TEACHER GUIDE

EXPLORE 2 LESSON 10

Food and Agriculture Center for Science Education

Module Question: *How could cow burps be influencing climate change?*

What We Figure Out:

We learn how matter, in the form of various carbon molecules, flows from one component of the Earth system to another. We see that the Earth system includes many places that carbon can move to, which we call carbon sinks, and the movement process itself, which we call flows. We see that burning fossil fuels can lead to carbon dioxide buildup in the atmosphere. Methane produced from cattle also moves into the atmosphere, but it is shortly thereafter converted to carbon dioxide. Carbon dioxide accumulates in the atmosphere because the inputs to the atmosphere from human burning of fossil fuels greatly outweigh how much carbon dioxide moves out of the atmosphere via photosynthesis and movement of carbon into the ocean, for example. We see that methane doesn't tend to accumulate in the atmosphere because it is converted to carbon dioxide. Therefore, methane has a shorter residence time in the atmosphere than carbon dioxide. So, while methane can contribute to the greenhouse effect, its effects are shorter-lived than carbon dioxide.

3D Learning Objective:	Time estimate:	Materials:
Students develop and use a model of how carbon flows between components of the Earth system, including among the biosphere, hydrosphere, oceans, and geosphere, through chemical, physical, geological, and biological processes.	100 minutes	Lesson 10 Student Guide Lesson 10 Student Handout Carbon Adventure Story Lesson 10 Teacher Resource Carbon Travel Game 6-sided dice for each station Chart Paper Markers

Targeted Elements

SEP:	DCI:	CCC:
MOD-H3: **Develop, revise, and/or use a model based on evidence to illustrate** and/or predict **the**	**LS2.B-H3:** **Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged among the**	**EM-H2:** **Changes of** energy and **matter in a system can be described in terms of** energy and

relationships between systems or between **components of a system.**	**biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes.**	**matter flows into, out of, and within that system.**

Directions

Part 1: Our Motivation

Ask students to revisit the Class Consensus Model from Lesson 9. Ask students what they need to know to explain our Module Question, *"How could cow burps be influencing climate change?"* that isn't present yet in their models. Listen for student responses such as:

- We don't know if human activities producing carbon dioxide or cow burps producing methane contribute more greenhouse gases to the atmosphere.
- We don't know enough about how to compare the effects of methane and carbon dioxide yet.

Build off student responses to share that we will now compare the effects of carbon dioxide and methane to better understand their relative contribution to the greenhouse effect.

Finally, point to the Greenhouse Gas and Climate category of questions on the Driving Question Board. Share a few selected questions that align with what students will investigate in the upcoming lesson.

Example student questions or ideas could include:

- Which contributes more to greenhouse gases in the atmosphere: human activities or cow burps?
- How is the greenhouse effect different for carbon dioxide and methane in the atmosphere?
- Which is worse for the atmosphere, carbon dioxide or methane?

Students can record these questions in Lesson 10 Student Guide Part 1: Our Motivation. This will help students understand how this lesson connects to what they were trying to figure out about the Module Phenomenon. Use students' questions to transition to the introduction of residence time data in this lesson.

Part 2: Analyzing Greenhouse Gas Residence Time

Introduce the residence time data set to students. Share with students that they analyze a data set showing how long carbon dioxide and methane last in the atmosphere after they are added, which is known as the **residence time** of the gases. Students can record their findings in Lesson 10 Student Guide Part 2: Analyzing Greenhouse Gas Residence Time.

Look for responses like the following example student response:

- Methane has the shortest lifetime in the atmosphere of 12 years. Carbon dioxide spends much more time in the atmosphere, at 50-200 years.

Have students share their questions about residence time on their Lesson 10 Student Guide Part 2: Analyzing Greenhouse Gas Residence Time. Look for the following student questions or similar questions:

- Why does CO_2 stay in the atmosphere longer than methane?
- Where do the gases go if they do not stay in the atmosphere?

Build off student responses to share that the class will investigate these questions in the remainder of this lesson.

STUDENT SUPPORT

Create a learning extension opportunity by encouraging students to research the residence times or greenhouse warming potential of other greenhouse gases on their own time and share their findings with the teacher or class during a later lesson.

TEACHER SUPPORT

Though greenhouse warming potential is another factor by which carbon dioxide and methane impact the greenhouse effect differently, it is not one we will focus on in this lesson. This is because the mechanism explaining why they have different global warming potentials includes scientific ideas beyond this unit's scope, such as how these molecules interact with electromagnetic radiation.

Part 3: Using a Model to Investigate Movement of Methane and Carbon Dioxide

Share with students that, to investigate why carbon dioxide and methane have different residence times in the atmosphere, they will use a hands-on model showing what happens to carbon dioxide and methane when they are added to the atmosphere.

To start, students will work with a partner and read the Lesson 10 Student Handout Carbon Adventure Story to get an overview of the model they are about to work with. Have students record a summary of what they learned about carbon in their Lesson 10 Student Guide Part 3: Using a Model to Investigate Movement of Methane and Carbon Dioxide.

Hold a brief, whole-class discussion for students to share their findings. Listen for responses that explain:

- That carbon is an atom that exists in many different types of molecules.
- The different forms of carbon molecules are present at different locations throughout the Earth, such as soil, atmosphere, oceans, and rocks. Each of these is called a carbon pool.
- The carbon cycle is the process by which carbon moves from one location to another.
- The movement of carbon from one pool to another is called a carbon flux.

STUDENT SUPPORT

For students who need additional support, consider reading the passage out loud. Stop at every paragraph break and allow students to highlight or underline unknown words. They can also discuss with a partner to reflect on what they think those words mean using context clues from the story.

Building off what students found in the reading, share that we will now look closer at how carbon molecules move from one pool to another to determine why methane and carbon dioxide stay in the atmosphere for different amounts of time. Share with students that we will use a hands-on “science theater” model called the Carbon Travel Game to act out the processes by which carbon fluxes move carbon molecules from one pool to another.

To play the first half of the Carbon Travel Game, students will need their Lesson 10 Student Guide. Direct students to Part 3: Using a Model to Investigate Movement of Methane and Carbon Dioxide. Before starting, place the carbon pool signs and Fossil Fuel cards at various locations in the room using the signs provided in the Lesson 10 Teacher Resource Carbon Travel Game. Each of those stations should have one six-sided die. If you can, provide each student with a die they can take from station to station to expedite the game.

Have all students start at the fossil fuels station to start the game. Tell students they will now model what happens to carbon dioxide after it is burned as a fossil fuel and enters the atmosphere. Working with a partner, students will roll the die to determine their flux to the next carbon pool. At each pool, students will act as various molecules that contain carbon as they move from pool to pool. Have students read their cards and ask different pairs which kinds of molecules they represent. Students will record their data in Lesson 10 Student Guide Part 3: Using a Model to Investigate Movement of Methane and Carbon Dioxide, on the Journey - Fossil Fuel Emissions Table. Students should complete ten turns/fluxes before the game ends.

TEACHER SUPPORT

You may want to demonstrate one round of the game yourself to students or have one or two students do so before starting the full game. This will allow students to see a clear example of how to enact each step of the procedure.

As students play the game, circulate the room to support students in understanding what the model represents. You can ask questions like:

- Which carbon-containing molecule are you representing right now?
- Which pool are you in? Where are you moving to?
- What process or flux are you representing right now? What mechanism is responsible for this?

After all students have completed ten rounds, move to making a class model of students' carbon fluxes. Draw the carbon pools from each station as boxes on the board or on chart paper. Ask students to come up and show their journey by adding arrows to the class model that represent each flux they recorded. They should show one arrow for each turn they took in the game, and each arrow should move from the pool they came from to the pool they arrived at.

After students have added all their fluxes to the model, it should demonstrate a large flux of carbon from fossil fuel deposits moving to the atmosphere. It should also show carbon being trapped in ocean sediment for a longer period (and movement is limited).

Take a moment for the class to analyze what the class model shows. Ask a few students to share what they notice with the class. Listen for responses that notice:

- There are a lot of arrows that go from fossil fuels to the atmosphere.
- After the carbon enters the atmosphere, it moves to a lot of different places.
- Carbon doesn't really get stored anywhere else like it did when starting in fossil fuels. This is because it takes a long time to accumulate in the sediments in the ocean.

To play the second half of the game, place the cow burp and methane cards at each station. Tell students they will model what happens to cow burps after entering the atmosphere. In this round of the game, all students will start at the Terrestrial Life station to act as cellulose in a plant that is eaten by cattle. Students will once again complete ten turns of the game and record their data in their Lesson 10 Student Guide Part 3: Using a Model to Investigate Movement of Methane and Carbon Dioxide, on the Journey – Cow Burps and Methane Table.

As students finish the game, they will return to the class model. Using a different color marker than the one they used for the first half of the game, students will show their new journey again using arrows from one carbon pool to another. This should be done on the same drawing from the first half of the activity for comparison.

Ask students to review the class model and analyze what they see. Ask a few students to share what they notice with the class. Listen for responses that notice:

- Methane is converted to carbon dioxide in the atmosphere.
- That carbon dioxide then moves to other carbon pools as it did in the first half of the game. For example, it can enter the ocean or be taken up by plants through photosynthesis.

FORMATIVE ASSESSMENT OPPORTUNITY

Students develop and use a model of how carbon flows between components of the Earth system, including among the biosphere, hydrosphere, oceans, and geosphere, through chemical, physical, geological, and biological processes.

Assessment Artifacts:

- Class consensus model of the movement of carbon through various components of the Earth system (Class Model).
- Students' use of the model to explain why carbon dioxide and methane have different residence times in the atmosphere (Lesson 10 Student Guide Part 4: Using a Model to Explain Residence Times and Greenhouse Effect for Carbon Dioxide and Methane)

Look Fors:

- Class Consensus Model shows and defines each of the different Earth system and illustrates relationships between components of the system. (MOD-H3)
- The model shows carbon exchanged among the biosphere, atmosphere, oceans, and geosphere. (EM-H2) (LS2.B-H3)
- The movement of carbon is happening through chemical, physical, geological, and biological processes. (LS2.B-H3)
- Students use the model to explain how movement of carbon from one pool to another can explain the different atmospheric residence times of carbon dioxide and methane (LS2.B-H3, EM-H2).

	Emerging	Developing	Proficient
Sample Student Response	The class model shows: • Components of the system, including soil, fossil fuels, atmospheric carbon dioxide, atmospheric	The class model shows: • Components of the system, including soil, fossil fuels, atmospheric carbon dioxide, atmospheric methane, marine life, terrestrial life, surface ocean, deep ocean, and ocean sediment.	The class model shows: • Components of the system, including soil, fossil fuels, atmospheric carbon dioxide, atmospheric methane, marine life, terrestrial life, surface ocean, deep ocean, and ocean sediment. • Fluxes of carbon from one pool to another, according to results of students' game.

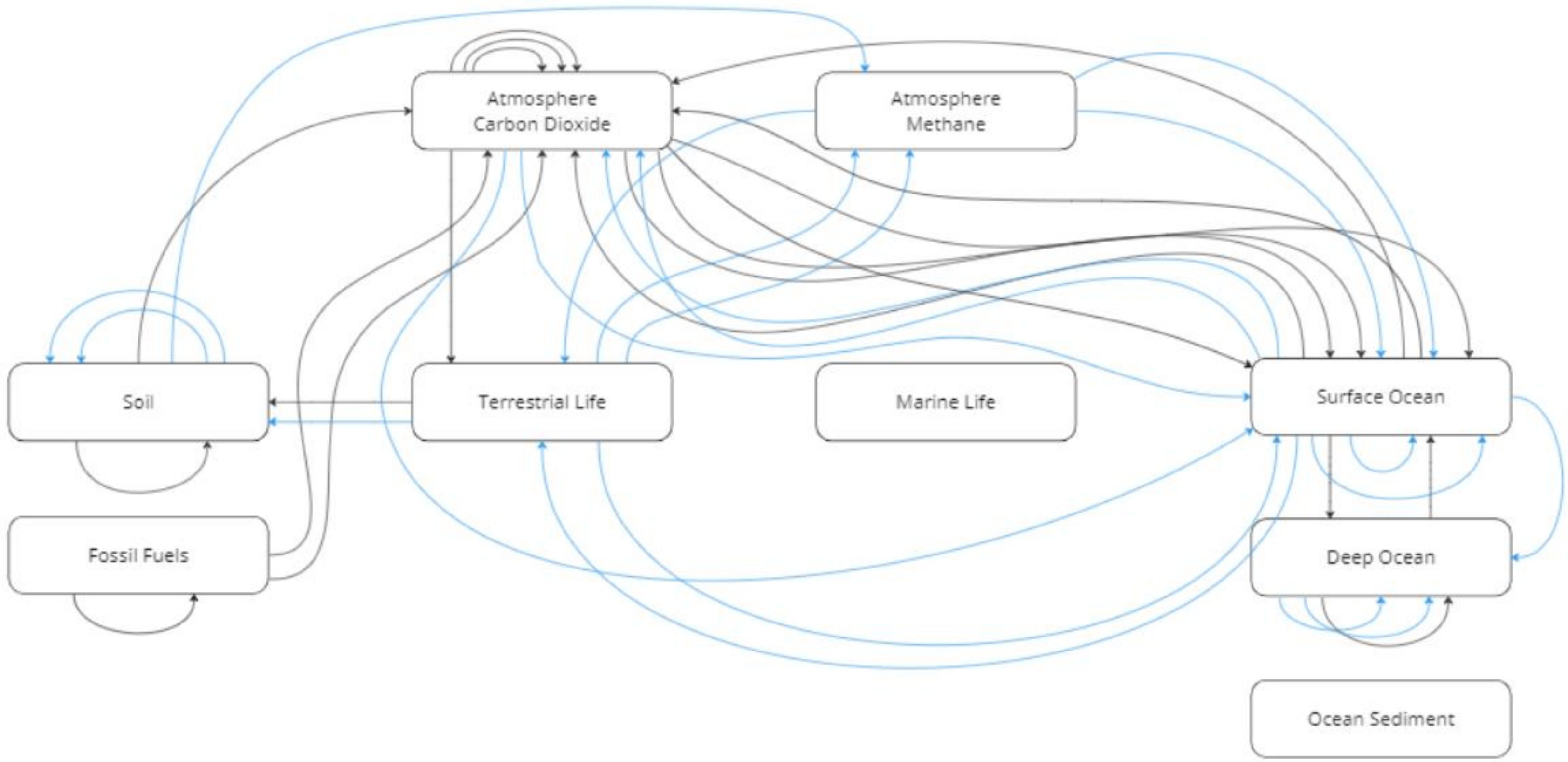
	methane, marine life, terrestrial life, surface ocean, deep ocean, and ocean sediment. • Fluxes of carbon from one pool to another, according to results of students' game. Students use the model to explain: Carbon moves from one part of the Earth system to another.	• Fluxes of carbon from one pool to another, according to results of students' game. • Movement of matter, including movement of carbon from the geosphere to the atmosphere, and movement of methane from the atmosphere to other pools. Students use the model to explain: The burning of fossil fuels greatly increased movement of carbon into the atmosphere since industrialization. This has resulted in CO2 building up in the atmosphere. Methane does not stay in the atmosphere as long as carbon dioxide (only 12 years residence time) because it gets transformed into carbon dioxide and then moves to other carbon pools.	• Movements of matter between components of the system, including how carbon dioxide in the atmosphere moves from the atmosphere to terrestrial life and to the surface ocean. • Movement of matter between components of the system, including how atmospheric methane moves to atmospheric carbon dioxide. Students use the model to explain: The burning of fossil fuels greatly increased movement of carbon into the atmosphere since industrialization. This has resulted in CO2 building up in the atmosphere because the flux of carbon from fossil fuels to the atmosphere is larger than the flux of carbon dioxide out of the atmosphere. It also has a long residence time (anywhere from 50 to 200 years). Methane does not stay in the atmosphere as long as carbon dioxide (only 12 years residence time) because it gets transformed into carbon dioxide and then moves to other carbon pools. We can see that the flux of methane into the atmosphere is about the same as the fluxes that take methane out of the atmosphere.
How to Achieve This Level	Student completes 0-1 out of 4 Look Fors	Student completes 2-3 out of 4 Look Fors	Student completes 4 out of 4 Look Fors

To Provide Additional Support for Students:
As students are working on the model, observe their progress. If students are struggling, consider providing the following prompts:

- How have you integrated the information from the cards?
- What are the different systems carbon is moving to and from?

- What is causing carbon to move from one system to another?
- What patterns and/or trends do we see with how and where carbon is moving?
- If students need support thinking about why carbon dioxide builds up in the atmosphere, and methane does not, consider using the bathtub analogy. Carbon dioxide in the atmosphere has more inputs (aka lots of water filling the tub) and less quantity of outputs (aka less water going down the drain). Methane does not tend to fill up the tub because, even though its inputs are high (e.g., activity from cattle), its outputs are high as well (conversion to CO_2). The methane from the cattle bathtub fills as fast as it drains.

Below is a sample diagram of the model of how carbon dioxide and methane are removed from the atmosphere that will be created. This is representative of two sample student journeys through both carbon and methane. Carbon and methane are shown in different colors on the model, with carbon in black and methane in blue. Please note that your actual results will vary based on their individual game outcomes.



CCSS SUPPORT

RST 9-10.4: Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 9–10 texts and topics.

When drawing out the representative journeys of carbon dioxide and methane, students will draw the various carbon pools and use arrows to show the pathways taken by each of the compounds. This requires an understanding that the pools should be in boxes and what key terms are needed for each pool relative to those in the Carbon Travel Game. Additionally, students see that arrows indicate the directionality of movement of carbon in the model.

After reviewing the class model, build off student responses to introduce the term **carbon cycle** to describe how carbon molecules move from one carbon pool to another over time.

Part 4: Using a Model to Explain Residence Times for Carbon Dioxide and Methane

As a final step in this lesson, students will return to the data of the residence times of carbon dioxide and methane. Students will use the evidence gathered in this lesson to explain why methane has a shorter residence time than carbon dioxide in the atmosphere. They can record these explanations in their Lesson 10 Student Guide Part 4: Using a Model to Explain Residence Times for Carbon Dioxide and Methane. Have students use a Think-Pair-Share routine to write their responses and share them with a peer and with the class.

LOOK FOR

This response should demonstrate that methane is transformed into carbon dioxide after 12 years and then recycled evenly among carbon pools that remove it from the atmosphere. For carbon dioxide, it builds up in the atmosphere and leads to increased global temperatures.