# TEACHER GUIDE
## EXPLAIN 2 LESSON 11

Food and Agriculture Center for Science Education

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

**What We Figure Out:**

We create models that show how cow burps contribute methane to the atmosphere and how the carbon cycle converts it to $CO_2$, which then moves out of the atmosphere. On the other hand, we show how emissions from transportation contribute additional carbon dioxide into the atmosphere, and those molecules remain in the atmosphere for a longer period and allow the greenhouse effect to take place.

| **3D Learning Objective:** | **Time estimate:** | **Materials:** |
|---|---|---|
| Students revise their greenhouse effect models to illustrate the interactions between components of the Earth system as carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere, which can influence the buildup of carbon in the atmosphere and the greenhouse effect. | 50 minutes | Lesson 11 Student Guide |

## Targeted Elements

### SEP:

**MOD-H3:**
Develop, **revise,** and/or use **a model based on evidence to illustrate** and/or predict **the relationships between systems or between components of a system.**

### DCI:

**ESS2.D-H3:**
**Changes in the atmosphere due to human activity have increased carbon dioxide concentrations and thus affect climate.**

**LS2.B-H3:**
**Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged among the**

### CCC:

**SYS-H3:**
**Models** (e.g., physical, mathematical, computer models) **can be used to simulate systems and interactions – including energy, matter,** and information **flows – within and between systems at different scales.**

**EM-H2:**

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| | | |
|---|---|---|
| | **biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes.** | **Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system.** |

## Directions

### Part 1: Our Motivation

Ask students to review their models from Lesson 9. The goal of this individual review is to see what gaps exist in the model compared to what they learned in the previous lesson. Ask students to think about what they have figured out since they last updated their models and how that new understanding can be applied to their existing models. Listen for:

- I can now show how carbon dioxide and methane move out of the atmosphere and how this influences the greenhouse effect.

Build on student responses to share that our models show the Earth system, and we can now add new components to the model - the different carbon pools that exist within the Earth system. We can use boxes as model conventions to represent carbon pools. Ask students how figuring this out will help us make progress on figuring out the Module Phenomenon.

In student responses, listen for:

- Adding a new component to the model will help us show how the methane from cow burps can contribute to the greenhouse effect.
- Adding carbon pools in the Earth system to our models can help us understand more about where carbon dioxide and methane go after they enter the atmosphere.

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:

- How does carbon move in the carbon cycle?
- Why do methane and carbon dioxide have different residence times in the atmosphere?

Students can record these questions in Lesson 11 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 investigative phenomenon.

Use students' questions to transition to the Module Question: "*How could cow burps be influencing climate change?"*

## Part 2: Revising Models of How Cow Burps May Be Influencing Climate

Share with students that they will now revise their models from Lesson 10 of how cow burps influence climate change. Remind students that they can show the movement of matter differently than the movement of energy by using different model conventions to show matter vs. energy (e.g., two different colors of arrows).

Allow students time to revise their models. They can draw their new models on the Lesson 11 Student Guide Part 2: Revising Models of How Cow Burps May Be Influencing Climate. As students work, circulate the room and ask pressing questions:

- What new ideas did you add to your model? What are you trying to show?
- Where does carbon dioxide go after it enters the atmosphere? Where does methane go? How can you represent this in the model?
- How are you showing the Earth system in your model? What are the boundaries of this system now?
- How does matter (methane and carbon dioxide) move within this system?
- How are you representing the movement of matter differently than the movement of energy?
- How does the accumulation of matter in the atmosphere influence the balance of energy in the Earth system?
- What flows of energy within, into, and out of the system should we show in this model? How will that help us explain the greenhouse effect?

**CCC SUPPORT**

Develop**, revise,** and/or use a **model based on evidence to illustrate** and/or predict **the relationships between systems or between components of a system.**

Some of the questions you ask students at this point in the lesson are designed to support students in engaging with the above CCC element. Students will represent the movement of matter between the different carbon pools of the Earth system and the movement of energy from the Sun to the Earth system, from the Earth and getting trapped in the system by greenhouse gases, and from the Earth out of the system into space.

**SEP SUPPORT**

**MOD-H3: Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.**
Some of the questions you ask students at this point in the lesson are designed to support students in engaging with the above SEP element. Students will represent the movement of matter between the different carbon pools of the Earth system.

**FORMATIVE ASSESSMENT OPPORTUNITY**
Students revise their greenhouse effect models to illustrate the interactions between components of the Earth system as carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere, which can influence the buildup of carbon in the atmosphere and the greenhouse effect.

**Assessment Artifacts:**
- Students' revised models of how cow burps could influence climate change (Lesson 11 Student Guide Part 2 Revising Models of How Cow Burps May Be Influencing Climate).

**Look Fors**:
- Models illustrate the components of the Earth system and interactions between these components. (MOD-H3) (SYS-H3)
- Models show the processes that move matter (carbon molecules) between the different components of the Earth system, such as between the atmosphere and the biosphere (LS2.B-H3)
- Model shows how energy moves into and out of the Earth system and how energy interacts with different forms of matter (EM-H2).
- Student models show a buildup of carbon in the atmosphere leading to the greenhouse effect. (ESS2.D-H3)

**Assessment Rubric:**

| | Emerging | Developing | Proficient |
|---|---|---|---|
| **Sample Student Response** | Student model shows:<br>• Light energy from the Sun entering the Earth system<br>• Atmospheric temperatures increase when thermal energy is | Student model shows:<br>• Light energy from the Sun entering the Earth system<br>• Some light energy from the Sun enters the Earth system, and some is reflected back out to space.<br>• Light energy warms the Earth.<br>• Thermal energy interacts with | Student model shows:<br>• Light energy from the Sun entering the Earth system<br>• Some light energy from the Sun enters the Earth system, and some is reflected back out to space.<br>• Light energy warms the Earth, and the Earth re-radiates thermal energy back towards |

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|---|---|---|---|
| | trapped in the Earth system.<br>• Changes in climate therefore are due to human activity, including adding carbon dioxide and methane to the atmosphere. | greenhouse gases in the atmosphere. Some thermal energy is reflected back into the Earth system, and some escapes to space.<br>• Methane traps more thermal energy in the Earth system than carbon dioxide.<br>• Atmospheric temperatures increase when thermal energy is trapped in the Earth system.<br>• Changes in climate therefore are due to human activity, including adding carbon dioxide and methane to the atmosphere. | space.<br>• Greenhouse gases accumulate in the atmosphere and move into other Earth carbon pools, such as the ocean and terrestrial life.<br>• Thermal energy interacts with greenhouse gases in the atmosphere. Some thermal energy is reflected back into the Earth system, and some escapes to space.<br>• Methane traps more thermal energy in the Earth system than carbon dioxide.<br>• Methane transforms to carbon dioxide and does not stay in the atmosphere as long as carbon dioxide.<br>• Atmospheric temperatures increase when thermal energy is trapped in the Earth system.<br>• Changes in climate therefore are due to human activity, including adding carbon dioxide and methane to 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 work on their models, approach them to see their work. If students are struggling, consider providing the following prompts:

- Asking students to refer to their resources from the previous lessons and try to find new components and processes to add to their model.
- Focusing students' attention on areas of their models that may be missing something and asking them what might help explain the connection between carbon and the greenhouse effect.

- Providing students with a graphic organizer to help keep track of the flows of matter from cows or factories to the next components of the system, and to keep track of flows of energy from the Sun into the Earth system.

## Part 3: Creating a Class Consensus Model

After students have created their individual models, hold a whole-class discussion in which the class builds a Class Consensus Model. You can use the following steps:

1. Each group should select one or more reporters to share their model. Have the first group share their model and add one part of it to the consensus model. This can be one component, arrow, relationship, or any other feature the group wants to select.
2. The next reporters can agree with, disagree with, or revise parts of the model that have already been added or can add new parts. Continue this process until the full Class Consensus Model is built.
3. As students share, some strategies you can use to help the class build the consensus model are:
    a. Helpful sentence starters such as:
        i. We agree with _____'s group, and we also want to add _____.
        ii. We disagree with _____'s group because _____
        iii. We would like to change _____ because (evidence).
    b. Use discussion prompts such as asking the class:
        i. What evidence do you have for _____?
        ii. How come you did not include ____ in the system?
        iii. How are you defining your system in your model?
        iv. How do your system components compare to ____'s?
        v. What energy flows within, into, and out of the system are we showing?
        vi. How do changes in energy flows into this system relate to the greenhouse effect?
        vii. What similarities should we show between the methane panel and the $CO_2$ panel? What differences?

As you are building the class model, if you find disagreements, follow these steps to help resolve the disagreement:

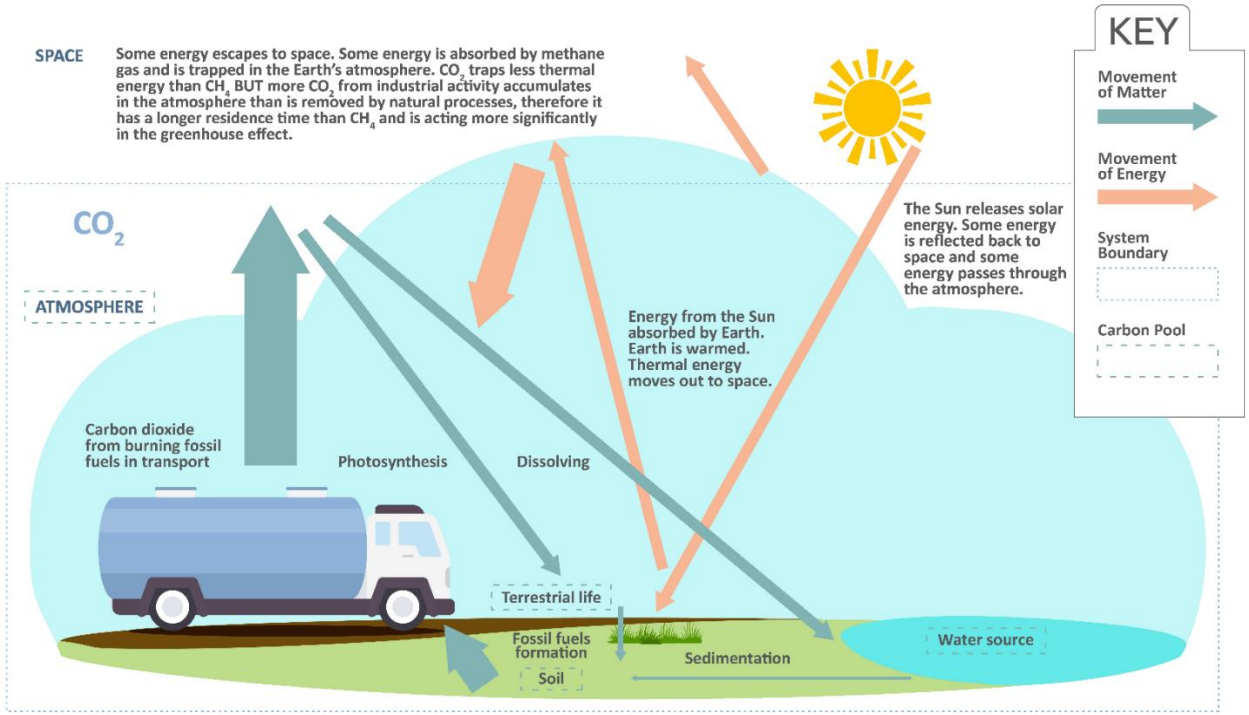
1. Summarize the two sides of the disagreement.
2. Ask the students to pause and reflect on their reasonings to be on that side.
3. Prompt students to again re-discuss the area of disagreement.
4. If students still disagree, suggest that we can represent areas of disagreement on the class model with question marks or other annotations of uncertainty.

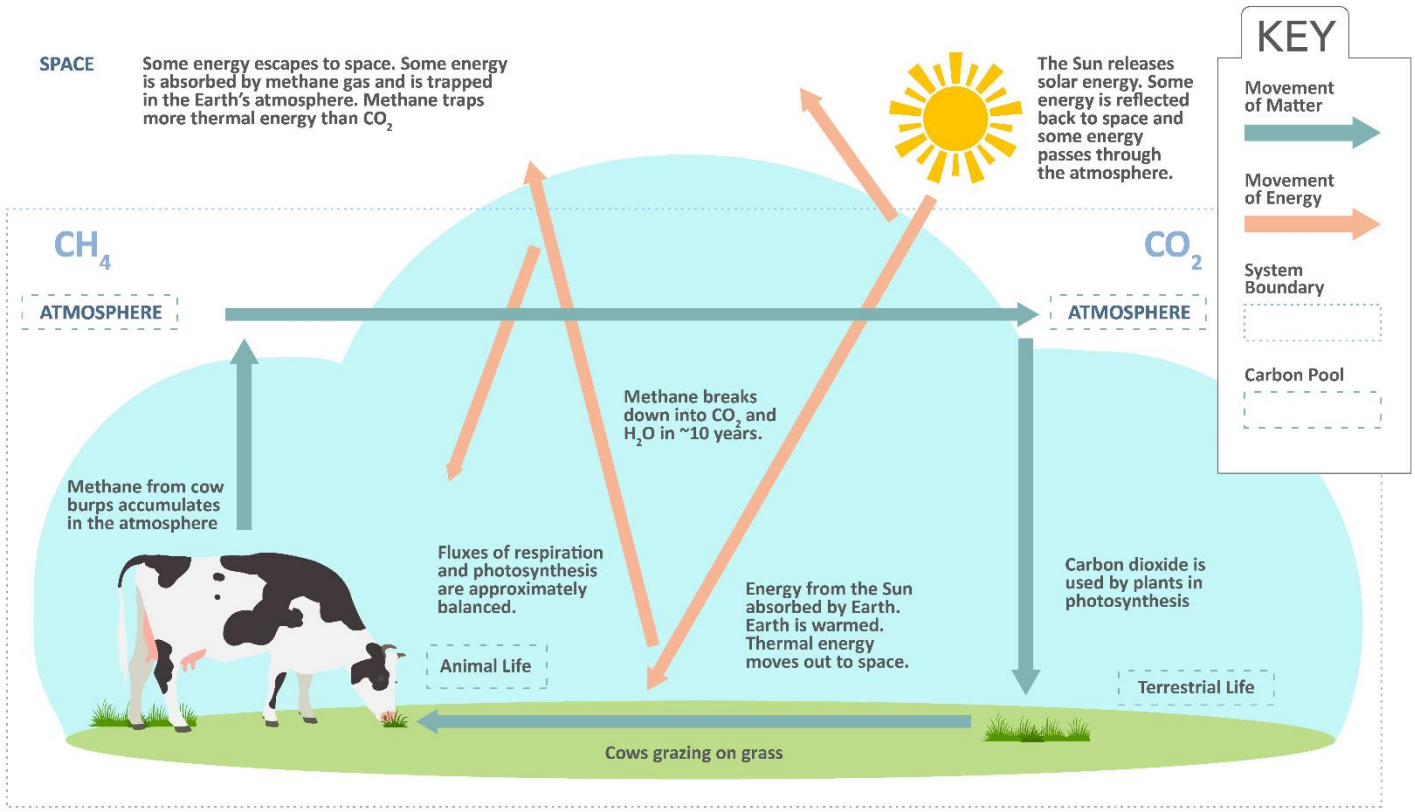
**CCSS SUPPORT**

**SL 9-10.1(d):** Respond thoughtfully to diverse perspectives, summarize points of agreement and disagreement, and, when warranted, qualify or justify their own views and understanding and make new connections considering the evidence and reasoning presented.
The goal of this standard is to challenge students to respond to diverse perspectives. At this point in the lesson, students may disagree on what elements should be presented on the model. Remind students to use evidence from their previous learning to support their perspective when necessary.

Here is one example of what a Class Consensus Model may look like, though you will want to follow the ideas of your class rather than drive them to this exact model. Students will copy the final Class Consensus Model in Lesson 11 Student Guide Part 3 Creating a Class Model.

## Example Class Consensus Model






Cattle release methane through burps into the atmosphere. Methane is a type of greenhouse gas. When a greenhouse gas, including methane and carbon dioxide, builds up in the atmosphere, it produces the greenhouse effect, which acts to reduce the outputs of thermal energy in the Earth system that is leaving to space, resulting in an increase in average surface temperature. Methane and carbon dioxide are both a part of the carbon cycle. Through the carbon cycle, carbon is exchanged through carbon pools such as Earth's oceans, plants and animals on both land and sea, soil sediments, ocean sediment, and fossil fuel deposits. The specific ways carbon is moved from one pool to another is called carbon flow or flux. These movements can include photosynthesis, making long carbon chains, carbon dioxide dissolving into water, and carbon being trapped in rock layers, among others. Carbon can be exchanged between the oceans, land, and atmosphere through the processes of photosynthesis and respiration.

These processes are particularly relevant to cow burps. In the carbon cycle, methane breaks down into carbon dioxide and water after about 12 years in the atmosphere. Photosynthesis then converts the carbon dioxide and water into energy (glucose) in the crops cattle eat, or the carbon dioxide is absorbed into the ocean to become carbonic acid. In contrast, the carbon dioxide emitted from burning fossil fuels in transit results in carbon moving from the Earth's surface to the atmosphere, then to the oceans, where it slowly moves back into other parts of the Earth's surface. This buildup prevents carbon dioxide from leaving the atmosphere quickly, resulting in its longer residence time in the atmosphere.

**STUDENT SUPPORT**

For students who show interest in the topic, you may want to ask them to research other greenhouse gases, such as Nitrous oxide ($N_2O$), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs), Sulfur hexafluoride ($SF_6$), or Nitrogen trifluoride ($NF_3$). Ask students to figure out what industrial processes these greenhouse gases are produced by and what happens to them when they enter the atmosphere.

## ?? Part 4: Asking New Questions

As a final step in this lesson, students will create a new list of questions that can help them determine additional information they need to know to help them figure out how cow burps are influencing climate change. They can write these questions on their Lesson 7 Student Guide Part 5: Asking New Questions. Add these questions to the Greenhouse Gas and Climate category of the Driving Question Board so they can continue to be referenced in the coming lessons.

To facilitate students asking questions, use the Question Formulation Technique.

1. With their group, students take 5 minutes to brainstorm questions about what they need to know about how dairy foods are created and distributed.
2. Students then look at all their questions and choose the 3-5 questions they think are most important to be answered to help them figure out the Module Question.
3. A representative from each group will then share their prioritized questions with the whole class. As students share their prioritized questions, they will add them to the Driving Question Board.

**LOOK FOR**

In student responses, listen for the following ideas:

- Which contributes more to greenhouse gases in the atmosphere: human activities or cow burps?
- How do the greenhouse gas contributions of the dairy system compare to other industries?
- What happens to Earth's temperature when there gets to be too many greenhouse gases?

- What will happen to Earth in the future if we keep generating methane and carbon dioxide?
- Is there more carbon dioxide or methane in the atmosphere?
- Is there any way to get rid of greenhouse gases in the atmosphere?

Highlight student questions that they will next investigate related to comparing the amounts of greenhouse gases that come from different industries to see if cow burps from dairy production and other aspects of the dairy system are contributing more greenhouse gases than other industries.