RESOURCE LIBRARY I LESSON

Modeling the Carbon Cycle to Inform Others

In this set of activities, students explore the power of creating visual models in science by first researching then constructing models of the rock cycle, the water cycle, and the processes of photosynthesis and respiration in jigsaw groups. Using these models, students teach other groups about their assigned topic, and then collaborate to integrate this information into a larger model of the global carbon cycle. Finally, an experiment, reading, and video about the greenhouse effect help students consider the role of greenhouse gasses in their model of the global carbon cycle. This lesson is part of the Carbon Trackers unit.

GRADES

6, 7, 8

SUBJECTS

Earth Science, Climatology

CONTENTS

3 Activities

In collaboration with

ACTIVITY 1: MATTER AND ENERGY CYCLES: RESEARCH I 1 HR 40 MINS

DIRECTIONS

This activity is part of the Carbon Trackers unit

1. Help students draw the comparison between the work they have done and will continue to do throughout this unit and the work that scientists do: make observations and ask questions.

- Read aloud or have students partner up to read the *Explorer Profile: Mark E. Olson, Plant Biologist*. Then prompt students' thinking by asking: *How was Mark Olson inspired to look at the ways plants do photosynthesis? How do scientists come up with questions to explore?*
- Follow up by showing students *The Real Process of Science* interactive chart and focusing on the "Exploration and Discovery" circle. Draw their attention to the step involving "making observations" and "asking questions" that generally leads into the "gathering data" part of "testing ideas."
- Point out that in the *Tracking Down the Carbon* activity, students made observations about the objects they sorted, which led them to generate initial ideas and note areas they want to investigate further. Explain that this is similar to what Mark E. Olson and other scientists do as they make observations and explore; questions that arise as you move through a process of research and observation are iterative.

2. Revisit the class-generated model of the carbon cycle, created in the *Tracking Down the Carbon* activity. Focus on the parts of the cycle on which students indicated a need for more information. Tell students that this activity will focus on gathering that information.

- First, review the *Know & Need to Know* chart from the *Putting the "Fossil" in Fossil Fuels* activity and remind students what they identified in the "Need to Know" column.
- Focus attention on areas that correspond to the rock cycle, water cycle, and photosynthesis and respiration cycle. Tell the class that they will split into three teams to dive into each cycle, enabling them to add more detail to the larger carbon cycle model.
- Emphasize that this activity will help students work towards answering the unit driving question (*Where does the energy in fossil fuels come from and where does it go*) and the lesson driving question (*Are fossil fuels important to Earth's matter and energy cycles?).*
    - You may also want to clearly state for students the connection between these sub-cycles and the carbon cycle: that most fossil fuel material was originally created via photosynthesis, that photosynthesizing organisms need water, and that to become fossilized this material needs to be preserved for a long time (millions of years) in rocks.

3. Break students into three teams to begin research on either the rock cycle, water cycle, or photosynthesis and respiration cycle.

- How you divide your students will depend on how large the class is. One suggestion is to break the class into six teams with roughly three students in each team if possible, with two teams focusing on the same cycle, but working separately and then coming together to compare/share their work at the end.
- Distribute the *Researching Earth's Cycles* handout to every student. This handout includes suggested articles, infographics, and videos to help them learn more about their assigned cycle. Explain that while students can help each other gather information, each student needs to complete their own document to keep and study/work from later. Review the questions on the document with the class to make sure students know what to look for in the videos and readings.
- This is an activity where you can strategically assign groups to accommodate multiple students' needs.
    - In a group of advanced readers or independent learners, it may be useful to assign one article or video to each team member. Each person can take notes on their assigned article or video, and then share the information with their group in a Jigsaw style, helping other team members complete the document.
    - Other students may benefit from taking turns reading each article aloud as a group, highlighting or underlining important points as they go.
- Remind the class of the following to help make their research successful:
    - All group members will participate equally in information gathering and information sharing.
    - Each person is responsible to ask for ideas and information from quieter group members.
    - Any individual group member, if randomly called upon at the end of the activity, should be able to summarize the ideas from all of the sources on the document.
    - Check your group for understanding by asking them specific questions about what they learned and explained. If they cannot answer them, try to explain the ideas in a new way.
- Remind them that they only need to complete the part of *Researching Earth's Cycles* that is relevant to their team's cycle right now. They will fill in the remainder in another activity.

Modification

Step 2: If students will not have easy access to one-to-one computers, you can choose to print the articles and show the videos in a class setting.

Tip

Step 2: The research materials for the water cycle are fewer and contain a video, making that cycle well-suited to students who may struggle with reading. The other two cycles have similar amounts of reading and complexity, but both are more challenging than the water cycle.

Informal Assessment

You can collect the *Researching Earth's Cycles* document from students to assess their understanding of the readings and give feedback where needed. After reviewing the documents, remember to redistribute them prior to the next activity, *Matter and Energy Cycles: Modeling*, during which students will begin to share their knowledge with other groups.

OBJECTIVES

Subjects & Disciplines

Earth Science

Learning Objectives

Students will:

- Model and describe the detailed parts and processes of either the water cycle, the rock cycle, or photosynthesis and respiration.
- Collaborate to read and synthesize across multiple scientific texts in order to describe patterns about the natural world.

Teaching Approach

- Project-based learning

Teaching Methods

- Jigsaw
- Multimedia instruction
- Research

Skills Summary

This activity targets the following skills:

- 21st Century Student Outcomes
  - Information, Media, and Technology Skills
    - Information Literacy
    - Information, Communications, and Technology Literacy
    - Media Literacy
  - Learning and Innovation Skills
    - Communication and Collaboration
  - Life and Career Skills
    - Flexibility and Adaptability
    - Initiative and Self-Direction
    - Leadership and Responsibility
    - Productivity and Accountability
    - Social and Cross-Cultural Skills
- 21st Century Themes
  - Environmental Literacy
  - Global Awareness
- Science and Engineering Practices
  - Obtaining, evaluating, and communicating information

National Standards, Principles, and Practices

COMMON CORE STATE STANDARDS FOR ENGLISH LANGUAGE ARTS & LITERACY

• **CCSS.ELA-LITERACY.RST.6-8.2**:
Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.
• **CCSS.ELA-LITERACY.SL.7.2**:
Analyze the main ideas and supporting details presented in diverse media and formats (e.g., visually, quantitatively, orally) and explain how the ideas clarify a topic, text, or issue under study.
• **CCSS.ELA-LITERACY.WHST.6-8.8**:
Gather relevant information from multiple print and digital sources, using search terms effectively; assess the credibility and accuracy of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation.
• **CCSS.ELA-LITERACY.WHST.6-8.9**:
Draw evidence from informational texts to support analysis, reflection, and research.

NEXT GENERATION SCIENCE STANDARDS

• **Crosscutting Concept 4**:
Systems and system models
• **Crosscutting Concept 5**:
Energy and matter: Flows, cycles, and conservation
• **ESS2.A: Earth Materials and Systems**:
All Earth processes are the result of energy flowing and matter cycling within and among the planet’s systems. This energy is derived from the sun and Earth’s hot interior. The energy that flows and matter that cycles produce chemical and physical changes in Earth’s materials and living organisms.   The planet’s systems interact over scales that range from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth’s history and will determine its future.
• **ESS2.C: The Roles of Water in Earth's Surface Processes**:
Water continually cycles among land, ocean, and atmosphere via transpiration, evaporation, condensation and crystallization, and precipitation, as well as downhill flows on land. (MS-ESS2-4)
• **LS1.C: Organization for Matter and Energy Flow in Organisms**:
Plants, algae (including phytoplankton), and many microorganisms use the energy from light to make sugars (food) from carbon dioxide from the atmosphere and water through the process of photosynthesis, which also releases oxygen. These sugars can be used immediately or stored for growth or later use. (MS-LS1-6)

• **MS-ESS2-1**:
Develop a model to describe the cycling of Earth’s materials and the flow of energy that drives this process.
• **MS. Matter and Energy in Organisms and Ecosystems**:
MS-LS2-3. Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem
• **PS3.D Energy in Chemical Processes and Everyday Life**:
The chemical reaction by which plants produce complex food molecules (sugars) requires an energy input (i.e., from sunlight) to occur. In this reaction, carbon dioxide and water combine to form carbon-based organic molecules and release oxygen. (secondary to MS-LS1-6) Cellular respiration in plants and animals involve chemical reactions with oxygen that release stored energy. In these processes, complex molecules containing carbon react with oxygen to produce carbon dioxide and other materials. (secondary to MS-LS1-7)
• **Science and Engineering Practice 2**:
Developing and using models

Preparation

BACKGROUND & VOCABULARY

Background Information

The global carbon cycle is the way that carbon moves through various reservoirs on Earth. There is a slower part of the carbon cycle and a faster part of the carbon cycle. Understanding how carbon moves in these two cycles requires knowledge of other sub-cycles and processes, namely photosynthesis and respiration, the rock cycle, and the water cycle.

The slow carbon cycle moves carbon through the lithosphere, atmosphere, and hydrosphere over 100- to 200-million-year timescales, primarily through the processes of the rock cycle. The fast carbon cycle moves carbon from the atmosphere into the biosphere via photosynthesis in plants and phytoplankton. It can then move back into the atmosphere if the plant matter is burned, the plants die and decay via bacterial processes, the plants are eaten by animals or people and carbon is released into the atmosphere as a product of digestion, or it is exhaled through the process of respiration.

Prior Knowledge

["Students need to understand that matter and energy move through and within various major Earth reservoirs (or “spheres”) in various important cycles to keep things in balance."]

Recommended Prior Activities

- Putting the "Fossil" in Fossil Fuels
- Researching Fossil Fuels
- Tracking Down the Carbon

Vocabulary

Term	Part of Speech	Definition
condensation	*noun*	process by which water vapor becomes liquid.
energy	*noun*	capacity to do work.
erosion	*noun*	act in which earth is worn away, often by water, wind, or ice.
evaporation	*noun*	process by which liquid water becomes water vapor.
hydrologic cycle	*noun*	system of recycling liquid, gas, and solid water throughout a planet. Also called the water cycle.
photosynthesis	*noun*	process by which plants turn water, sunlight, and carbon dioxide into water, oxygen, and simple sugars.
precipitation	*noun*	all forms in which water falls to Earth from the atmosphere.
respiration	*noun*	breathing.
rock cycle	*noun*	processes that explain the relationship between the three rock types: igneous, sedimentary, and metamorphic. Any rock type can become any other.
sedimentation	*noun*	process of accumulating small solid deposits.
sublimation	*noun*	the process by which snow or ice becomes water vapor without first melting and passing through the liquid phase.
weathering	*noun*	the breaking down or dissolving of the Earth's surface rocks and minerals.

ACTIVITY 2: MATTER AND ENERGY CYCLES: MODELING | 1 HR 40 MINS

DIRECTIONS

This activity is part of the Carbon Trackers unit.

1. Tell students that they will be sharing information and building a visual model of the cycle or processes they researched in the *Matter and Energy Cycles: Research* activity. Show them two videos on the power of models to kick off the activity.

- Begin with the short video on *Models in Marine Science* (the first video linked on the page), and follow directly with the second video on the page, *Models in Science*.
- Ask students to use the Think-Pair-Share model to answer the following questions:
  - *What is a scientific model?* (Correct response based on content of the videos: In science, a model is a representation of an idea, an object, or even a process or a system that is used to describe and explain phenomena that cannot be experienced directly.)
  - *How and why are models used in science?* (Correct response based on content of the videos: Models have a variety of uses—from explaining complex data to presenting a hypothesis. Models are a visual way of linking theory with experiment. They guide research by being simplified representations of reality that enable predictions to be developed and tested by experiment. Emphasize for students the point that models are simplified versions of the real world, and that there are assumptions involved in working with a model.)
  - *Can you think of an example of a scientific model not featured in the videos?* (Possible student responses include: scale solar system model, model of a human body, weather map on TV, model of an atom.)

2. Ask each team to use what they learned in the *Matter and Energy Cycles: Research* activity to create a more polished visual model of the cycle they have been assigned (water cycle, rock cycle, or photosynthesis and respiration).

- These may be very similar to the sketches they produced in the previous activity (on their *Researching Earth's Cycles* handout), but this is the time to finalize them to be shared with the other groups that researched the other cycles. These may also be used to present to the final audience in Lesson 3, *Educate to Inspire.*
- Briefly review the terms from the introduction to systems thinking processes (ways that matter or energy is transferred between reservoirs) and reservoirs (where matter or energy is stored).

- Present and explain the *Cycle Model Rubric* so students have a general understanding of the criteria for the models and presentation. The rubric can be used to evaluate their presentations now (though the model they are creating in this activity will only be a sub-cycle, and not the full carbon cycle) and in the final presentation in Lesson 3.
- The model should contain all relevant processes of their assigned cycle (water cycle, rock cycle, or photosynthesis or respiration), arrows showing which way flow or exchange happens, clear labels with correct scientific terms, and be visually organized and appealing to help others understand the cycle. Energy should be shown moving through the cycle, where relevant and possible, in one color, and needs to be indicated on a legend or key off to the side. If needed, use examples from the *Tracking Down the Carbon* activity to refresh their memory of the processes).
- It can be created by hand with paper, colored pencils, or using digital tools, depending on your students' experience and your access to technology.
- Allow about 15 minutes for students to create their visual models.
- As students work, circulate through the teams to support their collaboration, clarify ideas, and encourage creativity.

3. Prompt each team to present their model to the rest of the class, giving each team roughly five minutes to present.

- You may choose to use the rubric at this point to evaluate students' sub-cycle model and their presentation skills for this section. The rubric will be used again when they present a smaller piece in the class presentation for the final project, but this is a good test run of using it with each person and small group.
- The rest of the class should use the presentation to complete the relevant portion of the *Researching Earth's Cycles* handout as they listen, with particular attention paid to the sketch section where they should draw, as much as possible, the model the presenting team is showing.
- After all teams have presented their models, jigsaw the groups such that you have at least one representative from each team in a mixed group. Provide them with five extra minutes to compare their research handouts and correct errors or fill in missing pieces.

4. Have students collaborate to link their cycles into a larger carbon cycle model.

- Display the collaborative initial carbon cycle model generated in the *Tracking Down the Carbon* activity and focus on the question marks or missing pieces. Students will now use the new cycle models they have made to address those areas.

- Have students work in the mixed groups that they formed at the end of Step 3 so that each group contains at least one representative from each sub-cycle.
- Explain that their new assignment is to integrate the details and new information about the three models into the initial carbon cycle model (developed in the *Tracking Down the Carbon* activity). Emphasize that this is now a third draft of the initial carbon cycle model and the first draft of one that will be used in their final presentation to educate an outside audience, so it needs to be visually appealing and easy to interpret.

- Carefully evaluate which reservoirs and processes involve carbon or energy movement directly, and which don't. For example, the processes from the hydrologic cycle, precipitation, and evaporation aren't ways that carbon is moved, so they may be dropped from this final model because they aren't a major component of the carbon cycle itself.
- Distribute the *Cycle Model Rubric* and thoroughly review the target example so that students understand the criteria by which their revised carbon cycle model and presentation will ultimately be assessed.
- Prompt students to collaborate to create their new integrated model, giving them about 25 minutes.

Announce that teams will now share their models through a gallery walk, and then collaboratively decide upon the key features needed for their final version.

- Display each team's cycle model on the wall or on desks, and have the teams rotate through to look at the other team's models, giving them about five minutes with each.
    - Ask students to write down on sticky notes at least three strengths and three areas for improvement for each model and leave the feedback on the wall or desk near that model.

- Follow up with a class discussion. Hold up each team's model and read aloud some of the strengths and areas of improvement, asking for elaboration when needed. Ask: *What strategies did you see that were particularly effective at integrating the sub-cycles with the carbon cycle?*
- Record responses, which will help the class create the final model in the *Final Carbon Cycle Model Creation* activity.
- Ask students if they have any other ideas to think through, add, or investigate further to ensure their final class model is complete and clear. Record any questions or research avenues for later use in the *Final Carbon Cycle Model Creation* activity.

Tip

Step 2: You may also choose to engage students in adding additional criteria to the rubric.

Tip

Step 4: If you are generating digital models, be sure to have computers for each team for this activity.

Tip

Step 4: Some groups may want to start over entirely using large poster paper or butcher paper versus adding onto the initial models. It may help to have supplies like sticky notes, scissors, paper, pens/markers, masking tape, etc., to help them creatively start to link the models. The act of physically creating the rough draft of their model will help students to generate ideas.

Tip

Step 4: Students need to have printed copies of the carbon cycle model they generated in the *Tracking Down the Carbon* activity, as well as the other three models at hand to use for this step.

Rubric

Collect the models that each team creates of their assigned cycle (rock cycle, water cycle, or photosynthesis and respiration) and use the *Cycle Model Rubric* to assess the team's understanding.

OBJECTIVES

Subjects & Disciplines

Earth Science

Learning Objectives

Students will:

- Understand the detailed parts and processes of the water cycle, the rock cycle, and photosynthesis and respiration.
- Collaborate with a team to create an informative model of a cycle and use it to teach peers about that cycle.

Teaching Approach

- Project-based learning

Teaching Methods

- Cooperative learning
- Discussions
- Jigsaw

Skills Summary

This activity targets the following skills:

- 21st Century Student Outcomes
  - Learning and Innovation Skills
    - Communication and Collaboration
    - Creativity and Innovation
    - Critical Thinking and Problem Solving
  - Life and Career Skills
    - Flexibility and Adaptability
    - Leadership and Responsibility
    - Productivity and Accountability
    - Social and Cross-Cultural Skills
- 21st Century Themes
  - Environmental Literacy
  - Global Awareness
- Science and Engineering Practices
  - Developing and using models

- Obtaining, evaluating, and communicating information

National Standards, Principles, and Practices

COMMON CORE STATE STANDARDS FOR ENGLISH LANGUAGE ARTS & LITERACY

• **CCSS.ELA-LITERACY.SL.7.1:**
Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on Grade 7 topics, texts, and issues, building on others' ideas and expressing their own clearly.
• **CCSS.ELA-LITERACY.SL.7.4:**
Present claims and findings, emphasizing salient points in a focused, coherent manner with pertinent descriptions, facts, details, and examples; use appropriate eye contact, adequate volume, and clear pronunciation.

NEXT GENERATION SCIENCE STANDARDS

• **Crosscutting Concept 4:**
Systems and system models
• **Crosscutting Concept 5:**
Energy and matter: Flows, cycles, and conservation
• **ESS2.A: Earth Materials and Systems:**
All Earth processes are the result of energy flowing and matter cycling within and among the planet’s systems. This energy is derived from the sun and Earth’s hot interior. The energy that flows and matter that cycles produce chemical and physical changes in Earth’s materials and living organisms.   The planet’s systems interact over scales that range from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth’s history and will determine its future.
• **ESS2.C: The Roles of Water in Earth's Surface Processes:**
Water continually cycles among land, ocean, and atmosphere via transpiration, evaporation, condensation and crystallization, and precipitation, as well as downhill flows on land. (MS-ESS2-4)
• **LS1.C: Organization for Matter and Energy Flow in Organisms:**
Plants, algae (including phytoplankton), and many microorganisms use the energy from light to make sugars (food) from carbon dioxide from the atmosphere and water through the

process of photosynthesis, which also releases oxygen. These sugars can be used immediately or stored for growth or later use. (MS-LS1-6)

- **MS-ESS2-1:**

Develop a model to describe the cycling of Earth’s materials and the flow of energy that drives this process.

- **MS-LS2-3:**

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

- **PS3.D Energy in Chemical Processes and Everyday Life:**

The chemical reaction by which plants produce complex food molecules (sugars) requires an energy input (i.e., from sunlight) to occur. In this reaction, carbon dioxide and water combine to form carbon-based organic molecules and release oxygen. (secondary to MS-LS1-6) Cellular respiration in plants and animals involve chemical reactions with oxygen that release stored energy. In these processes, complex molecules containing carbon react with oxygen to produce carbon dioxide and other materials. (secondary to MS-LS1-7)

- **Science and Engineering Practice 2:**

Developing and using models

- **Science and Engineering Practice 8:**

Obtaining, evaluating, and communicating information

Preparation

BACKGROUND & VOCABULARY

Background Information

The global carbon cycle is the way that carbon moves through various reservoirs on Earth. There is a slower part of the carbon cycle and a faster part of the carbon cycle. Understanding how carbon moves in these two cycles requires knowledge of other sub-cycles and processes, namely photosynthesis and respiration, the rock cycle, and the water cycle.

The slow carbon cycle moves carbon through the lithosphere, atmosphere, and hydrosphere over 100- to 200-million-year timescales, primarily through the processes of the rock cycle. The fast carbon cycle moves carbon from the atmosphere into the biosphere via photosynthesis in plants and phytoplankton. It can then move back into the atmosphere if the plant matter is burned, the plants die and decay via bacterial processes, the plants are eaten by animals or people and carbon is released into the atmosphere as a product of digestion, or it is exhaled through the process of respiration.

Prior Knowledge

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Recommended Prior Activities

- Matter and Energy Cycles: Research
- Putting the "Fossil" in Fossil Fuels
- Researching Fossil Fuels
- Tracking Down the Carbon

Vocabulary

Term	Part of Speech	Definition
condensation	*noun*	process by which water vapor becomes liquid.
erosion	*noun*	act in which earth is worn away, often by water, wind, or ice.
evaporation	*noun*	process by which liquid water becomes water vapor.
hydrologic cycle	*noun*	system of recycling liquid, gas, and solid water throughout a planet. Also called the water cycle.
photosynthesis	*noun*	process by which plants turn water, sunlight, and carbon dioxide into water, oxygen, and simple sugars.
precipitation	*noun*	all forms in which water falls to Earth from the atmosphere.
respiration	*noun*	breathing.
rock cycle	*noun*	processes that explain the relationship between the three rock types: igneous, sedimentary, and metamorphic. Any rock type can become any other.
sedimentation	*noun*	process of accumulating small solid deposits.
sublimation	*noun*	the process by which snow or ice becomes water vapor without first melting and passing through the liquid phase.
weathering	*noun*	the breaking down or dissolving of the Earth's surface rocks and minerals.

ACTIVITY 3: GREENHOUSE EFFECT I 1 HR 15 MINS

DIRECTIONS

This activity is part of the Carbon Trackers unit.

1. Introduce the greenhouse effect by leading a brief class discussion.

- Ask: *What do you think happens if there is too much carbon moved from other reservoirs (or "spheres") into the atmosphere?*
  - Students will likely have ideas around global warming or the greenhouse effect. Help them get as specific as possible about what they think is happening, as well as the causes and mechanisms, so that you can target instruction to their current level of understanding.
  - During the discussion, it may be helpful to sketch their ideas on the board to get a clear idea of their understanding of the terms.
- Confirm that this activity will explore the greenhouse effect.
  - Ask: *What is a greenhouse? What does it do? How might Earth be like a greenhouse?* (Correct responses: Heat comes in through the Earth's atmosphere, but not all of it escapes, which causes the planet to get warm.)

2. Challenge students, either in pairs or small groups, to carry out a brief experiment to understand the basic concept of the greenhouse effect.

- In this experiment, students will compare the air temperatures in two bags, one sealed with added carbon dioxide from sodium bicarbonate tablets and another with no sodium bicarbonate tablets (i.e., no added carbon dioxide), as a model of the greenhouse effect.
- Distribute the *Greenhouse Effect Exploration Lab Guide* and review the steps with students.
- Prompt the students to predict the temperature of the air inside each bag and record it under the "Prediction" section of the lab guide. Then have students complete the lab with a partner or a small group.
- When the whole class has completed the investigation, lead a discussion to debrief. Emphasize the following ideas:

    - The bags are a proxy for the Earth's atmosphere. The bag with added carbon dioxide represents added greenhouse gases.
    - In a greenhouse, solar energy (light) is converted into thermal energy (heat) that can't escape the glass and thus it heats up. Incoming solar energy is mostly short wavelength (mostly visible light), and outgoing energy from the planet is mostly long wavelength (infrared).
    - Sunlight interacts with chemicals in the atmosphere and is converted into heat that remains trapped. Of the incoming solar radiation, roughly 25 percent is reflected by the atmosphere (it just bounces off and doesn't heat anything up), 25 percent is absorbed by the atmosphere (it heats things up), 5 percent is reflected by the Earth's surface, and 45 percent is absorbed by the Earth's surface. Greenhouse gasses are doing more than absorbing some energy directly from the sun; they are absorbing and then reemitting heat radiating from the Earth that would otherwise be lost to space.

3. Direct students to deepen their understanding of the greenhouse effect through a video and a reading.

- Show a short introduction video from PBS, *Global Warming: The Physics of the Greenhouse Effect*.
- Follow the video by having students read the *Greenhouse Effect* article and asking them to highlight or take notes on key information.
- Once they complete the reading, have students answer the questions in Part B of the *Greenhouse Effect Exploration Lab Guide*. Give students roughly 20 minutes to read and answer the questions.

4. Ask each student to individually respond to the following questions to help them reflect on their learning during the *Modeling the Carbon Cycle to Inform Others* lesson:

- *How do greenhouse gasses impact Earth's systems? Answer the question in two paragraphs using evidence from your readings, videos, discussions, diagrams, and the experiment you completed today.*
- Ask students to address the following in their answer:

    - Explain the science of why increased greenhouse gas emissions contribute to rising global temperatures.

- Explain how the greenhouse effect supports life on Earth, and why elevated greenhouse gasses can create a less supportive environment for life on Earth.
- Explain where greenhouse gasses come from (think back to the carbon cycle listing natural sources and human activities that contribute).
- Explain how plants impact atmospheric greenhouse gasses.

Modification

Step 2: It's best to do this experiment outdoors in bright sunlight. If this isn't possible because of weather or location, use a heat lamp to do a class demonstration in lieu of the student experiment.

Informal Assessment

Collect and review students' writing from Step 4 and the completed *Greenhouse Effect Exploration Lab Guide* to assess their understanding.

Extending the Learning

PhET Simulation

An alternative to the video and article in Step 3 is the *Greenhouse Effect PhET Simulation*, an interactive computer simulation where students explore how various levels of greenhouse gasses impact temperatures.

Global Sources of Greenhouse Gasses

If you'd like to have students explore sources of greenhouse gas emissions in a more global way, show them the graphs at the *Center for Climate and Energy Solutions*, which show how various countries and industries contribute.

OBJECTIVES

Subjects & Disciplines

Earth Science

- Climatology

Learning Objectives

Students will:

- Understand that human activities can create an increase in carbon dioxide concentrations.

Teaching Approach

- Project-based learning

Teaching Methods

- Hands-on learning
- Lab procedures
- Research

Skills Summary

This activity targets the following skills:

- Science and Engineering Practices
  - Analyzing and interpreting data
  - Constructing explanations (for science) and designing solutions (for engineering)
  - Developing and using models
  - Obtaining, evaluating, and communicating information
  - Planning and carrying out investigations

National Standards, Principles, and Practices

COMMON CORE STATE STANDARDS FOR ENGLISH LANGUAGE ARTS & LITERACY

• **CCSS.ELA-LITERACY.RST.6-8.2:**
Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.

• **CCSS.ELA-LITERACY.RST.6-8.3**:
Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.

NEXT GENERATION SCIENCE STANDARDS

• **Crosscutting Concept 7**:
Stability and change
• **Crosscutting Concepts: Cause and Effect**:
• **ESS3.D: Global Climate Change**:
Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth’s mean surface temperature (global warming). Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding of human behavior and on applying that knowledge wisely in decisions and activities. (MS-ESS3-5)
• **MS. Earth and Human Activity**:
MS-ESS3-5. Ask questions to clarify evidence of the factors that have caused the rise in global temperatures over the past century.
• **Science and Engineering Practice 2**:
Developing and using models
• **Science and Engineering Practice 3**:
Planning and carrying out investigations
• **Science and Engineering Practice 4**:
Analyzing and interpreting data
• **Science and Engineering Practice 8**:
Obtaining, evaluating, and communicating information

Preparation

BACKGROUND & VOCABULARY

Background Information

When energy from the sun enters Earth’s atmosphere, greenhouse gasses in the atmosphere such as carbon dioxide, methane, and water vapor absorb some of the energy and radiate some of it either back into space, to other molecules in the atmosphere, or to Earth’s surface.

This effect helps maintain Earth's temperature.

However, when greenhouse gasses increase in the atmosphere, they can hold onto more heat, increasing the planet's temperature and impacting climate in various ways. Fossil fuel combustion is one way that we add additional greenhouse gasses to the atmosphere at a rapid rate.

Prior Knowledge

["Students need to understand that fossil fuel combustion adds carbon dioxide emissions to the atmosphere."]

Recommended Prior Activities

- Matter and Energy Cycles: Modeling
- Matter and Energy Cycles: Research
- Putting the "Fossil" in Fossil Fuels
- Researching Fossil Fuels
- Tracking Down the Carbon

Vocabulary

Term	Part of Speech	Definition
electromagnetic radiation	*noun*	energy waves affected by both electricity and magnetic fields; includes radio waves, microwaves, infrared, visible light, ultraviolet, X-rays, and gamma rays.
greenhouse effect	*noun*	phenomenon where gases allow sunlight to enter Earth's atmosphere but make it difficult for heat to escape.
greenhouse gas	*noun*	gas in the atmosphere, such as carbon dioxide, methane, water vapor, and ozone, that absorbs solar heat reflected by the surface of the Earth, warming the atmosphere.
solar energy	*noun*	radiation from the sun.
thermal energy	*noun*	heat, measured in joules or calories.

Informal Assessment

Cooperative Learning Group Interaction (Critical Thinking, Problem Solving, Communication, Teamwork)

The teacher, acting as a team facilitator when necessary, will informally assess students' cooperative learning skills as demonstrated within their pairs and/or small groups for the duration of the lesson. Students will be evaluated based on their individual and group performance; that is, their ability to collaborate, listen attentively, and show willingness to take on various research and sharing roles as they investigate global matter and energy cycling.

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