UNIT 5: WYOMING’S COAL

The past and future of Powder River Basin

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OVERVIEW

In this unit, students will gain an understanding of the importance of Wyoming coal to our nation's energy. As the primary producer of coal for the nation, Wyoming's coal industry has been a staple contributor to the state's economy. Students will receive foundational lessons on the properties of coal that make it such a valuable hydrocarbon. They will then study the life cycle of coal from cradle to grave, from a coal seam in the Powder River Basin, to the Union Pacific Railroad, to a power plant in one of 34 states, to the electricity grid focusing on its economic importance to the state. This study will cover the successes, and challenges of coal including the social, economic, and ecological implications of the coal life cycle. The unit concludes with a case study on one of Wyoming’s most famous coal reserves in the Powder River Basin. The summative evaluation will apply what students learn about media literacy and how to share information in a non-biased way as they are tasked with writing a newspaper/journal style article to present the current situation and stakeholders in the Powder River Basin discussion.

ESSENTIAL QUESTIONS

● Why is coal such a valuable energy resource?
● How can coal compete with other fuels in a carbon-based economy?

ENDURING UNDERSTANDINGS

● Students will understand the life cycle of coal and its value as an energy source.
● Students will identify the different perspectives on the future of coal resources through a case study on the Powder River Basin.

DURATION

Nine to ten 45 minute lessons

STANDARDS

Next Generation Science Standards

● Disciplinary Core Ideas
  ○ Physical Science
  ○ Earth & Space Science
  ○ Life Science

● Crosscutting Concepts
  ○ Patterns
  ○ Cause & effect
  ○ Stability & change
  ○ Energy & matter
  ○ Scale, proportion & quantity
  ○ Structure & function
  ○ Systems & system models

● Science and Engineering Practices
  ○ Asking questions and defining problems
o Planning & carrying out investigations
o Analyzing & interpreting data
o Using mathematics & computational thinking
o Constructing explanations
o Engaging in arguments from evidence
o Obtaining, evaluating & communicating information

Wyoming Science Standards
- SC11.1
- SC11.1.4
- SC11.1.6
- SC11.1.7
- SC11.1.12
- SC11.1.13
- SC11.2.2
- SC11.2.3
- SC11.2.5
- SC11.3
- SC11.3.2

Wyoming Social Studies Standards
- SS12.4.2
- SS12.4.3
- SS12.4.4
- SS12.5.3
- SS12.5.4
- SS12.6.1
- SS12.6.2
- SS12.6.3
- SS12.6.4

Common Core Math Standards
- CCSS.MATH.CONTENT.HSS.IC.B

Common Core Language Arts Standards
- CCSS.ELA-LITERACY.W.11-12.1
- CCSS.ELA-LITERACY.W.11-12.2
- CCSS.ELA-LITERACY.W.11-12.4
- CCSS.ELA-LITERACY.RI.11-12.7
- CCSS.ELA-LITERACY.W.11-12.8
- CCSS.ELA-LITERACY.W.11-12.9
- CCSS.ELA-LITERACY.SL.11-12.1
- CCSS.ELA-LITERACY.SL.11-12.2
- CCSS.ELA-Literacy.RST.11-12.3
OBJECTIVES

Science and Energy Literacy
- Students will examine the biological and geological processes that form coal in a lab activity.
- Student will investigate and identify the properties of hydrocarbons like coal through a lab.
- Students will use a flowchart to identify the pathways of coal’s life from beginning to end.
- Students will develop skills of scientific process by completing a lab activity.

Stewardship, Community, and Place
- Students will explore the economic benefits of coal in Wyoming including importing and exporting coal.
- Students will identify the major coal mining areas, power plants, and transportation centers across Wyoming.

STEM Careers and Leadership Development
- Students will identify professionals in various fields associated with coal: geologists, coal technicians, and engineers
- Students will understand that Wyoming is a leader in coal mining and reclamation efforts.

Applied Problem Solving & 21st Century Skills
- Students will identify and discuss the current economic, social, and environmental challenges and opportunities to Wyoming’s current coal situation.
- Students will collaborate to find creative solutions to implement technology that maximizes Wyoming coal productivity in the future.
- Students will apply science and engineering practices in a lab activity.

ASSESSMENT EVIDENCE

Diagnostic:
At the beginning of the unit, students will demonstrate understanding by:
- Completing a KWL chart with what they know and wonder about coal.
- Using a quick-write activity to recall their knowledge of coal and coal development from previous lessons.

Formative:
During the unit, students will demonstrate understanding by:
- Completing a KWL chart with what they have learned throughout the unit.
- Interpreting the results of a Properties of Coal Lab.

Summative:
By the end of the unit, students will demonstrate understanding by:
- Completing a KWL chart with what they have learned throughout the unit.
- Creating a flowchart outlining coal’s life cycle from beginning to end.
- Writing an unbiased newspaper/journal style article about coal in Wyoming.
DIAGNOSTIC ASSESSMENT: WHAT DO YOU KNOW/WONDER ABOUT COAL?

*To be completed at the beginning of the unit

Standards:

<table>
<thead>
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<th>WY Science Standards</th>
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</thead>
<tbody>
<tr>
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<td>ELA-Literacy.W.11-12.2</td>
<td>SC11.1</td>
</tr>
<tr>
<td>CCC - Patterns; Energy &amp; matter</td>
<td>ELA-Literacy.RI.11-12.7</td>
<td>SC11.1.7</td>
</tr>
<tr>
<td>SEP - Obtaining, evaluating &amp; communicating information</td>
<td>ELA-Literacy.SL.11-12.1</td>
<td>SC11.1.13</td>
</tr>
<tr>
<td></td>
<td>ELA-Literacy.SL.11-12.2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>WY Social Studies Standards</td>
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<tr>
<td></td>
<td></td>
<td>SS12.6.1</td>
</tr>
</tbody>
</table>

Instructions:

Have students spend a few minutes filling in a simple version of a KWL chart with 3-5 things that they already know, or think they know about the natural resource of coal and 3-5 things they wonder about coal. Ask students to think specifically about:

- Coal in Wyoming
- Geology of coal
- History of coal
- Technology for coal extraction
- Turning coal into usable end products

Discuss the results as a class and draw out any preconceptions to address during this unit. This KWL chart will be revisited after Lesson 5 in this unit to determine what students have learned.
LESSON 1: RESOURCE BASICS

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<td></td>
<td>SC11.1.7</td>
</tr>
<tr>
<td>SEP - Analyzing &amp; interpreting data</td>
<td></td>
<td>SC11.1.13</td>
</tr>
</tbody>
</table>

Lesson Overview:
In this lesson students will re-engage with prior understandings of coal - Wyoming’s rich coal resources, coal formation, history of coal, and importance of coal on a global scale. Students will be introduced to different types or ranks of coal, their properties, and what each type of coal is best suited for. Students will also learn what rank of coal is common in Wyoming.

Guiding Question:
What are the different types of coal and what are they used for?

Duration:
90-120 minutes

Materials:
Computer with internet access, projector, properties of coal descriptions, Lesson 1 Resources see Lab 1 for additional materials

Engage: Coal review
Watch this 2 minute video to introduce the Powder River Basin and review mining history, technology, and the geological formation of coal https://www.youtube.com/watch?v=dajoJMXEE0o#t=43

Explore: Properties of Coal Lab
Complete the properties of coal lab included in this unit

Explain: Ranks of Coal
Depending on the conditions under which coal was formed, it ends up having different characteristics. Certain types of coal are more preferable for activities depending on their properties. Explore the geological processes in which each type of coal is made (See Lesson 1 Resources), and answer the following questions:

- Describe the biological processes that lead to the formation of coal.
- How do geological processes determine the quality of coal?
- Describe the chemical process associated with burning coal.
Elaborate: Uses for each type of coal

Because of the different properties of coal, each type is preferred for certain uses. Review the types of coal introduced in the Properties of Coal Lab and see below for a list of primary uses for each type of coal. As an alternative, ask students to match the type of coal the corresponding characteristics and human history.

Types of Coal:

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peat</td>
<td>Peat has been used as a form of energy for at least 2,000 years. It was useful as an alternative to firewood for cooking and heating in temperate and boreal regions.</td>
</tr>
<tr>
<td>Lignite</td>
<td>Also known as brown coal, lignite is generally yellow to dark brown or sometimes black coal that formed from peat at shallow depths and temperatures lower than 100 °C (212 °F). It is the first product of coalification and is intermediate between peat and sub-bituminous coal.</td>
</tr>
<tr>
<td>Subbituminous</td>
<td>Subbituminous coal has properties that range from those of lignite to those of bituminous coal. It is used primarily as fuel for steam-electric power generation.</td>
</tr>
<tr>
<td>Bituminous</td>
<td>Also known as black coal, bituminous coal is a relatively soft coal containing a tar-like substance called bitumen. It is of higher quality than lignite coal but of poorer quality than anthracite. Formation is usually the result of high pressure being exerted on lignite.</td>
</tr>
<tr>
<td>Anthracite</td>
<td>Anthracite coal has the highest carbon content, the fewest impurities, and the highest calorific content of all types of coal. Anthracite is the most metamorphosed type of coal, with carbon content between 92.1 - 98%. Anthracite is considered the cleanest burning of all coal types and produces more heat and less smoke than other coals. Anthracite has been nicknamed &quot;hard coal,&quot; especially by locomotive engineers who used it for fueling trains.</td>
</tr>
</tbody>
</table>

Evaluate: How Wyoming Coal Stacks Up

Have students use the EIA Coal Data Browser to answer the following questions by changing the options in the drop down menu for the dataset http://www.eia.gov/beta/coal/data/browser/

- How does Wyoming's coal compare to other coal in terms of heat, sulfur, and ash content?
- What do you think is meant by "recoverable reserves?" How large are Wyoming's recoverable reserves?
- Find the maps that show "aggregate coal production" as of 2012, and "Market Average Price." What do you think about the relationship between Wyoming's coal production and average price? Why do you think this relationship exists? Use information from other maps and graphs to help inform your response.
- Write 3-5 interesting or surprising facts that you learned from the Coal Data Browser.
UNIT 5: WYOMING’S COAL

LESSON 1 RESOURCES

CHANGES IN RANK OF COAL

PEAT
Carbon content: 50%
Volatile matter: > 43%
Average calorific value: 1,600 kJ/kg
Moisture content: >75% (in-situ).

BROWN COAL
Carbon content: 50 - 71%
Volatile matter: > 43 - 49%
Average calorific value: 2,800 kJ/kg
Moisture content: >35% (in-situ).

Sub-bituminous Coal
Carbon content: 71 - 77%
Volatile matter: > 49 - 52%
Average calorific value: 2,930 kJ/kg
Moisture content: 25 - 30% (in-situ).

Bituminous Coal
Carbon content: 77 - 87%
Volatile matter: > 42 - 29%
Average calorific value: 36,000 kJ/kg
Moisture content: 8% (in-situ).

LAB 1: PROPERTIES OF COAL

Standards:

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<td>SC11.1</td>
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<td>MATH.Content.HSS.IC.B</td>
<td>SC11.1.7</td>
</tr>
<tr>
<td>SEP - Asking questions/Defining problems; Planning &amp; carrying out investigations; Analyzing &amp; interpreting data; Using mathematics &amp; computational thinking; Constructing explanations</td>
<td></td>
<td>SC11.1.12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SC11.1.13</td>
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<td></td>
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<td>SC11.2</td>
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<td></td>
<td></td>
<td>SC11.2.2</td>
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<tr>
<td></td>
<td></td>
<td>SC11.2.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>SC11.2.5</td>
</tr>
</tbody>
</table>

Lesson Overview:
In this lesson, students will explore the properties of different forms of coal through a series of labs. Students will understand different qualities of coal have different properties and the environmental conditions that existed in order to form each type of coal. This information is important because economic value and environmental impact is directly related to coal quality.

Guiding Question:
What are the properties of different types of coal?

Duration:
45-90 minutes

Materials:
Lab notebook or graph paper, Hand lenses, Streak plate (optional), Properties of Coal Lab worksheet, descriptions of how to conduct different rock and mineral tests (See Lab 1 Resources)
- Coal Samples (1 each): Lignite, Subbituminous, Bituminous, Anthracite
- Hardness Test Materials: penny, nail, glass plate
- Density Test Materials: Small scale, Water, Measuring cups
- Energy Content Test Materials: Bunsen burner, tongs, cup of water to cool coal

Engage: How do you define coal?
Each coal bed is unique in its formation, which results in coal with different qualities. Ask students to think-pair-share to come up with a class definition and description of coal. Explain that the objective of this lab is to explore the properties of coal types.

Explore: Properties of Coal Lab
Students will work in small groups. Each group should have a lab notebook or graph paper. Each group should gather the materials listed in the materials section for the lab. See Lab 1 Resources for the lab procedure and hand out additional information on carrying out each test/descriptive portion of the organizer.
**Explain: Combustion and Heat Content**

We use coal by combusting it for electricity, fuel, and heat. Ask students to consider the following questions: What happens in a combustion reaction? What elemental component of coal and other fossil fuels allows combustion to occur? Carbon!

![Chemical reaction diagram](image)

\[
\text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O}
\]

**Elaborate: Combustion of coal**

Based on the observations you have made about coal properties so far, hypothesize which coal you believe will burn the fastest and which will burn the slowest. Which one do you believe will emit the highest heat? Why?

Tell students that you will be conducting a class demonstration in which you will ignite a small piece of each coal sample. Have them observe the following as they watch the demonstration and record in the corresponding graphic organizer:

- a. Speed of ignition
- b. Color of the flame
- c. Speed of burning
- d. Odor

Using tongs, safety gloves, and goggles, ignite a small piece of each sample of coal over a Bunsen burner. Upon ignition, remove each sample from the flame and allow students to observe how the sample burns.

***Safety note: This demonstration should be done in a well-ventilated area, coal will smoke as it burns. Outside in an area sheltered from wind or in a lab with a fan would be the best places to conduct this portion of the lab.***

**Evaluate: Conclusions about coal?**

Using the data tables from the lab, have students work within lab groups to draw conclusions about the types of coal.

- What clues do color, hardness, density, and energy content of the rock give you about the relationships between these samples?

**Resources:**

Lab 1 Resources

Rock and Mineral Test Resources

- Test descriptions: [http://jersey.uoregon.edu/~mstrick/MinRockID/MinTests.html](http://jersey.uoregon.edu/~mstrick/MinRockID/MinTests.html)
- Hardness test scale:

<table>
<thead>
<tr>
<th>Mohs' Scale</th>
<th>Comparison Mineral</th>
<th>Mineral Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Talc</td>
<td>Powdered by fingernail</td>
</tr>
<tr>
<td>2</td>
<td>Gypsum</td>
<td>Scratched by fingernail, fingernail (2.5)</td>
</tr>
<tr>
<td>3</td>
<td>Calcite</td>
<td>Scratched by copper coin, copper penny (3)</td>
</tr>
<tr>
<td>4</td>
<td>Fluorite</td>
<td>Easily scratched by penknife, knife blade (5)</td>
</tr>
<tr>
<td>5</td>
<td>Apatite</td>
<td>Just scratched by penknife, glass (5.5–6)</td>
</tr>
<tr>
<td>6</td>
<td>Orthoclase</td>
<td>Scratched by steel file, it scratches window glass, steel file (5.5)</td>
</tr>
<tr>
<td>7</td>
<td>Quartz</td>
<td>Scratches window glass or steel easily</td>
</tr>
<tr>
<td>8</td>
<td>Topaz</td>
<td>Easily scratches quartz</td>
</tr>
<tr>
<td>9</td>
<td>Corundum</td>
<td>Easily scratches topaz</td>
</tr>
<tr>
<td>10</td>
<td>Diamond</td>
<td>Cannot be scratched, hardest of all minerals</td>
</tr>
</tbody>
</table>

Properties of Coal Lab Worksheet

Part 1: Descriptive characteristics

Fill in the data table to help describe characteristics of each type of coal.

1. **Color Description:** Describe the color of the sample as detailed as possible.

2. **Luster:** Luster is a term used to describe if an object appears metallic. In the table, record if the sample appears metallic or nonmetallic.

3. **Hardness:** Use the hardness test materials to estimate how hard the sample is. The following table describes the objects that can be used to measure hardness. The nail should be used in place of the knife. Record the estimated hardness in the table.

4. **Cleavage/fracture:** If possible, break the rock. Does it break into two regular, smooth faces? If so, it has a regular cleavage. If it breaks into uneven faces, it has an irregular fracture pattern. If you cannot break the sample, simply observe the sample and describe its sides.

5. **Other descriptions:** Note if there are any other interesting features of your sample.

<table>
<thead>
<tr>
<th>Coal Sample</th>
<th>Color description</th>
<th>Luster (metallic/nonmetallic)</th>
<th>Hardness</th>
<th>Cleavage/Fracture</th>
<th>Other descriptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample 1: Lignite</td>
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<tr>
<td>Sample 2: Subbituminous</td>
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<td>Sample 3: Bituminous</td>
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<tr>
<td>Sample 4: Anthracite</td>
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</tbody>
</table>

Part 2: Density

Determine the density of the samples using the formula Density (D) = Mass (M) / Volume (V).

1. Weigh a sample of lignite coal on a scale. Record the mass in grams.

2. Fill measuring cup about ⅓ of the way. Record the volume of water in measuring cup in milliliters (mL).

3. Place coal in measuring cup. Measure the volume of the water with coal in mL and record.

4. Subtract the volume of water from volume of the water and coal to find the volume of the coal sample. Record in the table.
5. Divide the mass by the volume of coal to determine the density. Record in the table.

6. Repeat for each sample.

<table>
<thead>
<tr>
<th>Coal Sample</th>
<th>Mass (g)</th>
<th>Volume: water (mL)</th>
<th>Volume: water and coal (mL)</th>
<th>Volume: coal (mL)</th>
<th>density (g/mL)</th>
</tr>
</thead>
<tbody>
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</table>

Part 3: Visualize the results
1. Plot the densities of the coal samples. The x-axis should represent each sample. The y-axis is density.
2. What is the relationship between sample type and density?

Part 4: Coal Combustion
Watch demonstrations of different samples of coal being combusted and record observations in the table below.

<table>
<thead>
<tr>
<th>Coal Sample</th>
<th>Speed of ignition</th>
<th>Flame color</th>
<th>Speed of burning</th>
<th>Odor</th>
<th>Other observations</th>
</tr>
</thead>
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LESSON 2: EXTRACTION AND CONVERSION OF COAL

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<td>SC11.1.13</td>
<td></td>
</tr>
</tbody>
</table>

Lesson Overview:
In this lesson, students will examine Wyoming’s coal production from “Cradle-to-Grave.” Students will understand the connections between geology and the predominant surface mining in Wyoming. They will follow the path of coal from coal mines to the consumer, including power plants, transportation by railroad, and transmission by power lines to their households, along with the other consumers of coal.

Guiding Question:
How is coal removed from the ground and turned into something more useful?

Duration:
45 minutes

Materials:
Computer with internet access, projector, computer lab access for students or print outs of information, Lesson 2 Resources, student notebooks, “Coal Products Tree” http://www.coalcampmemories.com/coaltree.html

Engage: Surface Mining
Since a number of Wyoming’s coal reserves are in seams near the surface, the coal industry in the state uses surface mining techniques to remove much of the coal. See Lesson 2 Resources for a diagram of surface mines. Other types of underground coal mining exist, but are not as productive as surface mining operations. Watch a video on the world’s largest coal mine operation, the surface mine at North Antelope Rochelle mine in Wyoming’s Powder River Basin http://www.history.com/videos/worlds-largest-coal-mine#worlds-largest-coal-mine

Explore: Where does Wyoming Coal Go?
Provide students with printouts of maps or place maps around the room (See Lesson 2 Resources for maps). Students should look at maps and make connections between them. Students can write questions they have while looking at maps or the teacher can provide prompts to give students guidance. Small groups of 2-3 students would work best for this. Students should share the themes that emerged from their small groups. Possible prompts:
- What are the common trends and themes among these maps?
- What conclusions can you make about Wyoming’s coal resources from these maps?
Explain: Mining and Production

As you found by analyzing the maps, Wyoming's Powder River Basin is an incredibly productive area. In fact, the PRB produces 40% of the nation's coal. The PRB provides an important economic benefit to the state as well as thousands of jobs. Use the following mapping program to locate the coal-fired power plants in Wyoming. EIA Mapping: Like Google Earth, this mapping program has many layers of mines, power plants, etc: [http://www.eia.gov/state/maps.cfm?src=home-f3](http://www.eia.gov/state/maps.cfm?src=home-f3)

See the diagram in Lesson 2 Resources for an outline of a coal fired power plant or take a virtual tour of a coal-fired power plant:


Elaborate: Coal Tree

While the major use of coal is for production of electricity, its use as "coke" in industrial ovens extends the uses of coal far beyond electricity and heat. Check out the "Coal Tree" to see just how many products depend on coal: [http://www.coalcampmemories.com/coaltree.html](http://www.coalcampmemories.com/coaltree.html).

Evaluate: Coal Cradle to Grave

Students should individually draw a flowchart that shows the path of coal from "cradle to grave." Encourage students to share with partners or in small groups, then as a class to create a comprehensive diagram. Alternatively, break students into small groups and have them draw a flowchart for coal during different life stages.
LESSON 2 RESOURCES

Surface Mine Diagram


Powder River Basin Distribution Maps

UNIT 5: WYOMING’S COAL


http://ops.fhwa.dot.gov/freight/freight_analysis/nat_freight_stats/docs/08factsfigures/figure3_13.htm

Coal Fired Power Plant Diagram

http://www.intechopen.com/source/html/26045/media/image4.jpg

DRAFT – August 2015
LESSON 3: SUCCESSES OF COAL - RECLAMATION

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Lesson Overview:

The goal of this lesson is to highlight that surface mines cause a very large impact on the landscape. However, we will also look at how surface mine operations have been able to mitigate some of the negative results of large scale landscape changes.

Guiding Question:

What happens when all the coal has been removed from a mine?

Duration:

45 minutes

Materials:

Computer with internet access, projector, Lesson 3 Resources

Engage: Revisit surface mining

Re-engage the students’ understanding of surface mines by looking at images of surface mining operations in Lesson 3 Resources. How do surface mines operate? What is the end result? What are the implications? Make sure to draw out the negative impact of large-scale open pits leaving a giant scar on the landscape.

Explore: Reclamation

Mine reclamation is the process of restoring land that has been mined to a natural or economically usable state. Although the process of mine reclamation occurs once mining is completed, the preparation and planning of mine reclamation activities occur prior to a mine being permitted or excavated.

Watch a brief video that shows an active coal mine in the southeastern United States and different phases and ages of reclaimed surface mines: https://www.youtube.com/watch?v=P1d6-3NmYI. Ask students to compare the video with the definition they just learned of reclamation. Was the mine in this video returned to a natural or economically usable state? What was the natural state before the mine was started? What is the new “economically usable state?” How do they think reclamation of this landscape compares with that of coal mines in Wyoming?
Explain: Sagebrush Habitat

Reclamation is important because it helps return habitat to a more natural condition and promotes biodiverse plant and animal resources to return to the area. In Wyoming, 85% of the state is covered by sagebrush steppe communities which may take decades to return to a natural state after it has been disturbed. See Lesson 3 Resources for more information on sagebrush plant communities. While sagebrush may not seem very diverse at first glance, it is home to a number of unique species including pronghorn antelope and greater sage grouse.

Sage grouse are threatened bird species in Wyoming and many other Western states and are being considered for listing as endangered species. See Lesson 3 Resources for distribution maps of the species. Sage grouse are “obligate residents” of sagebrush during all parts of their life meaning they only live in sagebrush country in the West. Sage grouse eat sagebrush and require large intact areas of sagebrush with specific sagebrush cover for breeding and nesting.

Elaborate: Sage Grouse Critical Habitat

Sage grouse are especially important to the coal industry in Wyoming because the listing of the sage grouse as an endangered species would have major implications for energy development industries in Wyoming because it would require many companies to stop or extremely limit their production. Instead, many companies have been proactively looking at ways to prevent damage to sage grouse critical habitat so as to keep it from becoming endangered. See the Lesson 3 Resources for maps to compare overlap in coal reserves and sage grouse critical habitat.

Evaluate: Sage Grouse Conservation Plans

Read the following excerpts from reports on coal development and reclamation by stakeholders in the Powder River Basin project. Then ask students to quick-write or have a discussion in response to the following prompt: Based on what you have learned and what you know about surface mining and sage grouse critical habitat, does reclamation seem to be effective? Why or why not?

Northeast Wyoming Sage Grouse Conservation Plan (2006): “In summary, Powder River Basin coal mine reclamation efforts support wildlife in general and sage grouse in particular by: Setting the conditions for post-mine climax communities; Creating diverse habitats; Sustaining data collection and reporting.”

Bureau of Land Management sage grouse viability in Powder River Basin study (2012): “Management of energy development based on current core area configurations and associated lease stipulations, conditions of approval, and best management practices, may not provide enough contiguous habitat sufficient to protect the remaining viability of Greater Sage-Grouse populations within the Powder River Basin without substantial investment in restoration activities.”

Resources:

Lesson 3 Resources

Images of surface mining operations

http://en.wikipedia.org/wiki/Mining

Sagebrush (*Artemesia tridentata*) distribution in the West

http://en.wikipedia.org/wiki/Artemisia_tridentata

Sage Grouse Distribution

http://greatbasin.wr.usgs.gov/LWG/Maps.asp

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LAB 2: COOKIE MINING

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Lesson Overview:
Students will explore the economic and environmental challenges of mining through this simple activity that simulates coal mining and reclamation.

Guiding Question:
What are the economic and environmental challenges of coal mining?

Duration:
45 minutes

Materials:
Play Money, Three different types of commercially packaged chocolate chip cookies, Grid paper, Pencils, Flat toothpicks, Round toothpicks, Paper clips, Cookie Mining Worksheet from the American Coal Foundation website

Engage: Mining industry
Explain that the mining industry, like any other business, faces challenges to make itself profitable. To understand some of these challenges, students will attempt to conduct a profitable mining business in an experiment that requires them to mine the “coal” chips from chocolate chip cookies.

Explore: Cookie mining activity
1. Give each student $19 in play money, a sheet of grid paper, and a Cookie Mining Worksheet. Allow each student to purchase one “mining property” (a cookie) from three separate brands available. Montana costs $3, Pennsylvania costs $5, and Kentucky costs $7. Students may want to examine the cookies before deciding which one to purchase.
2. Once all the students have purchased their property, have them measure it by placing it on the grid paper and tracing it. Then have them count the number of squares that fall inside the circle (partial squares count as full squares). Tell students to record this number on the Cookie Mining Worksheet under D. Reclamation.
3. Have each student purchase “mining equipment” (i.e. flat and round toothpicks and paper clips). More than one piece of equipment may be purchased, but no tools may be shared among students. Sell a flat toothpick for $2, a round toothpick for $4, and a paperclip for $6. Sell replacement tools when necessary.
4. Explain that each minute of mining (labor) costs $1 and that each chocolate chip mined from their property will result in a $2 profit. Broken chips may be combined to form a whole chip. Consumed chips will eat into profits!

5. Do not allow students to spend more than five minutes mining. If they spend less time, their labor cost will be lower. Have them record their mining time and labor cost under C. Mining/excavation costs on the Cookie Mining Worksheet.

6. After everyone is finished mining, have students restore their property to its original condition, within the drawn circle on the grid paper. This “reclamation” should also be timed (no more than three minutes) and students may only use their tools, not fingers. After time is up, collect additional reclamation costs ($1) for each square covered outside the original outline. Disburse profits for chips mined. Students can use the Cookie Mining Worksheet to calculate profit or loss.

Explain/Elaborate: Reclamation and industry
Review the costs associated with coal mining: land acquisition, labor, equipment, and reclamation. Coal companies are required by federal law to return the land they mine to its original, or an improved, condition. This process, known as reclamation, is a significant expense for the industry.

- How does land reclamation impact the industry?
- What were some of the other costs associated with mining coal? How do these affect the industry?

Evaluate: Analyze the simulation
Allow students to share their experiences with the class. Was making a profit easier or harder than they expected? How accurate is this simulation in illustrating the challenges of making money in the mining industry? What costs or possibilities for profits were not included in this exercise?

Resources:
- Lesson plan adapted from American Coal Foundation: http://teachcoal.org/lesson-plan-cookie-mining
LESSON 4: CHALLENGES OF COAL PRODUCTION - CARBON

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Lesson Overview:
Students will analyze the potential social, economic, and environmental challenges of coal. Students will examine economic challenges to coal in relation to other competing resources, mainly natural gas. They will identify the hazardous byproducts of coal to the environment and reclamation challenges.

Guiding Question:
What challenges face coal energy as a hydrocarbon?

Duration:
45 minutes

Materials:
Computer with internet access, projector, Lesson 4 Resources

Engage: Ranks of Coal
Revisit the types of coal described in the Properties of Coal lab and recall what type of coal is the majority of what is found in Wyoming? Most of Wyoming’s younger coal is subbituminous, and most of the older coal is subbituminous to bituminous. What are the common properties of subbituminous coal? Sub-bituminous coal contains less carbon, more water and is a less efficient source of heat than bituminous coal. See Lesson 4 Resources for a map of distribution of coal types across the United States.

Explore: Coal emissions
Most of the coal mined in the Powder River Basin today is 0.2-0.3% sulfur, which is why it is the very lowest sulfur and naturally the “cleanest coal” in the United States.

Despite Wyoming coal having lower emissions than other types of coal, coal overall still produces more emissions including carbon dioxide, sulfur, and other pollutants than any other fuel source on earth. Show students the graphic of carbon emissions by energy source in Lesson 4 Resources to note where subbituminous coal falls on the scale. How does Wyoming’s coal compare to other sources of coal from around the US? Use the map of coal types in the Engage section of this lesson to help make comparisons.
Explain: Policies for coal mining
While coal production is one of the most important contributors to Wyoming’s economy, it also produces less desirable environmental impacts. Coal is high in sulfur and other hazardous byproducts. When burned, coal releases carbon dioxide, as well as sulfur dioxide and other pollutants. The sulfur in coal emissions has contributed to air quality issues and acid rain. Coal burning power plants, according to BLM figures, create 13 percent of U.S. carbon dioxide emissions – more than any other single activity. The coal and power industries now face new Environmental Protection Agency emissions limits. The government has released many policies in the last several decades to help mitigate the negative effects of coal production and encourage cleaner emissions from companies.

Historically, a number of federal policies have driven the development and expansion of the coal industry in the United States. In the second half of the 20th century, emissions were identified as needing stricter regulation. Because coal has high emissions, it is subject to a number of these policies on development and production.

Many national policies developed to help manage the coal industry include:
- 1970 National Environmental Policy Act (NEPA) requires all projects with any federal support to assess potential environmental impacts before project can begin
- 1972 Clean Water Act
- 1970 Clean Air Act, last updated in 1990
- 1977 Surface Mining Control and Reclamation Act (SMCRA) - required coal industry to reclaim land
- 1986 Clean Coal Technology Act
- 1996 Energy Policy Act

Elaborate: Federal regulations on the ground
In 1970 Congress passed the Clean Air Act to help manage sulfur emissions that led to acid rain. Fortunately for Wyoming’s economy, Wyoming coal has naturally lower sulfur than other coal deposits in the US. How do you think this policy affected coal production in Wyoming? For the decades following the Clean Air Act, Powder River Basin mining increased 6 percent a year. http://www.oregonlive.com/environment/index.ssf/2012/06/coal_clash_out_of_the_gigantic.html

However, the EPA has revisited the Clean Air act and is proposing new regulations that would affect coal fired power plants, the single greatest generator of electricity in the United States. The goal of this new version of the act, the Clean Power Plan aims to help cut carbon emissions nationwide by 30% from 2005 levels by making progress toward meaningful reductions by 2020 and 2030.

Ask students to review the Clean Power Plan fact sheet and make 3-5 observations about the key points and implications http://www2.epa.gov/carbon-pollution-standards/fact-sheet-clean-power-plan

Evaluate: Economic policy analysis
Wyoming ships coal to fire power plants in 34 states across the United States. Encourage a classroom discussion or debate in response to the following questions. What are potential impacts on Wyoming as a result of new federal regulations? What could happen to coal production if coal fired power plants don’t comply with new policies? What are possible solutions to this mismatch?
Lesson 4 Resources

Distribution of coal types in the United States

Coal is the most carbon-intense fuel on earth

http://tva.maripo.com/images/Coal_Basin.gif

LESSON 5: ECONOMIC IMPACTS - COAL AND NATURAL GAS

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Lesson Overview:
In this lesson students will learn about current trends in coal production and the challenges it is facing with competition from natural gas as an alternative electricity generation source. Students will then learn about some strategies coal industry in Wyoming is using to try to combat a declining market.

Guiding Question:
What are current trends in coal production in the United States and why?

Duration:
45 minutes

Materials:
Computer with internet access, projector and/or speakers, Lesson 5 Resources

Engage: Coal Country
Download and listen to or read the transcript of some, or all, of the podcast documentary called “Power and Smoke” produced by American Public Media, discussing the history of America as built by coal: http://americanradioworks.publicradio.org/features/coal/. Some interesting segments include: 3:20-6:45; 9:00-10:40; 22:20-23:20

Explore: Coal use over time
Compare the history of coal in the US as described in the documentary with a graph of coal use in the US over time (See Lesson 5 Resources). What is happening to coal use? What is happening to the use of other energy sources for electricity production? Hypothesize what this could be a result of. What could this mean for the next stage in the history of coal in the US?

Explain: Coal Annual Report
Review the facts in the Annual Coal Report published by the Energy Information Administration and identify any trends: http://www.eia.gov/coal/annual/. Note that every “Highlight of 2013” includes the word “decreased.”
What explains this trend? This article gives us some idea: “Natural Gas and the Brutal Dethroning of King Coal” [http://www.zerohedge.com/contributed/2012-08-16/natural-gas-and-brutal-dethroning-king-coal](http://www.zerohedge.com/contributed/2012-08-16/natural-gas-and-brutal-dethroning-king-coal)

**Elaborate: Finding new markets**

Coal markets in the United States are declining as natural gas markets are booming. Low prices of natural gas and fewer emissions make it a much preferred energy alternative in the US currently. Ask students to think-pair-share in order to brainstorm some potential solutions or actions the coal industry in the US can take to help mitigate this problem.

One solution being implemented by coal companies is to export coal overseas. As of 2013 five coal export terminals were proposed in the Pacific Northwest to export coal from the Powder River Basin to China and other Asian markets. This map shows proposed rail lines to transport coal to ports in the Pacific Northwest: [http://projects.oregonlive.com/coal/map.php](http://projects.oregonlive.com/coal/map.php)

Look the graph US coal exports over time in [Lesson 5 Resources](#) and see how it compares with the trends in coal use in the United States as seen above.

**Evaluate: Advantages and disadvantages of export**

Have students complete a quick-write response, and then have a classroom discussion: Why are coal companies starting to export to other countries? What are the advantages and disadvantages to this? What is a possible outcome of this?

Have students revisit the KWL chart from the diagnostic assessment and draw a third column to write down 3-5 things they have learned about coal during this unit so far.
UNIT 5: WYOMING’S COAL

LESSON 5 RESOURCES

Annual share of fossil-fired electric power generation, 1950 - 2012*

United States Coal Exports Over Time

U.S. coal exports expected to hit record high

Asian economies, hungry for coal, stand to gain from a U.S. program meant to keep domestic power cheap and abundant.

Source: EIA

http://www.washingtonpost.com/blogs/wonkblog/wp/2012/10/18/are-u-s-taxpayers-subsidizing-asias-coal-use/
LESSON 6: CASE STUDY - POWDER RIVER BASIN

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Lesson Overview:
In this lesson, students will apply their knowledge on coal resources to a case study of coal development in Wyoming. Students will review the project overall through newspaper articles and a look at the Record of Decision regarding project development. Students will summarize the major public comments related to the project and then will research issues relating to coal development. Students will synthesize their research on coal development in Wyoming in the Summative Evaluation of the unit by preparing a newspaper/journal style article that reports on current projects in the Powder River Basin.

Guiding Question:
What is happening with coal development in Wyoming?

Duration:
45 minutes

Materials:
Computer with internet access, projector and/or speakers, newspaper articles relating to Powder River Basin, coal trivia, example opinion/editorial articles, Lesson 6 Resources

Background information:
Record of Decision and Resource Management Plan for Powder River Basin

Engage: Powder River Basin trivia!
- Wyoming has how many of the largest coal mines in the US? Answer: 6
- There are how many major coal mines in Wyoming? Answer: 17
- How many of those coal mines are in the Powder River Basin? Answer: 11
- How many coal mines are in the United States? Answer: 1,032
- What fraction of US coal is produced in the Powder River Basin? Answer: ⅓
Explore: WY Coal Forum
"Open Spaces" (http://wyomingpublicradio.net/post/wyoming-public-medias-2014-forum-coal-open-spaces) from Wyoming Public Radio describes fundamental issues surrounding coal production in the future. It explores the social, economic, and environmental challenges to Wyoming's coal industry from the perspectives of a number of stakeholders - Rocky Mountain Power VP, Clean Energy Action co-founder, and Wyoming State Treasurer. It links the geology, economics, social, and environmental components of the coal industry in Wyoming together to call for action in the future.

Explain: Powder River Basin Quick Facts
The coal mines in the Wyoming portion of the Powder River Basin produced about 382 million short tons in 2014 and employed over 6,500 personnel. Other quick facts include:
- The electricity used by 1 out of 5 homes and businesses in the US is produced from coal mined in Wyoming.
- Over 100 coal trains enter Wyoming empty and leave loaded and bound for all points daily.
- Nearly one in six Wyoming workers are directly or indirectly employed in coal development.
- The largest US coal mine, Black Thunder, lies within Wyoming’s Powder River Basin.

Elaborate: Media Literacy
There are many stakeholders with differing opinions on all sides of the conversation. Wyoming has a long history of coal development and the rest of the United States has greatly benefited from Wyoming’s valuable resources. The future of coal looks uncertain, but the outlook varies depending on who you talk to. The way coal is covered in the media varies depending on who is writing and for what source. How is this topic covered in the media?

This is an introduction to media literacy. Good journalism should be unbiased and share facts rather than opinions. Break students into small groups and have them read a number of news articles on Powder River Basin and Wyoming’s coal resources and rate each story in terms of how unbiased or objective it is. See Lesson 6 Resources for example articles and links. For each article, ask students to determine:
- The author’s main point
- Whether or not the author is biased on the issue
- What stakeholder group, if any, the author might favor

Evaluate: Coal journalism
Give the students an example of an opinion/editorial style article to read and ask them to make comparisons between the op-ed and the articles they read earlier. How does the writing style compare and contrast? What are the advantages and disadvantages of writing an objective article versus a subjective article? The goal of this activity is to prime them for the summative evaluation of this unit.
- Example op-ed from a newspaper: http://www.dallasnews.com/opinion/editorials/20110912-editorial-let-high-school-students-text-outside-class.ece
Lesson 6 Resources:

Possible news articles include:

SUMMATIVE EVALUATION: COAL JOURNALISM

*To be completed at the end of the unit

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Instructions:

Good journalism should be objective and present all the facts in an unbiased manor. The goal of this activity is for students to put biases and preconceptions aside to practice writing that presents facts and not opinions or emotions of the author. The guiding question here is: How do people discuss complex issues without bias?

Using information presented in the Open Space forum and outside research, students should prepare an objective, newspaper/journal style article style that reports on the future of coal in Wyoming. Encourage students to focus on a smaller section of the topic overall rather than the whole picture. The article should include:

- What is the issue? Why is it important?
- What are the major events? Why are they important?
- Who is involved? What are their opinions? Why do they have these opinions?