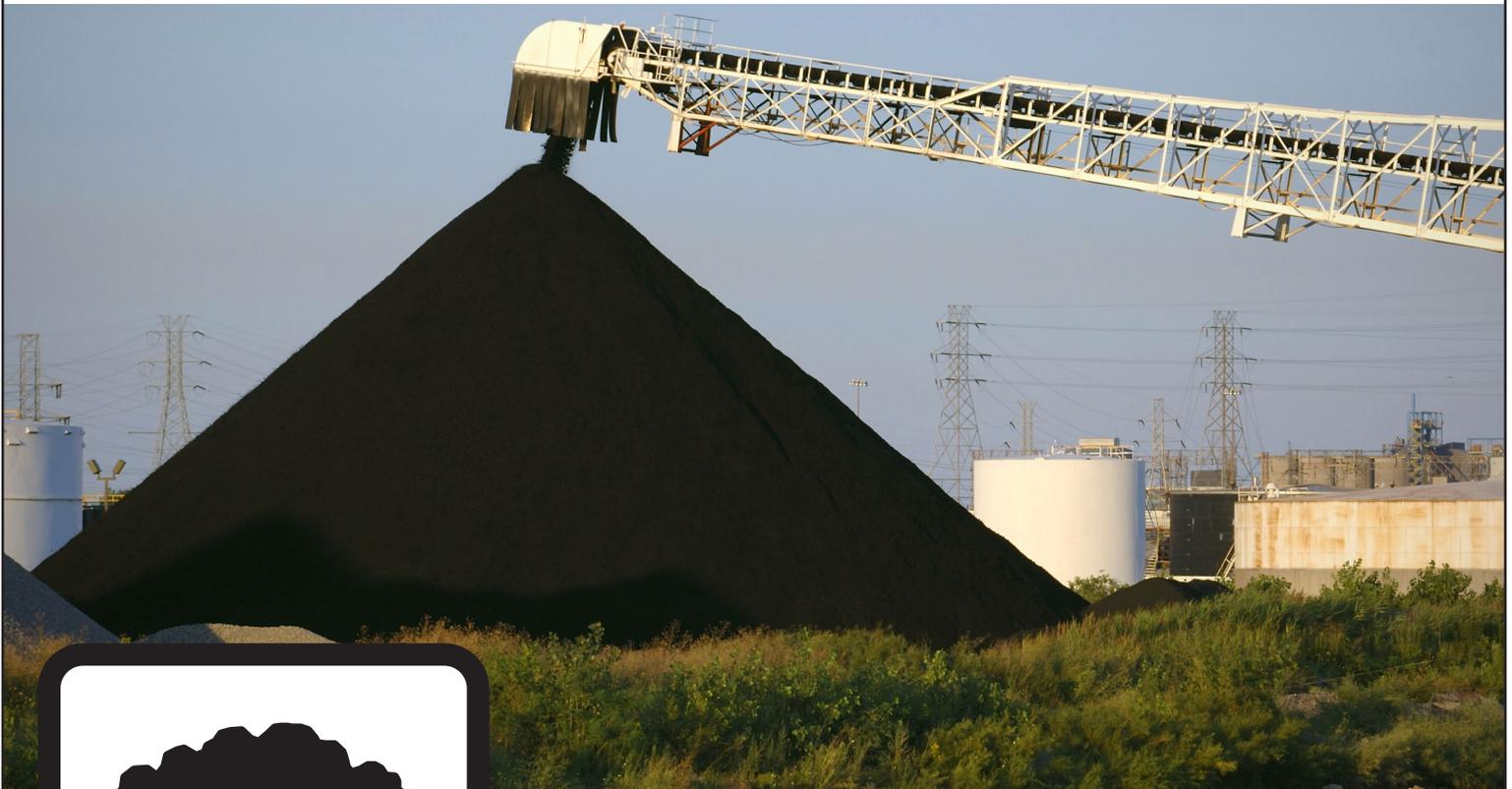


# Understanding Coal

Hands-on, critical thinking activities that introduce intermediate students to the formation of coal, the coal mining process, reclamation of lands, uses of coal, electricity generation, and advantages and disadvantages of utilizing coal.



## Grade Level:

**Int** Intermediate

## Subject Areas:



Science



Social Studies



Language Arts



Math



Careers



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## Teacher Advisory Board

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## 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](http://www.eia.gov).



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# Understanding Coal

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## Table of Contents

▪ Standards Correlation Information	4	▪ A Cool Coal Story Role Sheet	73
▪ Materials	5	▪ Electric Connections	74
▪ Teacher Guide	6	▪ Graphing Analysis	78
▪ Rubrics for Assessment	26	▪ Sample Bill Explanation Key	80
▪ Coal Bingo Instructions	27	▪ Sample School Electric Bill	81
▪ Coal in the Round Instructions	29	▪ Sample School Natural Gas Bill	82
▪ Student Informational Text	30	▪ Baseload Balance	
▪ Q&A with Industry Professionals	44	▪ Student Information	83
▪ Coal KWL Chart Master	48	▪ Game Board	86
▪ The Tale of Fern Fossil Master	49	▪ Game Pieces	88
▪ How Coal Was Formed Master	50	▪ Generation Parameters	90
▪ Simulating the Formation of Coal	51	▪ Hang Tag Template	91
▪ Comparing Coal	54	▪ Incident Cards	96
▪ Coal Mine Match	55	▪ Cheat Sheet	97
▪ Land Development Worksheet	59	▪ Career Networking Template	98
▪ Mining Challenge	60	▪ Culminating Activity: Power Plant Letter Prompt	100
▪ Map Analysis	63	▪ Coal Bingo	101
▪ Science of Electricity Model Instructions	66	▪ Coal in the Round Cards	102
▪ Science of Electricity Model	69	▪ Assessment	105
▪ Burning Coal to Generate Electricity	70	▪ Glossary	106
▪ A Cool Coal Story Master	71	▪ Evaluation Form	111





# Standards Correlation Information

[www.NEED.org/curriculumcorrelations](http://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.

The screenshot shows the NEED website interface. At the top left is the NEED logo (National Energy Education Development Project) and a search bar. Below the logo is a navigation menu with links: About NEED, Educators, Students, Partners, Youth Awards, Contact, and Shop. On the left side, there is a vertical menu with dropdown arrows for: Curriculum Resources, Professional Development, Evaluation, Supplemental Materials, Curriculum Correlations, and Distinguished Service and Bob Thompson Awards. The main content area is titled '> Educators > Curriculum Correlations' and 'Curriculum Correlations'. The text states: 'NEED has correlated their materials to the Disciplinary Core Ideas of the Next Generation Science Standards. NEED has also correlated all of their materials to The Common Core State Standards for English/Language Arts and Mathematics. All materials are also correlated to each state's individual science standards. Most files are in Excel format. NEED recommends downloading the file to your computer for use. Save resources, don't print!'. Below this text is a list of links: 'Navigating the NGSS? We have What You NEED!', 'NEED alignment to the Next Generation Science Standards', 'Common Core State Standards for English and Language Arts', and 'Common Core Standards for Mathematics'. At the bottom of the list are state-specific links: Alabama, Alaska, Arizona, Arkansas, and California. On the left side of the screenshot, there is a green calendar icon and a partial text snippet: 'NEED is adding new energy workshops all the time. Want to'.



# Understanding Coal Materials

The chart below lists activities that require specific materials other than paper, pencils, or computer access. Review the teacher guide beginning on page 6 for a full listing of activities and more information on the types and amounts of materials required. Contact NEED with any questions about materials listed or how to find materials unfamiliar to you.

ACTIVITY	MATERIALS REQUIRED	
<i>Formation of Coal</i>	<ul style="list-style-type: none"> <li>▪ 2-liter Bottles</li> <li>▪ Dirt</li> <li>▪ Sand</li> <li>▪ Twigs, grass, ferns, and other plant matter</li> <li>▪ Ruler</li> <li>▪ Water</li> <li>▪ Foam plate</li> <li>▪ Small rocks</li> <li>▪ Scissors</li> <li>▪ Pie pan</li> </ul>	
<i>Comparing the Types of Coal</i>	<ul style="list-style-type: none"> <li>▪ Samples of coal (optional)</li> </ul>	
<i>Types of Mining</i>	<ul style="list-style-type: none"> <li>▪ Cardstock</li> </ul>	
<i>This Mine of Mine</i>	<ul style="list-style-type: none"> <li>▪ Small plastic bowls</li> <li>▪ Plastic spoons</li> <li>▪ Large plastic bowls</li> <li>▪ 5 lb Bag of sand</li> <li>▪ 5 lb Bag of small, gray pebbles</li> <li>▪ 5 lb Bag of small, white pebbles</li> <li>▪ 5 lb Bag of topsoil</li> <li>▪ 5 lbs of Clay</li> </ul>	<ul style="list-style-type: none"> <li>▪ 50-100 Small pieces of coal or black pebbles</li> <li>▪ Table coverings</li> <li>▪ Grass, leaves, twigs</li> <li>▪ Markers</li> <li>▪ Clear straws</li> <li>▪ Grass seed</li> <li>▪ Container</li> </ul>
<i>Mining Challenge</i>	<ul style="list-style-type: none"> <li>▪ Wooden toothpicks</li> <li>▪ Plastic toothpicks</li> <li>▪ Large paper clips</li> <li>▪ Napkins or paper towels</li> <li>▪ Play money</li> <li>▪ Chocolate chip cookies</li> </ul>	
<i>Science of Electricity</i>	<ul style="list-style-type: none"> <li>▪ Small bottle</li> <li>▪ Rubber stoppers with holes</li> <li>▪ Wooden dowel</li> <li>▪ Foam tube</li> <li>▪ 4 Rectangle magnets</li> <li>▪ 2 Nails</li> <li>▪ Small spool of magnet wire</li> <li>▪ Push pin</li> <li>▪ Hand operated pencil sharpener</li> </ul>	<ul style="list-style-type: none"> <li>▪ Ruler</li> <li>▪ Permanent marker</li> <li>▪ Sharp scissors</li> <li>▪ Masking tape</li> <li>▪ Fine sandpaper</li> <li>▪ Utility knife (optional)</li> <li>▪ Multimeter</li> <li>▪ Alligator clips</li> </ul>
<i>A Cool Coal Story</i>	<ul style="list-style-type: none"> <li>▪ Props (optional)</li> <li>▪ Art supplies</li> </ul>	
<i>Baseload Balance</i>	<ul style="list-style-type: none"> <li>▪ Tape</li> <li>▪ Scissors</li> <li>▪ String</li> <li>▪ Colored paper</li> <li>▪ Rope</li> </ul>	<ul style="list-style-type: none"> <li>▪ Marker boards</li> <li>▪ Erasers</li> <li>▪ Dry-erase markers</li> </ul>



# Teacher Guide

## Grade Level

- Intermediate, grades 6-8

## Time

- Ten to fifteen class periods, depending on the activities selected, time available, and adaptations of lessons 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/>

## Background

The majority of our energy consumption comes from petroleum, natural gas, and coal. Coal is the leading energy source for electricity generation in the United States, and our third leading source for energy overall. The use of energy sources for electricity has changed greatly over the past 15 years. Coal used to make up a much larger percentage of our electricity generation. Currently, about 33% of our electricity generation comes from coal. Coal is a good source for electricity because of its high energy content. However, it does have its drawbacks, and there are several reasons coal use has declined in recent history.

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 hands-on activities provide students with cross-curricular learning experiences as they understand the role coal has played in the generation of electricity and the possibilities for coal in the future.

## Preparation

- Familiarize yourself with the activities and informational text included in the guide.
- Select the activities you will use with your students.
- Gather materials necessary for the activities selected. Refer to the materials chart on page 5 for a listing of materials needed.
- 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 26.

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.

## Introduction

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### Objective

---

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

### Materials

---

- *Student Informational Text*, pages 30-43
- *Coal KWL Chart* master, page 48

### Preparation

---

- Make a copy of the master for each student or prepare a copy to project.

### Procedure

---

1. Distribute the worksheets to the students or ask students to create their own charts in their notebooks.
2. Introduce coal as an important source of energy using the KWL chart for coal. Have the students make a list of the things they know and questions they have about coal and energy.
3. Have students read the informational text, taking notes and adding to their KWL charts. Discuss the questions they have and have them research specific questions as homework.

## Activity 1: Formation of Coal

---

### Background

---

Coal is a rock made of mineralized plants and is considered a fossil fuel like petroleum and natural gas. These energy rich substances were formed from the remains of decaying organisms millions and even hundreds of millions of years ago. Coal formed specifically from plant matter in swampy regions. This decaying plant matter, also known as peat, went through bacterial decay where it was deprived of oxygen. This anaerobic decay leaves behind carbon rich material. Layers of rock above the decayed material provided compaction or pressure. This pressure, coupled with heat and significant amounts of time, will produce coal. It is estimated that it takes approximately 10 vertical feet of peat to create one vertical foot of coal.

This activity has two components, a story and a simulation. The simulation will take several weeks to complete as it simulates the decay of plant matter to create coal and mimics the time-consuming steps in the formation process. The simulation can be done as a demonstration that is used throughout the course of the unit or can be completed individually by students. In the simulation, the foam plate is used to limit oxygen present during decay, and will represent the anaerobic decay process. The rocks used will simulate the layers of earth continually pushing down. With more time, more pressure is added, thus the addition of rocks throughout the course of the simulation.

### Objectives

---

- Students will be able to explain the formation process of coal.
- Students will be able to classify coal as an organic sedimentary rock.

**CONTINUED ON NEXT PAGE**

## Materials

---

- 2 2-liter Bottles
- Dirt
- Sand
- Twigs, grass, ferns, and other plant matter
- Ruler
- Water
- Foam plate
- Small rocks
- Scissors
- Pie pan
- *The Tale of Fern Fossil* master, page 49
- *How Coal Was Formed* master, page 50
- *Simulating the Formation of Coal*, pages 51-53

## Preparation

---

- Gather the materials necessary to complete the activity. Set up student work stations if completing the activity with students, rather than as a demonstration.
- Create adequate space on a window sill or in a warm place to store the bottle(s) as the formation of coal is simulated.
- Prepare a copy of *The Tale of Fern Fossil* to project or for individuals to take home.

## Notes Regarding This Activity

---

- The simulation takes place over approximately 4-5 weeks. It is suggested to set up this simulation ahead of the start of your coal unit. It may be helpful if the initial set-up is constructed on a Thursday, with the first reading taking place on Friday, and with regular measurements resuming the following Monday.
- This simulation can be done as a lab or as a demonstration to cut down on materials used. If done as a demonstration, assign a student or students to measure each layer and report their findings to the class and/or record findings in a class data table. If it is desired to complete this activity individually, ask each lab group to supply their own 2-liter bottles.
- Students can go outside together to collect plant matter, or they can bring it into class as a homework assignment.

## Procedure

---

1. Introduce the formation of coal by directing students to read *The Tale of Fern Fossil*. This can be assigned as homework, if desired.
2. Ask students to illustrate the story based on their interpretation. Students can be assigned certain sections of the story to illustrate individually or as a group. The illustrations can be pieced together into a class picture book. Students can also work individually to create their own version of the illustrated story.
3. Display the master and briefly discuss the process of creating coal. Explain to students that the simulation activity will attempt to model this process. Discuss as a class how models are meant to resemble a process but are not always perfect representations of a process.
4. Set up the coal formation simulation using the *Simulating the Formation of Coal* worksheets. Students should collect data in the data section of the applicable worksheet. Data will need to be collected three times per week. If conducting this simulation as a demonstration, it may be helpful to set up a class chart or digital shared version of the data table so that all students can view and add to the data.
5. After the formation simulation is complete, use the conclusions as a basis for discussion. Review the coal formation master and story and compare them to the simulation. Ask students how they would re-design this model to better reflect the process of formation.

## Extension

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- Have students read their illustrated stories to a younger group of students, or display them in the library.

## Activity 2: Comparing the Types of Coal

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### Background

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Coal is a sedimentary rock, rock that formed from layers of sediments compacted over time. Coal contains combustible materials and is mostly made of carbon. Coal typically starts out as peat. Peat, a porous material, consists mostly of plant material that decomposed. In order to make coal, the peat was buried and exposed to heat and pressure, which changed the peat physically and chemically. Changing the amount of pressure, heat, and time will create different types of coal with differing amounts of carbon. The more carbon in a coal sample, the greater its energy content will be. The physical and chemical properties of the coal help us to classify it as anthracite, lignite, subbituminous, or bituminous.

### Objectives

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- Students will be able to identify the four types of coal and explain their differences.
- Students will be able to describe the chemical properties of coal.

### Materials

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- *Comparing Coal* graphic organizer, page 54
- Samples of the 4 types of coal (optional)

**NOTE:** Samples of coal can be obtained by contacting The American Coal Foundation, [www.teachcoal.org](http://www.teachcoal.org).

### Preparation

---

- Make a copy of the graphic organizer for each student.

### Procedure

---

1. Introduce or review physical properties of rocks and minerals, such as luster, hardness, cleavage/fracture, color, etc.
2. Pass around samples of the different types of coal, if you have them. Some sample kits may come with peat and/or subbituminous coal, while some may not. Most kits will include anthracite, bituminous, and lignite.
3. Ask students to compare with a partner the different samples of coal. Discuss the observations as a class.
4. Have students read or review pages 32-33 of their informational text on the formation, chemistry, and types of coal.
5. As they read, or after they are finished reading, have the students complete the graphic organizer comparing the types of coal.

### Extension

---

- Have each student or a group of students do further research on one of the types of coal, where it can be found, its major uses, and the advantages and/or challenges with this type of coal. Have them prepare a short oral or digital presentation showcasing what they have learned.

## Activity 3: Types of Mining

### Objective

- Students will be able to identify and describe the different methods of coal mining and differentiate between each.

### Materials

- Cardstock
- *Coal Mine Match* cards, pages 55-58

### Preparation

- Copy the match game cards onto cardstock. Make enough for student pairs or small groups to each have their own set.
- Cut out the cards. Fold the cards on the center line. Tape or glue if necessary. Clip pairs of cards together so that one card has a picture of a type of mine, and the other has the blank space for writing. Assemble a whole set of mine match cards and place them in an envelope.

### Procedure

1. Direct the students to read the informational text. While reading they should complete their cards. Each matched pair of cards has a picture on one card, and space for writing on the other. On the card with this space, they should circle the type of mine for each and explain how each method retrieves the coal.
2. Have students lay their cards out face down, so that “Coal Mine Match” is facing up. Students will take turns revealing a card and trying to find its match. One card in the match will have a picture, the other will have its description.

### Extensions

- Have students make a match game for other vocabulary and terms they are using throughout the unit.
- Use this activity as a formative assessment or review activity throughout the unit.
- Have students draw their own diagrams of each mine type rather than using the prescribed pictures.

## Activity 4: This Mine of Mine

### Background

This activity allows students to explore the formation, geology, recovery, and uses of coal, as well as the reclamation of coal mine sites. Using sand, clay, soil, and rocks, students build a miniature plot of land containing coal deposits. Students then learn about surface mining as a method of recovering coal from the earth, and practice the method on their plot of land. After the coal is mined, students reclaim the plot of land and discuss the challenges of the process.

### Objective

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

### Materials

- Small plastic bowls
- Plastic spoons
- Large plastic bowls
- 5 lb Bag of sand
- 5 lb Bag of small, gray pebbles
- 5 lb Bag of small, white pebbles
- 5 lb Bag of topsoil
- 5 lbs of Clay
- 50-100 Small pieces of coal or black pebbles
- Table coverings
- Grass, leaves, twigs
- Markers
- Clear straws
- Grass seed
- Container for coal
- *Land Development Worksheet*, page 59

**CONTINUED ON NEXT PAGE**

## Preparation

- Make a copy of the worksheet for each student.
- Set up work stations with the materials needed so that students have access to all supplies. Make sure student work areas are covered with table coverings.
- Place one large bowl each of sand, gray pebbles, white pebbles, and topsoil at each station, as well as a portion of clay, a small bowl of coal, and a plastic spoon. Hint: The activity is more successful if the sand is slightly moist—the consistency of brown sugar.
- Depending on the time available, this activity can be split into three segments or parts, or all three can be done within one class period.

## Part 1: Land Development

1. Review the following vocabulary words:
  - **coal**: a black mineral that can be burned for energy
  - **mine** (verb): to remove natural resources from the ground by digging
  - **surface mining**: removing layers of earth to recover a natural resource
  - **natural resource**: something in nature that can be used to improve lives
  - **reclamation**: returning disturbed land back to the way it was before mining took place
2. Explain to the students that they will build their own plots of land that contain coal deposits.
3. Discuss how the Earth is made of layers of different materials, the crust, mantle, and core. In this activity, the layers in the crust are represented by sand, clay, soil, and pebbles.
4. Provide each student with a small plastic bowl and spoon. Have the students write their names on the bottoms of the bowls with markers, then send them to the work stations.
5. Distribute the worksheets and review the steps using the script below. The worksheets do not include the exact same script or the explanation of geological layers as described below:
  - Get a lump of clay about the size of your fist, or a bit smaller.
  - Roll the clay flat and press it into the bottom of your bowl.  
*This represents the clay layer in the Earth.*
  - Place one spoonful of coal on an area of the clay and flatten it. (This coal layer should not be distributed evenly throughout the clay; it should take up only a small area of the clay.)  
*This represents a seam of coal on top of the clay layer.*
  - Spread 6 spoonfuls of gray pebbles on top of the coal. Make a hill with the pebbles.  
*This represents the shale that typically covers a layer of coal.*
  - Spread 7 spoonfuls of white pebbles evenly in the bowl.  
*This represents a layer of limestone.*
  - Spread 8 spoonfuls of gray pebbles evenly on top of the white pebbles.  
*This represents another layer of shale.*
  - Spread 10 spoonfuls of sand evenly on top of the pebbles.  
*This represents sandy, rocky soil.*
  - Spread 12 spoonfuls of topsoil evenly on top of the sand.  
*This represents fertile topsoil.*
  - Use cut grass, leaves, and twigs to make fields and forests on your plot of land.
6. After the students have finished their plots of land, have them clean up and store them until the next class, if applicable. The topsoil, grass seeds, and spoons will be needed again.
7. Review and discuss how the Earth is made of layers of different types of rocks, topsoil, clay, and water. Some of these layers contain natural resources that we use for many different things.

**CONTINUED ON NEXT PAGE**

## Part 2: Geology and Mining

---

1. Discuss with the students things they use that are made from natural resources found underground, such as:
  - pencils made from graphite
  - jewelry made from gold, silver, gemstones
  - plastic items made from petroleum
  - nylon and polyester clothes made from petroleum
  - anything metal
  - coal used to generate electricity
  - natural gas, petroleum, and uranium used to generate electricity
  - steam from geysers—geothermal energy
2. Review and discuss the types of mining or review the mining match activity, as necessary. Ask students what type of mining they think they will be doing.
3. Have students retrieve their plots of land and return to the work stations. Explain that they will be mining the coal from their plots of land.
4. Instruct the students to take core samples of their plots, using drinking straws to carefully probe the soil. Explain how to cover the end of the straw with a finger and carefully remove the straw to look at its contents. If the pebbles are too large, this step of the activity will not work.
5. The students must use their spoons to carefully remove each layer of grass, sand, and pebbles, placing each layer in a separate pile on the work station. This simulates the use of bulldozers and other machines to move layers of earth.
6. When the coal layer is reached, the spoons should be used to remove the coal. Have the students place the coal in a coal container you designate.
7. When the mining is complete, discuss with the students what they have learned in the mining process and what questions they still have.

## Part 3 : Reclamation

---

1. Discuss with the students whether or not they should leave the plots of land as they are after mining. Introduce the concept of reclamation. By law, mine sites must be restored to a state that is as good as, or better than, it was before mining.
2. Direct the students to reclaim their plots of land. They should replace all of the layers so that they are the same as they were before the land was mined, except for the grass, leaves, and twigs, which must be thrown away because they are dead. New plant life must be planted.
3. When they have replaced the topsoil layer, have them sprinkle two pinches of grass seed onto the soil, then cover the seeds with another layer of topsoil. Have them water the soil and place the plots of land in a sunny area.
4. Clean up the work stations. Bring the class back together to discuss the reclamation process and add to the KWL chart. Lead the discussion by asking the following questions:

**Was it easy to replace each layer exactly as it was?** Reclamation is difficult and expensive. Imagine if the plots of land in our experiment were as big as our playground or school yard. It would take time and effort to replace the land.

**Why is it important to reclaim mined land?** The resources we get from the Earth are important to our lives. The environment that surrounds and covers those resources is equally important. It is our responsibility to return the land to a state that is as good as, or better than, it was before we removed the resources.

**What happens when land is not reclaimed?** What did our room look like right after we had mined our coal? It was a mess! We couldn't use it for the things we needed to do in our room. We needed to clean it up so that it was useful to us again. It is important to respect the Earth. Land that is not reclaimed ends up being an empty pit. It is ugly, can't be used, and can sometimes be dangerous. Reclaimed land can be used for farmland, camping, lakes, planting trees, livestock grazing, golf courses, and many other things.

**Could you plant trees and build homes on the site as soon as the earth is reclaimed?** It depends on many factors. The depth of the mine, the weather, and the type of soil in the mine can affect how long it takes before the land can be used for planting trees and building safe structures. Have the students compare how their plots looked before and after they added water.

## Activity 5: Mining Challenge

---

### Objective

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

### Materials

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- 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 60-62

### 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. It is also suggested to have enough cookies on hand to complete the activity and extra on-hand for eating, if desired. Be sure the cookies used will be safe for students with allergies.

### Preparation

---

- Make copies of the worksheets for students.
- Split up students 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.

### 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. For younger 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. For younger students, it is recommended that each team only purchase one mine site. Older students may 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 if at all. 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 assessing 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.

**CONTINUED ON NEXT PAGE**

## General Rules of the Challenge:

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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 the tools purchased only – 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 cookie.

**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:

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- 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 6: Map Analysis

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### Background

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Coal can be found in many parts of the United States and all over the globe. This activity helps students to synthesize and understand how geography, geology, and population can determine how we use a source for energy.

This activity is centered on the state of Kentucky, due to the prevalence of data and maps available related to coal in the state. However, if you prefer to have your students research their own state, or compare their state to Kentucky, you can find similar maps (not necessarily interactive) available from the United States Geological Survey (USGS), <http://www.usgs.gov/>.

### Objectives

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- Students will be able to identify locations where mining and power plants are located.
- Students will be able to describe the role of geography in siting plants and facilities for power generation.

### Materials

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- Computers with internet access
- *Map Analysis* worksheets, pages 63-65

### Preparation

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- Make copies of the worksheets for students.
- Familiarize yourself with the maps and controls of the interactive maps on the Kentucky Coal Resource Information website, <http://kgs.uky.edu/kgsmmap/kcrim/>.

### Procedure

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1. Introduce your students to the interactive map. It may be helpful to display the website to discuss how to interact with the data on the maps.
2. Instruct students on how and where to find geological map information to assist them in their map analysis activity.
3. Instruct students to complete the map analysis activity. Discuss the answers as a class.

### Extension

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- Have students research similar information for another state. Have them outline similarities and differences that they notice for each state.

## Activity 7: Science of Electricity

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### Background

---

Electricity is a necessary part of our daily lives. To many it is a mystery. This model helps students to visualize more simply what is involved in the generation of electricity: motion, wire, and magnets.

### Objective

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

### Materials

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- |  |  |
|--|--|
| ▪ 1 Small round bottle                   | ▪ Fine sandpaper   |
| ▪ 4 Strong rectangle magnets             | ▪ Multimeter   |
| ▪ 1 12" x 1/4" Wooden dowel              | ▪ Alligator clips  |
| ▪ 1 Rubber stopper with 1/4" center hole | ▪ Sharp scissors   |
| ▪ Foam tube                              | ▪ Ruler  |
| ▪ Spool of magnet wire                   | ▪ Hand operated pencil sharpener                                 |
| ▪ Masking tape                           | ▪ Push pin   |
| ▪ Permanent marker                       | ▪ Utility knife (optional)                                       |
| ▪ 1 Small nail                           | ▪ <i>Science of Electricity Model Instructions</i> , pages 66-68 |
| ▪ 1 Large nail                           | ▪ <i>Science of Electricity Model</i> worksheet, page 69         |

### Preparation

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- Prepare the model ahead of time.
- Make a copy of the worksheet for each student.

### Procedure

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1. As a class, review how electricity is generated from previous reading.
2. Show students the model. Ask them to explain how the model is working to generate electricity. Pass the model around for students to test.
3. After students have tested the generator by spinning it by hand, have them think about other ways that could be used to turn the dowel that would be easier and more consistent. Discuss as a class options for optimizing the model.
4. Ask students to complete the worksheet as an assessment.

### Extensions

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

## Activity 8: A Cool Coal Story

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### Objective

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- Students will be able to explain the energy transformation or flows involved with coal – from formation to use.

### Materials

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- Art supplies or props
- *Burning Coal to Generate Electricity* master, page 70
- *A Cool Coal Story* master, pages 71-72
- *A Cool Coal Story Role Sheet*, page 73

### Preparation

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- Make a copy of *A Cool Coal Story Role Sheet* for each student.
- Provide art supplies for students to assemble their props, or gather the suggested items shown on the story handout. You may also download paper props to print for students by visiting [www.need.org/files/curriculum/webcontent/CoolCoalStory\\_Props.pdf](http://www.need.org/files/curriculum/webcontent/CoolCoalStory_Props.pdf).
- Prepare copies of the masters to project.

### Procedure

---

1. Assign students to a specific role on the role sheet.
2. Project the electricity generation master. Discuss how electricity is produced in a coal-fired plant.
3. Have each student assemble his/her props, or provide each student with a suggested prop.
4. Review or introduce any new vocabulary, as needed. Project the story. Act out the story from beginning to end. Extra students may help read the story aloud.
5. Substitute in different students or props as necessary.
6. Ask students to write an essay explaining the energy flow involved to produce electricity from coal.

### Extensions

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- Have students act their energy flow out for another class.
- Have students design their own story for another energy source.

## Activity 9: Electric Connections

### Background

*Electric Connections* teaches students how different energy sources contribute to the generation of electricity. Students will be able to compare several states to the national generation picture and discuss similarities and differences. This activity demonstrates the advantages and disadvantages of working together in a group and reinforces the ideas of group sharing and cooperative learning.

### Objectives

- Students will be able to identify major sources used for electricity generation.
- Students will be able to identify factors that differ among states and regions in determining electric power generation sources.

### Materials

- *Electric Connections* worksheets, pages 74-77
- Computers with internet access (optional)

### Preparation

- Decide if you want students to use the *Electric Connections State by State* handout to procure data on the states, or if you would like them to retrieve the data themselves. If they are retrieving the data themselves for the states, take time to become familiar with the EIA website electricity data browser, [www.eia.gov/electricity/data/browser](http://www.eia.gov/electricity/data/browser).
- Make copies of the worksheets needed for each student.
- Divide students into groups of 3-5 students per group.

### Procedure

1. Give each student a copy of the *Electric Connections Game Instructions* worksheet. Review the instructions with the class.
2. Have the students individually rank the ten sources of energy in order of the contribution to U.S. electricity production and also to the production of Kentucky, Connecticut, and Idaho. Give them 5 minutes to complete this task.
3. As a group, give students 10 minutes to rank the ten sources of energy for all three states and the U.S. If necessary, remind students of the courtesies to be used when trying to gain group consensus.
4. After the groups have completed their rankings on the game instructions sheet, hand out the *Electric Connections U.S. Electric Power Generation Sources* worksheet. Have the students transfer their rankings from their game instructions sheet onto this sheet.
5. Ask students to read the statistics for the U.S. and record the actual rank for each source in the U.S. row. If providing your students with the data for the states, provide them with the *Electric Connections State by State* handout to analyze and record the rank for each source in the appropriate state's row. If you choose to have the student groups research the information for each state, direct them to use the Energy Information Administration's state pages for each, [www.eia.gov/states](http://www.eia.gov/states).
6. Ask students to calculate their error points to determine if they worked better as a group or individually.
7. Discuss the differences between the three selected states and the U.S. Why would their profiles be so different? Why do students think these states were chosen for this activity in comparison?

### Extensions

- Ask students to each look up the information for a different state, including the one they live in. How do each of their assigned states compare to those selected for the activity? To the country?
- As a faster way to play the game, you can provide the students with the states' source rankings. This may allow more time for discussion.

### Answer Key

	USA	KY*	CT**	ID***
Biomass	6	5	3	4
Coal	1	1	4	5
Geothermal	9	6	8	5
Hydropower	4	3	6	1
Natural Gas	2	2	2	2
Petroleum	8	4	5	6
Propane	10	6	8	6
Solar	7	6	7	6
Uranium	3	6	1	6
Wind	5	6	8	3

\*Geothermal, propane, solar, uranium, and wind all provide no electricity to Kentucky.

\*\*Geothermal, propane, and wind provide no electricity to Connecticut.

\*\*\*Petroleum, solar, and uranium provide no electricity to Idaho.

## Activity 10: Graph Analysis

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### Objectives

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- Students will be able to analyze graphs to identify trends.
- Students will be able to compare several graphs and synthesize the information to present a conclusion.
- Students will be able to identify trends in coal production and electricity generation based on graphical representations of the data.

### Materials

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- *Graphing Analysis* worksheets, pages 78-79

### Preparation

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- Make copies of the worksheets for each student as needed.

### Procedure

---

1. Give each student the graphs for analysis. Alternatively, you may also assign each student to a different set of graphs and have them complete a jigsaw with the information they analyzed on the graphs.
2. Discuss the graphs as a class.

## Activity 11: Electric Bill Analysis Activity

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### Objective

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

### Materials

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- *Sample Bill Explanation Key*, page 80
- *Sample School Electric Bill*, page 81
- *Sample School Natural Gas Bill*, page 82

### Preparation

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- 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

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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. Refer students to the glossary for definitions of terms unfamiliar to them.
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: Baseload Balance

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### Background

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

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

### Objectives

---

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

### Materials

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- Scissors and tape for each student or small group
- String
- Rope
- Colored paper
- Individual marker boards with markers and erasers
- *Baseload Balance Student Information*, pages 83-84
- Game board for each student or small group, pages 86-87
- Game pieces for each student or small group, pages 88-89
- *Generation Parameters* master, page 90
- Hang tags, pages 91-95
- *Incident Cards*, page 96
- *Cheat Sheet*, page 97

### Vocabulary *SPECIFIC TO THE GAME*

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

**CONTINUED ON NEXT PAGE**

## Preparation

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- 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

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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.
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

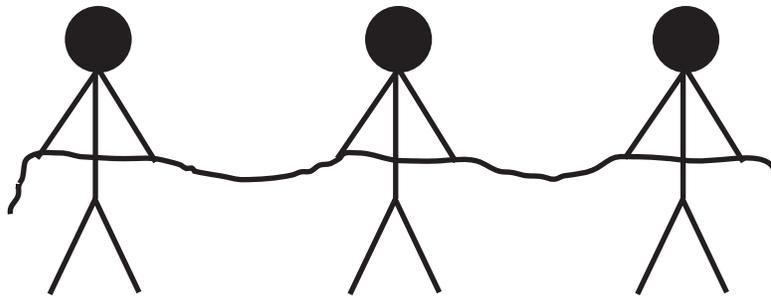
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1. What is the peak demand time? When is the least amount of power needed?
2. What was the average cost per megawatt-hour during daylight hours?
3. What was the average cost per megawatt-hour over the entire 24-hour period?
4. Everyone needed to use 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?

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### ✓ Procedure FOR SIMULATION ACTIVITY

1. Assign each student a role that corresponds to each hang tag. A list of the roles can also be found below. The Transmission roles are best assigned to students who are able to think quickly on their feet and have good math skills. 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.
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 will 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 power all the time.
6. At the appropriate time indicated on each hang tag, each load student will join the grid, increasing the load demand. Residential demand comes up (online) at about 7:00 a.m. as people begin to wake. Demand continues to rise as more residential, commercial, and industry users 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.

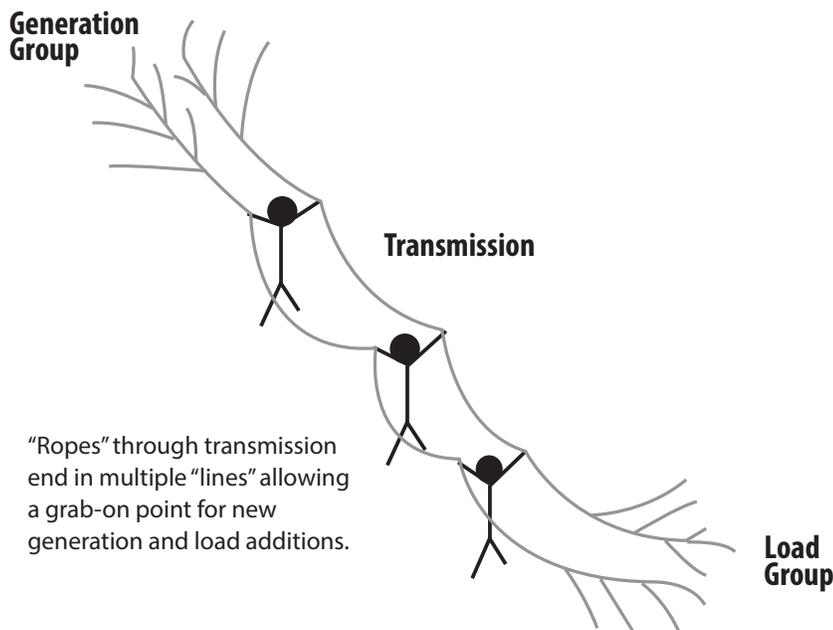
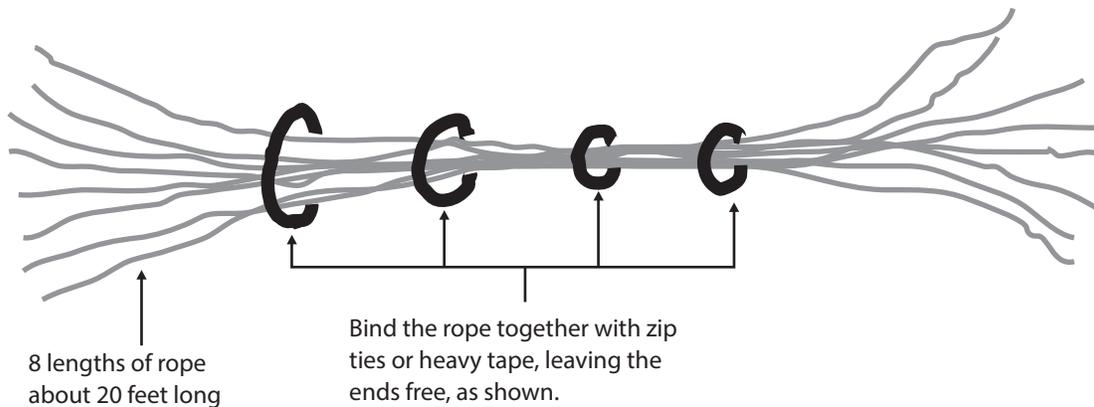
### Student Roles for Ending Activity

- 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

**CONTINUED ON NEXT PAGE**

## 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.



## Activity 13: Careers in Coal

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### Objective

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- Students will be able to identify and describe careers in the coal and energy industry, and list skills and qualifications for each job description.

### Materials

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- Computers with internet access
- *Career Networking Template*, pages 98-99

### Preparation

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- Make a copy of the template for each student, or provide a digital copy to project or share with students.

### Procedure

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1. Have students read pages 43-47 of the informational text on careers in the coal industry.
2. Allow students time to research other careers in the coal industry that were not highlighted in the text. Ask students to select a career they would like to research further or might have an interest in.
3. Explain to students that they will be constructing a career profile, much like a digital resume used in online networking sites for employment.
4. Instruct students to create a profile using the basic information requested on the template. You may wish to specify more or less items depending on the depth of the profile you might like them to complete. Profiles can be created on paper or using a software of your choice.

### Extensions

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- Create a sample Facebook page as a class about coal. Include elements such as friends, music, locations they lived/worked, etc.
- Ask students to conduct interviews (in person or through correspondence) about careers in the industry.

## Activity 14: Letter Writing Campaign

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### Objective

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- Students will identify the advantages and challenges of mining and utilizing coal.

### Materials

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- *Power Plant Letter Prompt*, page 100

### Procedure

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1. Brainstorm with students some of the opportunities and challenges they see for mining and utilizing coal.
2. Make a list of the advantages and disadvantages in a T-chart.
3. Once the class has come up with a list, review the informational text. Ask students if they missed any items.
4. Discuss the list as a class. Are there some items that are more important than others? Why? What might need to be taken into consideration if you were to decide whether or not to use coal in your power plant or to change to another source?
5. Have students complete additional research to write a persuasive letter to an elected representative, other decision maker, or their town newspaper. Letters should advocate for the use of coal or against the use of coal to meet the energy demand locally. Letters may be submitted to the teacher, or, you may give students the option to actually send their letters to the intended recipients. Further details of the letter assignment are on page 100. If desired, students may work in groups to complete their research and letters.
6. Evaluate student work. A sample rubric is provided on page 26.

### Extension

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- Work cooperatively with your school's language arts department to address the proper format and technique used for writing a persuasive essay or letter.

### Unit Assessments

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- Have students complete the *Assessment* on page 105. This can also be given as a pre-assessment at the start of the unit to gauge student's preliminary knowledge and assist in determining activities to use in the implementation of the unit.
- Have students play *Coal Bingo* or *Coal in the Round* as formative assessments or review activities. Instructions for these activities are found on pages 27-29.
- Revisit the *Coal Mine Match* game as a review activity or assessment.
- Rubrics for assessing student work can be found on page 26. These rubrics can be adapted to meet the needs of your students or the activities.
- Evaluate the unit with students using the *Evaluation Form* on page 111 and return it to NEED.



# 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 and adapted for assessing student work on *The Tale of Fern Fossil* books, *A Cool Coal Story* student work, *Career Networking Templates*, or the *Letter Writing Campaign*.

	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 good.	Content is logically organized.	Project shows some original thought. 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 with 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 several members are not doing a fair share of the work.



# Coal BINGO Instructions

## Get Ready

Duplicate as many *Coal Bingo* sheets (found on page 101) 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](http://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<sub>2</sub> 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 |

<b>A</b> Organic sedimentary	<b>B</b> Removes pollutants (sulfur, NOx) before, during, and after burning	<b>C</b> Wyoming, West Virginia, Kentucky, Illinois, Pennsylvania	<b>D</b> Peat
<b>E</b> Electricity generation Non-CHP (combined heat and power) Industry	<b>F</b> Anthracite Bituminous Subbituminous Lignite	<b>G</b> United States	<b>H</b> Surface mining Deep mining
<b>I</b> Time Heat Pressure Originates with stagnant water / swamp	<b>J</b> <b>Advantage:</b> energy density, supply, domestic <b>Disadvantage:</b> Pollution, greenhouse gases, mine safety	<b>K</b> Railroad car	<b>L</b> Chemical Energy
<b>M</b> Ask for details	<b>N</b>	<b>O</b> Sulfur	<b>P</b> CO <sub>2</sub>



# Coal in the Round Instructions

## Get Ready

- Copy one set of the *Coal in the Round Cards* on pages 102-104 on cardstock and cut into individual cards.
- Have the *Student Informational Text* 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.

## 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

COALIFICATION

COKE

ORGANIC

ELECTRICITY

SULFUR

GASIFICATION

ANAEROBIC

LAW OF CONSERVATION OF ENERGY/MATTER

LIGNITE

LONGWALL MINING

CARBON DIOXIDE

METHANE

MOUNTAINTOP REMOVAL

OVERBURDEN

PEAT

RANK

RECLAMATION

ROOM-AND-PILLAR MINING

SWAMPS OR MIRES

SUBBITUMINOUS

SURFACE MINING

THERMAL POWER PLANT

TURBINE

UNDERGROUND MINING

SEDIMENTARY

*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](http://www.NEED.org).

- Hydrogen in the Round—*H<sub>2</sub> 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*



# Student Informational Text

## What Is Energy?

**Energy** makes change; it does things for us. It moves cars along the road and boats over the water. It bakes a cake in the oven and keeps ice frozen in the freezer. It plays our favorite songs and lights our homes. Energy makes our bodies grow and allows our minds to think. Scientists define energy as the ability to do work.

## Forms of Energy

Energy is found in different forms, such as light, heat, sound, and motion. There are many forms of energy, but they can all be put into two categories: potential and kinetic.

### POTENTIAL ENERGY

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

- **Chemical energy** is energy stored in the bonds between **atoms** and **molecules**. It is the energy that holds these particles together. Biomass, petroleum, natural gas, propane, and the foods we eat are examples of stored chemical energy.
- **Elastic energy** is energy stored in objects by the application of a force. Compressed springs and stretched rubber bands are examples of elastic energy.
- **Nuclear energy** is energy stored in the nucleus of an atom; it is the energy that holds the nucleus together. The energy can be released when the nuclei are combined or split apart. Nuclear power plants split the nuclei of uranium atoms in a process called **fission**. The sun combines the nuclei of hydrogen atoms in a process called **fusion**.
- **Gravitational potential energy** is the energy of position or place. A rock resting at the top of a hill contains gravitational potential energy because of its position. Hydropower, such as water in a reservoir behind a dam, is an example of gravitational potential energy.

### KINETIC ENERGY

**Kinetic energy** is motion; it is the motion of waves, **electrons**, atoms, molecules, substances, and objects.

- **Electrical energy** is the movement of electrons. Everything is made of tiny particles called atoms. Atoms are made of even smaller particles called electrons, protons, and neutrons. Electrons are always moving. Applying a force can make some of the electrons move faster or in a desired direction. Electrons moving through a wire are called **electricity**. Lightning is another example of electrical energy.
- **Radiant energy** is **electromagnetic** energy that travels in vertical (transverse) waves. Radiant energy includes visible light, x-rays, gamma rays, and radio waves. Solar energy is an example of radiant energy.

## Forms of Energy

### POTENTIAL

Chemical Energy



Elastic Energy



Nuclear Energy



Gravitational Potential Energy



### KINETIC

Electrical Energy



Radiant Energy



Thermal Energy



Motion Energy



Sound Energy



- **Thermal energy**, or heat, is the internal energy in substances; it is the vibration and movement of the atoms and molecules within a substance. The more thermal energy in a substance, the faster the atoms and molecules vibrate and move. Geothermal energy is an example of thermal energy.
- **Motion energy** is the movement of objects and substances from one place to another. Objects and substances move when an unbalanced force is applied according to **Newton's Laws of Motion**. Wind is an example of motion energy.
- **Sound energy** is the movement of energy through substances in longitudinal (compression/rarefaction) waves. Sound is produced when a force causes an object or substance to vibrate; the energy is transferred through the substance in a longitudinal wave.

## Conservation of Energy

Your parents may tell you to conserve energy. “Turn out the lights,” they say. To scientists, **energy conservation** is not just about saving energy. The **Law of Conservation of Energy** says that energy is neither created nor destroyed. When we use energy, it doesn't disappear. We change one form of energy into another.

A car engine burns gasoline, converting the chemical energy in gasoline into motion energy. Solar cells change radiant energy into electrical energy. Energy changes form, but the total amount of energy in the universe stays the same.

## Efficiency

**Energy efficiency** is the amount of useful energy you get from a system. A perfect, energy efficient machine would change all the energy put in it into useful work—a technological impossibility today. Converting one form of energy into another form always involves a loss of usable energy.

Most energy transformations are not very efficient. The human body is a good example of this. Your body is like a machine, and the fuel for your machine is food. Food gives you the energy to move, breathe, and think.

Your body isn't very efficient at converting food into useful work. Most of the energy in your body is transformed and released as thermal energy (heat). You can really feel that heat when you exercise! This is very much like most energy transfers. The loss of useable energy is often in the form of thermal energy (heat).

## Sources of Energy

We use many different energy sources to do work for us. They are classified into two groups—renewable and nonrenewable.

In the United States, most of our energy comes from **nonrenewable** energy sources. Coal, natural gas, petroleum, propane, and uranium are nonrenewable energy sources. They are used to make electricity, heat our homes, move our cars, and manufacture all kinds of products. These energy sources are called nonrenewable because their supplies are limited. Petroleum, a **fossil fuel**, for example, was formed hundreds of millions of years ago from the remains of ancient sea plants and animals. We can't make more crude oil deposits in a short time.

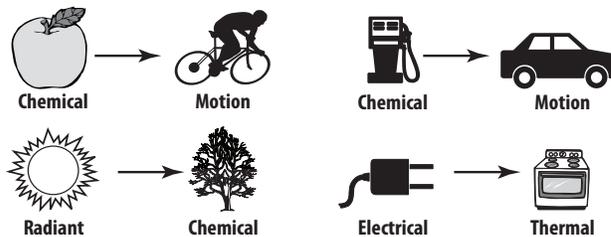
**Renewable** energy sources include biomass, geothermal energy, hydropower, solar energy, and wind energy. They are called renewable because they are replenished in a short time. Day after day, the sun shines, the wind blows, and the rivers flow. We use renewable energy sources mainly to make electricity.

## Electricity

Electricity is different from the other energy sources because it is a **secondary source of energy**. We must use another energy source to produce electricity. In the U.S., coal is the number one energy source used for generating electricity.

Electricity is sometimes called an **energy carrier** because it is an efficient and safe way to move energy from one place to another, and it can be used for so many tasks. As we use more technology, the demand for electricity grows.

## Energy Transformations



## U.S. Energy Consumption by Source, 2015

**NONRENEWABLE, 90.2%**

**RENEWABLE, 9.7%**



**Petroleum 36.6%**

Uses: transportation, manufacturing - Includes Propane



**Natural Gas 29.0%**

Uses: electricity, heating, manufacturing - Includes Propane



**Coal 16.0%**

Uses: electricity, manufacturing



**Uranium 8.6%**

Uses: electricity



**Propane**

Uses: heating, manufacturing

\*Propane consumption is included in petroleum and natural gas figures.



**Biomass 4.9%**

Uses: electricity, heating, transportation



**Hydropower 2.4%**

Uses: electricity



**Wind 1.8%**

Uses: electricity



**Solar 0.4%**

Uses: electricity, heating



**Geothermal 0.2%**

Uses: electricity, heating

Data: Energy Information Administration

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

## What Is Coal?

**Coal** is a fossil fuel formed from the remains of plants that lived and died hundreds of thousands to hundreds of millions of years ago, when parts of the Earth were covered with huge swampy forests. Coal is called a nonrenewable energy source because it takes a very long time to form.

The energy we get from coal today comes from the energy that plants absorbed from the sun long ago. All living plants store solar energy through a process known as **photosynthesis**. When plants die, this energy is usually released as the plants decay. Under conditions favorable to coal formation, however, the decay process is interrupted, preventing the release of the stored solar energy. The energy is locked into the coal.

Plants that fell to the bottom of the swamp began to decay as layers of dirt and water were piled on top. Heat and pressure from these layers caused a chemical change to occur, eventually creating coal over time, a **sedimentary** rock. Seams of coal—ranging from a fraction of an inch to hundreds of feet—may represent hundreds of thousands of years of plant growth.

## Formation and Chemistry of Coal

Coal is considered an **organic** sedimentary rock. Sedimentary rocks are rocks that form from the compaction of sediment over time. Coal is classified as organic because the rock contains the remains of something that once lived and decomposed.

Coal is formed from organic material that is buried and changed by the combination of pressure, heat, and time. This process is often

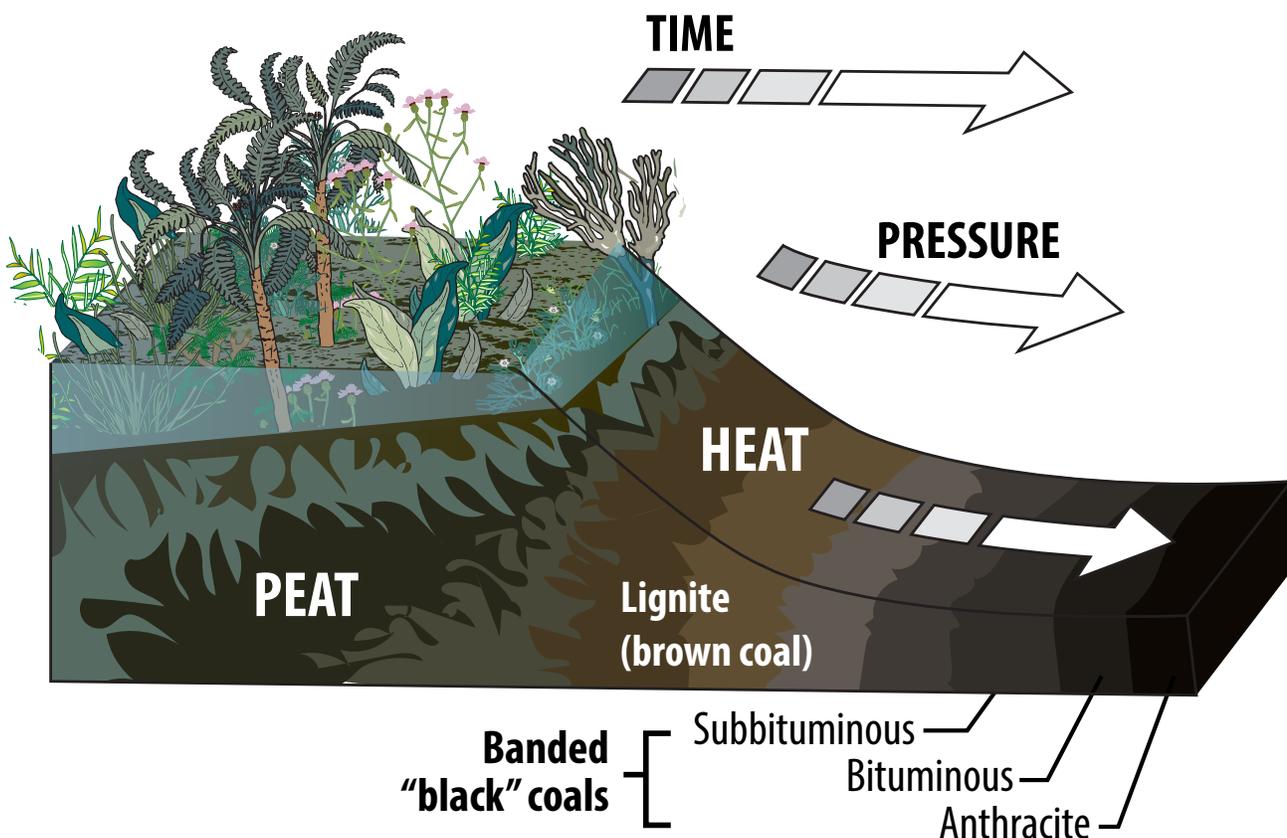
called **coalification**. The process of coalification starts with **peat**. Peat is a material that is made of vegetation in wetlands, swamps, or waterlogged areas. These swampy, mucky areas are also known as **mires**. Water does not move in these mires. This **stagnating** water creates an environment that is low on oxygen. These **anaerobic** conditions allow plant debris in the area to be preserved.

The next step in coalification is that the peat is buried by sediments, pushing water out and compacting the leftover material. Continuous pressure and heat over time will cause a chemical change, altering the composition of the plant matter. The amount of chemical change over time will determine the type of coal that is formed.

It would be very difficult to find two identical coal deposits that have the same chemical composition. However, all coal is composed of a combination of the same elements that can vary. Coal consists of carbon, oxygen, hydrogen, nitrogen, sulfur, ash, moisture, and other elements in small amounts.

Coal contains differing amounts of sulfur. The sulfur content depends upon the type of water that covered the ground during formation. Ancient sea water contained large amounts of sulfur. As the seas dried up, large amounts of sulfur were left behind. Freshwater contains very little sulfur. Coal seams east of the Mississippi River contain high amounts of sulfur. They were formed when that region was covered by an ocean. Conversely, coal seams west of the Mississippi contain far less sulfur. These seams were likely to have formed from freshwater swampy regions.

## Coal Formation



## Types of Coal

Coal is classified by **rank** 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** 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** 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. Forty-eight percent of the coal mined in 2015 in the U.S. was subbituminous. Subbituminous coal is sometimes grouped with bituminous.

**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. Forty-four percent of the coal mined in 2015 was bituminous coal.

**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 northeastern 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.

## History of Coal in America

Today, coal provides 16.0 percent of America's energy needs. About 33.1 percent of our electricity comes from coal-fired **power plants**. However, coal has been used throughout our history in the U.S.

Native Americans used coal long before the first settlers arrived in the New World. Hopi Indians used coal to bake the pottery they made from clay.

European settlers discovered coal in North America during the first half of the 1600s. They used very little coal at first. Instead, they relied on water wheels and burning wood to power colonial industries.

Coal became a powerhouse by the 1800s. People used coal to manufacture goods and to power steamships and railroad engines. By the time of the American Civil War, people also used coal to make iron and steel. And by the end of the 1800s, people began using coal to make electricity.

As coal became the powerhouse for American electricity, coal mining ramped up. Coal mining companies built towns and camps to house their workers and their families. The coal mining industry attracted many immigrants from countries like Great Britain, Ireland, Italy, Greece, and parts of Eastern Europe. At the time conditions for workers were poor, and many various cultural clashes occurred between immigrant groups and residents. The harsh conditions, treatment of workers (both immigrant and non-immigrant), and cultural clashes led to a movement in support of labor rights. Coal

miners fought to become some of the first organized, or unionized laborers in the United States.

Steam-powered ships and railcars were being used heavily by the start of the 1900's. Steam engines were also used for coal mining! In fact, very large steam shovels were used to do everything from digging the Panama Canal to carving out roadways. Some of the largest steam shovels used at the Panama Canal even made their way back to the U.S. for mining of coal and other ores.

As labor conditions and mining equipment began to evolve, so did the workforce itself. To many in the mining community, Ida Mae Stull was regarded as one of the very first female miners. Ida Mae began going to the mine with her father as a young girl in the 1930's who took little interest in school. However, many states held strict regulations at the time, forbidding women from entering the mines for work. If a woman worked at the mine, it was typically a clerical or service position. It wasn't until 1973 that the first female coal miners were officially hired. Diana Baldwin and Anita Cherry became the first legally hired female coal miners, working at Beth-Elkhorn Corporation's mine 29 in West Virginia. Women took interest in the mining jobs to help support their families with higher wages than other, traditionally female-filled positions. Women in the mining industry also helped to increase awareness about workplace discrimination and fair treatment. Today, females make up less than 10 percent of the coal mining workforce.

## Coal Mining

There are two ways to remove coal from the ground—surface and underground mining. **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 soil and 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.

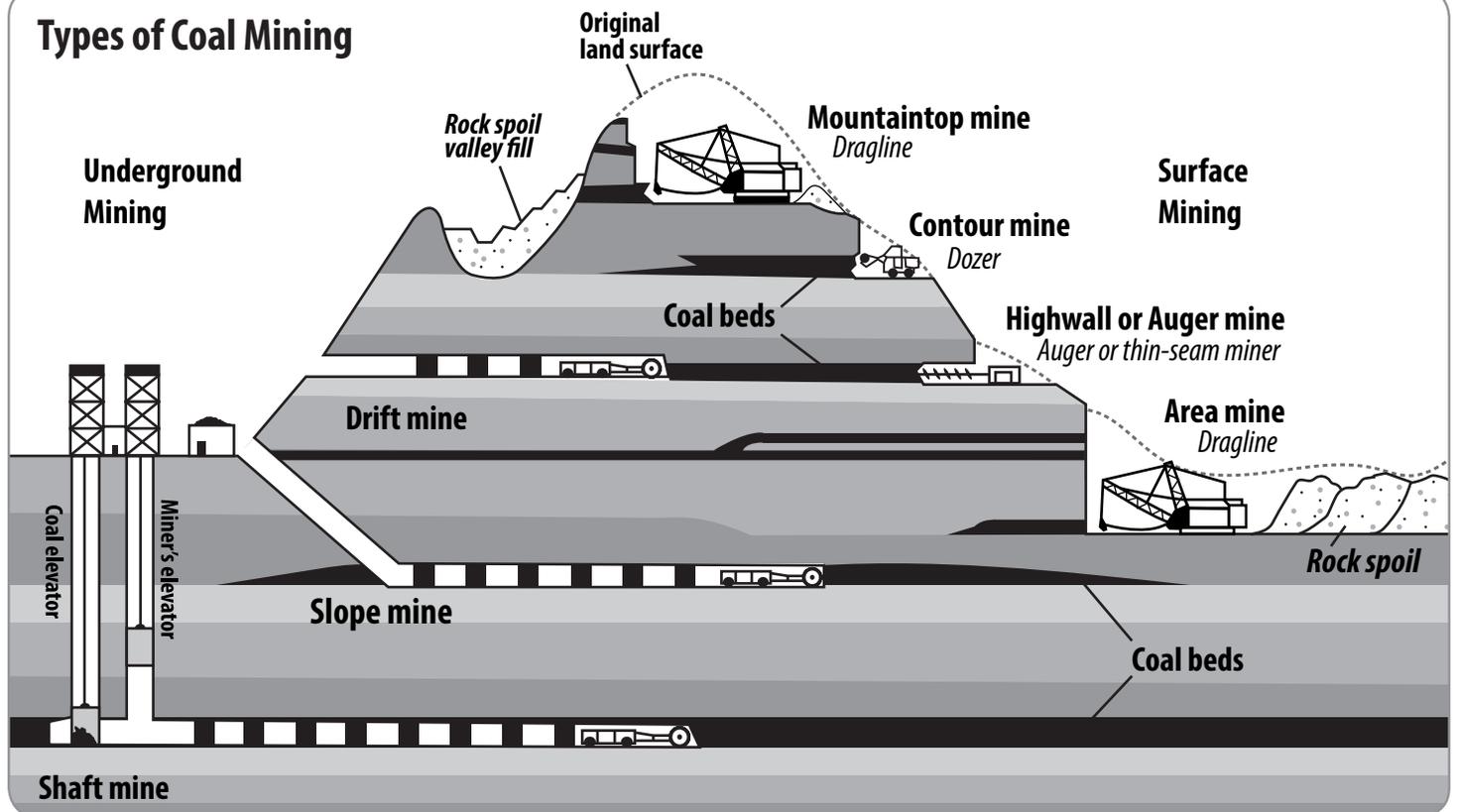
Surface mining occurs when the earth above the coal seam is removed. This overburden is taken away to allow access to the coal bed. Surface mining operations include quarries, open pits, auger, area, and contour mines. Surface mining is also commonly referred to as strip mining.

**Area mining** is a type of mining where the shallow coal is removed from a broad, flat piece of land. **Dragline** shovels are used to remove the materials above the coal and to place the materials in pits. Area mines can often access several coal seams within the same pit.

### DRAGLINE



## Types of Coal Mining



**Contour mining** happens on a hillside. A piece or wedge of overburden is removed from the side of the hill. This forms a bench or shelf at the same level as the coal. Often, contour mining is coupled with **auger mining**.

Auger mining uses a large drill to cut into a hillside to remove coal. It is often used when the overburden is too thick. **Highwall mining** is similar, but utilizes a machine to remove coal under the surface rather than people. This machine enters in to cuts in the ground that are 10-12 feet wide.

After surface mining is complete at a mine, workers replace the overburden, grade it, cover it with topsoil, and fertilize and seed the area. 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.

About two-thirds of the nation's coal can be 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 about 34 percent of U.S. coal mined.

**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.

When underground mining is taking place, if the mine travels horizontally to the seam of coal underground, it is called a **drift mine**. If the mine reaches the seam of coal at an angle, it is referred to as a **slope mine**. If the miners must take an elevator vertically down into the seam of coal, it is referred to as a **shaft mine**.

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** is another type of mining. A mountaintop mine uses explosives and heavy equipment to remove the top of the mountain and access the coal seam. Often coal from this type of mine contains lower amounts of sulfur and is used in power plants that do not have pollution control equipment. It can also, therefore, be more expensive to purchase coal from this type of mine.

### LONGWALL MINING



Image courtesy of Eickhoff Engine Works via wikimedia commons  
Understanding Coal

## The Future of Coal Mining Technology

One of the biggest challenges in the mining industry is keeping workers safe while using the machinery needed to extract coal and other ores. In some cases, companies must abandon areas with valuable resources because it is unsafe to mine and too difficult to approach. What if workers were taken out of the equation? Robotic and autonomous (self-driving) vehicles may just be the future of mining in these circumstances, and perhaps beyond! Mining companies in Australia already use robotic drilling equipment, and driverless trucks, drills, and locomotives. The companies can utilize the equipment round-the-clock, while keeping staff safe working from afar. And, the equipment? It doesn't need a lunch break!

## Processing and Transporting Coal

After coal comes out of the ground, it goes to a preparation plant for cleaning. The plant cleans dirt and other impurities from the surface of the coal. Washing the coal lowers the ash content, which will increase the heat value of the coal.

After cleaning, the coal is ready to be shipped to market. Trains are used to transport most coal. Sometimes, river barges and trucks are used to ship coal. For short distances, coal can also be moved using conveyors. Deciding how to ship coal is very important because it can cost more to ship it than to mine it.

## Coal Concerns

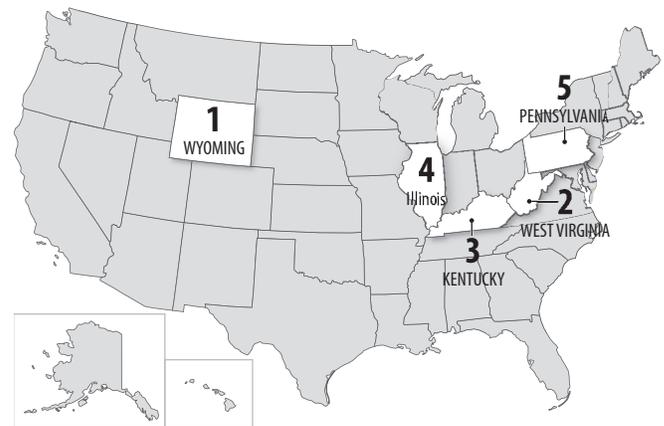
Mining coal has always been a dangerous occupation. The first coal miners were sent underground with nothing more than a candle for light and a caged canary to help detect dangerous levels of gases in the mine. The early 1900s were the most dangerous for coal miners. Since 1970, Federal and state regulations have significantly improved working conditions for both underground and surface mines, and the number of fatalities in mines has decreased dramatically.

Coal seams often contain methane, which is a major component of natural gas. It is flammable and dangerous to breathe, and if it builds up within a coal mine can be an explosion hazard or be toxic to workers. Canaries were used by miners to detect methane and other gases. Because they are so small, canaries are affected by methane faster than people; if the bird was unconscious, miners knew the air was unsafe and they should leave before they themselves became sick or died.

Methane also contributes to explosions within coal mines. Mining coal generates a significant amount of coal dust. When coal dust and methane are combined, the result is a highly explosive mixture that can ignite with just a spark or single flame from a candle. Most of the coal mine disasters where five or more people have been killed were explosions. The worst coal mine disaster in the U.S. was at the Monongah Mine in West Virginia in 1907, where 362 miners were killed by an explosion.

Even if the ignition of coal dust does not kill workers, it can create significant problems at the surface. Coal fires are difficult to extinguish, especially when they are underground. A coal seam near Centralia, Pennsylvania, began burning in 1962 and is still burning. The town had to be evacuated and remains a ghost town because of the high temperatures and toxic gases released by the fire, and sinkholes that have formed at the surface as the burned-out seams collapse. A few brave souls returned to their family properties, but only the fire department remains regularly staffed.

## Top Coal Producing States, 2015



Data: Energy Information Administration

## CENTRALIA PA



A view of the closed, damaged section of PA 61 south of Centralia



A small part of the Centralia mine fire as it appeared after being exposed during an excavation in 1969

Coal dust can also be an inhalation hazard. Respiratory diseases, including black lung disease, can occur when coal dust is inhaled over time. The Centers for Disease Control state that each year, 1,000 coal mine workers die from black lung disease. Respiratory equipment designed to minimize the amount of coal dust inhaled can help prevent these illnesses.

Improvements in mine safety began with the Coal Act of 1969 and have led to better equipment, mining techniques, and training for workers. The Occupational Safety and Health Administration (OSHA) and the Mine Safety and Health Administration (MSHA) are sister agencies within the U.S. Department of Labor that oversee working conditions for miners and others that work in industries related to mining. These Federal agencies and state regulators inspect mines on a regular basis – four times a year for underground mines and twice a year for surface mines – and make sure workers are properly trained before they enter a mine. In spite of the vast improvements in worker safety and training, accidents do still occur. In 2010, thirty-three miners in Chile were trapped when part of the mine collapsed. They were all safely rescued two months later. Also in 2010, twenty-nine American coal miners were killed by a coal dust explosion in the Upper Big Branch Mine in Montcoal, West Virginia.

## Coal Reserves and Production

**Coal reserves** are beds of coal still in the ground that can be mined. The United States has the world's largest known coal reserves. Depending on consumption rates, the U.S. has enough coal to last for at least 283 years.

Coal production is the amount of coal that is mined and sent to market. Coal is mined in 25 states. Wyoming mines the most, followed by West Virginia, Kentucky, Illinois, and Pennsylvania.

Some coal produced in the United States is exported to other countries. In 2015, foreign countries bought about 8.3 percent of all the coal produced in the U.S. The biggest foreign markets for U.S. coal are the Netherlands, India, Brazil, and South Korea.

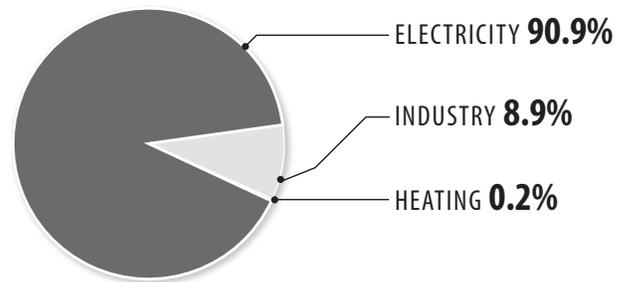
## How Coal Is Used

The main use of coal in the United States is to generate electricity. In 2015, about 91 percent of all the coal in the United States was used for electricity production. Coal generates about 33 percent of the electricity used in the U.S. Other energy sources used to generate electricity include natural gas, uranium (nuclear power), hydropower, biomass, and wind.

Another major use of coal is in iron and steelmaking. The iron industry uses coke ovens to melt iron ore. **Coke**, an almost pure carbon residue of coal, is used as a fuel in **smelting** metals. The United States has the finest coking coals in the world. These coals are shipped around the world for use in coke ovens. Coal is also used by other industries. The paper, brick, limestone, and cement industries all use coal to make products.

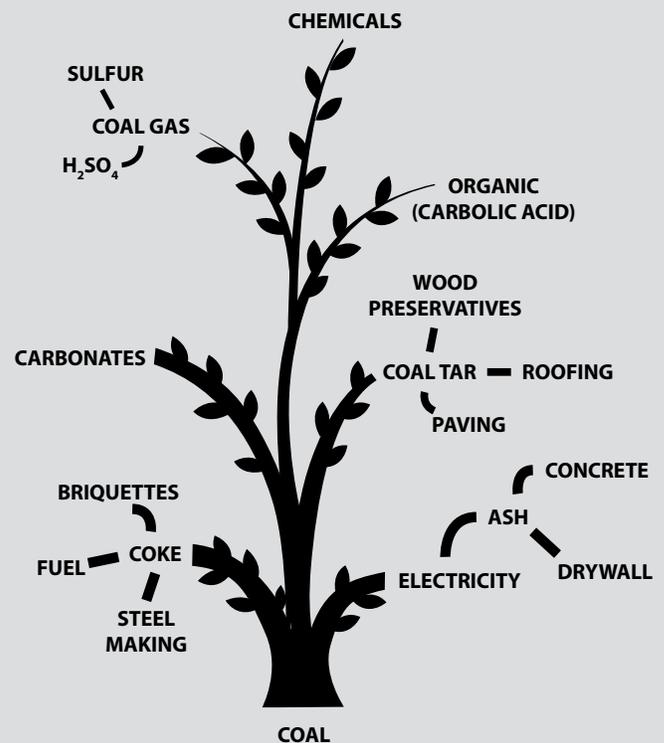
Several years ago, researchers in South Africa were looking for a way to capture the tiny coal particles and coal dust that were wasted in standard coal mining operations. The dust was carried away in water used to rid coal of other contaminants. The research team at Nelson Mandela Metropolitan University, 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

## U.S. Coal Consumption by Sector, 2015



Data: Energy Information Administration

## Coal Tree



Coal is used predominately for electricity production. However, it can still play a part in the production of common, everyday items. The coal tree above shows the branches of production and some of the items that could be produced in each branch. Not all of these items make sense for companies to create from coal, because there is a great cost associated to produce them. However, byproducts of coal could be used. The U.S. Minerals Education Coalition estimates that every American born will require more than 355,000 pounds of coal in their lifetime for the items above.

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.

# Rare Earth Elements

The names of rare Earth elements may only be familiar if you've spent time studying the periodic table of elements. These seventeen elements are in such low concentrations in Earth's crust that they're designated as rare. So why are they important? According to the American Chemistry Council they are critical in \$329 billion worth of economic activity in North America, and are critical in manufacturing electronics such as cell phones and computers. The vast majority of currently produced rare Earth elements, or REEs, come from China; only a tiny fraction are produced in the United States. Finding an affordable domestic source of REEs is a priority because the types of products that require REEs are also critical to the U.S. military.

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

Group																		18																															
1		2												13		14	15	16	17	18																													
IA		IIA		3			4	5	6	7		8		9		10		11	12	IIIA		IVA	VA	VIA	VIIA	VIIIA																							
1	<b>H</b> Hydrogen 1.00794																			2	<b>He</b> Helium 4.002602																												
2	<b>Li</b> Lithium 6.941	<b>Be</b> Beryllium 9.012182																	5	<b>B</b> Boron 10.811	6	<b>C</b> Carbon 12.0107	7	<b>N</b> Nitrogen 14.0067	8	<b>O</b> Oxygen 15.9994	9	<b>F</b> Fluorine 18.9984032	10	<b>Ne</b> Neon 20.1797																			
3	<b>Na</b> Sodium 22.989770	<b>Mg</b> Magnesium 24.3050																	13	<b>Al</b> Aluminum 26.981538	14	<b>Si</b> Silicon 28.0855	15	<b>P</b> Phosphorus 30.973761	16	<b>S</b> Sulfur 32.065	17	<b>Cl</b> Chlorine 35.453	18	<b>Ar</b> Argon 39.948																			
4	<b>K</b> Potassium 39.0983	<b>Ca</b> Calcium 40.078	<b>Sc</b> Scandium 44.955910	<b>Ti</b> Titanium 47.867	<b>V</b> Vanadium 50.9415	<b>Cr</b> Chromium 51.9961	<b>Mn</b> Manganese 54.938049	<b>Fe</b> Iron 55.845	<b>Co</b> Cobalt 58.933200	<b>Ni</b> Nickel 58.6934	<b>Cu</b> Copper 63.546	<b>Zn</b> Zinc 65.409	<b>Ga</b> Gallium 69.723	<b>Ge</b> Germanium 72.64	<b>As</b> Arsenic 74.92160	<b>Se</b> Selenium 78.96	<b>Br</b> Bromine 79.904	<b>Kr</b> Krypton 83.798																															
5	<b>Rb</b> Rubidium 85.4678	<b>Sr</b> Strontium 87.62	<b>Y</b> Yttrium 88.90585	<b>Zr</b> Zirconium 91.224	<b>Nb</b> Niobium 92.90638	<b>Mo</b> Molybdenum 95.94	<b>Tc</b> Technetium (98)	<b>Ru</b> Ruthenium 101.07	<b>Rh</b> Rhodium 102.90550	<b>Pd</b> Palladium 106.42	<b>Ag</b> Silver 107.8682	<b>Cd</b> Cadmium 112.411	<b>In</b> Indium 114.818	<b>Sn</b> Tin 118.710	<b>Sb</b> Antimony 121.760	<b>Te</b> Tellurium 127.60	<b>I</b> Iodine 126.90447	<b>Xe</b> Xenon 131.293																															
6	<b>Cs</b> Cesium 132.90545	<b>Ba</b> Barium 137.327																	<b>Hf</b> Hafnium 178.49	<b>Ta</b> Tantalum 180.9479	<b>W</b> Tungsten 183.84	<b>Re</b> Rhenium 186.207	<b>Os</b> Osmium 190.23	<b>Ir</b> Iridium 192.217	<b>Pt</b> Platinum 195.078	<b>Au</b> Gold 196.96655	<b>Hg</b> Mercury 200.59	<b>Tl</b> Thallium 204.3833	<b>Pb</b> Lead 207.2	<b>Bi</b> Bismuth 208.98038	<b>Po</b> Polonium (209)	<b>At</b> Astatine (210)	<b>Rn</b> Radon (222)																
7	<b>Fr</b> Francium (223)	<b>Ra</b> Radium (226)																	<b>Rf</b> Rutherfordium (261)	<b>Db</b> Dubnium (262)	<b>Sg</b> Seaborgium (266)	<b>Bh</b> Bohrium (264)	<b>Hs</b> Hassium (277)	<b>Mt</b> Meitnerium (268)	<b>Ds</b> Darmstadtium (281)	<b>Rg</b> Roentgenium (280)	<b>Cn</b> Copernicium (285)	<b>Nh</b> Nihonium (286)	<b>Fl</b> Flerovium (289)	<b>Mc</b> Moscovium (289)	<b>Lv</b> Livermorium (293)	<b>Ts</b> Tennessine (294)	<b>Og</b> Oganesson (294)																
			<table border="1"> <tr> <td><b>57</b> <b>La</b> Lanthanum 138.9055</td> <td><b>58</b> <b>Ce</b> Cerium 140.116</td> <td><b>59</b> <b>Pr</b> Praseodymium 140.90765</td> <td><b>60</b> <b>Nd</b> Neodymium 144.24</td> <td><b>61</b> <b>Pm</b> Promethium (145)</td> <td><b>62</b> <b>Sm</b> Samarium 150.36</td> <td><b>63</b> <b>Eu</b> Europium 151.964</td> <td><b>64</b> <b>Gd</b> Gadolinium 157.25</td> <td><b>65</b> <b>Tb</b> Terbium 158.92534</td> <td><b>66</b> <b>Dy</b> Dysprosium 162.500</td> <td><b>67</b> <b>Ho</b> Holmium 164.93032</td> <td><b>68</b> <b>Er</b> Erbium 167.259</td> <td><b>69</b> <b>Tm</b> Thulium 168.93421</td> <td><b>70</b> <b>Yb</b> Ytterbium 173.04</td> <td><b>71</b> <b>Lu</b> Lutetium 174.967</td> </tr> <tr> <td><b>89</b> <b>Ac</b> Actinium (227)</td> <td><b>90</b> <b>Th</b> Thorium 232.0381</td> <td><b>91</b> <b>Pa</b> Protactinium 231.03588</td> <td><b>92</b> <b>U</b> Uranium 238.02891</td> <td><b>93</b> <b>Np</b> Neptunium (237)</td> <td><b>94</b> <b>Pu</b> Plutonium (244)</td> <td><b>95</b> <b>Am</b> Americium (243)</td> <td><b>96</b> <b>Cm</b> Curium (247)</td> <td><b>97</b> <b>Bk</b> Berkelium (247)</td> <td><b>98</b> <b>Cf</b> Californium (251)</td> <td><b>99</b> <b>Es</b> Einsteinium (252)</td> <td><b>100</b> <b>Fm</b> Fermium (257)</td> <td><b>101</b> <b>Md</b> Mendelevium (258)</td> <td><b>102</b> <b>No</b> Nobelium (259)</td> <td><b>103</b> <b>Lr</b> Lawrencium (262)</td> </tr> </table>																	<b>57</b> <b>La</b> Lanthanum 138.9055	<b>58</b> <b>Ce</b> Cerium 140.116	<b>59</b> <b>Pr</b> Praseodymium 140.90765	<b>60</b> <b>Nd</b> Neodymium 144.24	<b>61</b> <b>Pm</b> Promethium (145)	<b>62</b> <b>Sm</b> Samarium 150.36	<b>63</b> <b>Eu</b> Europium 151.964	<b>64</b> <b>Gd</b> Gadolinium 157.25	<b>65</b> <b>Tb</b> Terbium 158.92534	<b>66</b> <b>Dy</b> Dysprosium 162.500	<b>67</b> <b>Ho</b> Holmium 164.93032	<b>68</b> <b>Er</b> Erbium 167.259	<b>69</b> <b>Tm</b> Thulium 168.93421	<b>70</b> <b>Yb</b> Ytterbium 173.04	<b>71</b> <b>Lu</b> Lutetium 174.967	<b>89</b> <b>Ac</b> Actinium (227)	<b>90</b> <b>Th</b> Thorium 232.0381	<b>91</b> <b>Pa</b> Protactinium 231.03588	<b>92</b> <b>U</b> Uranium 238.02891	<b>93</b> <b>Np</b> Neptunium (237)	<b>94</b> <b>Pu</b> Plutonium (244)	<b>95</b> <b>Am</b> Americium (243)	<b>96</b> <b>Cm</b> Curium (247)	<b>97</b> <b>Bk</b> Berkelium (247)	<b>98</b> <b>Cf</b> Californium (251)	<b>99</b> <b>Es</b> Einsteinium (252)	<b>100</b> <b>Fm</b> Fermium (257)	<b>101</b> <b>Md</b> Mendelevium (258)	<b>102</b> <b>No</b> Nobelium (259)	<b>103</b> <b>Lr</b> Lawrencium (262)
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Atomic Number: 58  
Symbol: Ce  
Name: Cerium  
Atomic Weight: 140.116

Coal is no longer a major energy source for heating American homes or other buildings. A tiny percentage (0.3%) of the coal produced in the U.S. today is used for heating. Coal furnaces, which were popular years ago, have largely been replaced by oil or gas furnaces or by electric heat pumps.

Coal is rich in carbon, which is what makes it a good energy source. But 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 and the Environment

Burning coal produces emissions that pollute the air. It also produces **carbon dioxide**, a **greenhouse gas**, which is a major factor in climate change. When coal is burned, a chemical called sulfur may also be released. Sulfur mixes with oxygen to form sulfur dioxide, a chemical that can affect trees and water when it combines with moisture to produce **acid rain**.

Coal companies look for low-sulfur coal to mine. They work hard to remove sulfur and other impurities from the coal. Power plants install machines called **scrubbers** to remove most of the sulfur from coal smoke so it doesn't get into the air. Other byproducts, like the ash that is left after coal is burned, once were sent to landfills. Now they are being used to build roads, make cement, and make ocean reefs for animal habitats.

After a company decides to stop production on a surface or underground mine, the site must go through the process of reclamation. Reclamation is the restoring or reclaiming of disturbed areas from surface and underground mining. A site that is reclaimed must be restored to the original quality of the land before mining occurred, or better. This process involves reestablishing the vegetation cover, soil stability, and water conditions at the site. Mines can also be reclaimed for fish and wildlife, grazing, forestry, wetlands, and commercial and industrial uses.

Each site must have a reclamation plan that they follow and have reviewed by several state and federal government agencies before starting, and periodically after the process is complete. Sometimes companies must return after reclamation is complete to continue rehabbing the site. Sites often try their best to protect the land during the mining process to make sure the reclamation process goes smoothly. Companies are required by law to set aside money to ensure that the process of reclamation is completed satisfactorily.

## Coal Combustion Byproducts

Burning coal produces emissions, but it also produces, or leaves behind products that can be useful for other industries.

### ▪ 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 captures the fly ash for removal.

## Cleaner Coal Technology

The Clean Coal Technology Program is a government and industry funded program that began in 1986 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.

Fly ash contains a lot of silicon dioxide and aluminum oxide, which are key ingredients in making cement. The different ranks of coal produce fly ash with different amounts of silica and aluminum oxide in them, but it is highly sought after as an ingredient in making cement.

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 bubbles 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, research has uncovered a way to combine coal dust with algae and change it into crude oil. Dr. Ben Zeelie's team in South Africa 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, providing the nutritional needs of the algae. The growing algae consume all the NO<sub>x</sub> and most of the CO<sub>2</sub> 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 can 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 using density. Water is mixed with magnetite, a mineral high in iron, making 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.

Increasing costs in mining magnetite have led to higher costs for coal mines. 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.

We have known for a long time that fly ash has a lot of magnetite. However, recovering the magnetite was too expensive to make it worthwhile. Recently techniques have been developed that bring these costs down to make it useful. 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.

## Carbon Capture, Utilization, and Storage

Research and demonstration projects are underway in the United States and around the world to capture or trap carbon dioxide from coal and other power plants and use it for producing products or store it deep underground, rather than releasing it into the atmosphere.



# Electricity

## The Nature of Electricity

Electricity is a little different from the other sources of energy that we talk about. Unlike coal, petroleum, or solar energy, electricity is a secondary source of energy. That means we must use other primary sources of energy, such as coal or wind, to make electricity. It also means we can't classify electricity as a renewable or nonrenewable source of energy. The energy source we use to make electricity may be renewable or nonrenewable, but the electricity is neither.

## Making Electricity

Almost all electricity made in the United States is generated by large, central power plants. There are more than 7,000 power plants in the U.S. Most power plants use coal, nuclear fission, natural gas, or other energy sources to superheat water into steam in a boiler. The very high pressure of the steam (it's 75 to 100 times normal atmospheric pressure) turns the blades of a turbine. (A **turbine** turns the linear motion of the steam into circular motion.) The blades are connected to a **generator**, which houses a large **magnet** surrounded by coiled copper wire. The blades spin the magnet rapidly, rotating the magnet inside the coil producing an **electric current**.

The steam, which is still very hot but now at normal pressure, is piped to a condenser, where it is cooled into water by passing it through pipes circulating over a large body of water or cooling tower. The water then returns to the boiler to be used again. Power plants can capture some of the heat from the cooling steam. In old plants, the heat was simply wasted.

Not all power plants use thermal energy to generate electricity. Hydropower plants and wind farms use motion energy to turn turbines, turning a generator, which produces electricity. Photovoltaic plants use radiant energy to generate electricity directly.

## Fuels that Make Electricity

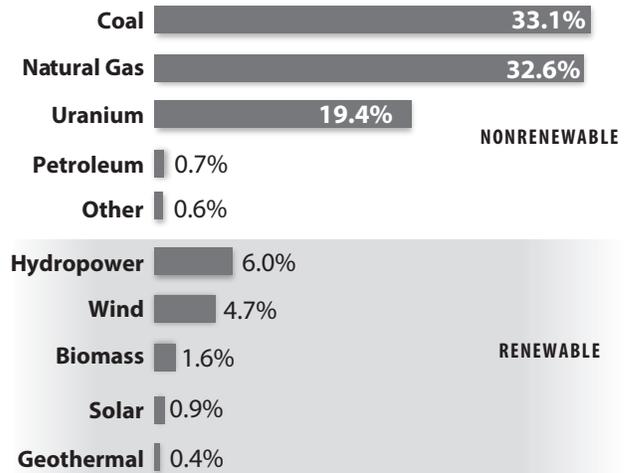
Four kinds of power plants produce most of the electricity in the United States: coal, natural gas, nuclear, and hydropower. Coal plants generate about 33 percent of the electricity we use. There are also wind, geothermal, waste-to-energy, and solar power plants, which together generate less than ten percent of the electricity produced in the United States.

### Fossil Fuel Power Plants

Fossil fuel plants burn coal, natural gas, or oil 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.

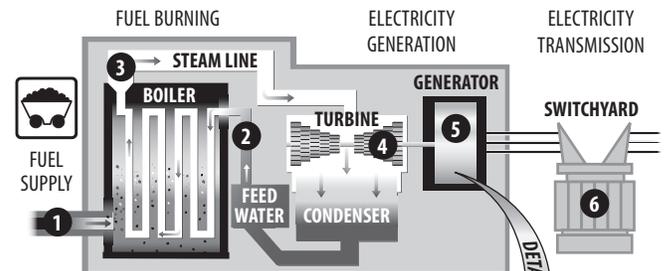
Power plants burn the fossil fuels and use the heat to boil water into steam. The steam is channeled through a pipe at high pressure to spin a turbine generator to make electricity. Fossil fuel power plants produce emissions that can pollute the air and contribute to global climate change.

## U.S. Electricity Net Generation, 2015

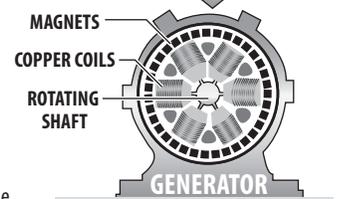


\*\* Other: non-biogenic waste, fossil fuel gases.  
Data: Energy Information Administration

## Thermal Power Plant



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.



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 most power plants because it is cheap 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. About 91 percent of the coal mined in the United States is sent to power plants to make electricity.

### ■ Coal Power Plants

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 used boilers fed by hand. 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. It uses a boiler system that is controlled by the speed with which coal is added. The coal moves in on a conveyor at a steady rate. Increasing the speed of the conveyor increases how hot the fire burns inside. One disadvantage of this type of combustion is that much of the coal does not burn and goes to waste. Most of these kinds of boiler systems have been phased out or will be replaced by newer technology soon.

**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 air and pulverized coal are injected. The combustion temperature is very high, (1300 -1700 °C) which allows for a quick increase in electric power by increasing the feed of fuel. Combustion temperatures this high, however, increase the production of nitrogen oxides (NO<sub>x</sub>), which are harmful emissions.

**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. Adding heated combustion air causes the combustion mixture to spin like a cyclone. The advantage of this style of combustion is that the ash and wastes are heated to melting and can be collected easily. However, the temperatures are so high that a lot of NO<sub>x</sub> is also produced.

**Fluidized Bed Combustion** has many benefits over other boiler systems because of its lower combustion temperature (840 – 950 °C). Not as much NO<sub>x</sub> is produced, and the coal bits (slag) and ash are not melted. A layer of solid coal and limestone are combined with sand and air supported by a fine mesh, which creates a bed that can flow. The limestone helps remove sulfur from the flue gases. As air is added to the mixture, it behaves similarly to a boiling liquid. This style is much more efficient because tubes can be placed through and around the bed to collect and transfer thermal energy 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. 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 technologies for generating electricity using coal. Using IGCC increases the efficiency for electricity from 35 percent seen in regular systems to around 60 percent. IGCC is a two-step process. First, the fuel is gasified into a mixture of hydrogen and carbon monoxide. This synthetic gas 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.

**Oxyfuel Combustion** uses pure oxygen rather than air for the combustion of coal and other fossil fuels. In this combustion the major by products are carbon dioxide and water. Nitrogen and other gases are removed from air, so nitrogen oxides are greatly reduced. This style of combustion is good for capturing and isolating carbon dioxide.

**Polygeneration** refers to producing electricity with synthetic gases (syngas) combined with other technology to create other marketable products such as fertilizer, polymer feed stock, sulfur, and compressed CO<sub>2</sub> for enhanced oil recovery. This is similar to IGCC, but can be changed to producing other products besides electricity as needs change.

**Supercritical CO<sub>2</sub> Power Cycle** is a new technology where carbon dioxide is used to transfer thermal energy instead of water or steam to turn a turbine. CO<sub>2</sub> does not exist as a liquid at standard pressures, so to reach a liquid state the compound must be at a pressure of 73 atmospheres and a temperature of 300 Kelvin (27 degrees Celsius).

CO<sub>2</sub> in a supercritical state (sCO<sub>2</sub>) gives the compound properties of both a liquid and a gas, which enhances its ability to transfer thermal energy. Supercritical CO<sub>2</sub> is not as corrosive as water to the parts of a turbine. The sCO<sub>2</sub> 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<sub>2</sub> turbines can be retrofitted to existing electric power plants, thereby increasing significantly their efficiency and power output.

### ▪ 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.

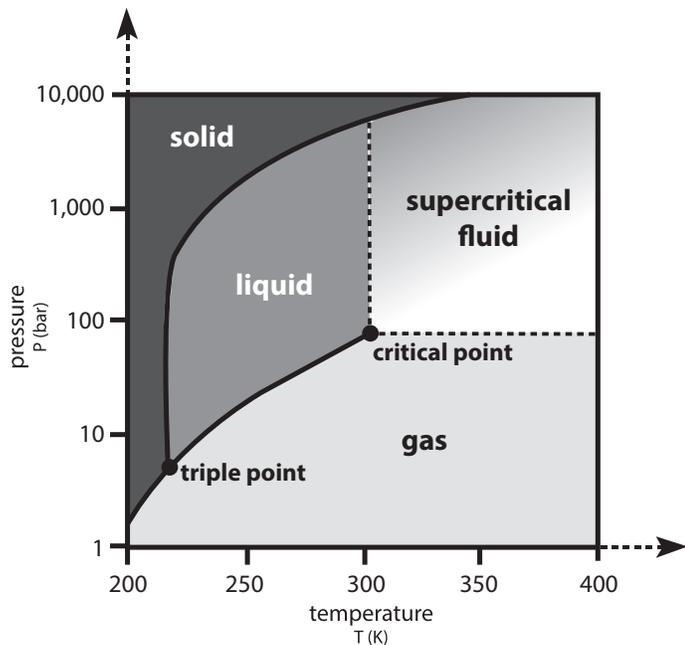
Uranium is a mineral found in rocks underground. A nuclear power plant splits the nuclei of uranium atoms to make smaller atoms in a process called fission that produces enormous amounts of thermal energy. The thermal energy is used to turn water into steam, which drives a turbine generator.

Nuclear power plants don't 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.

## Phase Diagram of CO<sub>2</sub>



## Moving Electricity

We are using more and more electricity every year. One reason that electricity is used by so many consumers is that it's easy to move from one place to another. Electricity can be produced at a power plant and moved long distances before it is used. Let's follow the path of electricity from a power plant to a light bulb in your home.

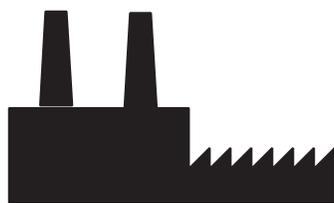
First, the electricity is generated at the power plant. Next, it goes by wire to a **transformer** that "steps up" the voltage. A transformer steps up the voltage of electricity from the 2,300 to 22,000 volts produced by a generator to as much as 765,000 volts (345,000 volts is typical). Power companies step up the voltage because less electricity is lost along the lines when the voltage is high.

The electricity is then sent on a nationwide network of **transmission lines** made of aluminum. Transmission lines are the huge tower lines you may see when you're on a highway connected by tall power towers. The lines are interconnected, so should one line fail, another will take over the load.

Step-down transformers located at substations along the lines reduce the voltage to 12,000 volts. Substations are small buildings in fenced-in areas that contain the switches, transformers, and other

## Transporting Electricity

Power plant generates electricity



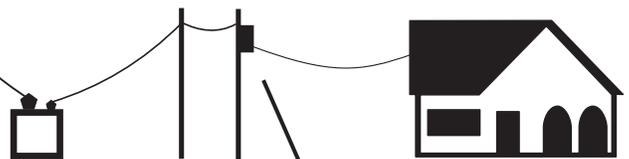
Transmission line carries electricity long distances



**POWER TOWER**

Transformer steps up voltage for transmission

Distribution line carries electricity to house



**ELECTRIC POLES**

Neighborhood transformer steps down voltage

Transformer on pole steps down voltage before entering house

electrical equipment. Electricity is then carried over distribution lines that bring electricity to your home. Distribution lines may either be overhead or underground. The overhead distribution lines are the electric lines that you see along streets.

Before electricity enters your house, the voltage is reduced again at another transformer, usually a large gray can mounted on an electric pole. This neighborhood transformer reduces the electricity to 240 and 120 volts, the amount needed to run the appliances in your home.

Electricity enters your house through a three-wire cable. The “live wires” are then brought from the circuit breaker or fuse box to power outlets and wall switches in your home. An electric meter measures how much electricity you use so the utility company can bill you. The time it takes for electricity to travel through these steps—from power plant to the light bulb in your home—is a tiny fraction of one second.

## Power to the People

Everyone knows how important electricity is to our lives. All it takes is a power failure to remind us how much we depend on it. Life would be very different without electricity—no more instant light from flicking a switch, no more television, no more refrigerators, or stereos, or video games, or hundreds of other conveniences we take for granted. We depend on it, business depends on it, and industry depends on it. You could almost say the American economy runs on electricity.

It is the responsibility of electric utility companies to make sure electricity is there when we need it. They must consider reliability, capacity, baseload power, peak demand, and power pools.

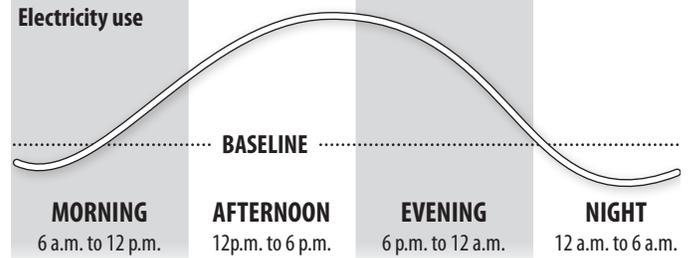
**Reliability** is the capability of a utility company to provide electricity to its customers 100 percent of the time. A reliable electric service is without blackouts or brownouts. To ensure uninterrupted service, laws require most utility companies to have 15 to 20 percent more capacity than they need to meet peak demand. This means a utility company whose peak demand is 12,000 **megawatts** (MW) must have 14,000 MW of installed electrical capacity. This ensures that there will be enough electricity to meet demand even if equipment were to break down on a hot, summer afternoon.

**Capacity** is the total quantity of electricity a utility company has on-line and ready to deliver when people need it. A large utility company may operate several power plants to generate electricity for its customers. A utility company that has seven 1,000 MW plants, eight 500 MW plants, and 30 100 MW plants has a total capacity of 14,000 MW.

**Baseload power** is the electricity generated by utility companies around-the-clock, using the most inexpensive energy sources—usually coal, nuclear, and hydropower. Baseload power stations usually run at full or near capacity.

When many people want electricity at the same time, there is a **peak demand**. Power companies must be ready for peak demands so there is enough power for everyone. During the day’s peak, usually between 12:00 noon and 6:00 p.m., additional generators must be used to meet the demand. These peak load generators run on natural gas, diesel, or hydropower and can be put into operation in minutes. The more this equipment is used, the higher our utility bills. By managing the use of electricity during peak hours, we can help keep costs down.

## Peak Demand



Peak demand, also called peak load, is the maximum load during a specified period of time.

## TRANSMISSION TOWERS



The use of **power pools** is another way electric companies make their systems more reliable. Power pools link electric utilities together so they can share power as it is needed. A power failure in one system can be covered by a neighboring power company until the problem is corrected. There are eight regional power pool networks in North America. The key is to share power rather than lose it.

The reliability of U.S. electric service is excellent, usually better than 98 percent. In some countries, electric power may go out several times a day for several minutes or several hours at a time. Power outages in the United States are usually caused by such random occurrences as lightning, a tree limb falling on electric wires, or a fallen utility pole.

## Cost of Electricity

How much does it cost to make electricity? It depends on several factors, such as:

- **Fuel Cost:** The major cost of generating electricity is dependent on the cost of the fuel. Many energy sources can be used. Hydropower is typically the cheapest source while solar cells are usually the most expensive way to generate power. Of the nonrenewable fuels, coal and uranium are often the cheapest fuels to use in a power plant. Natural gas prices are highly variable.

▪ **Building Cost:** Another key 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 their fuel—coal—is more expensive.

▪ **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.

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. A typical coal plant burns about 4,500 tons of coal each day. Coal is often more expensive than uranium. Renewable sources of energy are often considered free to use, however, wind turbines and solar facilities have a significantly higher cost to build. New coal plants must include the clean coal technologies and scrubbers to control emissions. Older, existing coal plants must be upgraded to meet those environmental regulations. There is often a high cost associated with this upgrade.

## Future Demand

Home computers, microwave ovens, and video games have invaded our homes and they are demanding electricity! Electronic devices are part of the reason why Americans use more electricity every year.

The U.S. Department of Energy predicts the nation will need to increase its current generating capacity of 1,063,033 megawatts by more than one-fourth by 2040. Demand for electricity is projected to increase in the future despite technological energy efficiency improvements in electric devices and appliances.

Some parts of the nation, especially California, have begun experiencing power shortages. Utilities can resort to rolling blackouts—planned power outages to one neighborhood or area at a time—because of the limited power. Utilities often warn that there will be increasing outages nationwide during the summer months even if consumers implement energy conservation techniques. However, well planned and managed energy efficiency and conservation programs can help avoid these electricity shortages.

Conserving electricity and using it more efficiently will help, but everyone agrees we need more power plants now. That's where the challenge begins. Should we use coal, natural gas, or nuclear power to generate electricity? Can we produce more electricity from renewable energy sources such as wind or solar? And where should we build new power plants? No one wants a power plant in his or her backyard, but everyone wants the benefits of electricity.

Most new generation comes from natural gas or wind. However, one coal plant can provide more megawatts of generation at a time than several other source plants combined. Although coal plants can be replaced with plants run by other sources more cleanly, coal plants do help to maintain the baseload power requirements, and are an important part of the nation's energy picture.

## Careers in Coal

Coal industry careers include miners, engineers, geologists, electricians, and even emergency medical technicians (EMTs). Workers in this industry are often in high demand and receive very competitive wages. Workers at a coal site must go through job specific training, safety training, and most often complete an apprenticeship before becoming a certified employee. These employees continually re-train to make sure they are staying current on safety and other important regulations. The following pages include interviews with professionals in many parts of the coal and energy industry.

### COAL MINERS



# 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.



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.



# Coal KWL Chart

**What I Think I Know**

**What I Want to Know**

**What I Learned**



# The Tale of Fern Fossil

Once upon a time, a beautiful fern tree grew in a swamp. All day, she soaked up sunlight and stored it in her fronds. The sun's energy helped her grow tall.

The biggest frond was Fern Fossil. Every day she stretched closer to the sun. She was proud to be the tallest frond on the tree.

One day, the sky grew dark and a strong wind blew. The other fronds huddled together. They gave each other strength. But Fern was too high. She was all alone. There were no fronds tall enough to help her.

The wind blew harder and Fern's stem snapped. She fell from the tree into the dark water. Fern sank to the bottom of the swamp. She thought her journey was over, but nature had a different plan for Fern. For a long time, she lay in the swamp. More plants fell into the water. They covered Fern like a blanket.

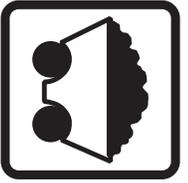
After many years, the water dried up and the swamp turned into land. Dinosaurs roamed over the Earth. Fern lay under the ground, buried deeper and deeper.

The weight of the dirt and the heat of the Earth changed Fern. She was no longer green. She lost her leafy shape, but she still had the sun's energy stored in her.

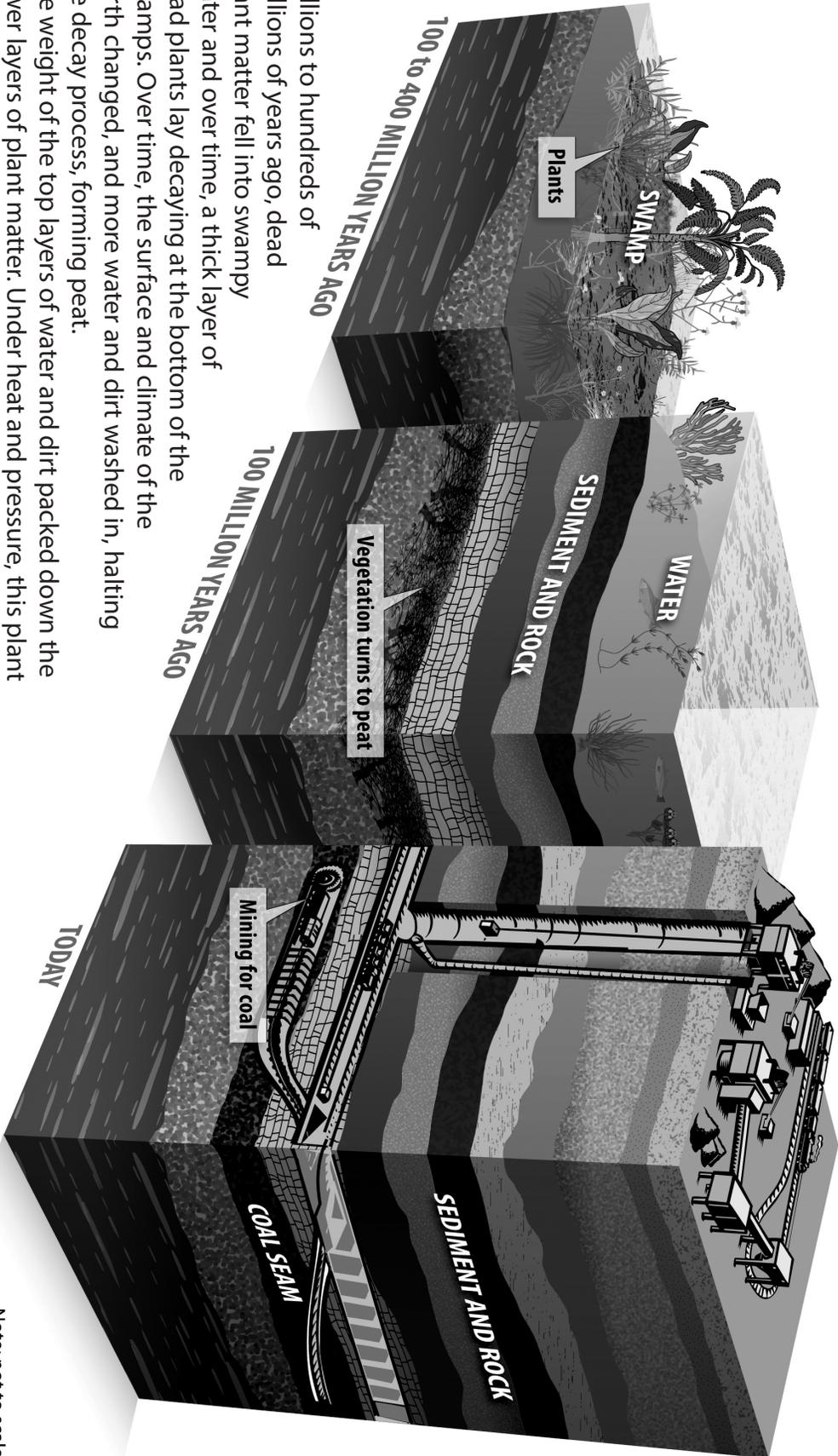
Fern Fossil had turned into a shiny black rock full of energy. She was a piece of coal. Fern and many other plants were now a big seam of coal buried under the ground.

One day, a big machine dug into the earth. It took away the dirt on top of the coal. It lifted Fern from the earth and put her into a huge truck. She was taken to a building where she was washed, then put on a train. The train chugged through the night to a power plant. Fern was burned. Her energy produced a lot of heat.

The power plant used Fern's energy to make electricity. It traveled through a power line to a house. A little boy turned on a light so that he could read. The energy that Fern had gotten from the sun millions and millions of years ago was lighting the night. Fern had traveled a long way.



# How Coal Was Formed



Millions to hundreds of millions of years ago, dead plant matter fell into swampy water and over time, a thick layer of dead plants lay decaying at the bottom of the swamps. Over time, the surface and climate of the Earth changed, and more water and dirt washed in, halting the decay process, forming peat. The weight of the top layers of water and dirt packed down the lower layers of plant matter. Under heat and pressure, this plant matter underwent chemical and physical changes pushing out oxygen and leaving rich hydrocarbon deposits. What once had been plants gradually turned into coal. Coal can be found deep underground (as shown in this graphic), or it can be found near the surface.

Note: not to scale



# Simulating the Formation of Coal

## Question

How does coal form?

## Materials

- 2 – 2 liter Bottles
- Dirt
- Sand
- Twigs, ferns, leaves, grass, stems, other plant matter
- Water
- Ruler
- Foam plate
- Small rocks
- Scissors
- Pie pan

## Procedure

1. Take one of the 2 liter bottles and mark it as Bottle A. Make a dotted line around the bottle where the main part of the bottle slopes up to the neck. See figure 1. Cut the top off of the bottle using this line as your guide.
2. Take the second bottle and mark it as Bottle B. Measure up 3.5 cm from the bottom of Bottle B. Mark this spot with a dotted line around the bottle and proceed to cut off the bottom. See figure 2. Trim the edges so that this piece will slide down inside the other bottle.
3. Place Bottle A upside down on the foam plate. See figure 3. Press firmly down on the bottle and trace the opening of the bottle. Cut out the circle from the plate and trim as needed so that the circle fits firmly inside the bottle but can slide down inside the bottle as weight is added to the circle. This foam circle will help to keep an air-tight seal in the bottle.
4. Measure up from the bottom of Bottle A and make marks at 2 cm, 4 cm, 14 cm, 16 cm, and 18 cm.
5. Pour dirt into the bottle to the 2 cm mark.
6. Pour sand into the bottle to the 4 cm mark.
7. Place plant matter into the bottle, tamping it down each time, until it reaches the 14 cm mark. Make sure to place the widest leaves on the top of the plant matter. This will help to keep sand from seeping through the plant matter in the future.
8. Observe the plant matter and write a short description of your observation on the next page.
9. Place the bottle into the pie pan and slowly add water until the plant matter is just covered.
10. Slowly pour sand on top of the plant matter to the 16 cm mark. Slowly add dirt to the 18 cm mark. See figure 4.



FIGURE 1 - Bottle A

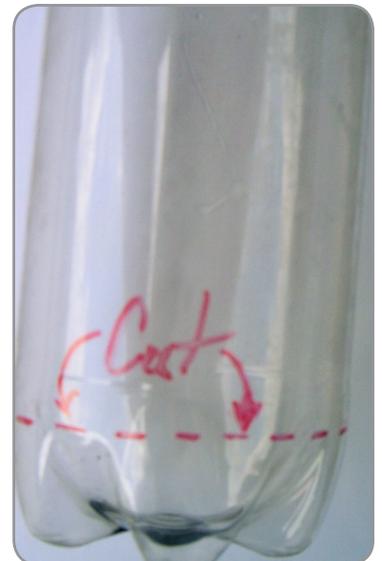


FIGURE 2 - Bottle B



FIGURE 3 - Bottle A



FIGURE 4 - Bottle A

11. Place the foam circle on top of the dirt. Slowly slide the bottom piece from Bottle B onto the foam circle so that the 4 nobs on the bottle piece are placed in the sand and dirt. This piece will act as a cradle to hold rocks. Add as many rocks as possible into the cradle.
12. Place the bottle system on a window sill so that it receives sunlight. If sunlight is not available, place it in a warm location.
13. Develop a hypothesis that explains what you think is going to happen to the plant matter over time and what it might look like at the end of the experiment. Record your hypothesis below.
14. Allow the bottle to stand overnight or for a day and measure the thickness of each layer. Record this as the starting thickness.
15. Measure the thickness of each layer and observe the water color every other day, approximately 3 times per week.
16. At the end of each week, add a few more rocks. Aim to add the same number of rocks each week. Record the number of rocks added after week 1 in the data table.
17. At the end of the 4th or 5th week, carefully remove the rocks and the bottle cradle. You may need to use tongs or a similar tool for help. Holding the foam circle in place, slowly and carefully pour off any remaining water from the top of the system. Remove the foam circle.
18. Allow the system to stand for 5-7 days in a warm location so that the material has a chance to dry out.
19. Carefully remove the materials from the bottle. Break the plant matter apart and record observations on your table or in your science notebook.

 **Beginning Plant Matter Observation**

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 **Hypothesis**

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 **Data**

Number of rocks added per week \_\_\_\_\_

	DIRT	SAND	PLANT MATTER	SAND	DIRT	WATER COLOR
<b>STARTING THICKNESS</b>						
<b>WEEK 1</b>						
Day 1						
Day 3						
Day 5						
<b>WEEK 2</b>						
Day 1						
Day 3						
Day 5						
<b>WEEK 3</b>						
Day 1						
Day 3						
Day 5						
<b>WEEK 4</b>						
Day 1						
Day 3						
Day 5						
<b>WEEK 5</b>						
Day 1						
Day 3						
Day 5						





# Comparing Coal

Describe the properties of coal:

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Describe the chemical make-up of coal:

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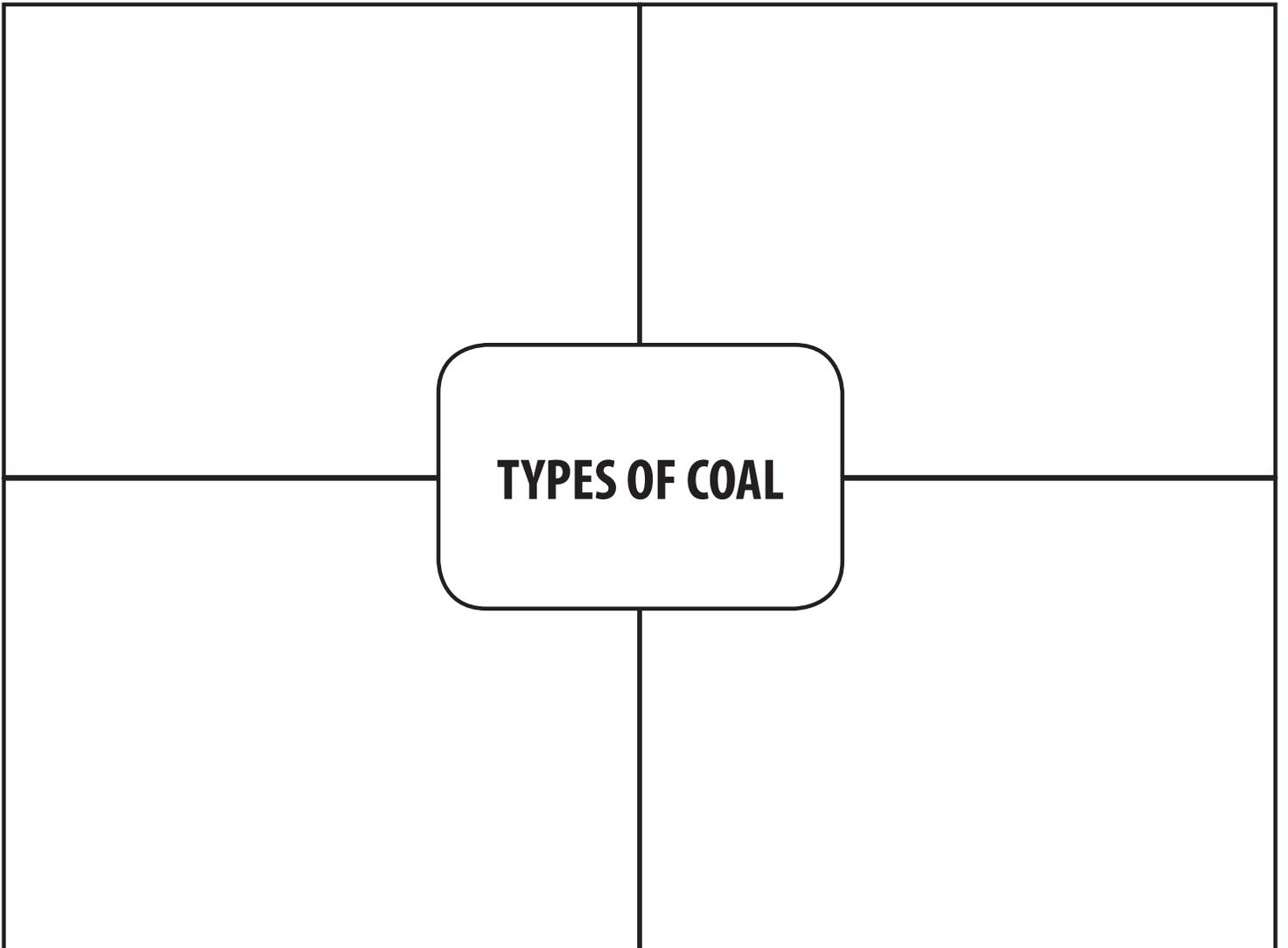
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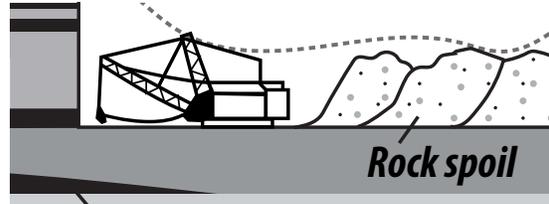


# Coal Mine Match

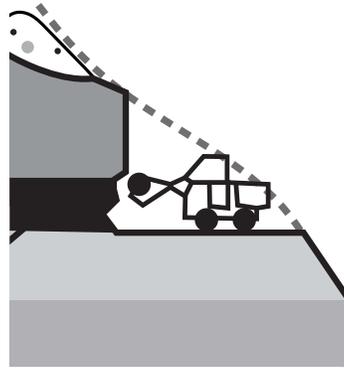
<p><b>COAL MINE MATCH</b></p>	<p><b>AREA</b></p> <p>SURFACE or UNDERGROUND</p> <p><i>HOW IT IS DONE:</i></p>
<p><b>COAL MINE MATCH</b></p>	<p><b>CONTOUR</b></p> <p>SURFACE or UNDERGROUND</p> <p><i>HOW IT IS DONE:</i></p>
<p><b>COAL MINE MATCH</b></p>	<p><b>AUGER/HIGHWALL</b></p> <p>SURFACE or UNDERGROUND</p> <p><i>HOW IT IS DONE:</i></p>
<p><b>COAL MINE MATCH</b></p>	<p><b>DRIFT</b></p> <p>SURFACE or UNDERGROUND</p> <p><i>HOW IT IS DONE:</i></p>

<p><b>COAL MINE MATCH</b></p>	<p><b>SLOPE</b></p> <p><b>SURFACE</b>    or    <b>UNDERGROUND</b></p> <p><i>HOW IT IS DONE:</i></p>
<p><b>COAL MINE MATCH</b></p>	<p><b>SHAFT</b></p> <p><b>SURFACE</b>    or    <b>UNDERGROUND</b></p> <p><i>HOW IT IS DONE:</i></p>
<p><b>COAL MINE MATCH</b></p>	<p><b>MOUNTAINTOP</b></p> <p><b>SURFACE</b>    or    <b>UNDERGROUND</b></p> <p><i>HOW IT IS DONE:</i></p>

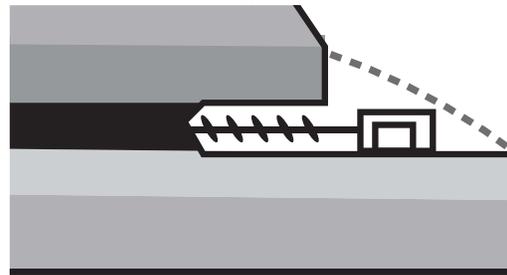
**COAL MINE MATCH**



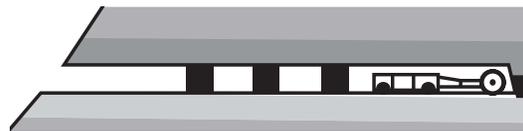
**COAL MINE MATCH**



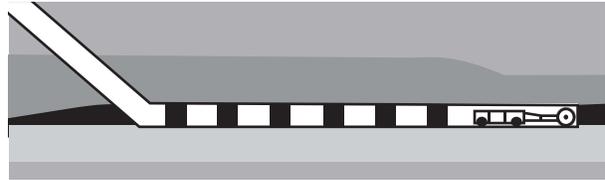
**COAL MINE MATCH**



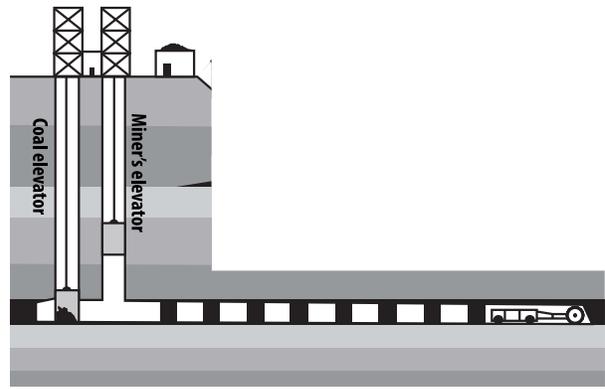
**COAL MINE MATCH**



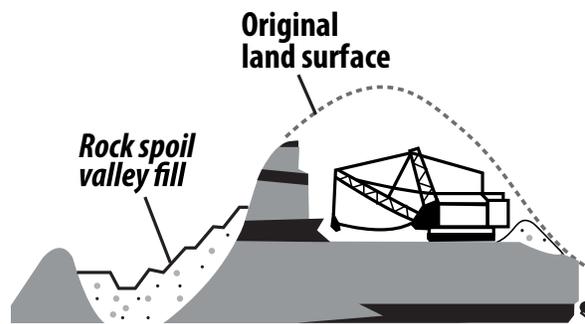
**COAL MINE MATCH**



**COAL MINE MATCH**



**COAL MINE MATCH**



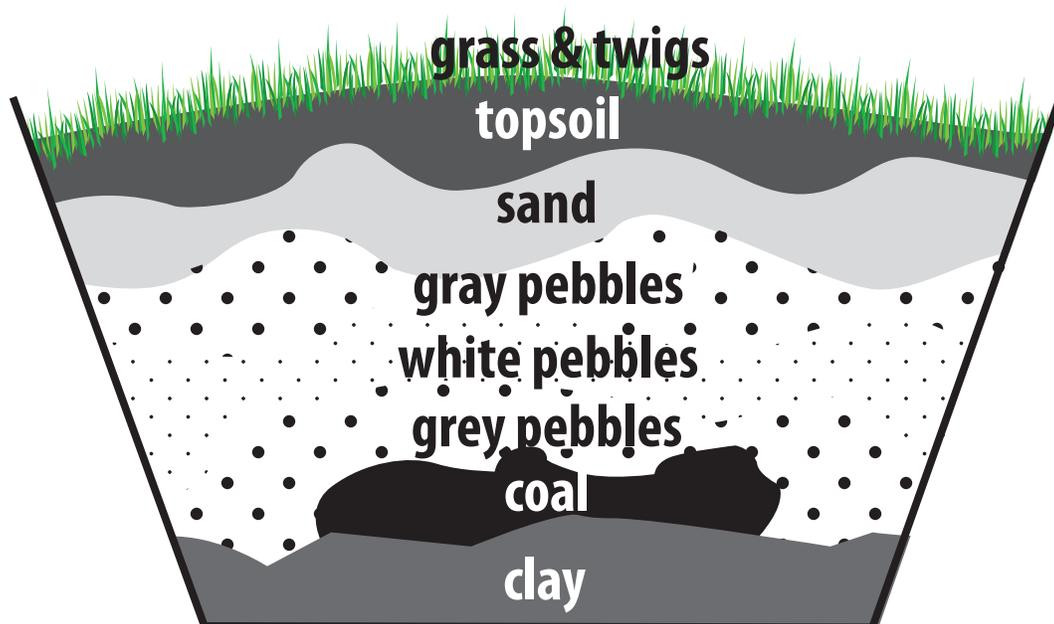


# Land Development Worksheet

Follow these steps to build your plot of land. Check off each step in the box on the left as you do it.

- Get a lump of clay about the size of your fist or a bit smaller.
- Flatten the clay into the bottom of your bowl.
- Place 1 spoonful of coal in any area of the clay and spread it flat.
- Spread 6 spoonfuls of gray pebbles over the coal, making a small hill.
- Spread 7 spoonfuls of white pebbles evenly into the bowl.
- Spread 8 spoonfuls of gray pebbles evenly into the bowl.
- Spread 10 spoonfuls of sand evenly into the bowl.
- Spread 12 spoonfuls of topsoil evenly into the bowl.
- Use cut grass, leaves, and twigs to make fields and forests on the top.

This is what your plot of land should look like:





# Mining Challenge

## Objective

You will work in teams of 3 to 5. 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.







# Map Analysis

## Background

Geography can play a big role in how energy is generated and used within a town, city, county, state, or even country. Synthesizing the data from a group of maps can help piece together why energy is used the way it is in your area. This activity focuses on the state of Kentucky as an example. For a challenge, conduct an online search for similar maps of your home state or a different state and answer the applicable questions.

## Question

Where are energy resources located in my state?

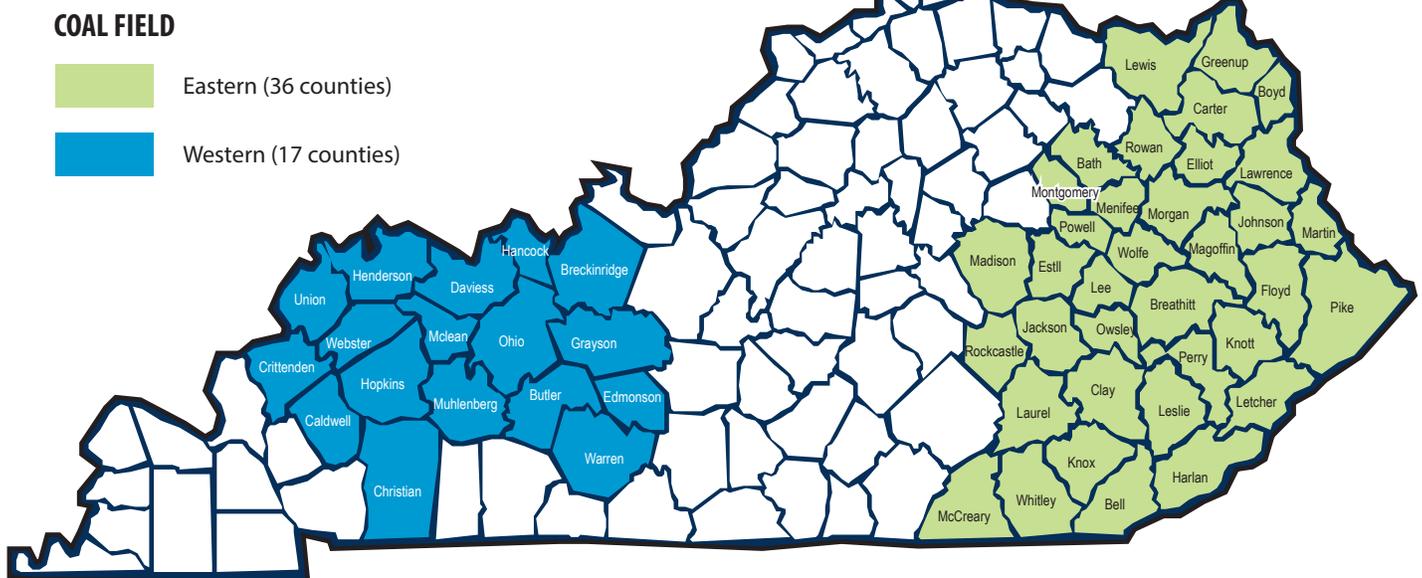
## Procedure

Use the interactive map system for Kentucky by visiting <http://kgs.uky.edu/kgsmmap/kcrim/>. You can zoom in on the map to answer questions or even select a specific county to examine. You may enlarge the map by clicking the image to the right of 'Map Setup' in the upper right hand corner of the map. It may be helpful to compare this map to other geological or demographics maps of your state. Sample maps can be found on this activity sheet. Use the interactive map and any other maps you need to answer the questions below. Answer the questions for Kentucky and then complete them for your home state or another state to compare.

1. Which type of power plant is most abundant in the state? \_\_\_\_\_  
Which type of plant is the second most abundant? \_\_\_\_\_
2. Where in the state are the majority of active mines located?
3. List several reasons that the majority of the power plants might be located where they are?
4. Besides the 2 most abundant power plants, name 3 other types of power plants found in the state.
5. Other than trucking, how is coal shipped in the western coal fields compared to the eastern coal fields?
6. What is the name of the coal seam(s) that is being mined in the county closest to your location?

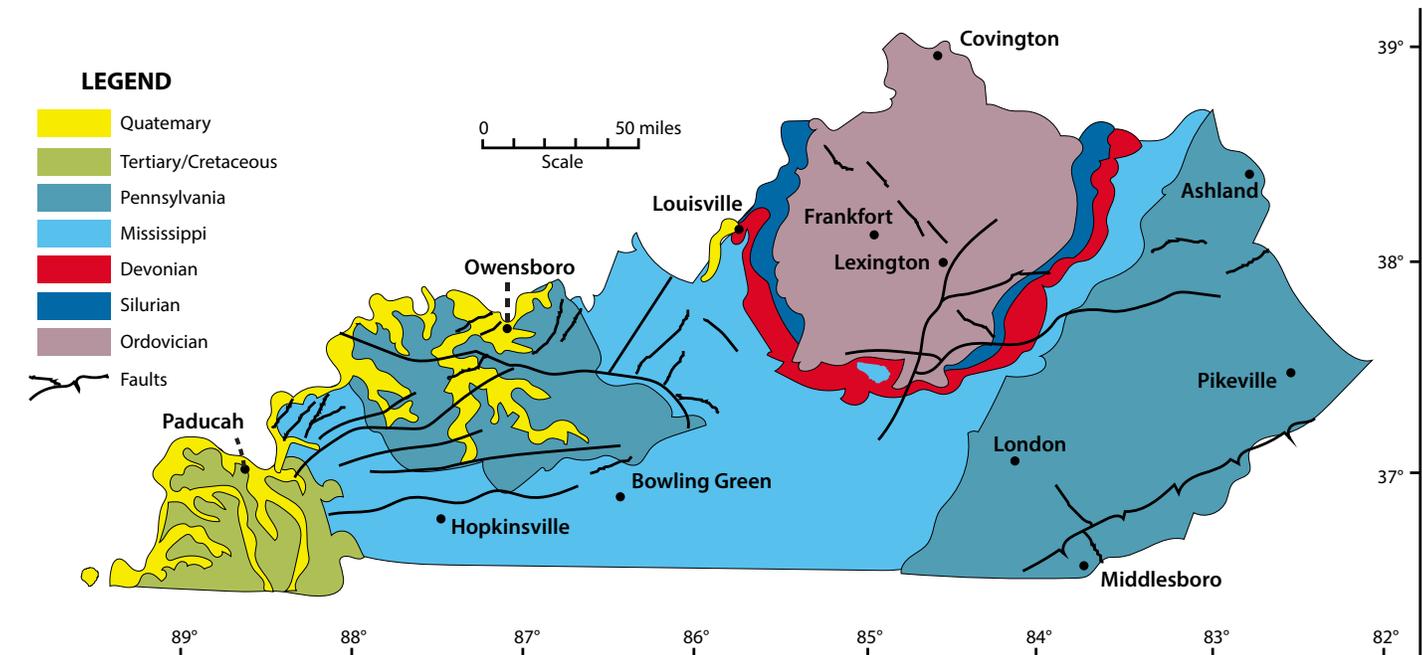
7. Coal beds in the western counties differ from those in the eastern counties. What might account for the differences?
  
8. Why are the majority of coal mines located in the eastern and western counties, but very few to none are found in the central counties of Kentucky?

## Kentucky Coal Counties



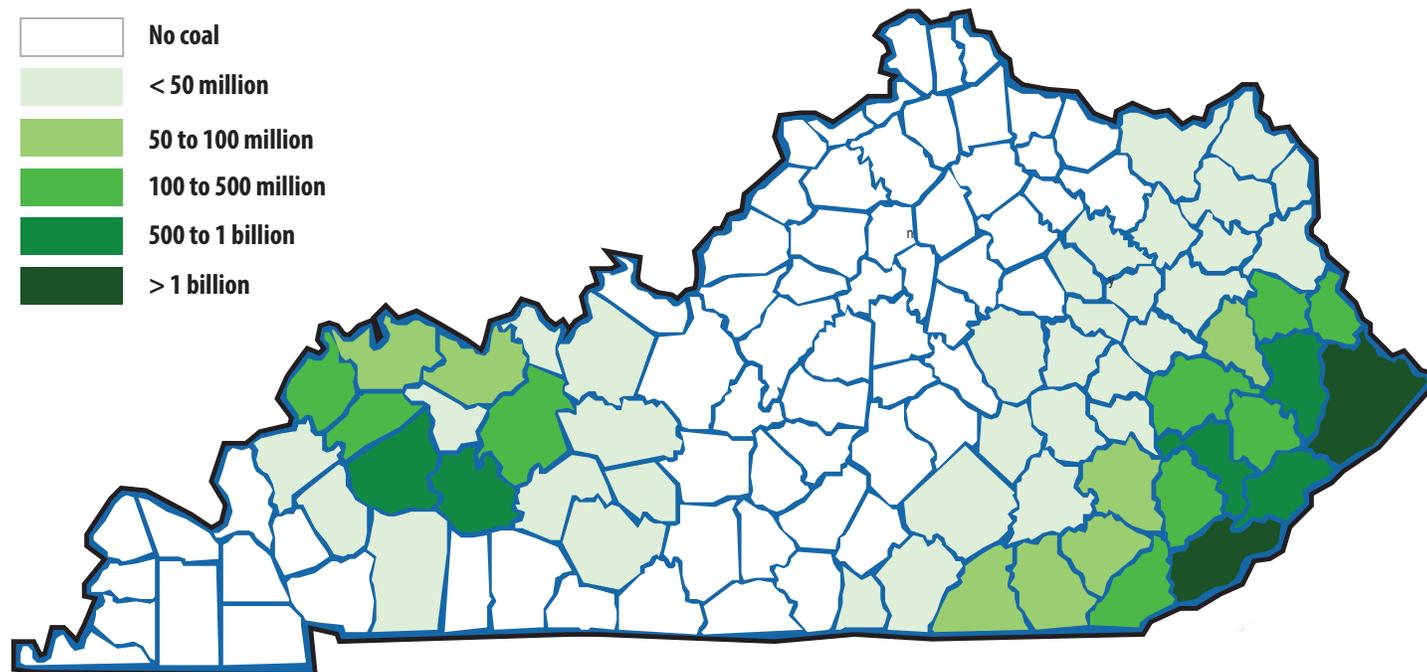
Data: Kentucky Department of Mines and Minerals

# Geology of Kentucky



Data: Kentucky Department of Mines and Minerals

# Cumulative Coal Production (tons) since 1790



Data: Kentucky Department of Mines and Minerals



# Science of Electricity Model Instructions

## 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

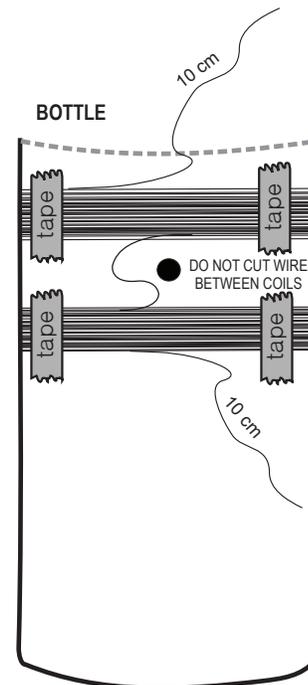
- |                                |                        |                                    |
|--------------------------------|------------------------|------------------------------------|
| ▪1 Small bottle                | ▪1 Large nail          | ▪1 Push pin                        |
| ▪1 Rubber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

## 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.



- Wrap the wire 200 times clockwise, again stacking each wrap on top of each other. Hold the coil in place with tape (see diagram).
- Unwind 10 cm of wire (for a tail) from the spool and cut the wire.
- 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.
- 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

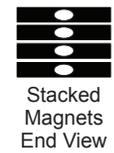


Diagram 2

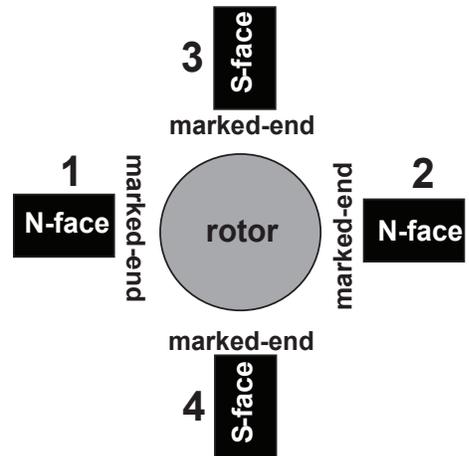
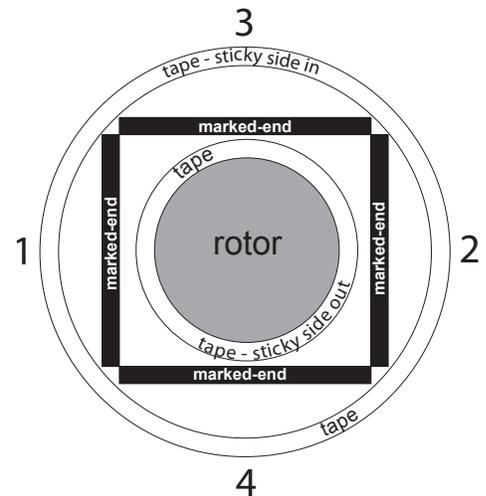


Diagram 3



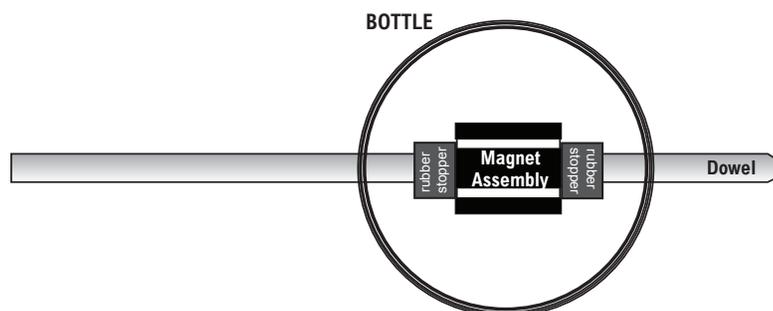
## Rotor Assembly

- 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.
- On the flat ends of the rotor, measure to find the center point. Mark this location with a permanent marker.
- Insert the small nail directly through the rotor's center using your mark as a guide.
- Remove the small nail and insert the bigger nail.
- Remove the nail and push the dowel through, then remove the dowel and set aside. Do **NOT** enlarge this hole.
- 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.
- 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.
- Wrap a piece of masking tape around the curved surface of the rotor, sticky side out. Tape it down at one spot, if helpful.
- Lift the marked end of Magnet 1 to a vertical position and attach it to the rotor. Repeat for Magnets 2, 3, and 4.
- Secure the magnets in place by wrapping another piece of masking tape over the magnets, sticky side in (Diagram 3).

**WARNING:** These magnets are very strong. Use caution when handling.

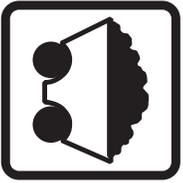
## Generator Assembly: Part 2

- Slide the sharp end of the dowel through Hole A of the bottle.
- 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.
- Slide the sharp end of the dowel through Hole B until it sticks out about 4 cm from the bottle.
- Make sure your dowel can spin freely. Adjust the rotor so it is in the middle of the bottle.

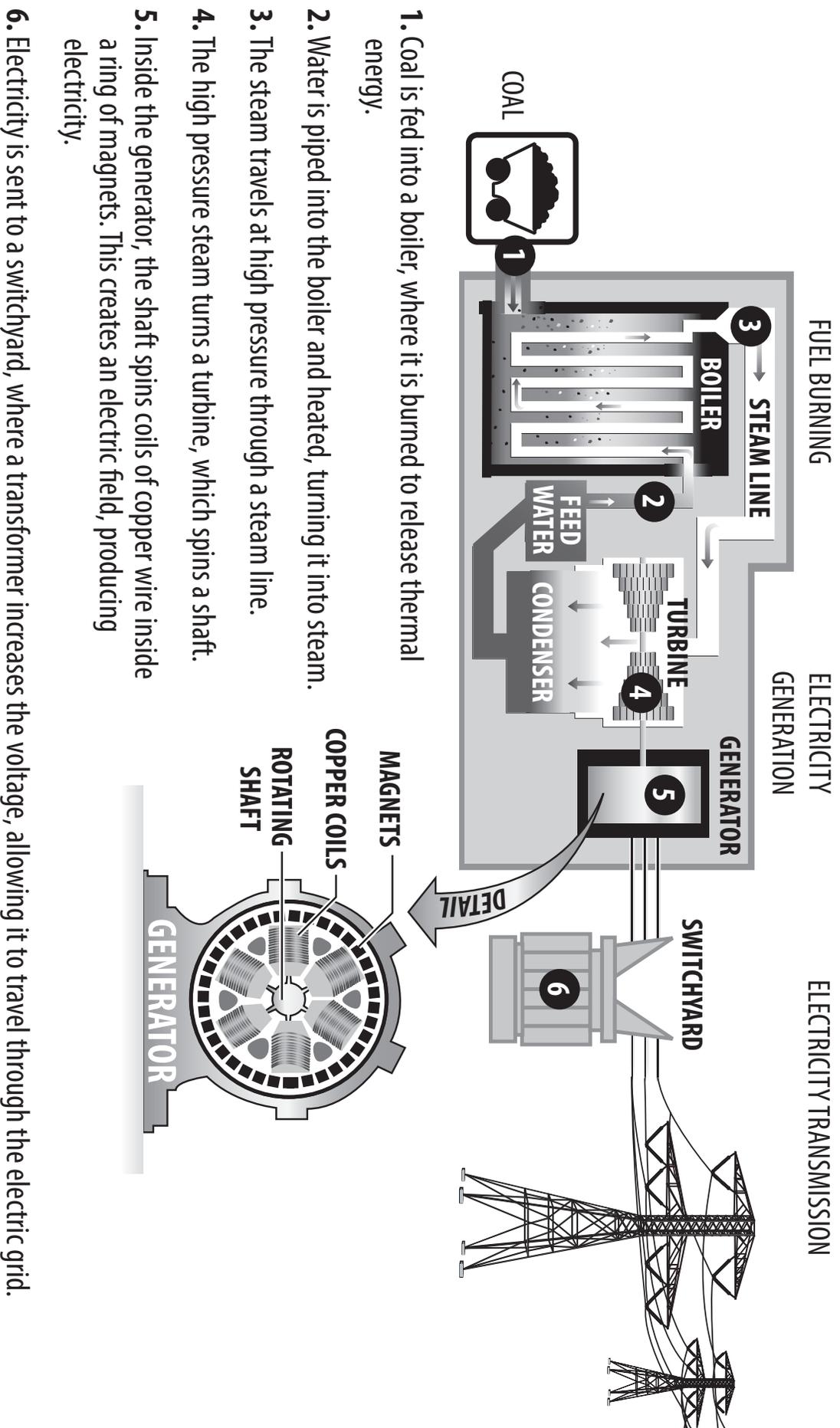








# Burning Coal to Generate Electricity





## A Cool Coal Story

A long, long time ago before even the dinosaurs roamed the Earth, the sun shone in the sky and giant plants grew in swampy forests. Like all living things, these plants died.

And more plants grew and died. This happened over and over for millions of years—plants grew and died and fell into the swamp.

The plants on the bottom got squished—really, really squished. After millions of years of being really squished those plants turned into COAL.

Now the coal is buried in the ground. Big machines—giant bulldozers and steam shovels—dig it up.

The machines load the coal onto trains and barges to take it to the power plant.

Inside the power plant there is a giant tub of water with a big oven in the middle. The coal is put into the big oven and burned.

The smoke from the fire is cleaned with big scrub brushes before it goes up the smokestack and into the air.

Inside the oven it gets really hot. So hot, the water in the tub boils and turns into steam. The oven is called a boiler because it boils the water and turns it into steam.

That steam comes roaring through a big pipe and turns a giant pinwheel, called a turbine.

The middle of the pinwheel has coils of wire wrapped around it. On the blades of the pinwheel are big magnets. When the magnets spin around the wire, it makes electricity. That is amazing!

Now, we can't go down to the power plant to buy a bag of electricity. So, the electricity comes to us.

A wire from the turbine runs out of the power plant and up a tall, tall pole. The electricity flows up the wire to the top of the pole. It flows through high-power lines from pole to pole until it gets to our town.

Then it flows into lots of small wires to our houses. Inside our houses—hidden in the walls—are lots of wires. They go to all the switches and all the outlets all over our house and the electricity flows through them.

When we flip on a light switch, the electricity flows into the light bulb and makes light.

When we plug a radio into an outlet, we get music. The electricity flows through the cord to make it work. Electricity runs our washers and dryers, TVs, and video games.

Lots of the electricity in our country is made by burning coal. The energy in the coal came from the sun.



# A Cool Coal Story Role Sheet

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

<b>Sun</b>	Nuclear fusion—produces energy
Prop & Action	Yellow ball
<b>Radiant Energy</b>	Nuclear energy in the sun is transformed to radiant energy and travels through space to Earth. Radiant energy travels in WAVES.
Prop & Action	Long pieces of yellow ribbon, several students wave in the air
<b>Chemical Energy</b>	Radiant energy is absorbed by green plants and through photosynthesis converts radiant energy to chemical energy.
Prop & Action	Green plants or silk plants, students bring up from floor
<b>Stored Chemical Energy</b>	Green plants die and are compressed under extreme pressure over a LONG period of time and become COAL. Chemical energy is stored in the coal.
Prop & Action	Green plants or silk plants, students step on leaves
<b>Coal</b>	Coal is mined and taken to a power plant. (Additional details may be added if desired.)
Prop & Action	Pieces of coal OR wads of black construction paper, students pick up coal from ground
<b>Thermal Energy</b>	Coal is burned in the furnace. Stored chemical energy produces thermal energy.
Prop & Action	Empty box, coal is put into "furnace" box
<b>Thermal Energy</b>	The thermal energy heats the water. Water becomes steam.
Prop & Action	Hot pot or bottled water, student lifts up hot pot
<b>Steam</b>	Steam travels down pipes (plastic tubing) to the turbine.
Prop & Action	Plastic hose or tubing, connect tube to hot pot used above
<b>Motion/Mechanical Energy</b>	Steam causes the turbine blades to spin.
Prop & Action	Student arms, student stands with arms outstretched and bent upwards at the elbow, student spins as steam touches them
<b>Electrical Energy</b>	The turbine is connected to the generator causing the magnets to spin around the copper coils producing electrical energy.
Prop & Action	Bar magnets, copper ribbons, three students hold bar magnets, one student is 'wrapped' in copper colored ribbon or wire, students with magnets 'spin' around copper wire
<b>Electrical Energy</b>	Electrical energy travels down the power lines to our homes.
Prop & Action	Twisted rope, start with twisted rope then pull away the smaller pieces to designate the low voltage lines that come into our homes
<b>Electrical Energy</b>	Electrical energy powers our homes.
Prop & Action	Light bulb and extension cord, student pulls chain on light bulb or switches it on
<i>Variations</i>	<i>Other energy flows can be demonstrated, substituting other sources for the coal (corn to ethanol; soybeans to biodiesel; decomposing garbage to methane, etc.)</i>



# Electric Connections

## GAME INSTRUCTIONS

Just under 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., Kentucky, Connecticut, and Idaho 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 each area's electricity generation.

### SOURCES USED TO GENERATE ELECTRICITY

SOURCE	YOUR RANK				GROUP RANK			
	U.S.	KY	CT	ID	U.S.	KY	CT	ID
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		ACTUAL RANK	YOUR RANK	ERROR POINTS	GROUP RANK	ERROR POINTS
<b>BIOMASS</b>	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.	U.S.					
		KY					
		CT					
		ID					
<b>COAL</b>	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.	U.S.					
		KY					
		CT					
		ID					
<b>GEOHERMAL</b>	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.	U.S.					
		KY					
		CT					
		ID					
<b>HYDROPOWER</b>	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.	U.S.					
		KY					
		CT					
		ID					
<b>NATURAL GAS</b>	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.	U.S.					
		KY					
		CT					
		ID					

SOURCE	STATISTICS		ACTUAL RANK	YOUR RANK	ERROR POINTS	GROUP RANK	ERROR POINTS
PETROLEUM	Petroleum provided 0.7 percent of U.S. electricity, generating 28.4 billion kilowatt-hours of electric power in 2015.	U.S.					
		KY					
		CT					
		ID					
PROPANE	There are no statistics available for propane's contribution to electricity generation. Very little propane is used to produce electricity.	U.S.					
		KY					
		CT					
		ID					
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.	U.S.					
		KY					
		CT					
		ID					
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.	U.S.					
		KY					
		CT					
		ID					
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.	U.S.					
		KY					
		CT					
		ID					

ERROR POINTS TOTALS \_\_\_\_\_

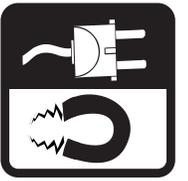
Error points are the absolute difference between your ranks and EIA's (disregard plus or minus signs).

Data: Energy Information Administration, Annual Energy Report

**SCORING:**

**0-12** Excellent  
**13-18** Good  
**19-24** Average

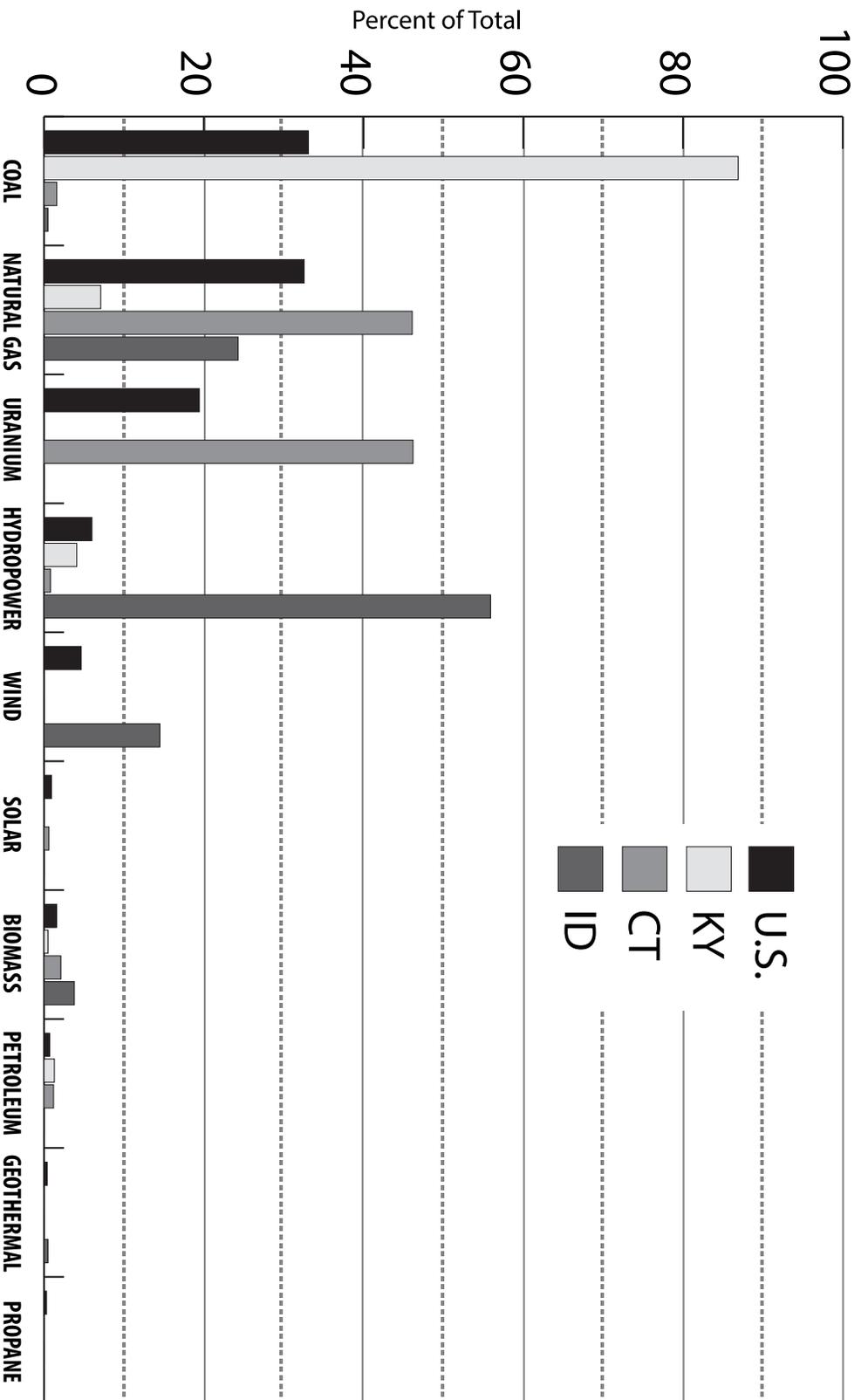
**25-30** Fair  
**31-36** Poor  
**37-42** Very Poor



# Electric Connections

## STATE BY STATE

### Comparing Electricity Portfolios, 2015



Data: EIA, State Electricity Profiles

Note: Some states do not generate any electricity from certain sources.



# Graphing Analysis

## Background

Kentucky is one of the United States' leading producers of coal. How much coal is mined in Kentucky and how many mines does it hold?

In Kentucky, coal mining is divided between two distinct geologic basins: The Central Appalachian Basin of Eastern Kentucky, and the Illinois Basin of Western Kentucky. Both of these resource fields contain rich deposits of bituminous coal. These regions, Eastern and Western Kentucky, contain all of Kentucky's mines and coal production. counties in the state of Kentucky produce coal; 17 in Western Kentucky and 36 in Eastern Kentucky.

The coalfield of Eastern Kentucky contains deposits of bituminous coal characterized by high heat content and frequently with low sulfur content. Coal produced in Western Kentucky typically has moderately high heat content and high sulfur content.

Underground mines make up the majority of Kentucky's coal production. 117 underground mines account for about 69% or more of the coal produced in the state. Surface mines, although greater in number, produce less coal and account for about 31 percent of the state's coal production. Both regions of Kentucky, Western and Eastern, rely on underground mines to produce the majority of their coal.

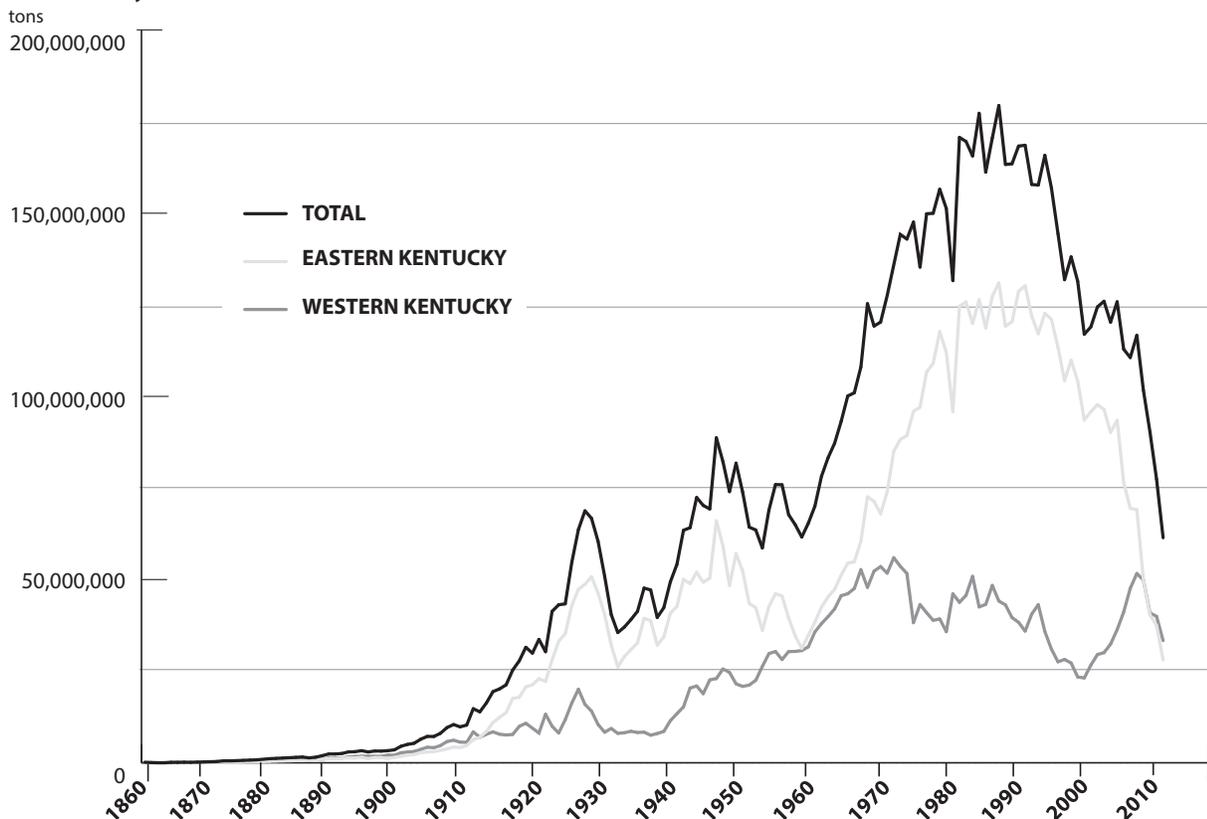
Since 2002, underground mine development in Western Kentucky counties has resulted in increased production for the region. Also, the location of economically accessible coal seams in Western Kentucky differs from deposits in Eastern Kentucky. The gentle topography and basin-like structure of the Western Kentucky coalfield limits access to surface coal. Surface accessible coal in Western Kentucky is limited mostly to the outer margin of the basin, and helps explain why surface mining has declined and underground mining has increased in the region since 1988. Surface mines in Eastern Kentucky remained the most efficient form of coal mining in the eastern region.

## Procedure

1. Use the graphs below and on the following page and the information above to help analyze important trends in Kentucky coal production.

### Graph 1

**Kentucky Coal Production 1860 - 2015**



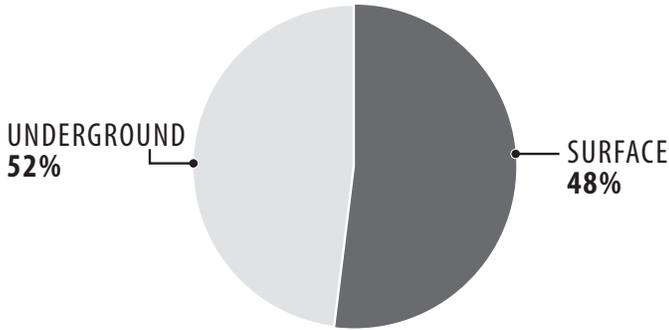
Data: Kentucky Energy Database, EEC-DEDI

## Questions

- What is Graph 1 showing you?
- What trend(s) do you see? Give specific details in your answer.
- What might account for the greater number of mines in the eastern counties compared to the western counties?

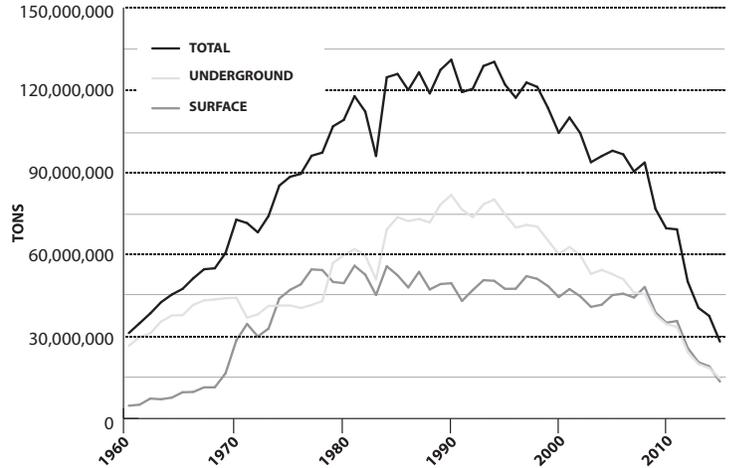
## Graphs 2&3

### Eastern Kentucky Total Coal Production, 2015



Data: Kentucky Energy Database, EEC-DEDI

### Eastern Kentucky Total Coal Production, 2015



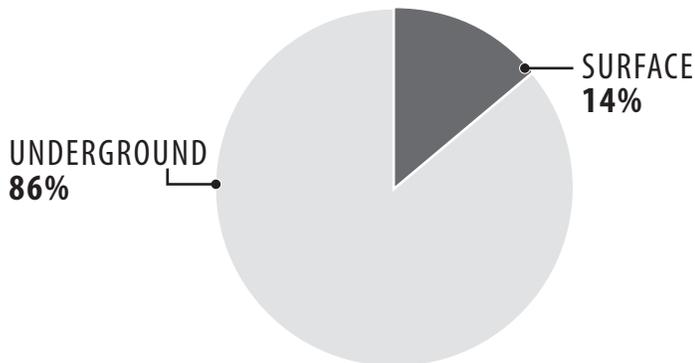
Data: Kentucky Energy Database, EEC-DEDI

## Questions

- What trend(s) do you see in Graphs 2 and 3? Give specific details in your answer.
- Since about 2007, the production of coal from underground and surface mines are almost equal. What reason(s) might explain this occurrence?

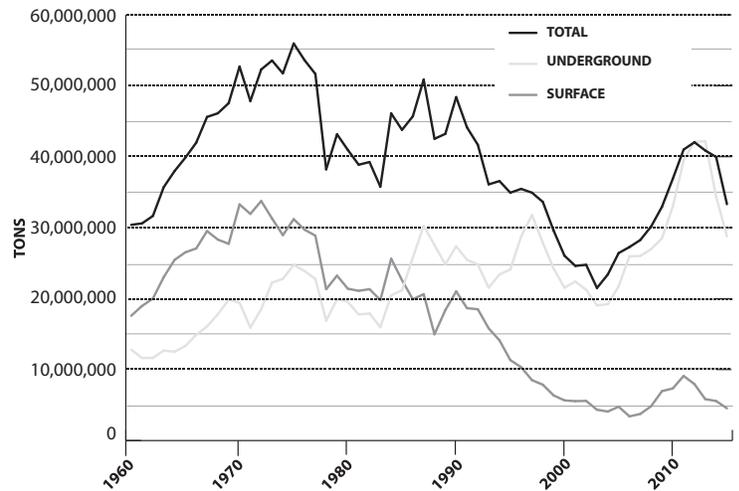
## Graphs 4&5

### Western Kentucky Total Coal Production, 2015



Data: Kentucky Energy Database, EEC-DEDI

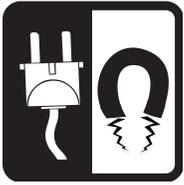
### Western Kentucky Total Coal Production, 2015



Data: Kentucky Energy Database, EEC-DEDI

## Questions

- What trend(s) do you see in Graphs 4 and 5? Give specific details in your answer.
- Comparing coal production between Western and Eastern Kentucky, what has been happening since 1990?



# 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

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 10

Demand 259.0

#### 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

### Usage History

### 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

#### 14 Non-Residential Service (Schedule 130) 10/23 - 11/26

#### 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.

Bill Date Nov 27, 2016 1

Please Pay by 01/02/2017 3

\$ 7,463.54 4

### Payment Coupon

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 0000000009368 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.

<b>1</b> Account Number 000-12345678	<b>2</b> Billing Date Nov 15, 2016	<b>3</b> Next Meter Reading Dec 3, 2016	<b>4</b> Next Billing Date Dec 4, 2016	Visit our web site at <a href="http://www.yourgascompany.com">www.yourgascompany.com</a>  If you have any questions call 1-800-000-0000
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### Credits & Charges Since Your Last Bill

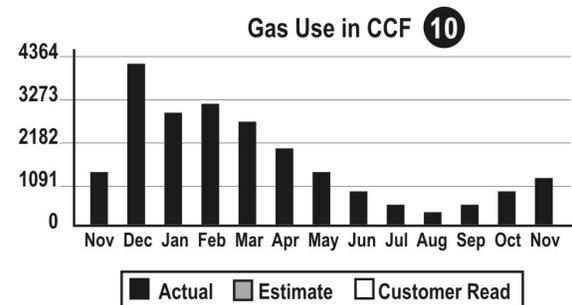
Payments Received - Thank You	\$1,302.60 CR <b>5</b>
Outstanding Balance	\$0.00

### Current Charges

<b>General Service</b>	
Delivery <b>6</b>	282.14
Gas Supply <b>7</b>	1,377.91
<b>Total Current Charges</b>	<b>\$1,660.05</b>
<b>Total Account Balance</b>	<b>\$1,660.05</b> <b>8</b>

### Monthly Usage Comparison

Heating Degree Days For	2015 <b>9</b>	2016	NORMAL
This Billing Period	160	51	138



### Billing Period and Meter Readings

Date	Read Type	Reading	
October 30, 2014	Actual	70320	<b>11</b>
October 01, 2014	Actual	68985	

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

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

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

<b>PREVIOUS BALANCE</b>	\$0.00
<b>Total Current Charges</b>	\$1,660.05 <b>15</b>
<b>Total Account Balance</b>	\$1,660.05
Account # 000-12345678	Amount Enclosed <b>16</b>

ABC Elementary School  
123 Main Street  
Anytown, USA 98765

Your Gas Company  
PO BOX 123456  
Anytown, USA 98765

0116600500000000000009368686868600012345678



# 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 10 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

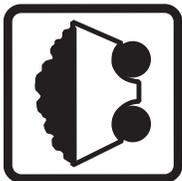
RTOs monitor power supply, demand, and other factors such as weather and historical data. This information is input into complex software that optimizes for the best combination of generation and load. They then post large amounts of price data for thousands of locations on the system at time intervals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

### The Continental U.S. Electric Grid



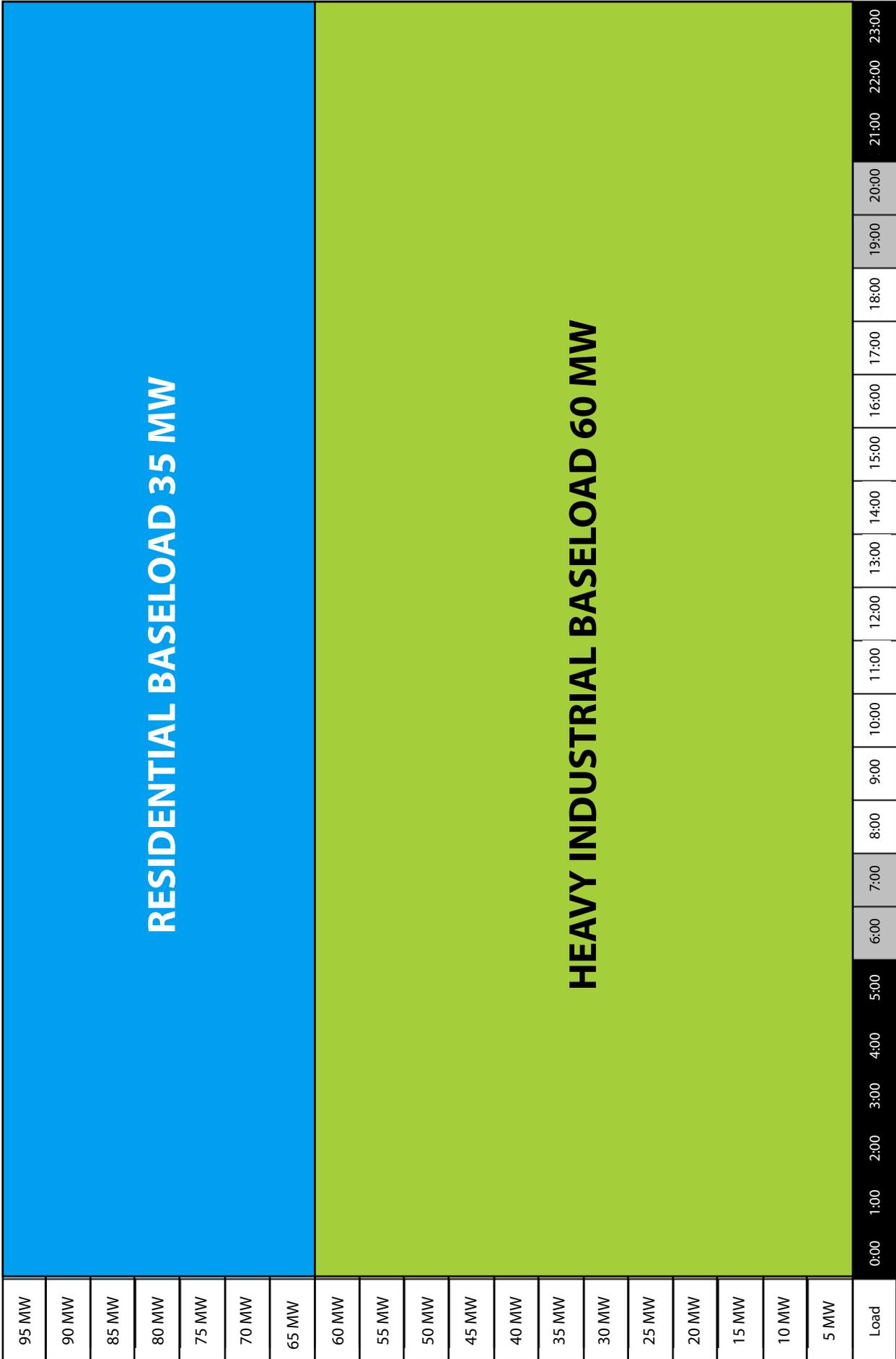
Data: Energy Information Administration

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# 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																									
105 MW																									
100 MW																									
<b>COMMERCIAL BASELOAD 20 MW</b>																									



**TIME OF DAY**







# 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

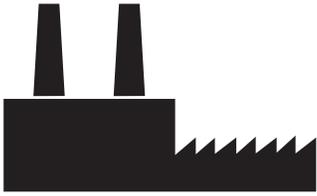


# Baseload Balance Hang Tag Template

## Generation

Baseload  
**Nuclear**

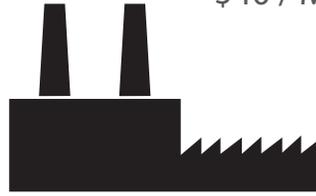
50 MW  
\$30 / MW-hour



## Generation

Baseload  
**Coal**

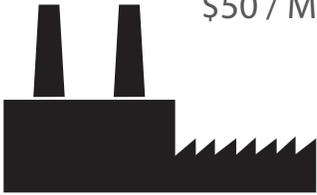
40 MW  
\$40 / MW-hour



## Generation

Baseload  
**Natural Gas CC**

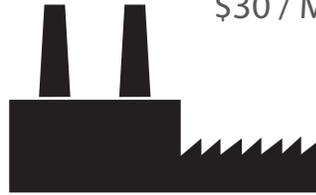
20 MW  
\$50 / MW-hour



## Generation

Baseload  
**Hydro**

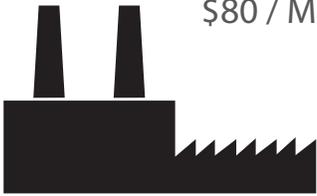
5 MW  
\$30 / MW-hour



## Generation

Baseload  
**Wind**

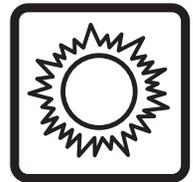
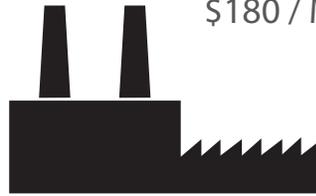
5 MW  
\$80 / MW-hour



## Generation

Baseload  
**Solar**

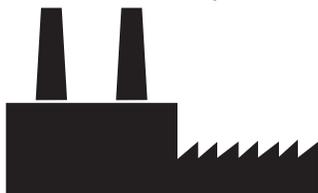
5 MW  
\$180 / MW-hour



## Generation

Peak Load  
**Natural Gas SC**

10 MW  
\$90 / MW-hour



## Generation

Peak Load  
**Natural Gas SC**

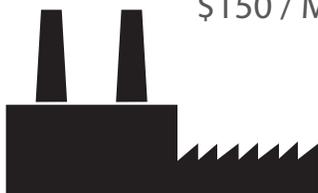
5 MW  
\$90 / MW-hour



## Generation

Peak Load  
**Natural Gas SC**

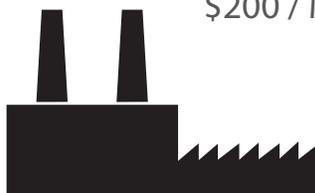
10 MW  
\$150 / MW-hour



## Generation

Peak Load  
**Natural Gas SC**

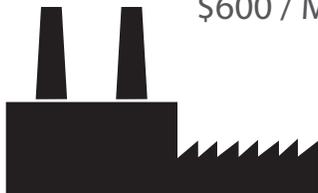
5 MW  
\$200 / MW-hour



## Generation

Peak Load  
**Natural Gas SC**

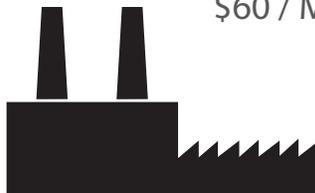
5 MW  
\$600 / MW-hour



## Generation

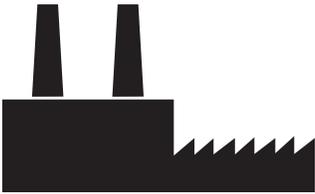
Peak Load  
**Hydro (pumped storage)**

10 MW  
\$60 / MW-hour

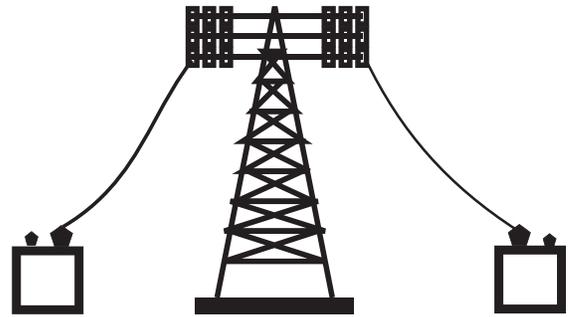


## Generation

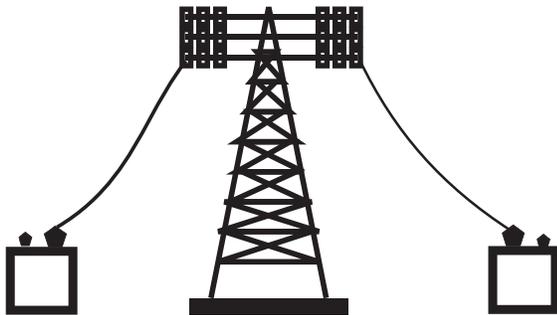
Peak Load  
**Hydro**  
5 MW  
\$50 / MW-hour



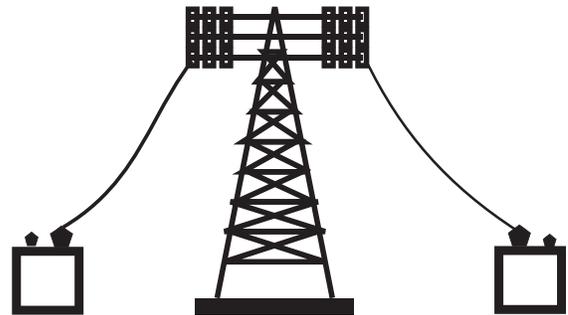
## Transmission



## 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



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?



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?



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)
<b>28 - 32</b>	<b>TOTAL</b>

## LOADS

	BASELOAD DEMAND
Residential	35 MW
Heavy Industry	60 MW
Commercial	20 MW
<b>TOTAL</b>	<b>115 MW</b>

	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
Hydropower Peak	5 MW	\$50/MW	5 MIN

### TOTAL ONLINE

**TOTAL BASELOAD DEMAND** | 115 MW

**TOTAL ONLINE**

### PEAK LOAD COMING 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

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



# Career Networking Template



## George Geologist

Mining Engineer | Mining Company B

West Virginia

Current Mining Engineer, Mining Company B

Past Miner, Mining Company B

Education Colorado School of Mines

United States Geological Survey <http://www.usgs.gov/>

American Geosciences Institute <http://www.americangeosciences.org/>

### Summary

Engineer working with Company B. Started as an hourly employee as a miner with the company and has worked for many years with the company after completing undergraduate and graduate degrees.

### Specialties

- Stratigraphy
- Explosive engineering / pyrotechnics
- Mine Safety (OSHA and MSHA regulations)

### Education

#### Colorado School of Mines

Masters of Science, Mining and Earth Systems Engineering

#### University of West Virginia

Bachelors of Science, Geology

### Experience

#### Mining Company B

1995 – present

- Manage up to 15 individuals
- Conduct safety trainings for employees
- Develop and monitor quality control measures of product
- Monitor and create plans for mining and reclamation



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\_\_\_\_\_ | \_\_\_\_\_  
\_\_\_\_\_

Current \_\_\_\_\_  
Past \_\_\_\_\_  
Education \_\_\_\_\_

\_\_\_\_\_  
\_\_\_\_\_

### Summary

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\_\_\_\_\_  
\_\_\_\_\_

### Specialties

- \_\_\_\_\_
- \_\_\_\_\_
- \_\_\_\_\_

### Education

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### Experience

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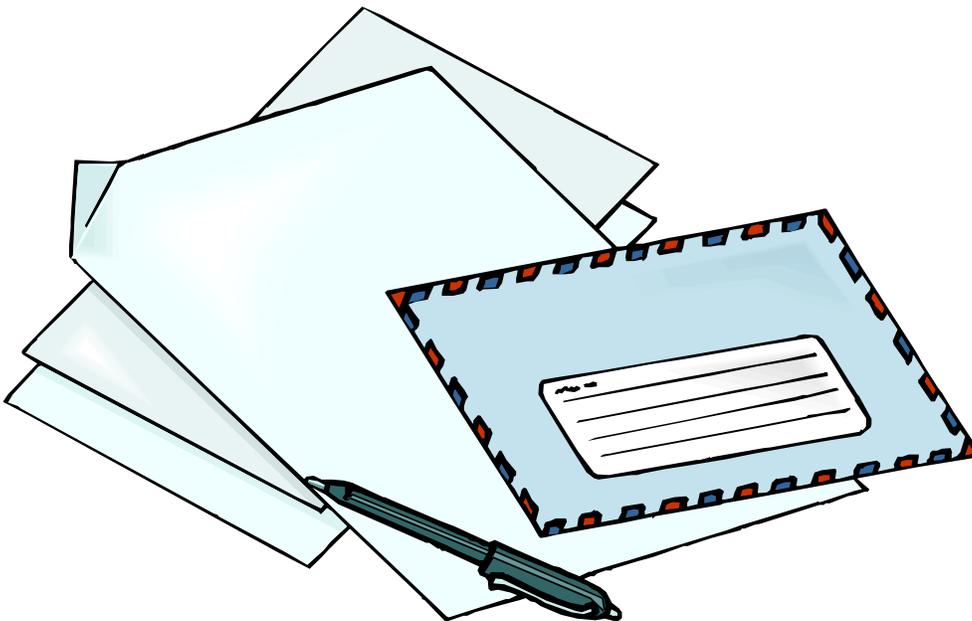


## Culminating Activity: Power Plant Letter Prompt

As the United States looks to increase electricity production while cutting greenhouse gas emissions, some folks advocate for a decreased use in coal. Others advocate for more or only clean coal use. Write a persuasive letter to a local or state representative presenting your position for or against coal use locally in a plant to meet demand.

***Your letter should have three parts, while following proper format for persuasive writing.***

- Explain your understanding of energy and why this is an important topic.
- Explain your understanding of how a coal power plant works.
- State your position for or against the use of coal. Support your position with at least three reasons and at least two pieces of evidence for each reason. Clearly communicate your position so that the representative might be persuaded to agree with you and think about your letter when he or she makes energy policy recommendations and decisions. This may include discussing and refuting possible counter arguments.





# 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

<b>A</b> NAME	<b>B</b> NAME	<b>C</b> NAME	<b>D</b> NAME
<b>E</b> NAME	<b>F</b> NAME	<b>G</b> NAME	<b>H</b> NAME
<b>I</b> NAME	<b>J</b> NAME	<b>K</b> NAME	<b>L</b> NAME
<b>M</b> NAME	<b>N</b> NAME	<b>O</b> NAME	<b>P</b> NAME



## Coal in the Round Cards

<p><b>I have anthracite.</b></p> <p>Who has a somewhat hard, satiny, dark coal with high carbon content?</p>	<p><b>I have organic.</b></p> <p>Who has the major use for coal in the United States?</p>
<p><b>I have bituminous.</b></p> <p>Who has energy stored within the bonds between atoms in compounds?</p>	<p><b>I have electricity.</b></p> <p>Who has the name of an element contained in some coal that contributes to pollution and must be scrubbed from plant emissions?</p>
<p><b>I have chemical energy.</b></p> <p>Who has the term for creating coal over time?</p>	<p><b>I have sulfur.</b></p> <p>Who has the process that changes fossil fuels into carbon dioxide, carbon monoxide, and hydrogen?</p>
<p><b>I have coalification.</b></p> <p>Who has material used for smelting metals that is made from coal?</p>	<p><b>I have gasification.</b></p> <p>Who has the type of conditions with low oxygen that contributed to coal formation?</p>
<p><b>I have coke.</b></p> <p>Who has the term to describe material made from or by living organisms?</p>	<p><b>I have anaerobic.</b></p> <p>Who has the scientific principle stating that energy and matter can neither be created nor destroyed?</p>

<p><b>I have Law of Conservation of Energy/Matter.</b></p> <p>Who has the lowest rank of coal that is soft, brown, and high in moisture?</p>	<p><b>I have mountaintop removal.</b></p> <p>Who has rocky layers removed from a surface mine that do not contain coal?</p>
<p><b>I have lignite.</b></p> <p>Who has an underground coal mine where a long wall of coal is removed in a single slice?</p>	<p><b>I have overburden.</b></p> <p>Who has decayed or decomposed plant material in a high-moisture environment without oxygen?</p>
<p><b>I have longwall mining.</b></p> <p>Who has a greenhouse gas produced from the combustion of coal?</p>	<p><b>I have peat.</b></p> <p>Who has a way of classifying coal by its energy content?</p>
<p><b>I have carbon dioxide.</b></p> <p>Who has the hydrocarbon that is the primary component in natural gas?</p>	<p><b>I have rank.</b></p> <p>Who has a process where a mine site is returned as closely as possible to its original condition?</p>
<p><b>I have methane.</b></p> <p>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?</p>	<p><b>I have reclamation.</b></p> <p>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?</p>

<p><b>I have room-and-pillar mining.</b> Who has mucky, waterlogged areas where coal formation originally began?</p>	<p><b>I have thermal power plant.</b> Who has a machine that turns, moving coils of wire within a magnetic field to generate electricity?</p>
<p><b>I have swamps or mires.</b> Who has coal that is dark gray in color, lower in carbon than bituminous, and lower in moisture than lignite?</p>	<p><b>I have turbine.</b> Who has a method of mining where one or more shafts is cut into the ground to reach a deep seam of coal?</p>
<p><b>I have subbituminous.</b> Who has a method of coal mining used to reach seams close to the surface?</p>	<p><b>I have underground mining.</b> Who has the type of rock formed from the compaction of sediment over time?</p>
<p><b>I have surface mining.</b> Who has a power plant that moves a turbine with steam made by using a fuel that releases thermal energy to boil water?</p>	<p><b>I have sedimentary.</b> Who has a type of coal that is hard, shiny, very dark, and has the highest carbon content?</p>



# Assessment

Answer each question with a complete sentence.

1. What is a natural resource?

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2. Why is coal a nonrenewable resource?

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3. How was coal formed?

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4. Where do we find coal?

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5. How do we get coal?

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6. Why is it important to reclaim land after it is mined?

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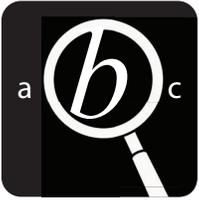
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7. How do we use the energy in coal?

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# Glossary

<b>acid rain</b>	precipitation that has a low pH, usually caused by man-made emissions that react with water molecules in the atmosphere
<b>anaerobic</b>	a condition where oxygen is absent or extremely limited
<b>anthracite</b>	highest rank of coal with a very high carbon content, hard and shiny
<b>area mine</b>	a type of surface mine where shallow coal is removed from broad, flat land; commonly called strip-mining
<b>atom</b>	a tiny unit of matter made up of protons and neutrons in a small, dense core, or nucleus, with a cloud of electrons surrounding the core
<b>auger mine</b>	a type of surface mine where coal deeper within a formation is removed from the side of a hill using special machinery to drill horizontally
<b>baseload power</b>	the minimum amount of electricity a utility must have available to its customers round-the-clock, using the most inexpensive sources
<b>bituminous coal</b>	second highest ranking coal, high carbon content, hard and satiny
<b>British thermal unit (Btu)</b>	a unit for measuring thermal energy content in a substance; the amount of thermal energy needed to raise the temperature of one pound of water one degree Fahrenheit
<b>capacity</b>	the amount of electric power a power plant can produce
<b>carbon dioxide</b>	a greenhouse gas produced from combustion
<b>Ccf</b>	a unit for measuring natural gas; most meters measure natural gas in cubic feet (cf) or hundreds of cubic feet (Ccf)
<b>coal</b>	a fossil fuel formed by the breakdown of plant material hundreds of thousands to hundreds of millions of years ago; black mineral that can be burned for energy
<b>coal reserves</b>	the amount of coal that can still be mined for use
<b>coalification</b>	the process of forming coal from plant matter
<b>coke</b>	hard, black material produced from the purification of coal at high temperatures, used in smelting of metals
<b>contour mine</b>	a type of surface mine that occurs on a hillside; land is removed from the hillside to create a bench to access the coal seam
<b>dragline</b>	large shovel machinery that is used to move large amounts of land and mine coal at the surface
<b>drift mine</b>	type of underground mining where miners follow the seam horizontally into a mountainside using special equipment, and often leaving pillars of coal behind
<b>electric current</b>	the flow of charged particles like electrons through a circuit, usually measured in amperes
<b>electricity</b>	a form of energy characterized by the presence and motion of charged particles generated by friction, induction, or chemical change; electricity is electrons in motion
<b>electromagnetic</b>	having to do with magnetism produced by an electric current
<b>electron</b>	a subatomic particle with a negative electric charge; electrons form part of an atom and move around its nucleus
<b>energy</b>	the ability to do work, produce change, or move an object; electrical energy is usually measured in kilowatt-hours (kWh), while heat energy is usually measured in British thermal units (Btu)
<b>energy carrier</b>	see secondary source of energy
<b>energy conservation</b>	energy can never be created or destroyed, it simply changes form; a behavior that saves energy such as riding a bike rather than driving a car
<b>energy efficiency</b>	the ratio of energy input to output; energy transformations have varying levels of efficiency, depending on the forms of energy involved; efficiency can be increased with the incorporation or substitution of equipment

<b>fission</b>	the splitting of atomic nuclei; this splitting releases large amounts of energy and one or more neutrons; nuclear power plants split the nuclei of uranium atoms
<b>fossil fuel</b>	fuels (coal, oil, natural gas) that result from the compression of ancient plant and animal life formed over millions to hundreds of millions of years
<b>fusion</b>	when the nuclei of atoms are combined or “fused” together; the sun combines the nuclei of hydrogen atoms into helium atoms in the process of fusion; energy from the nuclei of atoms, called “nuclear energy,” is released from fusion
<b>generator</b>	a device that turns motion energy into electrical energy; the motion energy is sometimes provided by an engine or turbine
<b>generation</b>	the process by which electricity is produced using a generator
<b>greenhouse gas</b>	gases that trap the heat of the sun in the Earth’s atmosphere, producing the greenhouse effect; the two major greenhouse gases are water vapor and carbon dioxide; lesser greenhouse gases include methane, ozone, chlorofluorocarbons, and nitrogen oxides
<b>heating value</b>	gross heat content, or number of British thermal units (Btu) produced by the combustion of a volume of gas or coal
<b>highwall mine</b>	see auger mine
<b>kilowatt-hour</b>	a unit for measuring electricity or power consumed in one hour
<b>kinetic energy</b>	energy of motion
<b>Law of Conservation of Energy</b>	the law governing energy transformations and thermodynamics; energy may not be created or destroyed, it simply changes form, and thus the sum of all energies in the system remains constant
<b>lignite</b>	lowest ranking coal that is soft, brown, and high in moisture content
<b>load</b>	a device or consumer that draws electric power
<b>longwall mine</b>	type of underground mining where a long wall of coal is removed in a single slice
<b>magnet</b>	any piece of iron, steel, etc., that has the property of attracting iron or steel
<b>megawatt</b>	one million watts; used to measure bulk electricity in power plants
<b>mine</b>	an area where resources are extracted from the Earth; to remove natural resources from the ground
<b>mire</b>	swamp or bog-like land
<b>molecule</b>	a particle that normally consists of two or more atoms joined together; an example is a water molecule that is made up of two hydrogen atoms and one oxygen atom
<b>mountaintop removal</b>	type of coal mining where the top of a mountain is removed, the coal is mined, and overburden is relocated to the valley
<b>natural resource</b>	a useful material that comes from the Earth; can be used to improve lives
<b>Newton’s Laws of Motion</b>	three physical laws that govern the force and motion interaction of all bodies, for example, the Law of Inertia
<b>nonrenewable</b>	fuels that cannot be easily made or replenished; we can exhaust nonrenewable fuels; uranium, propane, oil, natural gas, and coal are nonrenewable fuels
<b>organic</b>	describes materials that were once living or produced by living things
<b>overburden</b>	rocky layers of land removed from surface mining or mountaintop removal; does not contain coal
<b>peak demand</b>	a period when many consumers want electricity at the same time; peak demand often takes place during the day, and may require additional generation by utilities to satisfy demand
<b>peat</b>	decayed or decomposed plant material created in an area of high moisture and low oxygen
<b>photosynthesis</b>	the process by which green plants make food (carbohydrates) from water and carbon dioxide, using the energy in sunlight
<b>potential energy</b>	energy that is stored

<b>power plant</b>	a facility where power, especially electricity, is generated
<b>power pool</b>	a group of electric utilities able to share power as needed
<b>radioactive</b>	a natural process where atoms give up energy and particles to become stable; radioactive waste from a power plant has not yet become stable and, thus, can be harmful
<b>rank</b>	method of classifying coal by its energy content; higher ranking coals contain more carbon
<b>reclamation</b>	process where a mine site that is no longer in use is returned as closely as possible to its original state or better; returning disturbed land to pre-mining conditions
<b>reliability</b>	the ability of a utility provider to provide electricity to customers without disruption
<b>renewable</b>	fuels that can be easily made or replenished; we can never use up renewable fuels; types of renewable fuels are hydropower (water), solar, wind, geothermal, and biomass
<b>room-and-pillar mine</b>	method of coal mining where coal is left behind in column formations to prevent the mine from collapsing
<b>scrubber</b>	air pollution control device that power plants use to remove particulate matter and gases from their emissions
<b>secondary source of energy</b>	also known as energy carriers, these sources require another source of energy to be created; electricity is an example of a secondary source of energy
<b>sedimentary</b>	a type of rock formed by deposits of earth materials, or within bodies of water; oil and gas formations, as well as fossils are found within sedimentary rock formations; coal is a sedimentary rock
<b>shaft mine</b>	a type of underground mining where the mine is dug vertically underground and must be accessed by elevator
<b>slope mine</b>	a type of underground mining where the mine is dug at a slope under the ground
<b>smelting</b>	producing a metal from its ore, separating the metallic parts of an ore
<b>stagnating</b>	water that is stagnant is water that does not move or have a current, swamps often contain stagnating water
<b>subbituminous coal</b>	rank of coal between bituminous and lignite, dark gray in color, and lower in carbon than bituminous coal but less containing moisture than lignite
<b>surface mining</b>	method of coal removal that is used to reach seams that are close to the surface and can easily be exposed
<b>therm</b>	a measure of thermal energy; one of them equals 100,000 Btu
<b>transformer</b>	device that converts the generator's low-voltage electricity to higher-voltage levels for transmission to the load center, such as a city or factory
<b>transmission</b>	the movement of electricity over a distance
<b>transmission lines</b>	a set of conductors, insulators, supporting structures, and associated equipment used to move large quantities of power at high voltage, usually over long distances between a generating or receiving point and major substations or delivery points
<b>turbine</b>	a device with blades, which is turned by a force, e.g., that of wind, water, or high pressure steam; the motion energy of the spinning turbine is converted into electricity by a generator
<b>underground mining</b>	method of coal removal where one or more shafts is cut into the ground to reach a deep seam of coal that is not easily exposed
<b>uranium</b>	a heavy, naturally-occurring, radioactive element, used in nuclear power plants



# 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](mailto: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](http://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](http://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](http://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](http://www.issuu.com/theneedproject).

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Subscribe to our YouTube channel!  
[www.youtube.com/user/NEEDproject](http://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](http://www.NEED.org/booklist.asp).

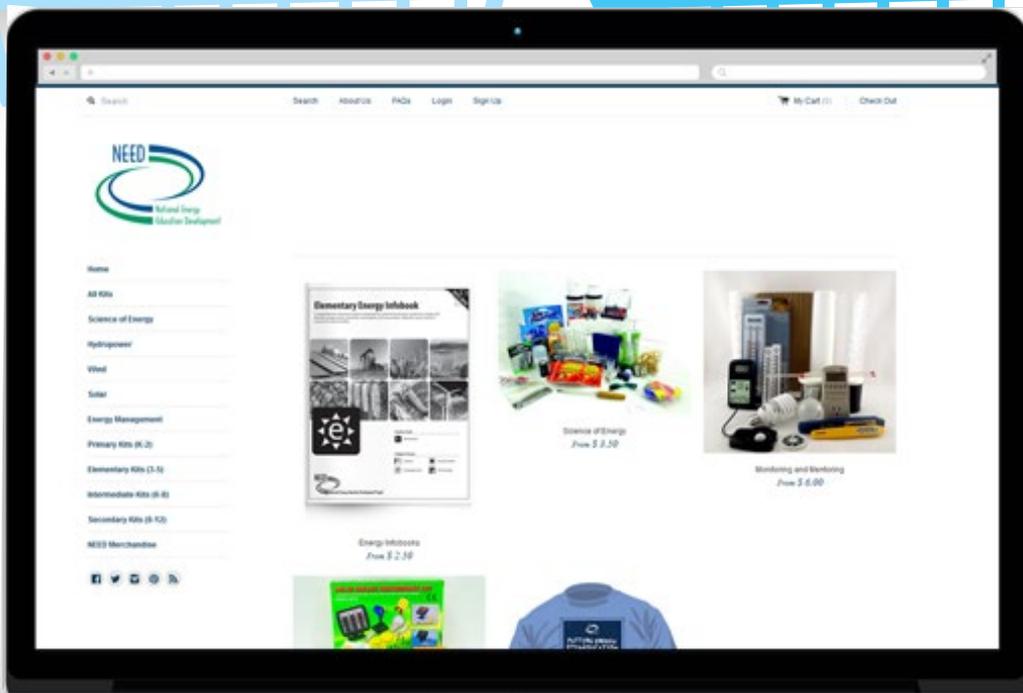
## U.S. ENERGY GEOGRAPHY

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](http://www.need.org/energyinsocietymaterials) to see energy production, consumption, and reserves all over the country!



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# Understanding Coal Evaluation Form

State: \_\_\_\_\_ Grade Level: \_\_\_\_\_ Number of Students: \_\_\_\_\_

- 1. Did you conduct the entire unit?  Yes  No

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- 2. Were the instructions clear and easy to follow?  Yes  No

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- 3. Did the activities meet your academic objectives?  Yes  No

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- 4. Were the activities age appropriate?  Yes  No

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- 5. Were the allotted times sufficient to conduct the activities?  Yes  No

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- 6. Were the activities easy to use?  Yes  No

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- 7. Was the preparation required acceptable for the activities?  Yes  No

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- 8. Were the students interested and motivated?  Yes  No

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- 9. Was the energy knowledge content age appropriate?  Yes  No

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- 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?

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Other Comments:

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



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