TEACHER GUIDE
EXPLORE 1 LESSON 8

Food and Agriculture Center for Science Education

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

What We Figure Out:

We learn that global greenhouse gas emissions and concentrations have increased over time, particularly since the Industrial Revolution, due to human activity. We learn how these increases in greenhouse gas concentrations in the atmosphere affect climate by changing the balance of energy entering and leaving the Earth system and influencing the average surface temperature of the Earth. We describe how carbon dioxide and methane play a role in the greenhouse effect.

3D Learning Objective:

Students use multiple types of models, based on model merits and limitations, to simulate the greenhouse effect, including flows of energy and matter within the Earth system and how human activity has altered the greenhouse effect.

Time estimate:

100 minutes

Materials:

Lesson 8 Student Guide
Lesson 8 Student Handout Analyze Climate Change Variables
Lesson 8 Student Handout Computer Model Directions
Lesson 8 Student Handout Computer Model Directions Key
PhET Simulation – "Greenhouse Effect" (choose the Waves version)
The Concord Consortium - Exploring Climate Change
HHMI BioInteractive – "Greenhouse Effect Video"

Targeted Elements

SEP:

MOD-H4:
Develop and/or **use multiple types of models to provide mechanistic accounts** and/or **predict phenomena, and move**

DCI:

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

CCC:

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

flexibly between model types based on merits and limitations. **DATA-H5:** **Evaluate the impact of new data on a working explanation and/or model of a proposed process or system.**		**within and between systems at different scales.**

Directions

Part 1: Our Motivation

USE OF PHENOMENA

Between Lessons 8 and 13, students will focus on the Module Phenomenon. In Lesson 14, they will return to evaluating the media claims from the Anchor Phenomenon using the knowledge they gain from this module.

Remind students that they concluded the last lesson by identifying gaps in their models of how cow burps could be influencing climate. Ask students to share what some of those gaps were. In student responses, look for the following ideas:

- I see greenhouse gases as part of the model, but I don't yet understand what they have to do with climate change.
- I have methane in my model, but I don't know what it does when it comes to the atmosphere.
- I need to know more about methane and other greenhouse gases.

Build off student responses to share that we will now gather evidence on what greenhouse gases are and how they influence global temperatures. Finally, point out 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 do cow burps influence climate?
- What is climate change?
- What do greenhouse gases have to do with climate change?

Students can record these questions in Lesson 8 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 Anchor and Module Phenomena.

Part 2: Analyzing Data on Human Activity and Climate Change

Remind students where their models left off in the previous lesson. Students agreed that they think cow burps produce methane, and this methane goes into the atmosphere and leads to climate change. Formalize students' current ideas by naming them in our current working explanation of the phenomenon: *Greenhouse gases, like methane from cow burps, can lead to climate change*. Share with students that we will look at new data in this lesson to figure out if our working explanation is accurate or needs to be revised.

Share the Lesson 8 Student Handout Analyze Climate Change Variables with students. Share that this data provides some new information about what changes in variables are happening that are related to climate change.

Students will analyze the data using a Jigsaw Method described below:

1. Create groups of three for a jigsaw where each student gets two data sets of their choice.
2. Instruct students to meet with a partner (outside of their group) who chose one of the same data sets as they did. Provide time for students to discuss and record the trends in the data set in their Lesson 8 Student Guide Part 2: Analyzing Data on Human Activity and Climate Change.
3. Next, have students meet with a new partner who also chose the second data set they did. Again, provide time for students to discuss and record the trends they see in the data set in their Lesson 8 Student Guide Part 2: Analyzing Data on Human Activity and Climate Change.

As students work to analyze the data, ask them pressing questions to help with their interpretation of the data. Questions might include:

- What trends do you see in this data?
- What do you think this trend has to do with climate change?
- What overall patterns do you see in this data?
- What are the limitations of these data?
- How can these data help us determine the causes of climate change?

STUDENT SUPPORT

If students need additional support analyzing the data sets, consider:

- Providing students with a data analysis strategy, such as breaking the graph into approximately four parts and annotating what changes they see in each part of the graph.
- Providing sentence stems for data analysis, such as:
    - As _____ increases/decreases, we see _____ increasing/decreasing.
    - This graph shows that over time, _____ was increasing/decreasing.
    - One major trend I saw in this graph was...

Students should then return to their group of three and share the trends they noticed in each data set. Instruct students to complete the remainder of the table as members of their group share their findings.

Next, the group will evaluate the impact of this new data on their working explanation of how cow burps cause climate change. They can record these answers in their Lesson 8 Student Guide Part 2: Analyzing Data on Human Activity and Climate Change. Ask students to look at the interpretations they drew from each of their data sets and consider if they still agree with the working explanation or if they would revise it considering this new evidence. As students are working, ask pressing questions such as:

- What ideas in the working explanation do you still agree with?
- What would you revise or add to the working explanation?
- What evidence from the data do you have to say that?
- What are the limitations of these data? What can they tell us, and what can they not tell us?
- Can these data help us determine the causes of climate change?

SEP SUPPORT

DATA-H5: Evaluate the impact of new data on a working explanation and/or model of a proposed process or system.

This is an opportunity for students to engage with the following SEP above. Students can do so by explicitly describing what pieces of new evidence they are using from the data sets and how this either supports their current working explanation or will lead them to revise it.

After the groups have finished discussing, write the current working explanation on the board. Hold a whole-class discussion for students to share their revisions to the working explanation. As students share, make edits to the working explanation, and use questions to help students establish a consensus on these edits with each other.

For example:

- What does everyone think about what ____ said? Do you agree or disagree?
- It sounds like I should add ____. Does everyone agree with that?

- Can anyone add to what ___ said?
- I heard you say ____. What do you think we can all take away from that?

As students agree on specific revisions to the working explanation, annotate the current explanation to show the revisions. Use strikethroughs or erase parts of the explanation students want to change and add words, phrases, or sentences as appropriate. At the end of this activity, the revised working explanation should have indications that:

- Methane from cow burps is one kind of greenhouse gas, and there are others, such as carbon dioxide.
- Carbon dioxide comes from factories, transit, and other industrial sources.
- Human greenhouse gas emissions have increased since the Industrial Revolution, and the overall atmospheric average temperature has as well.
- Dairy production and consumption have increased over time, but emissions from the dairy industry have remained stable or decreased.

STUDENT SUPPORT

For students who demonstrate high interest or increased knowledge of these social, economic, and energy topics, you may want to ask them to research each topic in more depth. Ask students to use the internet to investigate questions such as, "How was this data collected?", "What are limitations on what the data are showing?", "What are limitations on the conclusions we can draw from this data?", or "What do these data indicate about how our society uses energy?"

After you have revised the working explanation, ask students to evaluate if we have figured out the answer to our Module Question, "*How could cow burps be influencing climate change?"* Focus specifically on the cause-and-effect relationship. Ask students if, at this point, we have enough evidence to determine a cause-and-effect relationship. As students share, ask pressing questions such as:

- What kind of evidence do we have currently: correlational or causational? How do you know?
- Based on this data, can we reliably say that cow burps cause climate change? Why or why not?
- What else do we need to know about to explain how cow burps may be causing climate change?
- What do we know about methane's impact on climate when released into the atmosphere?

CCC SUPPORT

Students should have experience distinguishing between cause and effect and correlation from middle school. If your students are struggling with these questions, briefly introduce the two concepts. You can use a more familiar example, such as the correlation between

ice cream sales and shark attacks during summer months and how that relationship does not necessarily indicate a causal relationship. Then, ask students if the data they interpreted shows a correlational or cause-and-effect relationship.

Build on student responses to share that we currently have much data that shows correlations between methane from cows, the rise of greenhouse gases, and the changes in temperature on Earth, but that correlation is not causation. We will have to gather additional evidence to determine causation, such as identifying a mechanism that can link the two variables.

Part 3: Using a Series of Models of the Greenhouse Effect

Share with students that now that we have more context about how methane is only one type of greenhouse gas and that there are others, it will help us consider how all greenhouse gases contribute to climate change. Then, we can figure out if methane acts any differently than the other gases.

At this point in the lesson, students will use three computer models to investigate the mechanism of how greenhouse gas emissions may lead to rising global temperatures. Provide students with the Lesson 8 Student Handout Computer Model Directions and introduce students to the three simulations.

- PhET Simulation – "Greenhouse Effect" (choose the Waves version)
- The Concord Consortium - Exploring Climate Change
- HHMI BioInteractive – "Greenhouse Effect Video"

Explain to students that, in science, we often use multiple models to represent the same process or system. Each model can tell us something unique based on what it emphasizes. No single model is an exact representation of the real world. All models have strengths that clarify specific parts of how a phenomenon works, and all have limitations that obscure other parts of how a phenomenon works. Our task in this activity is to identify the strengths and limitations of models that show the same process and use what we can find from the models to explain how greenhouse gas emissions may be related to changing global average temperatures.

As students begin to explore each of the models, use a Think-Pair-Share to ask them how the model represents the system that was defined in the previous lesson (Earth, atmosphere, and human activity) and how the boundaries they used in their model compare to those presented in these simulations.
Build off student responses to agree that the models show the Earth, human activity, and atmosphere system, and the Sun lies outside the system. Agree that the models show matter movement by showing greenhouse gases added to the atmosphere and energy movement by tracking energy from the Sun.

As they continue to work with the models, ask students to:

- Identify which parts of the model are representing energy and which are representing matter.
- Track flows of energy and matter as the model unfolds.
- Determine how energy and matter are interacting in this system at an unobservable scale to result in different amounts of energy trapped in Earth's atmosphere.

SEP SUPPORT

MOD-H4: Develop and/or **use multiple types of models to provide mechanistic accounts** and/or **predict phenomena, and move flexibly between model types based on merits and limitations.**

As students use the models, they will reflect on the strengths and limitations of each to engage specifically with the SEP listed above.

CCC SUPPORT

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.**

Students will be directly engaging in the above CCC by considering what system is represented in the simulations and how the simulation represents the movement of matter and energy within the system.

Allow students time to work with the computer models and record their work on their Lesson 8 Student Guide Part 3: Using a Series of Models of the Greenhouse Effect.

As students work, circulate the room to ask students pressing questions. For example:

- What do you think this model is trying to show?
- What does this model seem to show well? (What are its strengths?)
- What does this model not seem to show well? (What are its limitations?)
- What is happening in this model? Can you tell me the story of what is happening?
- What does _____ represent in this model? What is it doing?
- I notice _____ in this model. How is that happening?
- What movement of matter/energy is shown in the model?
- I see the temperature changing. How can you use the movement of energy in the model to explain why the temperature is changing?

After students analyze the merits and limitations of the models, they will prepare an explanation of the mechanism for how greenhouse gas emissions may lead to an increase in Earth's average temperature to share with their peers. Students can capture this in Lesson 8 Student Guide Part 3: Using a Series of Models of the Greenhouse Effect. Student explanations should be sure to describe:

- How greenhouse gases like methane and carbon dioxide influence Earth's average temperature.
- How energy moves into and out of the Earth system, and what this has to do with the Earth's average temperature.
- The specific features from two models you found most useful in helping you understand the mechanism.

As students develop their explanations, circulate the room to ask students pressing questions such as:

- How are methane and carbon dioxide different from one another? Do they behave differently in the atmosphere?
- What is the system that each model explores? How do we know what is and is not included in this system from the computer model?
- What components are being shown in each model? Do these components help us to better understand how Earth's average temperature changes? Do they help explain how energy moves into or within the system?
- What do you consider the strengths of this computer model in explaining how Earth's average temperature increases?
- What do you think is missing from this computer model in explaining how Earth's average temperature increases?

FORMATIVE ASSESSMENT OPPORTUNITY

Students use multiple types of models, based on model merits and limitations, to simulate the greenhouse effect, including flows of energy and matter within the Earth system and how human activity has altered the greenhouse effect.

Assessment Artifacts:

- Students' identification of the merits and limitations of various models of the greenhouse effect (Lesson 8 Student Guide Part 3 Using a Series of Models of the Greenhouse Effect).
- Students' explanation of the mechanism of how Earth's temperature changes, including how features of different models most helped them (Lesson 8 Student Guide Part 3 Using a Series of Models of the Greenhouse Effect).

Look Fors:

- The strengths and limitations are identified for each computer simulation, and students' explanations incorporate these strengths and limitations (MOD-H4).

- Explanation incorporates information from each of the computer simulations to show how greenhouse gasses affect the Earth's average temperature (MOD-H4, ESS2.D-H3).
- Students' interpretations of the models and their explanations describe the mechanism, including human actions, for how different greenhouse gasses influence the atmosphere (ESS2.D-H3).
- Explanation includes how energy flows into and out of earth systems and how greenhouse gasses increase the Earth's average temperature (SYS-H3, EM-H2).

Assessment Rubric:

	Emerging	Developing	Proficient
Sample Student Response	Merits and Limitations of PhET Simulation: • Shows sunlight and infrared energy as waves. • Shows how some infrared radiation leaves to space. • Doesn't show exactly how greenhouse gases and infrared or sunlight energy interact Explanation: The Sun warms the Earth, and the Earth warms the atmosphere. The greenhouse gases trap in the heat in the	Merits and Limitations of PhET Simulation: • Shows sunlight and infrared energy as waves. • Shows the change in surface temperature • Shows balance of energy in vs. energy out. • Can change time period of GHG emissions (which also changes background). • Shows how some infrared radiation leaves to space. • Can set GHG concentration to lots or none (no actual value shown). • Doesn't show exactly how greenhouse gases and infrared or sunlight energy interact Explanation: As energy from the Sun comes down from the edge of the atmosphere, that sunlight	Merits and Limitations of PhET Simulation: • Shows sunlight and infrared energy as waves. • Shows the change in surface temperature • Shows balance of energy in vs. energy out. • Can change time period of GHG emissions (which also changes background). • Shows how some infrared radiation leaves to space. • Can set GHG concentration to lots or none (no actual value shown). • Doesn't show exactly how greenhouse gases and infrared or sunlight energy interact Explanation: As energy from the Sun comes down from the edge of the atmosphere, that sunlight energy is transformed into thermal energy. Some of the heat it brings is reabsorbed by gases at the edge of the atmosphere, causing it to warm. What

	atmosphere.	energy is transformed into thermal energy. Some of the heat it brings is reabsorbed by gases at the edge of the atmosphere, causing it to warm. What remains radiates down to warm Earth's surface as well. The energy that is reflected by Earth's surface goes back into space and some is not reflected and is absorbed by interacting with the greenhouse gas molecules, warming the Earth. As sunlight is reflected as infrared waves into the atmosphere, the molecules at Earth's surface heat up, causing a rise in temperature. When there is a greater amount of GHG in the atmosphere, less infrared radiation can pass outside of the system. The combination of all these factors causes Earth's average temperature to rise.	remains radiates down to warm Earth's surface as well. The energy that is reflected by Earth's surface goes back into space and some is not reflected and is absorbed by interacting with the greenhouse gas molecules, warming the Earth. As sunlight is reflected as infrared waves into the atmosphere, the molecules at Earth's surface heat up, causing a rise in temperature. When there is a greater amount of GHG in the atmosphere, less infrared radiation can pass outside of the system. The combination of all these factors causes Earth's average temperature to rise. The PhET Greenhouse Effect simulation showed actual surface temperature as more or less infrared radiation was absorbed by Earth, which explains how electromagnetic energy from the sun comes down from the edge of the atmosphere and is transformed into thermal energy. The other models had limitations because they did not demonstrate this in any way. The Concord Consortium Tool was helpful in showing what is happening with the actual molecules as sunlight is reflected into 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 interpreting the merits and limitations of the models and creating their explanations, approach each group to look at their work. If students are struggling, consider providing the following prompts:

- Focusing students' attention on specific features of the model that they may have missed.
- Sharing a more relatable example of how to identify strengths and limitations of models, such as two different kinds of weather maps.
- Asking students to view two models side-by-side and compare their features one at a time.
- Helping students define a system and the system boundaries as we think is best to communicate our ideas and set the focus for the analysis we are doing.

STUDENT SUPPORT
Due to the social relevance of this topic, some students might demonstrate an increased interest in these discussions and benefit from additional engagement with the concepts. Consider providing students the option to research the causes of climate change (e.g., deep history data on Earth's average atmospheric temperature, ice core sample analysis, solar and astronomic influences on climate, or paleoclimatology) further on their own time and share their findings with the class at a later lesson to honor their engagement.

Part 4: Sharing Explanations

Ask students to explain to their peers how what they learned from the simulations would help them update the class working explanation. Groups can present their new explanations to each other using a Stay and Stray Strategy.

1. After small group models are complete, ask groups to have one person "stay" at their table with the model they created to explain the model to classmates from other groups.
2. The rest of the team members "stray" to the other groups to learn about the other group's models, allot about 2 to 5 minutes per rotation.
3. During the rotation time, students can ask questions to help gain clarity on the decisions they made. Students can ask questions such as, "What parts of the models do we seem to agree on?"
4. At every signal to rotate to a new group, a different team member goes back to stay with the group's work, and everyone else (including the person who first stayed) moves on to view the next product. This allows everyone to see all but one product.
5. After visiting all groups, initial small groups regroup and share new information gathered.
6. Groups discuss new ideas and decide whether they will integrate them into their work.

Afterward, lead a whole class share out for students to share the explanations they generated and how different models have different strengths and limitations. To lead the conversation, you can start with questions such as:

- How would you explain how greenhouse gases lead to changes in average surface temperatures?
- Were all models showing greenhouse gases in the atmosphere and how they lead to climate change in the same way?
- Which models did you think had the most helpful strengths? What limitations did you notice?

Listen for responses like:

- The models are not all the same. Some were showing different parts of the system in their model than others. Because of this, they showed different components, inputs, and outputs.
- Some of the models showed more detail about how greenhouse gases move in the air and how they behave to trap additional heat.
- Some of the models had more limitations than others. A few strongly showed how greenhouse gases interact with Earth's thermal energy and their movement in the atmosphere, while others did not do this as well.
- Overall, the models did show us how radiation from the Sun could pass into Earth's atmosphere, warm the Earth, and then interact with greenhouse gasses to increase Earth's average surface temperature.

DEFINE TERM

At this point, you can define the term greenhouse effect. From the previous discussion, prompt the students to make their own definitions for the terms. You can say, "You mentioned that greenhouse gases become trapped in Earth's atmosphere to increase global temperatures. This is known as the greenhouse effect." Students might be familiar with this term, so it is important to come to an agreement on what it means before moving on to the next lesson.

Part 5: Revise the Class Working Explanation

To complete this lesson, students should be given time to revise the class working explanation based on their new understanding of the mechanism of the greenhouse effect. They can record this explanation on their Lesson 8 Student Guide Part 5: Revise the Class Working Explanation.

Show students their current working explanation from Part 2. Ask students how they would use the evidence they gathered from the simulations to revise the class working explanation of how cow burps cause climate change. Allow students to share their ideas. There is no need to reach a specific consensus at this time, so honor all student ideas shared. You can record student ideas in a list to save for the next lesson. In the next lesson, students will revise their models from Lesson 7 to better show how they think cow burps can lead to climate change.

SEP SUPPORT

DATA-H5: Evaluate the impact of new data on a working explanation and/or model of a proposed process or system.
This is a second opportunity for students to engage with the above SEP in this lesson. Students have new evidence from the different computer models that they used.

CCSS SUPPORT
WHST 9-10.5: Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience. Students engage with this standard as they revise the existing class explanation about how cow burps cause climate change. Students use the evidence they gathered via the computer models to present the information in a way that allows the class audience to understand the revised explanation.