed on both the loosely constructed as well as the tightly packed sides of the mountain and leave it on a window ledge until the grass sprouts and grows, about 2 weeks.
8. Compare the loosely constructed and tightly packed sides of the "mountain." Record observations with respect to how well the grass is growing.
9. Repeat step 2 one last time, observing the effect grass had on the reclaimed soil.

Data and Observations

MOUNTAIN CONSTRUCTION	GENTLE RAIN SIMULATION	HARD RAIN SIMULATION
Loose, mounded soil		
Loose soil with stones		
Loose soil with twigs		
Packed soil		
Loose soil with grass		
Packed soil with grass		
Quality and appearance of grass growing on loose soil		
Quality and appearance of grass growing on packed soil		

Conclusion

1. What was the effect of adding stones, twigs, and/or grass to the mountain? Cite your experimental evidence to support your statement.
2. Which addition (stones, twigs, or grass) was most effective in reducing erosion? Cite your experimental evidence to support your statement.
3. What effect did packing the soil have on the ability of the grass to grow? Old reclamation efforts included packing the soil tightly to prevent settling. Based on what you saw in this activity, describe what you believe tightly packing the soil in reclamation did with respect to vegetation growing on the site.

Properties of CO_2

What are the properties of CO_2 as a solid and a gas? Record your observations below.

Enhanced Fuel Recovery Model

OPTION A: DRY ICE

Background

Capturing carbon dioxide at the source of generation, pressurizing it to liquid form, and pumping it underground is one possible way to mitigate increasing carbon dioxide levels in the atmosphere. Using that pressurized carbon dioxide to increase production of a petroleum or natural gas reservoir is a way to turn a waste product into a useful tool for increasing petroleum or natural gas production.

Question

How does using carbon dioxide allow additional oil and gas to be recovered from reservoirs that are slowing production?

Hypothesis

Make a hypothesis to address the question using the following format: If (independent variable) then (dependent variable) because ...

Materials

- 1 pint-size Mason jar with lid with two ¼" holes
- 1 pint-size Mason jar lid with one ¼" hole
- 1 Empty water bottle
- 2 24" x ¼" Tubing
- 1 Piece of dry ice, about the size of an ice cube
- Assorted rocks, sand, and marbles
- 150 mL Vegetable oil or lamp oil
- 350 mL Water
- 1 Dark color of food dye
- Silicon sealant
- Tongs
- Gloves
- Safety glasses
- Tape

✔ Procedure

1. Put one piece of tubing through the lid with two holes. Slide the tube all of the way down into the bottom of one jar. Tape the tubing to the inside of the jar to hold it in place. This jar will serve as your **reservoir jar**. Place the open end of this tube into the water bottle. The water bottle will serve as your **production bottle**.
2. Insert the second piece of tubing about 5 cm through the second hole in the lid for the reservoir jar. Insert the other end of this tube about 5 cm into the lid with one hole for the other empty mason jar. The jar with one hole on the lid will serve as your **CO_2 injection jar.**
3. Secure the tubing in both lids with sealant. (If time permits, allow the sealant to dry prior to executing the experiment for better results.)
4. Fill the **reservoir jar** with marbles, rocks, and/or sand. Leave about an inch of open space at the top of the reservoir jar.
5. Add 150 mL of oil to the **reservoir jar**. This represents crude oil stuck within the rocks below ground.
6. Fill the remainder of space in the **reservoir jar** with water, being careful to fill only up to the top of the rocks/marbles/sand. Dye the water with food coloring if you desire.
7. Secure the lid with two holes on the **reservoir jar** tightly.
8. Pinch off the tubing and gently rotate and mix the **reservoir jar**.
9. Using tongs, place a piece of dry ice into the **CO_2 injection jar** with one tube in its lid. Secure the lid and be prepared for the **production bottle** to start filling up with recovered oil and water from the reservoir.

Observations

Draw a diagram of your reservoir model. Describe what is happening. Where is the CO_2 going? Where is the oil going? How much oil were you able to recover?

Conclusion

1. How does carbon dioxide allow for enhanced hydrocarbon recovery? What are some of the benefits? What are some of the challenges?

Enhanced Fuel Recovery Model

OPTION B: EFFERVESCENT TABLETS

Background

Capturing carbon dioxide at the source of generation, pressurizing it to liquid form, and pumping it underground is one possible way to mitigate increasing carbon dioxide levels in the atmosphere. Using that pressurized carbon dioxide to increase production of a petroleum or natural gas reservoir is a way to turn a waste product into a useful tool for increasing petroleum or natural gas production.

Question

How does using carbon dioxide allow additional oil and gas to be recovered from reservoirs that are slowing production?

Hypothesis

Make a hypothesis to address the question using the following format: If (independent variable) then (dependent variable) because ...

Materials

- 1 pint-sized Mason jar with lid with two ¼" holes
- 1 pint-sized Mason jar with lid with one ¼" hole
- 1 Empty water bottle
- 2 24" x ¼" Tubing
- Effervescent tablets
- Assorted rocks, sand, and marbles
- 150 mL Vegetable oil or lamp oil
- 350 mL Water
- 1 Dark color of food dye
- Silicon sealant
- Tongs
- Gloves
- Safety glasses
- Piece of tissue paper

✔ Procedure

1. Put one piece of tubing through the lid with two holes. Slide the tube all of the way down into the bottom of one jar. Tape the tubing to the inside of the jar to hold it in place. This jar will serve as your **reservoir jar**. Place the open end of this tube into the water bottle. The water bottle will serve as your **production bottle**.
2. Insert the second piece of tubing about 5 cm through the second hole in the lid for the reservoir jar. Insert the other end of this tube about 5 cm into the lid with one hole for the other empty mason jar. The jar with one hole on the lid will serve as your **CO_2 injection jar.**
3. Secure the tubing in both lids with sealant. (If time permits, allow the sealant to dry prior to executing the experiment for better results.)
4. Fill the **reservoir jar** with marbles, rocks, and/or sand. Leave about an inch of open space at the top of the reservoir jar.
5. Add 150 mL of oil to the **reservoir jar**. This represents crude oil stuck within the rocks below ground.
6. Fill the remainder of space in the **reservoir jar** with water, being careful to fill only up to the top of the rocks/marbles/sand. Dye the water with food coloring if you desire.
7. Secure the lid with two holes on the **reservoir jar** tightly.
8. Pinch off the tubing and gently rotate and mix the **reservoir jar**.
9. Pour 350 mL of water into the **CO_2 injection jar**.
10. Make a packet of 6 effervescent tablets out of a single thickness of tissue paper and twist it closed.
11. Holding the lid set-up of the **CO_2 injection jar** close to the mouth of the jar, quickly drop the tissue paper packet into the **CO_2 injection jar**.
12. Immediately secure and tighten the lid of the **CO_2 injection jar**.
13. The tissue paper will get wet, permitting the tablets to fizz. Swirl the jar around gently to encourage all of the tablets to dissolve. Be prepared for the **production bottle** to start filling up with recovered oil and water from the reservoir.

Observations

Draw a diagram of your reservoir model. Describe what is happening. Where is the CO_2 going? Where is the oil going? How much oil were you able to recover?

Conclusion

1. How does carbon dioxide allow for enhanced hydrocarbon recovery? What are some of the benefits? What are some of the challenges?

Electric Connections
GAME INSTRUCTIONS

Almost forty percent of the nation's energy is used to make electricity today. Experts predict that this figure will continue to increase. The U.S. is becoming more dependent on electricity to meet its energy needs as we depend on more technology. To meet the growing demand, many energy sources are used to generate electricity. Some energy sources produce a substantial amount of the electricity we consume, while others produce less than one percent.

Individual Instructions

Your task is to rank the ten sources of energy in order of their contribution to U.S. electricity production. Place a number **one** by the source that provides the **largest amount** of electricity, a number two by the source that provides the second largest, down to a number ten by the one that provides the least amount of electricity. Use critical reasoning skills to determine the order.

Group Instructions

Starting at the top of the list, ask members to contribute any knowledge they have about each energy source. Brainstorm by asking group members questions such as:

- Is this source limited to a certain area of the country?
- Are there any problems or limitations associated with this source?
- Have you ever seen a power plant that uses this particular source of energy?

One person in the group should take notes. Once the group has gone through the list, it should divide the ten energy sources into three levels of importance: the top three most significant energy sources, the middle four moderately significant energy sources, and the bottom three least significant energy sources. The group should then rank the ten sources of energy in order of their contribution to U.S. electricity production.

SOURCES USED TO GENERATE ELECTRICITY

SOURCE	YOUR RANK	GROUP RANK
BIOMASS		
COAL		
GEOTHERMAL		
HYDROPOWER		
NATURAL GAS		
PETROLEUM		
PROPANE		
SOLAR		
URANIUM		
WIND		

Electric Connections

U.S. ELECTRIC POWER GENERATION SOURCES

SOURCES USED TO GENERATE ELECTRICITY

SOURCE	STATISTICS	RANK	YOUR RANK	ERROR POINTS	GROUP RANK	ERROR POINTS
BIOMASS	In 2015, biomass produced 64.2 billion kilowatt-hours of electricity, 1.6 percent of the nation's total. Biomass electricity is usually the result of burning wood waste, landfill gas, and solid waste.					
COAL	Over 90 percent of the nation's coal is consumed by electric utility companies to produce electricity. In 2015, coal produced 1,356.1 billion kilowatt-hours of electricity, which was 33.1 percent of the nation's electricity.					
GEOTHERMAL	In 2015, geothermal power plants produced 16.8 billion kilowatt-hours of electricity, mostly from facilities in the western U.S. Geothermal energy produced 0.4 percent of the nation's electricity.					
HYDROPOWER	6.0 percent of U.S. electricity is generated by 2,200 hydro plants nationwide. Hydro plants produced 246.1 billion kilowatt-hours of electricity in 2015. It is the leading renewable energy source used to provide electricity.					
NATURAL GAS	Natural gas produced 1,335.1 billion kilowatt-hours of electricity in 2015, generating 32.6 percent of the nation's electricity. Natural gas is used by turbines to provide electricity during peak hours of demand.					
PETROLEUM	Petroleum provided 0.7 percent of U.S. electricity, generating 28.4 billion kilowatt-hours of electric power in 2015.					
PROPANE	There are no statistics available for propane's contribution to electricity generation. Very little propane is used to produce electricity.					
SOLAR	Solar energy provided just over 0.9 percent of U.S. electricity in 2015, amounting to 38.6 billion kilowatt-hours of electricity. Electricity was generated by solar thermal systems or photovoltaic arrays.					
URANIUM	99 nuclear reactors provided the nation with 19.5 percent of its electrical energy needs in 2015. Nuclear energy produced 797.2 billion kilowatt-hours of electricity.					
WIND	Wind energy produced 190.9 billion kilowatt-hours of electricity in 2015, providing 4.7 percent of the nation's electricity. Most of the wind-generated electricity is produced in Texas, Iowa, and Oklahoma.					

ERROR POINTS TOTALS ________ ________

Error points are the absolute difference between your ranks and EIA's (disregard plus or minus signs).

Data: Energy Information Administration, Annual Energy Report

SCORING:

0-12 Excellent
13-18 Good
19-24 Average
25-30 Fair
31-36 Poor
37-42 Very Poor

Geographical Electric Connections

Question

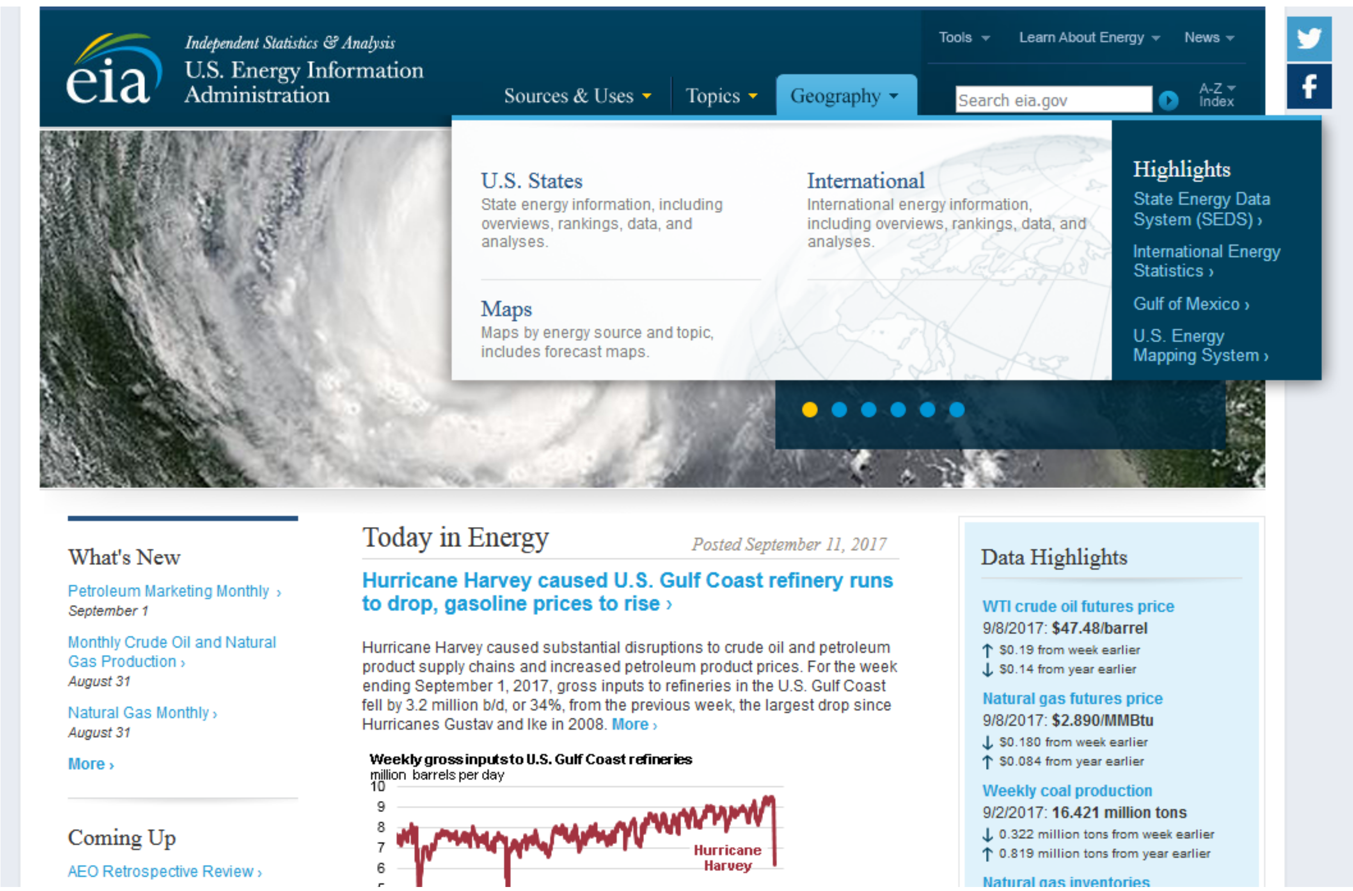
Which sources of energy provide the most electricity in the United States? How do individual states compare to the national average?

Materials

- Electric Connections Game
- Computer or tablet with internet access

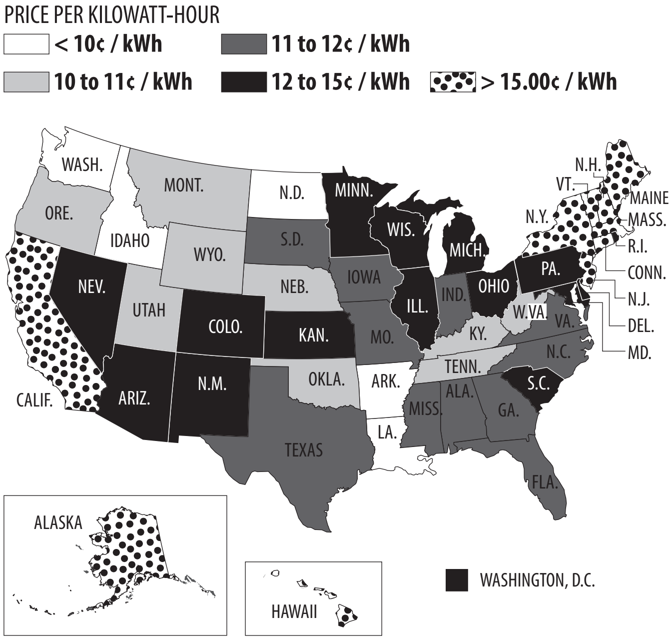
✔ Procedure

1. Navigate to the Energy Information Adminstration's web page, www.eia.gov, and click on the Geography tab. Select U.S. States.



2. Click on your state on the map.
3. Choose the Overview tab.
4. Scroll down beneath Quick Facts and click on the Electricity tab.
5. Record the sources used for electricity generation, and read the graph to determine the amount of electricity in gigawatt-hours generated by each source. Make note of the month or year for which data was reported. How might some months differ from other months?
6. Return to the U.S. States map and select another state. Try to choose a state that is very different from your own.
7. Repeat steps 4-5 for this second state.
8. Compare the sources used to generate electricity in these two states to their average residential cost per kilowatt-hour from the map on page 76.

Average Residential Price for Electricity, 2015



Data: Energy Information Administration

Data and Observations

SOURCE	STATE			
	GIGAWATT-HOURS	PERCENT OF TOTAL	GIGAWATT-HOURS	PERCENT OF TOTAL
TOTAL ELECTRICITY GENERATED	GWh		GWh	
RESIDENTIAL COST OF ELECTRICITY	¢/kWh		¢/kWh	

Conclusion

1. What source is used most for generating electricity in your state? Based on your state's geography, climate, and resources, does this make sense? Explain your answer.
2. What source is used most for generating electricity in the other state you chose? Based on that state's geography, climate, and resources, does this make sense? Explain your answer.
3. Hawaiians pay the most for electricity. Look at the sources Hawaii uses to generate electricity and explain why their cost is so high.
4. How do the two states you studied compare to the national average? In which ways are they similar, and in which ways are they different?

Sample Bill Explanation Key

Sample School Electric Bill 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— 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” kW 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.

Sample School Natural Gas Bill Explanation

1. Customer Account Number
2. Date of the Bill
3. Date of Next Meter Reading
4. Date of the Next Bill
5. Last Payment Received
6. Charge for Delivering the Natural Gas to the School
7. Charge for the Natural Gas
8. Total Amount Due
9. Comparison of Heating Degree Days. Degree day is a quantitative index that reflects demand for energy to heat or cool buildings. This index is derived from daily temperature observations at nearly 200 major weather stations in the contiguous United States. The heating year during which heating degree days are accumulated extends from July 1st to June 30th. A mean daily temperature (average of the daily maximum and minimum temperatures) of 65°F is the base for both heating and cooling degree day computations. Heating degree days are summations of negative differences between the mean daily temperature and the 65°F base.
10. Graph of Actual Gas Used by Month for the Last Year
11. The Actual Meter Readings for the Month
12. The Volume of Gas Used in CCF
13. The Meter Number
14. EnergyShare Fund. Most utilities are associated with a fuel fund for needy customers; paying customers can contribute any amount to the fund and note it here.
15. Due Date of Payment
16. Amount Enclosed by Customer

Sample School Electric Bill

Nov 27, 2016
1

Customer Bill
ABC Elementary School
Anytown, USA

Your Electric Company

Billing and Payment Summary

Account # 000-1234 2 **Due Date: Jan 02, 2017** 3
Total Amount Due: $ 7,462.61 4

To avoid a Late Payment Charge of 1.5% please pay by Jan 02, 2017

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	*10/23 - 11/26*	
Current Reading	4147	
Previous Reading	4020	
Total kWh	12192	6
Current Reading	.60	
Demand	57.60	11
Multiplier: 96		
Meter: 111-4567	*10/23 - 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, 2016

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

Payment Coupon

Bill Date Nov 27, 2016 1

Please Pay by 01/02/ 2017 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 Natural Gas Bill

ABC Elementary School
Anytown, USA

NOTE: The bill you received on or around Friday, Nov. 2 was calculated using estimated usage instead of the actual meter reading. This invoice reflects your actual meter reading. If your new amount due is more than what was indicated on your previous bill, please remit payment for the difference. If it is less, and you've already paid, the difference will be credited to your account and shown on your next bill. We apologize for the inconvenience.

1 Account Number	2 Billing Date	3 Next Meter Reading	4 Next Billing Date
000-12345678	Nov 15, 2016	Dec 3, 2016	Dec 4, 2016

Visit our web site at www. yourgascompany.com

If you have any questions call 1-800-000-0000

Credits & Charges Since Your Last Bill

Payments Received - Thank You	$1,302.60 CR 5
Outstanding Balance	$0.00

Current Charges

General Service

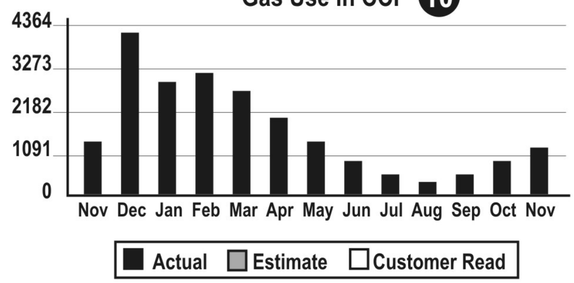
Delivery	6 282.14
Gas Supply	7 1,377.91
Total Current Charges	**$1,660.05**
Total Account Balance	8 **$1,660.05**

For Gas Leaks, call 1-800-123-4567

Monthly Usage Comparison

	2015	2016	NORMAL
Heating Degree Days For This Billing Period	160	9 51	138

Gas Use in CCF 10



Billing Period and Meter Readings

Date	Read Type	Reading
October 30, 2014	Actual	70320
October 01, 2014	Actual	68985

11

CCF used in 29 days: 1335 12
Meter Number 123456 13

Please pay by Dec 10, 2016 , To Avoid A Late Charge of 1.5% Per Month

EnergyShare has helped customers pay heating bills of all kinds. You can help by adding $1, $2, $5, $10, $15, or $20 to your gas bill payment. 14

Please make checks payable to Your Gas Company and return this portion with your payment. Thanks!

YOUR GAS COMPANY
PO Box 123456 Anytown, USA 98765

PREVIOUS BALANCE	**$0.00**	
Total Current Charges	**$1,660.05**	**Pay By Dec 10,** 2016 15
Total Account Balance	**$1,660.05**	
Account # 000-12345678	Amount Enclosed	16

ABC Elementary School
123 Main Street
Anytown, USA 98765

Your Gas Company
PO BOX 123456
Anytown, USA 98765

0116600500000000000009368686868600012345678

Careers in the Coal Industry

Question

What careers are available in the coal industry?

✔ Procedure

1. Read the student informational text, pages 52-55, about careers in the coal industry.
2. Choose the career that most interests you, or most closely matches the career you think you might want to enter.
3. Use a job search engine or other resources to find a specific job description within the career you have chosen.
4. Use your library or the internet to research the educational requirements, certifications, etc., needed for a person in this career. Check industry pages as well as university degree requirements.
5. Using the template from page 81, create a résumé for yourself or a fictional person who would be qualified for the specific job.

Résumé Template

First and Last Name
Address, City, State, Zip
Phone number and E-mail address

Employment Objective

Brief one- or two-sentence statement describing the ideal or desired employment position for this applicant.

Experience

Most recent relevant job related to desired position Month/year range in this position
Company Name, City, State
Responsibilities
Skills Acquired

Next most recent relevant job related to desired position Month/year range in this position
Company Name, City, State
Responsibilities
Skills Acquired

Third employment position, may or may not be relevant Month/year range in this position
Company Name, City, State
Responsibilities
Skills Acquired

Education

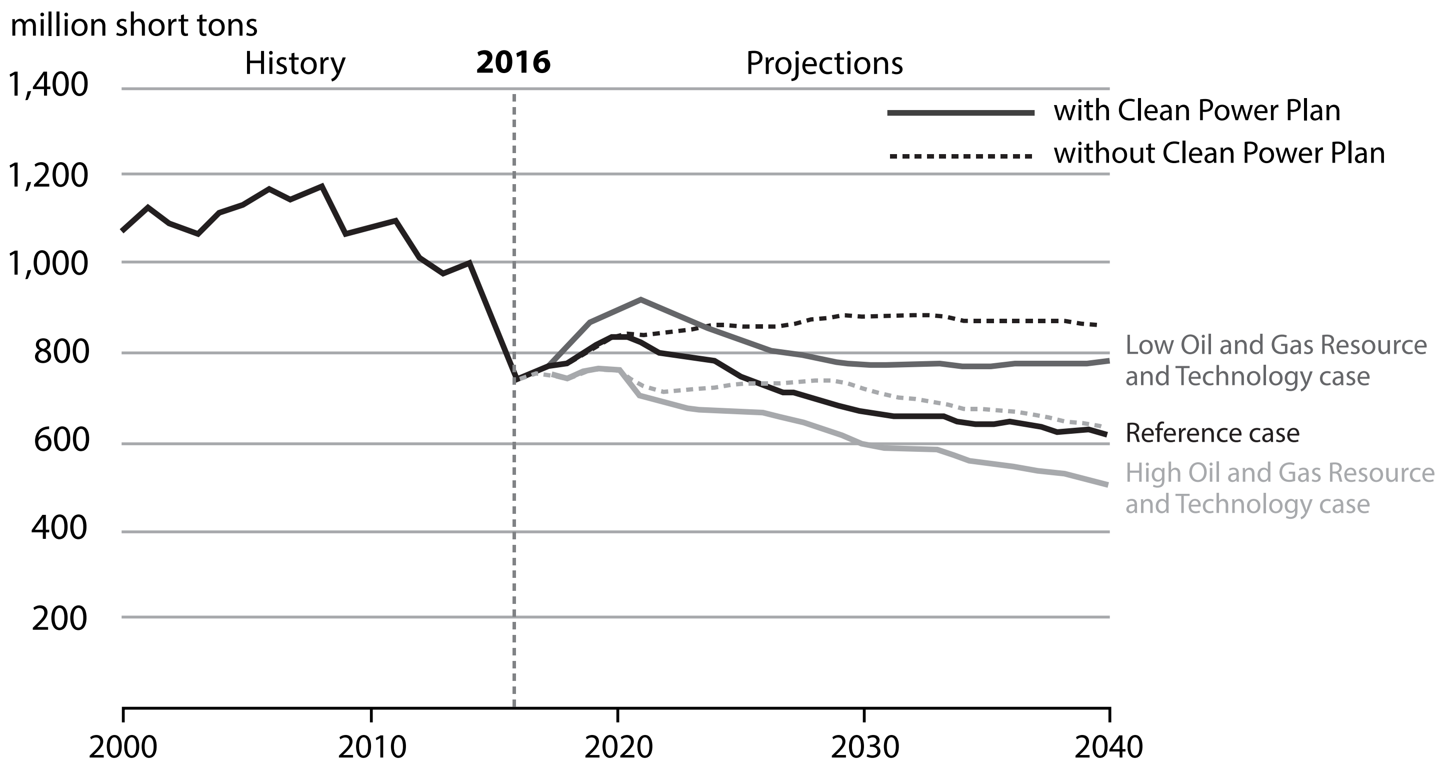
Graduate School (if applicable) Years Attended
City, State
Degree attained and date
Major
Anything else relevant, such as awards, honors, distinctions, or research area(s)

College or Trade School Years Attended
City, State
Degree attained and date
Major/minor
Anything else relevant, such as awards, honors, or distinctions

High School Years Attended
City, State
Year Graduated
Relevant classwork or focus

Analyzing Graphical Information

Coal Production, 2000-2040



Data: U.S. Energy Information Administration

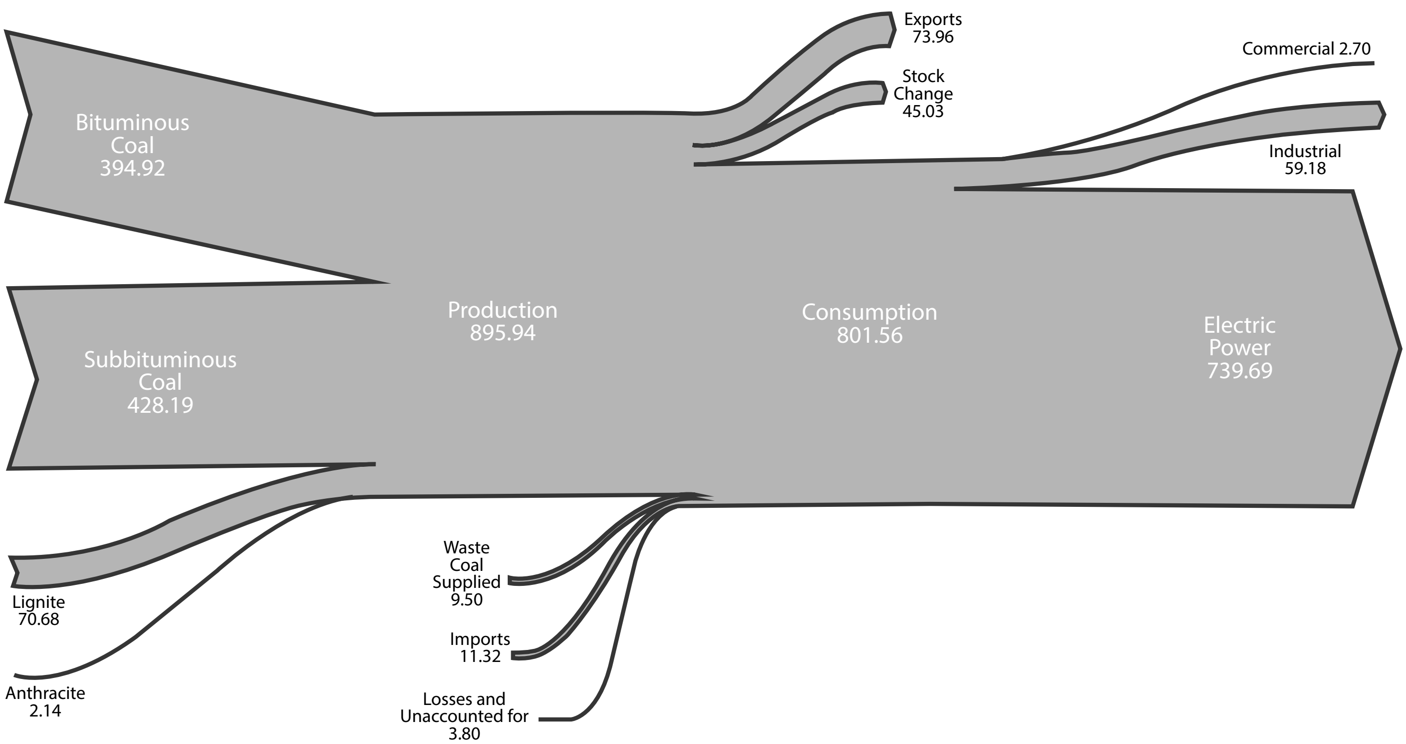
Projections for coal production vary from region to region. These projections are based on 2016 production data. Production by region is projected for both the Clean Energy Plan requirements as well as in absence of the Clean Energy Plan. The EIA projects that coal production in the United States could range from unchanged to continuing declines through 2040. Electric power generation accounts for more than 92% of U.S. coal demand, and domestic coal production has declined significantly over the past decade as coal has been displaced by natural gas and renewables in electric generation.

Study the figure above, then answer the following questions:

1. What does the graph show?
2. Why was this type of graph chosen? Support your answer.
3. What trend(s) do you see?
4. Use the accompanying text to explain and support one of the trends you recognize.

U.S. Coal Flow, 2015

(MILLION SHORT TONS)



*Totals may not equal sum of components due to independent rounding.
Data: U.S. Energy Information Administration, Monthly Energy Review

Study the figure above, then answer the following questions:

1. Calculate the amount of bituminous coal produced as a percentage of all coal produced in the U.S. in 2015.

2. Accounting for production, imports, and other sources, what is the total coal supplied in 2015?

3. Why is so little anthracite produced? Use the student text to support your answer.

4. What uses are represented by the coal being consumed in the commercial and industrial sectors? Use information from the student text to support your answer.

Coal in Kentucky

Question

How does the coal industry relate to the geography of Kentucky?

✔ Procedure

1. Navigate to http://kgs.uky.edu/kgsmap/kcrim/.
2. Use the interactive map and legend on the website to answer the questions below.

⁂ Conclusion

1. How many counties (1790 to present) are considered to be in the western coal mining region of Kentucky?

2. How many counties (1790 to present) are considered to be in the eastern coal mining region of Kentucky?

3. How many counties have operating surface mines in Kentucky?

4. How many counties have operating deep mines in Kentucky?

5. How many coal fired power plants are located in Kentucky?

6. What geographical feature do most of these plants occur close in proximity to?

7. How many other power plants besides coal are located in Kentucky?

8. How many of the power plants are within the coal field counties?

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. Coal plants generate about 33 percent of the electricity we use. There are also wind, geothermal, waste-to-energy, solar, and petroleum power plants, which together generate a little less than 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.

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.

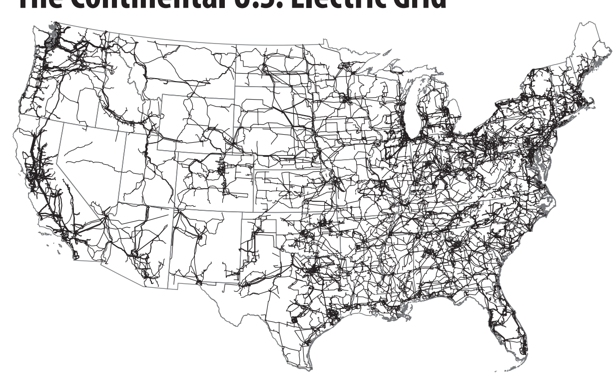
In the 1990s, the Federal Energy Regulatory Commission introduced a policy designed to increase competitive generation by requiring open access to transmission. Northeastern RTOs developed out of coordinated utility operations already in place. RTOs in other locations grew to meet new policies providing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

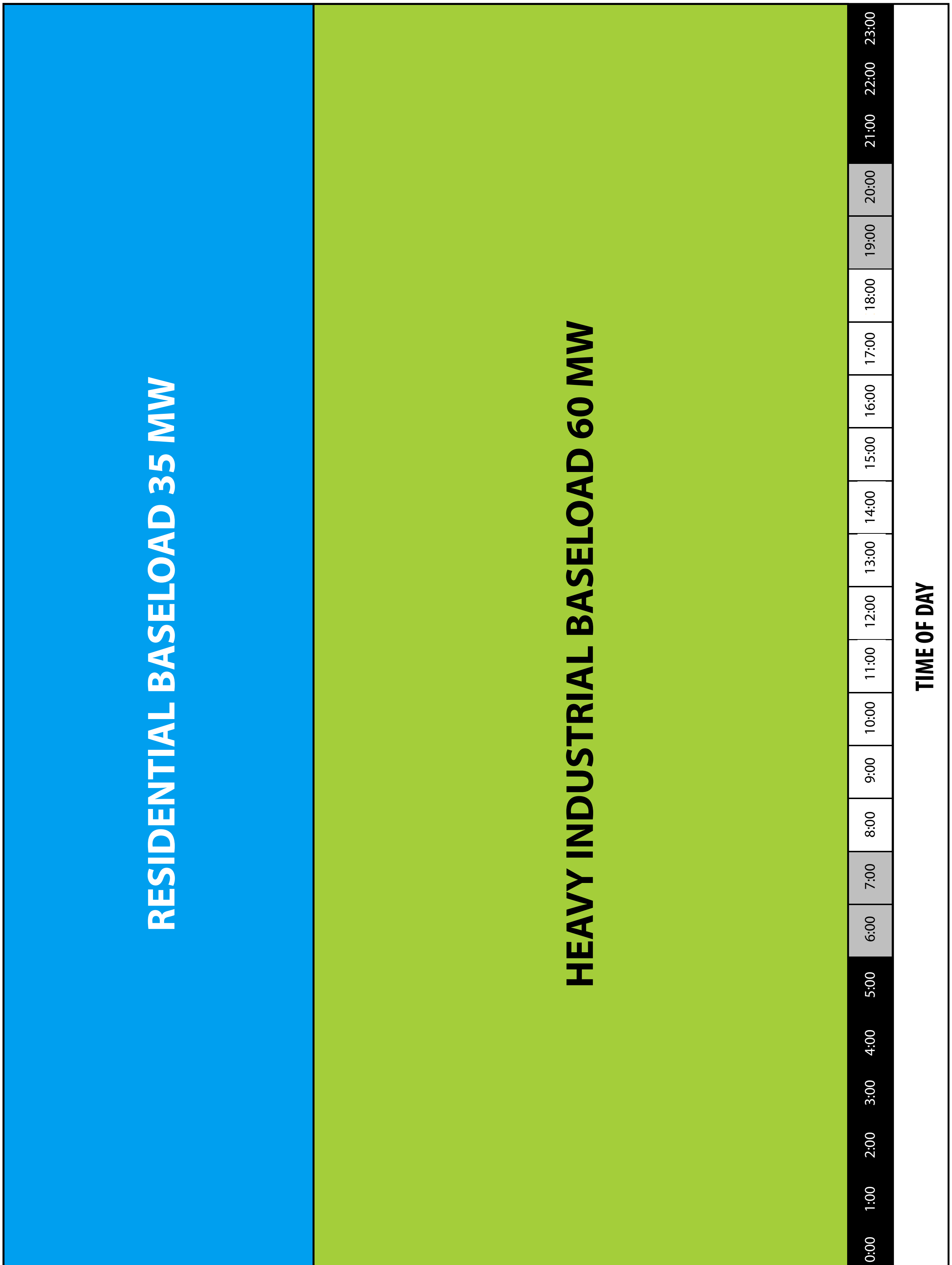


Data: Energy Information Administration

BLANK PAGE

Baseload Balance
GAME BOARD

Load	0:00	1:00	2:00	3:00	4:00	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
170 MW																								
165 MW																								
160 MW																								
155 MW																								
150 MW																								
145 MW																								
140 MW																								
135 MW																								
130 MW																								
125 MW																								
120 MW																								
115 MW																								
110 MW	COMMERCIAL BASELOAD 20 MW																							
105 MW																								
100 MW																								


RESIDENTIAL BASELOAD 35 MW
HEAVY INDUSTRIAL BASELOAD 60 MW
95 MW
90 MW
85 MW
80 MW
75 MW
70 MW
65 MW
60 MW
55 MW
50 MW
45 MW
40 MW
35 MW
30 MW
25 MW
20 MW
15 MW
10 MW
5 MW
Load
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
TIME OF DAY

Baseload Balance
GAME PIECES

<table>
<tr><th>Load</th><th>0:00</th><th>1:00</th><th>2:00</th><th>3:00</th><th>4:00</th><th>5:00</th><th>6:00</th><th>7:00</th><th>8:00</th><th>9:00</th><th>10:00</th><th>11:00</th><th>12:00</th><th>13:00</th><th>14:00</th><th>15:00</th><th>16:00</th><th>17:00</th><th>18:00</th><th>19:00</th><th>20:00</th><th>21:00</th><th>22:00</th><th>23:00</th></tr>
<tr><td>5 MW</td><td colspan="24" rowspan="8">Coal Baseload Generation 40 MW, $40/MWh</td></tr>
<tr><td>5 MW</td></tr>
<tr><td>5 MW</td></tr>
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<tr><td>5 MW</td></tr>
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<tr><td>5 MW</td></tr>
<tr><td>5 MW</td></tr>
<tr><td>5 MW</td><td colspan="24" rowspan="4">Natural Gas Combined Cycle Baseload 20 MW, $50/ MWh</td></tr>
<tr><td>5 MW</td></tr>
<tr><td>5 MW</td></tr>
<tr><td>5 MW</td></tr>
</table>

5 MW	Nuclear Baseload 50 MW, $30/MWh
5 MW	
5 MW	
5 MW	
5 MW	
5 MW	
5 MW	
5 MW	
5 MW	
5 MW	
5 MW	Hydropower Baseload, 5 MW, $30/MWh
5 MW	Wind Baseload, 5 MW, $80/MWh · Solar Baseload, 5 MW, $180/MWh · Wind Baseload, 5 MW, $80/MWh
5 MW	Hydropower Pumped Storage Peak Load, 10 MW, $60/MWh, 5 minutes lead-in time required
5 MW	
5 MW	Natural Gas Simple Cycle Peak Load, 10 MW, $90/MWh, 30 minutes lead-in time required
5 MW	
5 MW	Natural Gas Simple Cycle Peak Load, 5 MW, $90/MWh, 30 minutes lead-in time required
5 MW	Natural Gas Simple Cycle Peak Load, 10 MW, $150/MWh, 30 minutes lead-in time required
5 MW	
5 MW	Natural Gas Simple Cycle Peak Load, 5 MW, $200/MWh, 30 minutes lead-in time required
5 MW	Natural Gas Simple Cycle Peak Load, 5 MW, $600/MWh, 30 minutes lead-in time required
5 MW	Hydropower Peak Load, 5 MW, $50/MWh, 5 minutes lead-in time required

Baseload Balance
GENERATION PARAMETERS

Fuel	Capacity	Type of Generation	Time Required for Full Capacity	Cost per Megawatt-hour
Coal	40 MW	Baseload	24 hours	$40
Nuclear (Uranium)	50 MW	Baseload	24 hours +	$30
Natural Gas Combined Cycle (NGCC)	20 MW	Baseload	30 minutes +	$50
Wind	5 MW	Baseload	Immediate when wind speed is sufficient; primarily at night	$80
Solar	5 MW	Baseload	Immediate when solar intensity is sufficient; only during day	$180
Hydropower	5 MW	Baseload	5 minutes	$30
Hydropower Pumped Storage	10 MW	Peak load	5 minutes	$60
Hydropower	5 MW	Peak load	5 minutes	$50
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

$40 / MW-hour

Generation

Baseload

Natural Gas CC

20 MW

$50 / MW-hour

Generation

Baseload

Hydro

5 MW

$30 / MW-hour

Generation

Baseload

Wind

5 MW

$80 / MW-hour

Generation

Baseload

Solar

5 MW

$180 / 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

$200 / MW-hour

Generation

Peak Load

Natural Gas SC

5 MW

$600 / MW-hour

Generation

Peak Load

Hydro (pumped storage)

10 MW

$60 / MW-hour

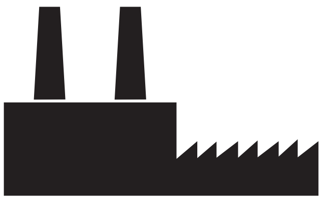
Generation

Peak Load

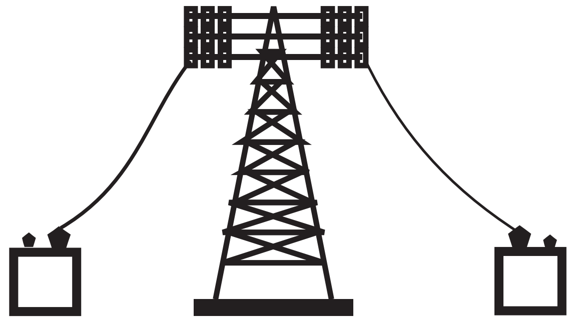
Hydro

5 MW

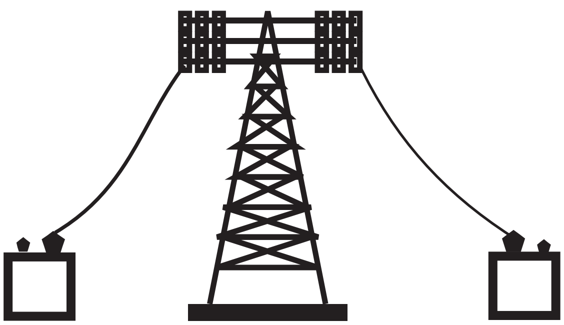
$50 / MW-hour



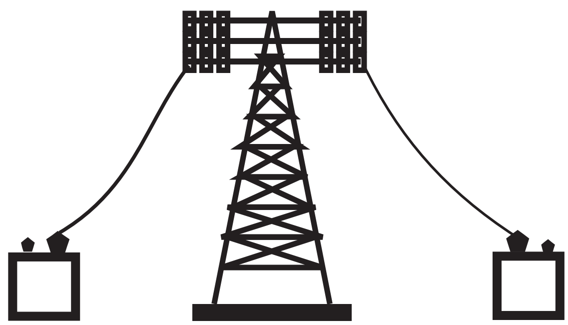
Transmission



Transmission



Transmission



Load

Commercial

20 MW

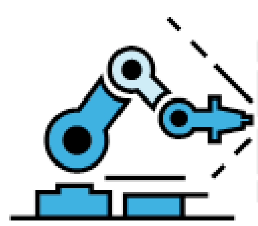
Baseload

Load

Heavy Industry

60 MW

Baseload



Load
Residential
35 MW
Baseload

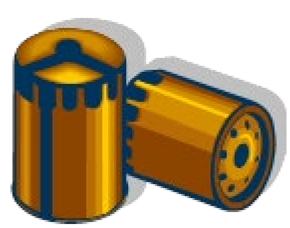
Load
Residential
5 MW
7:00 am – 12:00 am

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

Load
Commercial
10 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

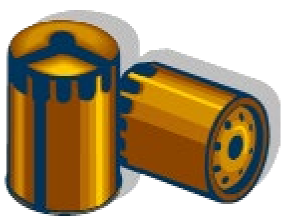


Load

Light Industry

5 MW

9:00 am – 8:00 pm



Load

Residential

10 MW

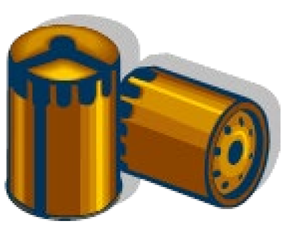
3:00 pm – 1:00 am

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	$40/MW
Natural Gas Baseload	20 MW	$50/MW
Nuclear Baseload	50 MW	$30/MW
Hydropower Baseload	5 MW	$30/MW
Solar Baseload	5 MW	$180/MW
Wind Baseload	5 MW	$80/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

Coal Plant Conundrum

Background

Many factors go into deciding what to do with an older coal power plant. Some of the factors include how well the plant is functioning; how expensive an upgrade vs. constructing a new plant would be; the cost to operate the plant in its current condition; the cost to operate an upgraded plant; the cost to change fuel systems; the cost and complexity to maintain different fuel options; air quality standard regulations; and the demand for the power being produced.

Many people from multiple professions and perspectives are affected when a generating company decides to switch over or close an existing power plant. Because no two situations are identical, careful consideration must be given to each option from many different people and perspectives.

This activity focuses on the fictitious community of Anthracity, Pennsylvania. On the outskirts of town there is an older coal power plant that was built in the late 1970s. The generating capacity of Coal Valley Power Plant is 250 MW, but in recent years it has only been operating at about 45 percent capacity due to demand and the cost of coal. New federal air quality regulations will require Coal Valley to either change its fuel or add new equipment to decrease the mercury, sulfur, nitrogen, and particulate matter in the emissions. The nearest natural gas pipeline is 60 miles away and the shortest route to connect Coal Valley to it runs through rural farm land.

The company that owns Coal Valley, WattsUp, is locally owned and operated. They must decide how to proceed and are going to hold a hearing on all of its options. At the hearing, community members and employees at Coal Valley will be permitted three minutes to express their opinion on the best route for WattsUp to take. There are four options available:

◆Options

1. Retrofit Coal Valley with the proper equipment needed to meet the new air quality standards. Change nothing about the fuel or equipment already existing in the power plant. This is the least expensive route for WattsUp, but also does not increase the production output of Coal Valley. The cost of retrofitting the plant would be passed along to its customers in Anthracity and throughout Pennsylvania.
2. Completely convert Coal Valley to natural gas. Doing so would require significant modifications to the plant, but the boiler and turbine would remain unchanged. The gas line would need to be extended to Coal Valley and employees would need to be retrained to operate a gas power plant. Coal Valley could be used for both baseload and peak load generation, and the cost to operate Coal Valley would decrease because natural gas is less expensive than coal. Increased power output would result in higher earnings for Coal Valley and WattsUp. However, because Coal Valley's main coal supply comes from the mine 15 miles away, many community members could lose their jobs. This is the second most expensive option for Coal Valley, and the capital costs would mean increased rates for many years to come in Anthracity and the surrounding areas.
3. Convert Coal Valley to a natural gas and coal co-fired plant. The gas line would need to be extended to Coal Valley and a boiler to accommodate natural gas would need to be installed. Some air quality equipment would need modification, but not as extensively as if the plant remained all coal. Co-firing would allow Coal Valley to be used as a baseload supplier as well as a peak load supplier. A gas line would need to be built to Coal Valley, and employees would need to be trained on natural gas use and safety. The amount of coal that Coal Valley uses would go down, and some employees at the nearby coal mine would lose their jobs.
4. Combine one of the three options above with the addition of an additional turbine, called combined cycling. A combined cycle plant uses the thermal energy remaining in the emission gases to generate more steam to turn a second turbine. The efficiency of the power plant is increased by 75-80 percent. Changing from a simple cycle to a combined cycle would increase the power output of the plant and increase the revenue at Coal Valley, but it is almost as expensive as building a second power plant on site. All of the costs listed in options 1-3 remain, plus the additional cost of building a second boiler-turbine system. This is the most expensive option, and its impact on the community also depends upon the type of fuel that WattsUp ultimately chooses for Coal Valley.

✔Procedure

In this activity, your teacher will assign each student a role to play. You, and the rest of your class, will research the opinions from the perspective of your assigned roles, and on the given date will present your opinions in an effort to influence WattsUp's decision. You must rely on good research skills, looking at all the angles, and the option you favor must be in line with the character you have been assigned to play. Each point you present must be backed up by at least two facts. These can include scientific evidence, economic principles, or moral or ethical standards. Use the graphic organizer to help organize your ideas.

At the mock hearing, you will be limited to three minutes to present your point-of-view. It will be helpful to write out or outline your key points so you don't forget anything. You will be graded on how well you present your perspective, the facts that back up your opinion, and whether you make a good case.

◆Roles

1. **Axe Meanything**, a local coal miner who works with Chip Chopper. Axe and Chip are best friends and have been close for many years.
2. **Big Banker**, manager and co-owner of the local bank. Big is very, very successful, and enjoys helping families purchase their first home because another mortgage is more interest income for the bank.
3. **Cary Cornplanter**, farmer who owns land through which the natural gas line must run. Can also make money selling land for the natural gas line, but is not concerned about lost revenue from crops because Cary is a dairy farmer, and the cattle can graze on the land after the line is completed.
4. **Cassie Cashkeeper**, a local wealth manager who is in charge of most retirement and investment funds for the people of Anthracity and its surrounding areas. Has invested significantly in WattsUp and is extremely interested in its financial success.
5. **Chip Chopper**, a coal miner at the mine 15 miles from Anthracity. Understands that the coal mined at his facility goes primarily to Coal Valley.
6. **Dr. Breatheright**, an allergist concerned about air quality and the health of his or her patients.
7. **Einstein Smith**, chemistry teacher at the high school. Einstein's special talent is being able to explain very complex concepts in simple terms.
8. **Ellie Electrified**, senior production manager at Coal Valley. Works very hard to maintain Coal Valley and thinks of the entire plant and its workforce as his/her pride and joy. Ellie is very protective of Coal Valley, and will do just about anything to keep Coal Valley operating for generations to come.
9. **Jesse Justaskme**, Ellie's administrative assistant. Fifteen years younger and works even harder than Ellie and is the only one who truly knows everything that goes on at Coal Valley. Jesse secretly wishes to be in charge one day, and is studying very hard to learn about new technology in power plants. He's taking online and night courses in electrical engineering and graduating in 18 months. At that point, Jesse will be qualified to oversee and operate any existing or additional part of Coal Valley.
10. **Larry Jones**, Kindergarten teacher, who is very kind, considerate, caring, and protective of his students. Has had three students absent this month with asthma-related illness and is concerned about the emissions from Coal Valley.
11. **Mark Middleaged**, a parent with one child in middle school, one child in high school, and one child in her first year of college. Works in middle management at Coal Valley and worries about being able to pay for 12+ years of college tuition.
12. **Mayor Milquetoast**, mayor of Anthracity who has a hard time standing up to political pressure. Would like to have better air quality in Anthracity but doesn't want to step on the toes of WattsUp or the managers at Coal Valley.
13. **Mel Fixit**, the local mechanic who fixes everything. Mel hasn't met a machine that can't be fixed, but wouldn't mind a new line of work, perhaps at Coal Valley if the pay was right.
14. **Natalie Nimby**, a parent with two children in Ms. Trampoline's preschool class. Natalie wants plenty of electricity to run her air conditioner, entertainment system, washer, dryer, double refrigerator, double freezer, wine chiller, hot tub, swimming pool filter, computer, and other necessities, but does not want any power plants near her house. Dislikes ugly construction projects. She requires more electric power than any of her neighbors.
15. **Ollie Oilcan**, the owner of the only gas station in town. Concerned with revenue. Sees an opportunity for business expansion if more employees are hired at Coal Valley.
16. **Pete the Plumber**, a pipefitter when there's work.
17. **Senator Smoothtalker**, U.S. Senator representing the state. Smoothtalker is concerned about the community of Anthracity. Wants to ensure the economic and environmental health of the area, but mostly wants to ensure another term as a U.S. Senator.
18. **Susie Shopper**, owner of a small grocery store in Anthracity. Concerned about keeping a steady stream of customers to support business.
19. **Taylor Trampoline**, a preschool teacher with an effervescent personality. Loves people, especially children, and is enthusiastic about new projects – any new projects. Doesn't have strong opinions one way or another but when a decision is made is very enthusiastic and helpful.
20. **Terry Traction**, farmer who owns land through which the natural gas line must run. Selling some of the land for construction of the natural gas line would put much-needed money into Terry's pocket right away, but would decrease Terry's revenue from crops Terry can plant in the future.
21. **Travis Treehugger**, whose personal opinion is that everything should be run on solar power, but is willing to compromise a little as long as the environment is considered first.

Debate Graphic Organizer

CHARACTER NAME		
PREFERRED OPTION		
Point	Fact 1	Fact 2

Coal Assessment

1. List the four types of coal by increasing order of energy content. Draw an arrow to point in the direction from youngest to oldest.

2. What are three macroscopic characteristics used to classify coal?

3. What are the three major categories of macerals?

4. Explain the difference between microscopic and macroscopic characteristics.

5. Describe the procedure for determining the moisture content of coal.

6. Why must dried coal be used to determine its ash content?

7. List and explain two examples of technology used to clean coal.

8. Make a diagram of a surface mine and label its important features.

9. Besides electricity, describe two uses for coal.

10. What are three environmental concerns stemming from the mining, transport, or use of coal? Be specific and explain each.

11. How is coal used to generate electricity? Explain with complete sentences. Include a diagram if you'd like.

12. Explain the major steps involved in reclamation in complete sentences. Be specific.

13. Write a paragraph stating your opinion on the use of coal. Support your position with at least three facts.

COAL BINGO

A. Knows what type of rock coal is

B. Can explain the purpose of clean coal technology

C. Can name three of the top five coal producing states

D. Knows what is compressed over time to form coal

E. Knows the top two uses of coal

F. Can name two types of coal

G. Can name the country with the most coal reserves

H. Can name one of the two types of coal mining

I. Can name one of the factors leading to the formation of coal

J. Can name one advantage and one disadvantage of using coal

K. Knows how most coal is transported

L. Knows the form of energy stored in coal

M. Has seen a coal mine

N. Has never seen coal

O. Knows the element in coal that contributes to acid rain

P. Knows the greenhouse gas released when coal is burned

A NAME	**B** NAME	**C** NAME	**D** NAME
E NAME	**F** NAME	**G** NAME	**H** NAME
I NAME	**J** NAME	**K** NAME	**L** NAME
M NAME	**N** NAME	**O** NAME	**P** NAME

Coal in the Round Cards

I have anthracite.
Who has a reasonably hard, satiny, dark coal with high carbon content?

I have bituminous.
Who has energy stored within the bonds between atoms in compounds?

I have chemical energy.
Who has satiny, banded coal that is brittle?

I have clarain.
Who has a hard, porous, black material that is low in phosphorus and sulfur made by purifying coking coal at a high temperature?

I have coke.
Who has banded coal that is dull, grainy, and tough?

I have durain.
Who has directed transfer of energy among electrons in a conductor?

I have electricity.
Who has the amount of energy contained within a unit volume of an energy source?

I have energy density.
Who has the word for dynamic balance?

I have equilibrium.
Who has banded, dull coal resembling charcoal that most commonly dirties hands and other objects it touches?

I have fusain.
Who has the process that changes fossil fuels into carbon dioxide, carbon monoxide, and hydrogen?

I have gasification. Who has a chemical compound containing only carbon and hydrogen?	**I have macerals.** Who has the single carbon hydrocarbon that is the primary component in natural gas and can be found in coal seams?
I have hydrocarbon. Who has the scientific principle stating that energy and matter can neither be created nor destroyed?	**I have methane.** Who has a method of coal mining where the top of a mountain is removed, the coal mined, and the overburden relocated to the adjacent valley?
I have Law of Conservation of Energy/Matter. Who has the lowest rank of coal that is soft, brown, and high in moisture?	**I have mountaintop removal.** Who has rocky layers removed from a surface mine that do not contain coal?
I have lignite. Who has underground coal mining where a long wall of coal is removed in a single slice?	**I have overburden.** Who has decayed or decomposed plant material in a high-moisture environment without oxygen?
I have longwall mining. Who has tiny, microscopic organic grains found in coal?	**I have peat.** Who has a way of classifying coal by its energy content?

I have rank. Who has a process where a mine site is returned as closely as possible to its original condition?	**I have surface mining.** Who has a power plant that moves a turbine with steam made by using a fuel that releases thermal energy to boil water?
I have reclamation. Who has an underground mining technique where most of a coal seam is removed, but large portions are left in place to hold up the ceiling?	**I have thermal power plant.** Who has a machine that turns, moving coils of wire within a magnetic field to generate electricity?
I have room-and-pillar mining. Who has combustion of a fuel that is carried out in multiple phases?	**I have turbine.** Who has a method of mining where one or more shafts is cut into the ground to reach a deep seam of coal?
I have staged combustion. Who has coal that is dark gray in color, lower in carbon than bituminous, and lower in moisture than lignite?	**I have underground mining.** Who has banded coal that is glossy, dark black, and brittle?
I have subbituminous. Who has a method of coal mining used to reach seams close to the surface?	**I have vitrain.** Who has a type of coal that is hard, shiny, very dark, and has the highest carbon content?

Glossary

acid rain	precipitation in liquid form with a pH lower than 7.0 resulting from dissolving NOx or sulfur oxides from the atmosphere
acidic	solution with a pH value lower than 7.0
anthracite	hard, shiny, very dark coal with very high carbon content
ash	clay, silt, or other noncombustible sediment mixed in coal
banded	coal with a striated or striped appearance
baseload	minimum power a utility must provide to consumers
basic	solution with a pH value higher than 7.0
bituminous	reasonably hard, satiny, dark coal with high carbon content
blocky	coal that breaks into large blocks rather than irregular pieces
boghead	dull, non-banded coal formed from ancient algae
bond	a monetary guarantee
bottom ash	ash created from combustion of coal that does not rise with flue ash
Btu	unit of energy; British thermal unit; amount of energy to heat or cool one pound of water by 1°F
calorie	the amount of energy needed to raise the temperature of one gram of water by one degree Celsius
cannel	dull, non-banded coal formed from ancient spores
carbon dioxide	greenhouse gas that is a product of hydrocarbon or carbon combustion; consists of one carbon atom covalently bonded to two oxygen atoms; each carbon-oxygen bond contains two pairs of electrons
carbon monoxide	gas that is a product of inefficient or incomplete hydrocarbon or carbon combustion; consists of one carbon atom covalently bonded to one oxygen atom via a triple bond
Ccf	one hundred cubic feet; unit used for measuring natural gas
chemical energy	energy stored within the bonds between atoms in compounds
clarain	satiny, banded coal that is brittle
cleats	fracture points within a coal seam
clinker	waste from coal combustion
coke	hard, porous, black material low in phosphorus and sulfur made by purifying coking coal at high temperature
combustion	exothermic chemical reaction where one of the reactants is oxygen; commonly referred to as burning
covalent bond	chemical bond where at least one pair of electrons is shared between two atoms
culm	black, rocky waste material remaining after coal is separated at a mine site
desiccant	sealed enclosure that protects a specimen from reacting with water
dull	not shiny
durain	banded coal that is dull, grainy, and tough
efficiency	the rate at which energy is transformed into useful work
elastic energy	energy stored in an object by applying a force, such as stretching a rubber band or compressing a spring
electrical energy	energy of moving electrons
electricity	directed transfer of energy among electrons in a conductor
emissions	the gases or particles that result from combustion, usually from a smoke stack on a factory or power plant, or the tail pipe of a car
energy	the ability to do work or make a change
energy consumption	the amount of energy that is used to do useful work
energy density	the amount of energy contained within a unit volume of an energy source such as coal or petroleum
fission	splitting of the nucleus of an atom; energy is released
fixed carbon	solids remaining after coal is heated and volatile matter is removed or expelled; determined by subtracting percentages of moisture, ash, and volatiles from a sample

flue gas	gas exiting a boiler or furnace
fly ash	residue created from coal combustion that rises with flue gas
foundry	a factory that works with metals
fusain	banded, dull coal resembling charcoal that most commonly dirties hands and other objects it touches
fusinite	the macerals included in coal that are the result of ancient peat fires
fusion	combination of small nuclei to make larger nuclei; energy is released
gasification	process that changes fossil fuels into carbon dioxide, carbon monoxide, and hydrogen
generation	refers to the creation of electric power by a generator
geothermal	thermal energy found within the Earth's crust, resulting from pressure beneath the crust or radioactive decay of minerals within the crust
gravitational potential energy	energy of position; stored energy resulting from being held up against the pull of Earth's gravity
greenhouse gas	atmospheric component that is able to absorb and retain thermal energy; gas that promotes the greenhouse effect of trapping thermal energy in the atmosphere
gross domestic product	market financial value of all goods and services produced in a country in one year's time
heating value	numeric quantification of the amount of thermal energy that can be obtained from a certain mass of fuel
hydrocarbon	chemical compound containing only carbon and hydrogen
inertinite	white macerals in coal that are the oxidation products of other macerals
isotope	atoms with differing numbers of neutrons but the same number of protons, therefore being of the same element but having different atomic masses
kinetic energy	energy of motion or moving objects
kilowatt-hour	a measure of electricity defined as a unit of work or energy, measured as 1 kilowatt (1,000 watts) of power expended for 1 hour; one kWh is equivalent to 3,412 Btu
Law of Conservation of Energy/Matter	scientific principle stating that energy and matter can neither be created from nothing nor destroyed to nothing, but can change form or appearance, and energy and matter can be changed into each other
lignite	lowest rank of coal that is soft, brown, and high in moisture
liptinite	dark gray macerals in coal that are made of hydrogen-rich hydrocarbons formed from plant spores, pollens, cuticles, and resins
liquefaction	process that turns a solid or semisolid into a liquid
load	a device or system that draws or uses electricity
longitudinal	waves where the direction of the vibration is parallel to the direction the wave is traveling
longwall mining	underground coal mine where a long wall of coal is removed in a single slice
macerals	tiny, microscopic organic grains found in coal
macroinvertebrate	organisms without a spine that are small, yet able to be seen with the naked eye or simple magnifying lens
macroscopic	characteristics or properties that can be distinguished with the naked eye or a simple magnifying lens
megawatt	one million watts; used to measure bulk electricity in power plants
methane	single carbon hydrocarbon; one carbon atom bonded to four hydrogen atoms; the gas that is the primary component in natural gas
mire	swamp or bog-like land
moisture content	used to classify coal by rank; high moisture is often related to poorer ranking of coal
mountaintop removal	method of coal mining where the top of a mountain is removed, the coal mined, and the overburden relocated to the adjacent valley
non-banded	coal that has no visible striations or stripes
nonrenewable	substance that cannot be replenished in a short amount of time
nuclear energy	energy within the nucleus of an atom that helps hold it together
oil embargo	act of limiting or eliminating oil exports to certain countries or all countries altogether
overburden	rock, soil, or land materials covering minerals or resources
oxidize / oxidation	half of a chemical reaction where an atom or group of atoms loses or transfers electrons; type of chemical reaction where an element is combined with oxygen and its resulting electrical charge increases

peak demand	a period where many cutomers want electricity at the same time; often takes place during the day; utilities need to generate additional power to balance loads
peat	decayed or decomposed plant material in a high-moisture environment without oxygen
permafrost	soil that remains below the freezing point of water for two or more years
pH	logarithmic scale used to determine the acidity or alkalinity of a solution; solutions with a low pH (<7.0) are acidic while solutions with a high pH (>7.0) are basic
photosynthesis	process in plants where radiant energy from the sun is used to make glucose from carbon dioxide and water
potential energy	stored energy
pozzolanic	substance which, when mixed with water, hardens like cement and does not require an activator like lime or kiln dust to do so
pyrite	mineral made of iron and sulfur (FeS_2) that looks like gold and is commonly referred to as "fool's gold"
pyrolysis	decomposition of organic material using high temperature and no oxygen
radiant energy	energy that is transferred via electromagnetic radiation, which are transverse waves having an electric field and a magnetic field
rank	way of classifying coal by its energy content; higher ranking coals have more carbon
reclamation	process where a mine site that is no longer operational is returned as closely as possible to its original condition, or better
reduce / reduction	half of a chemical reaction where an atom or group of atoms gains electrons and its resulting electrical charge decreases
renewable	substance that can be replenished in a reasonably short amount of time
room-and-pillar mining	underground mining technique where most of a coal seam is removed but large portions are left in place to hold up the ceiling of the mine
scrubber	a pollution control device used to remove gases and particulates after burning
solar energy	energy from the sun
sound energy	energy transferred through a substance by vibration, in longitudinal waves
specific heat	the amount of heat per unit of mass that will raise the temperature by one degree Celsius
splint	dull coal rich in durain
staged combustion	combustion of a fuel that is carried out in multiple phases or stages
stored mechanical energy	common term for elastic energy
subbituminous	rank of coal that is between lignite and bituminous; dark gray in color, lower in carbon content than bituminous and less moisture than lignite
surface mining	method of coal mining used to reach seams that are close to the surface; layers of soil and rock and removed until the coal seam is exposed
syngas	mixture of combustible gases synthesized from solid, carbon-based fuels like coal and municipal solid waste
therm	a unit of heat; 1000,000 Btu
thermal energy	energy within a substance that causes its particles – atoms or molecules – to vibrate in place; the higher the thermal energy of a substance, the more likely it is to be a liquid or gas
thermal power plant	electric power plant that moves a turbine with steam made by using a fuel that releases thermal energy to boil water
tonne	one thousand kilograms of a material; also called a metric ton
transmission	the transportation of electricity over long distances
transverse	waves where the direction of the vibration is perpendicular to the direction the wave is traveling
tundra	coldest of all the biomes; tundra has permafrost and is characterized by a lack of trees and very short growing season
turbine	machine which turns, moving coils of wire within a magnetic field, inducing electric current within the coils
underground mining	method of mining where one or more shafts is cut into the ground to reach a deep seam of coal; also referred to as deep mining
vitrain	banded coal that is glossy, dark black, and brittle
vitrinite	macerals that are medium to light gray in color that formed from wood, bark, and roots of ancient trees
volatiles	chemicals that exist as gases under normal temperature and pressure

NEED's Online Resources

NEED'S SMUGMUG GALLERY

http://need-media.smugmug.com/

On NEED's SmugMug page, you'll find pictures of NEED students learning and teaching about energy. Would you like to submit images or videos to NEED's gallery? E-mail info@NEED.org for more information.
Also use SmugMug to find these visual resources:

Videos
Need a refresher on how to use Science of Energy with your students? Watch the Science of Energy videos. Also check out our Energy Chants videos! Find videos produced by NEED students teaching their peers and community members about energy.

Online Graphics Library
Would you like to use NEED's graphics in your own classroom presentations, or allow students to use them in their presentations? Download graphics for easy use in your classroom.

AWESOME EXTRAS

Looking for more resources? Our Awesome Extras page contains PowerPoints, animations, and other great resources to compliment what you are teaching in your classroom! This page is available under the Educators tab at www.NEED.org.

THE BLOG

We feature new curriculum, teacher news, upcoming programs, and exciting resources regularly. To read the latest from the NEED network, visit www.NEED.org/blog_home.asp.

EVALUATIONS AND ASSESSMENT

Building an assessment? Searching for standards? Check out our Evaluations page for a question bank, NEED's Energy Polls, sample rubrics, links to standards alignment, and more at www.NEED.org/evaluation.

E-PUBLICATIONS

The NEED Project offers e-publication versions of various guides for in-classroom use. Guides that are currently available as an e-publication can be found at www.issuu.com/theneedproject.

SOCIAL MEDIA

Stay up-to-date with NEED. "Like" us on Facebook! Search for The NEED Project, and check out all we've got going on!

Follow us on Twitter. We share the latest energy news from around the country, @NEED_Project.

Follow us on Instagram and check out the photos taken at NEED events, instagram.com/theneedproject.

Follow us on Pinterest and pin ideas to use in your classroom, Pinterest.com/NeedProject.

Subscribe to our YouTube channel!
www.youtube.com/user/NEEDproject

NEED ENERGY BOOKLIST

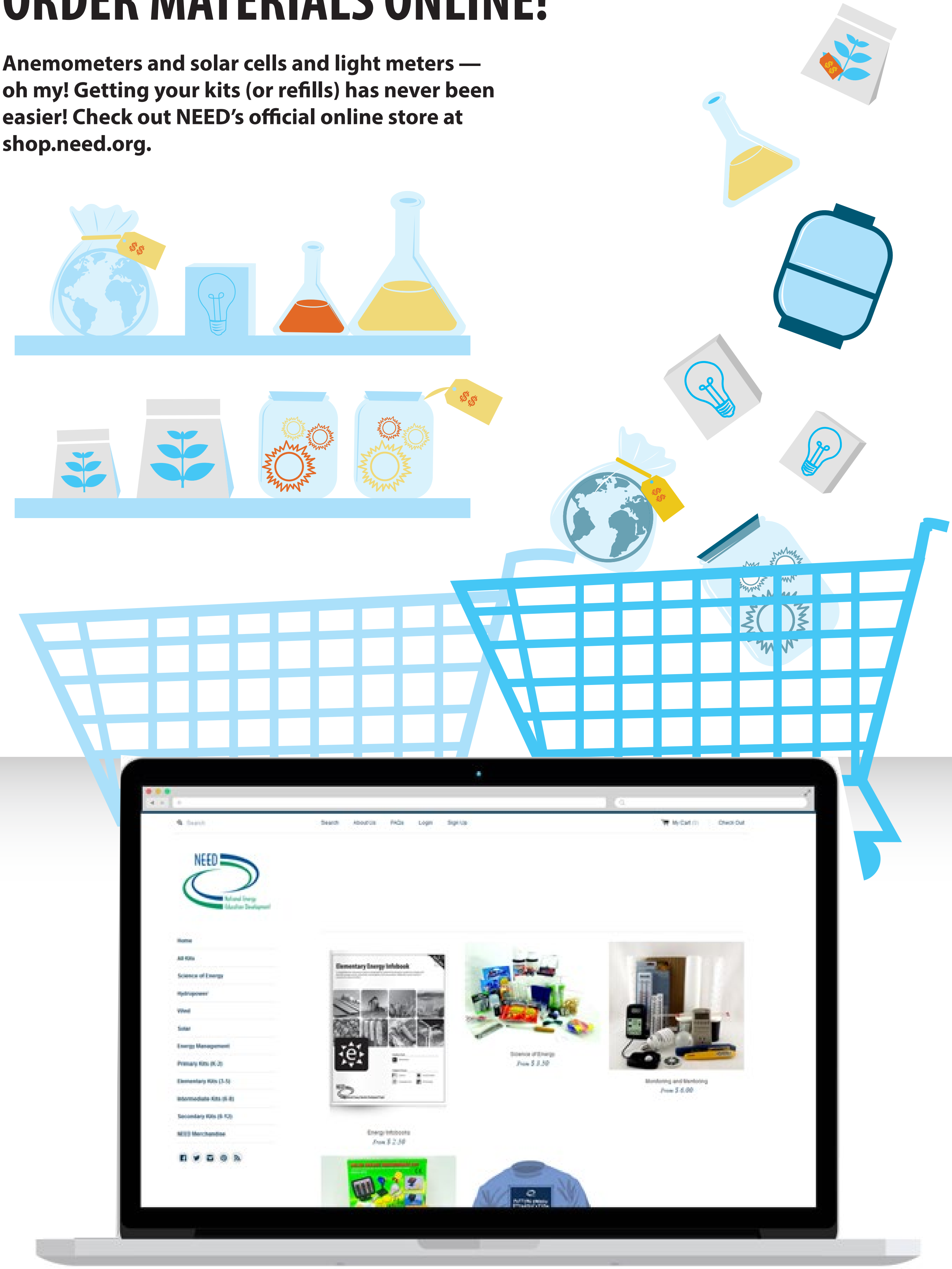
Looking for cross-curricular connections, or extra background reading for your students? NEED's booklist provides an extensive list of fiction and nonfiction titles for all grade levels to support energy units in the science, social studies, or language arts setting. Check it out at www.NEED.org/booklist.asp.

U.S. ENERGY GEOGRAPHY

Maps are a great way for students to visualize the energy picture in the United States. This set of maps will support your energy discussion and multi-disciplinary energy activities. Go to www.need.org/energyinsocietymaterials to see energy production, consumption, and reserves all over the country!

ORDER MATERIALS ONLINE!

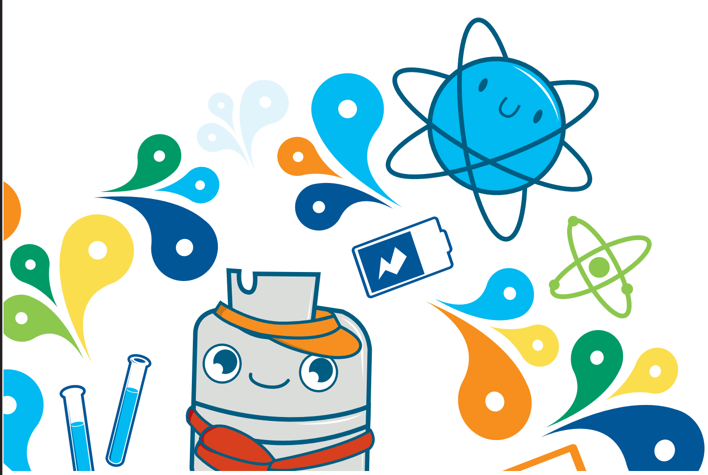
Anemometers and solar cells and light meters — oh my! Getting your kits (or refills) has never been easier! Check out NEED's official online store at shop.need.org.



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. A limited number of spaces are available for Full STEM Ahead, a special two-day pre-conference event, which allows students access to additional information, time to discuss energy with their peers, and access to industry professionals. The conference culminates with the Youth Awards Ceremony recognizing student work throughout the year and during the conference.

For More Info: www.youthenergyconference.org



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/Youth-Awards** for more application and program information, previous winners, and photos of past events.

Exploring Coal Evaluation Form

State: ____________ **Grade Level:** ____________ **Number of Students:** ___________

1. **Did you conduct the entire unit?**	❑ Yes	❑ No
2. **Were the instructions clear and easy to follow?**	❑ Yes	❑ No
3. **Did the activities meet your academic objectives?**	❑ Yes	❑ No
4. **Were the activities age appropriate?**	❑ Yes	❑ No
5. **Were the allotted times sufficient to conduct the activities?**	❑ Yes	❑ No
6. **Were the activities easy to use?**	❑ Yes	❑ No
7. **Was the preparation required acceptable for the activities?**	❑ Yes	❑ No
8. **Were the students interested and motivated?**	❑ Yes	❑ No
9. **Was the energy knowledge content age appropriate?**	❑ Yes	❑ No
10. **Would you teach this unit again?**	❑ Yes	❑ No

Please explain any 'no' statement below

How would you rate the unit overall?	❑ excellent	❑ good	❑ fair	❑ poor
How would your students rate the unit overall?	❑ excellent	❑ good	❑ fair	❑ poor

What would make the unit more useful to you?

Other Comments:

Please fax or mail to: **The NEED Project**
8408 Kao Circle
Manassas, VA 20110
FAX: 1-800-847-1820

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