Energy Explained: The Carbon Cycle

LESSON OVERVIEW

In this lesson students learn about the carbon cycle and how human energy use impacts this cycle. Students will begin by watching the three and a half minute Inside Energy video, *The State of Energy*, to introduce the idea that humans are using more energy than in the past, and most of this energy comes from fossil fuels. Students then explore the carbon cycle, including fossil fuels, by modeling the cycle in an interactive game. Finally, students are challenged to evaluate atmospheric carbon dioxide data to develop conclusions about the effect of human energy use on the carbon cycle. The lesson can be paired with the Inside Energy lesson, "Energy Explained: How Much Energy" or taught on its own. The lesson is organized using the 5E Instructional Model. While each section builds upon the previous, educators may find that they only need to use one or two sections to meet their teaching goals.

LEARNING OBJECTIVES

Students will:

- Explore and model the carbon cycle.
- Understand that the carbon cycle consists of both slow and fast cycles.
- Connect the carbon cycle to increased energy/electricity usage through the combustion of fossil fuels.
- Evaluate atmospheric data for evidence of human impact on the carbon cycle in the past 60+ years.

GRADE LEVELS: 6-8

KEY VOCABULARY/CONCEPTS

- Fossil fuels
- Petroleum
- Natural Gas
- Coal
- Carbon cycle
- Atom
- Energy

CREDITS: Lesson developed by Tiffany Kapler. Multimedia developed by Inside Energy.

MULTIMEDIA RESOURCES

Energy Explained: Where Does It Come From And How Much Do We Use? [Video]
Carbon Cycle Game Sheets
Carbon Cycle Station Signs
Mauna Loa CO_2 Data Set

SUGGESTED TIME: 2 days*

- Day 1: Engagement, Exploration, and Explanation*
- Day 2: Elaboration

**Timing may vary if educator chooses to focus more time on students drawing or creating models of the carbon cycle.*

MATERIALS

- 8 standard six-sided dice
- One set of Carbon Cycle Game Sheets and Signs
- One set of Mauna Loa CO2 Data Sheets per student or group
- Graph paper or computers with graphing software (Excel)

LESSON PREP

Print Carbon Cycle Game Sheets and Carbon Cycle Station Signs and set up eight stations around the room. Each station should include a station sign (posted visibly on the wall), a coordinating game sheet with 6 sets of instructions, and one standard die. Ample room should be provided for tossing the die. A desk, table, or floor space should work.

THE LESSON

<table>
<tr><td>Engagement</td><td>View the Inside Energy video Energy Explained

Discuss the following:
What are some reasons that we use – on average – three times more energy than our great-grandparents did 100 years ago?
Where do you think most of the energy for electricity in our community/city/state comes from? How do you know, or why do you think this?
Is our current energy usage sustainable? Will our current sources of energy be available in the future?
Why might it be important to understand that most US energy – including electricity – comes from petroleum?
What is petroleum? Coal? Natural gas? What do they have in common?
Evaluate the discussion for current understanding as well as misconceptions. Use these points to focus and redirect during the Exploration and Explanation phases.</td></tr>
<tr><td>Exploration</td><td>Carbon cycle game

From the video we can see that, globally, fossil fuels (coal, natural gas, and petroleum) are the biggest sources of energy. Fossil fuels also are part of the carbon cycle. Use the carbon cycle game to model the flow of carbon and how fossil fuels fit into the cycle.
Each student will play the role of a carbon atom and will start at a carbon station around the room. For each “move” they will roll the die and follow the posted instructions for the number that they roll.
Allow students to play the game by starting at a station (assigned or chosen), rolling the die, and following the corresponding instructions on the game sheet for that station. Students will have to take turns rolling the die if there is more than one person/atom at the station.</td></tr>
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	3. Students should record their travels in the carbon cycle in a science journal or on a sheet of paper and should play the game for about 5 minutes, recording every single “step,” including if they are instructed to stay at the station for another turn. 4. Pause the game after 5 minutes and change out the posted instructions for the Petroleum & Natural Gas and Coal stations to the instructions labeled “Part 2.” Have students record in their notebook/list when the change occurred. 5. Resume play for 5 more minutes. The new instructions at the fossil fuel stations will instruct students to sit down at the station until instructed to go back into the cycle. Have these students make observations of the game, as they watch other students. With about 30-60 seconds to go, loudly announce: a. “Burrrrrrr! It’s cold in here. Carbon in natural gas may escape to the atmosphere as you are burned to heat our homes.” b. Turn the lights off and then on. “Phew! Good thing we have all of this coal to keep the lights on. Carbon molecules in coal may escape to the atmosphere.” c. “Start your engines! Petroleum is being burned an unprecedented rates. Carbon atoms in petroleum all release into the atmosphere at the same time.” Teacher can use lab time to observe and converse with students to **evaluate** their understanding of their journeys as carbon atoms, as well as their understanding of their experiences.
Explanation	Have students work in small groups to compare their journeys as carbon atoms and to draw or otherwise develop a visual model of the carbon cycle. After working in small groups, conduct a full class discussion. Guiding questions and discussion prompts might include: • How does the Carbon Cycle Game act as a model of the carbon cycle? Is it accurate? What are the strengths and weaknesses of the model? • Describe the carbon cycle. Is it circular? • What did you notice happening when we paused the game and switched out the cards at the coal, petroleum, and natural gas stations? What happened at the very end? (*hint: what happened at the Atmosphere Station?*). • How quickly did fossil fuels form? How quickly could they be used for fuel? • Would you describe the carbon cycle as fast or slow? Both? Explain your answer. • Would you describe fossil fuels as renewable or nonrenewable natural resources? Explain your answer. *As the teacher, you may want to add information from the Background Information about the actual lengths of time associated with the formation of the various fossil fuels to enrich this discussion.* • Are there other “stations” of the carbon cycle that were not included in the game? *Depending on time you may want to introduce other carbon sources/sinks listed in the Background information and assess how they fit into the slow or fast carbon cycles.* • Where do *you* fit in the carbon cycle? • How do humans use the various fossil fuels? What happens to the carbon when we use fossil fuels for energy? • Consider where the majority of our energy comes from as described in the video, *The State of Energy*. Is our current energy usage sustainable? *You may want to review the graphic at 0:00:52 in the video.* Teacher and students should **evaluate** student understanding of the concepts with a specific focus on the connection between the carbon cycle and human use of fossil fuels as resources.

Elaboration	As shown in the video, fossil fuels are being used for energy at an increasing rate around the globe. Where is all of the carbon going? Let's see what the atmospheric data shows us. 1. Explain that data for $C0_2$ in the atmosphere has been recorded on top of Mauna Loa volcano in Hawaii since 1958. The location is ideal because there are no human activities or significant plant growth with seasonal or daily fluctuations to influence the measurements. In other words, the measurements reflect a global trend for CO_2 in the atmosphere. 2. Have the students graph the average CO_2 level data set. If computers are available, a graphing program, such as Excel, should be used. In this case, you may wish to have them graph the data set that includes monthly averages of April and October. Alternatively, students could create the graphs on graph paper or work as a class to create a large graph on the board or chart paper (small groups could be assigned small portions of the graph to complete once the axes and scale has been established). Be sure to put year on the x-axis and $C0_2$ level on the y-axis. 3. Discussion Questions: a. What pattern do you notice in the graph? b. How does the data change over time? c. CO_2 levels were at about 280 ppm in 1750. How have CO_2 concentrations changed since then? d. What factors might contribute to these changes? e. Consider the carbon cycle. How might increasing levels of carbon in the atmosphere affect carbon in other parts of the cycle? f. Based on the graph, predict what CO_2 concentrations will be in 2020 and 2050. g. Based on the data, how has the increase in human population and increased usage of fossil fuels affected the carbon cycle? h. What additional questions does this data bring to mind? i. You only graphed the Average CO_2 concentrations. What do you notice about the April and October concentrations? What might explain their fluctuations? Possible extensions: 1. Take students on a Carbon Cycle Fieldtrip around the school grounds or out into the neighborhood. Have them identify carbon cycle activity. 2. Have students conduct research to determine specific fossil fuel usage since 1958 (the date of the first Mauna Loa data). Does the data appear to be correlated with the rising atmospheric CO_2 levels? 3. Challenge students to research the subsequent potential and actual effects of additional CO_2 in the atmosphere. 4. Complete the Inside Energy lesson, "Energy Explained: How Much Energy" to help students make personal connections to the carbon cycle as they assess their own energy usage. **Evaluate** student understanding of concepts as they apply what they have learned and consider what they still do not know.
Evaluation	Teacher and students should evaluate student learning throughout the lesson.

TEACHER RESOURCES

BSCS 5E Instructional Model[1]
The BSCS 5E Instructional Model: Personal Reflections and Contemporary Implications[2]
Earth Observatory (NASA) – The Carbon Cycle[3]

BACKGROUND INFORMATION

Fossil Fuel Formation:

Coal represents the remains of giant plants in forests and swamps hundreds of millions of years ago. The plants were covered up by soil and water and then many more layers of rock. The pressure and heat from the layers of rock above physically and chemically changed the organic plant matter into coal. The carbon from the plants remained. The most favorable conditions for coal formation were 360 to 290 million years ago. This period is known as the Carboniferous (coal-bearing) Period. Coal continued to form in lesser amounts throughout the Permian (290-250 million years ago) and the Mesozoic Era (250-65 million years ago). Most of the accumulated plant matter younger than 65 million years is generally less "mature" and does not provide high-quality coal.

Natural gas and petroleum oil are what remain of ocean animals and plants (mostly very small ones called plankton) that died and sank to the bottom of the ocean between 300 and 400 million years ago. These animals and plants were covered by sand and silt – deeper and deeper. Over time the weight and pressure of the sediments on top, combined with heat from the earth, converted the organic material into oil and gas. Lower levels of heat resulted in natural gas, while higher levels of heat resulted in oil.

Other Sources/Sinks of Carbon in the Carbon Cycle

Calcium Carbonate ($CaCO_3$) is found in the earth's crust as limestone, chalk, marble and calcite. Over millions of years, carbon from $CaCO_3$ can enter the earth's atmosphere through ***volcanic activity***. This process is part of the slow carbon cycle. $CaCO_3$ is formed by ***ocean organisms*** from dissolved CO_2 in the ocean and used to build their shells. Over millions of years, these shells can form sediment on the bottom of the ocean that is covered and slowly become part of the rock cycle - later forming limestone, chalk, marble or calcite.

[1] https://bscs.org/bscs-5e-instructional-model
[2] http://static.nsta.org/files/sc1408_10.pdf
[3] http://earthobservatory.nasa.gov/Features/CarbonCycle/page1.php

STANDARDS ALIGNMENT

Colorado State Science Standards

SC09-GR.6-S.3-GLE.3 Earth's natural resources provide the foundation for human society's physical needs. Many natural resources are nonrenewable on human timescales, while others can be renewed or recycled

Next Generation Science Standards

MS-ESS3-4. Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.

MS-LS2-3. Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.

National Standards – Benchmarks for Science Literacy

4C/M7 (Grades 6-8): Human activities, such as reducing the amount of forest cover, increasing the amount and variety of chemicals released into the atmosphere, and intensive farming, have changed the earth's land, oceans, and atmosphere. Some of these changes have decreased the capacity of the environment to support some life forms.