TEACHER GUIDE
ELABORATE 2 LESSON 13

Food and Agriculture Center for Science Education

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

What We Figure Out:

Greenhouse gas emissions across industries may continue to increase over time. If these emissions remain at current-day levels or if they increase, global average temperatures are also predicted to continue to rise. We can use climate models to predict the exact degree to which global average temperatures may rise depending on the degree to which various industries change their levels of greenhouse gas emissions.

3D Learning Objective:	**Time estimate:**	**Materials:**
Students use a computational model to predict how changes to the quantity of greenhouse gas emissions by human activity in the future will influence future changes in average global temperatures.	100 minutes	Lesson 13 Student Guide Lesson 12 Student Handout Greenhouse Gas Emissions by Sector En-ROADS Simulation Lesson 13 Student Handout En-ROADS Lesson 13 Student Handout En-ROADS Key

Targeted Elements

SEP:	DCI:	CCC:
MATH-H2: **Use** mathematical, **computational,** and/or algorithmic **representations of phenomena** or design solutions **to describe and/or support claims and/or explanations.**	**ESS2.D-H4:** **Current models predict that,** although future regional climate changes will be complex and varied, **average global temperatures will continue to rise. The outcomes predicted by global climate models strongly depend on the amounts of human-generated greenhouse gases added**	**SPQ-H1:** **The significance of a phenomenon is dependent on the scale, proportion, and quantity at which it occurs.**

	to the atmosphere each year and by the ways in which these gases are absorbed by the ocean and biosphere.	

Directions

Part 1: Our Motivation

Return 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:

- What will happen to climate change in the future?
- How can we change our emissions to help stop climate change?
- What actions can be taken to help stop climate change?

Students can record these questions in Lesson 13 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 question, *"How will greenhouse gases from human activities continue to impact global temperatures in the future?"*

Part 2: Making Predictions About Future Global Temperature Changes

Ask students to share what predictions they have heard for the future of climate change. Student responses may vary widely, and that is okay at this moment. Honor and encourage the diverse perspectives on this issue that students bring to the classroom. Ask students what actions they think are being taken broadly and in their community to help reduce greenhouse gas emissions. Again, student responses may vary widely here. Give space for students to share their experiences and elevate those that seem particularly meaningful.

Build off student experiences to share those different actions taken at different scales, including all local, state, national, and global, will have consequences for the future directions that climate change takes. Remind students that they figured out that the dairy industry does

contribute methane and carbon dioxide to the atmosphere, even though its emissions are lower than those of other industries and even though methane converts to carbon dioxide in the atmosphere. Share with students that in this lesson, they will make predictions about how changes to the climate will occur based on different actions industries, such as the dairy industry, take to either further add to greenhouse gas emissions and the greenhouse effect or to reduce greenhouse gas emissions.

First, students will use data to make a prediction about how they think greenhouse gas emissions will change in the future. Direct students to return to the Lesson 12 Student Handout Greenhouse Gas Emissions by Sector, where they previously analyzed the greenhouse gas emissions by sector data. In Lesson 13 Student Guide Part 2: Making Predictions About Future Global Temperature Changes, students should record their analysis of how they think these trends of greenhouse gas emissions from each industry could change in the future and what factors those changes will depend on. Students can make these predictions based on the current trends they see in the data.

STUDENT SUPPORT

If students need additional support in making predictions, ask students to make a list of the human activities that are discussed in the data sets from Lesson 12. This list could include how greenhouse gas emissions are changing for each industry and how that would influence average global temperature change if this activity were decreased/increased.

Allow students time to analyze the data for trends over time, to make predictions about how they think these trends could change over time, and to describe what factors they think contribute to the trajectory of the trend in the future. As students work, circulate the room and ask questions to help students analyze the data, such as:

- What trend over time do you notice in this data?
- What factors seem to contribute to the way this trend is? What do people do and need in their lives that depend on this?

Hold a brief whole-class share out to have students share their predictions based on each graph. Build on student responses to confirm that the trends in many industries may indicate that overall, the greenhouse gas emissions across industries are decreasing.

Allow students an opportunity to ask questions about these predictions. Look for student questions about what quantity we need to decrease greenhouse gas emissions to prevent severe impacts of climate change. Build off student questions to share that students will next use a computational model to make a prediction about this.

Part 3: Using a Computational Model to Make Predictions

To better understand how changes to human activities can impact future changes to average temperatures, students will engage with a computational model, the En-ROADS Simulation. Students will need the Lesson 13 Student Handout En-ROADS and Lesson 13 Student Guide. Additional teacher supports can be found in the Lesson 13 Student Handout En-ROADS Key.

Before they begin, show students the main screen of the simulation and share that the simulation is meant to predict future temperature changes based on a variety of human activities. You can slide a few sliders back and forth and observe the changes that happen to future temperature predictions. Share that the simulation can make these temperature predictions because it is coded with a variety of mathematical formulas that take the input data and make predictions. The mathematical formulas encoded in the simulation are based on real-world data collected. Ask students to reflect on the previous discussion about the merits and limitations of computational models from earlier in the module. Ask them to briefly discuss the following question with an elbow partner, "The predictions output by a computer simulation are only as good as the assumptions built into them. What do you think that means?" Listen for:

- The simulation can have merits in that it probably accounts for some variables very accurately.
- The simulation is built on code that is made from known variables. Some variables might not be accounted for in how the simulation is made.
- Even though we try to add as many factors into the simulation as we are aware of, the simulation does not account for all factors that are present in real life.
- Simulations are computer code written by people and, therefore, are not perfect.

Have students open the simulation and give students instructions for setup for their activity. Students should view graphs on CO_2 emissions, CH_4 emissions, population growth, and GDP growth. Students can manipulate variables in the "Transport" category and the "Methane and Other Gases" category, among others.

Give student pairs time to use their directions to engage with the En-ROADS computer model to develop a scenario to decrease global average temperatures to under 2^{o}C.

While students are developing their scenarios, ask them to find an elbow partner and share the specifics of their scenario.

Use the following prompts:

- What choices did they make? How did those choices compare to their elbow partner?
- Are there more important factors influencing global temperature decreases that you did not previously consider?

Students should record the variables they changed and describe how the change they are making can produce fewer greenhouse gases. To find descriptions of each variable, click on the three-dot icon near the variable name. If students find any terminology confusing, encourage them to look the terms up on the internet.

CCSS SUPPORT

HSN.Q.A.1: Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.
Students engage in this standard as they analyze the EnRoads Data. Students interpret the various axes and axes scales used in the different graphs to extract trends from the data sets. This is important because the units used for each data set are unique and must be understood independently before they can be compared.

STUDENT SUPPORT

For a more structured way for students to engage with the model and debate which solutions are best, consider doing the EnRoads Climate Action Simulation game. In this game, student groups take on the roles of various global stakeholders. Each student group proposes a set of changes to the multiple variables in the simulation, and groups debate the choices each group makes to come to a compromise on the best solution that represents the needs of each stakeholder group.

FORMATIVE ASSESSMENT OPPORTUNITY

Students use a computational model to predict how changes to the quantity of greenhouse gas emissions by human activity in the future will influence future changes in average global temperatures.

Assessment Artifacts:

- Students' use of the computational model to predict how changes to industries can impact global temperature changes (Lesson 13 Student Guide Part 3 Using a Computational Model to Make Predictions)
- Students' explanation of how the computational model helped them understand how different industrial systems' contributions to greenhouse gas emissions and their impacts on future global temperature changes (Lesson 13 Student Guide Part 3 Using a Computational Model to Make Predictions)

Look Fors:

- Students use the computational model to predict changes to the quantity of greenhouse gas emissions by human activity in the future. (MATH-H2) (ESS2.D-H4) (SPQ-H1)

- Students use the computational model to determine how human activity in the future will affect average global temperatures. (MATH-H2) (ESS.D-H4)
- Students use the computational model to propose multiple solutions to reduce the quantity of greenhouse gas emissions by human activity in the future. (MATH-H2) (ESS.D-H2)

Assessment Rubric:

	Emerging	Developing	Proficient
Sample Student Response	Example Variable and Prediction: More taxes on the coal industry could result in less coal being burned. Explanation: The simulation says that global average temperatures would increase by +3.6 C. But if we change our actions, like make more taxes on coal, there will be less of a temperature increase.	Example Variable and Prediction: More taxes on the coal industry would result in burning of coal for electricity being more expensive, which might make it be used less and thus produce less greenhouse gas emissions. Explanation: If various industrial systems, including agricultural systems, remain on the same path, global average temperatures could increase by an estimated +3.6 C. One of the strongest merits to this computational model is that it is clear that if we make certain changes to various industry emissions, we can have X% impact on the overall temperature changes Earth experiences. The simulation showed that, by increasing energy efficiency and creating taxes on natural gas, oil, and coal, for example, GHG emissions could be reduced.	Example Variable and Prediction: More taxes on the coal industry would result in burning of coal for electricity being more expensive, which might make it be used less and thus produce less greenhouse gas emissions. Explanation: If various industrial systems, including agricultural systems, remain on the same path, global average temperatures could increase by an estimated +3.6oC. One of the strongest merits to this computational model is that it is clear that if we make certain changes to various industry emissions, we can have X% impact on the overall temperature changes Earth experiences. The simulation showed that, by increasing energy efficiency and creating taxes on natural gas, oil, and coal, for example, GHG emissions could be reduced. Additionally, low population and economic growth tend to have a large impact on the temperature reduction. Carbon removal technologies also play a role in future GHG emissions. This is where agriculture systems (particularly the dairy system) could play a role in

			reducing methane and other gases being emitted into the atmosphere. Developing or strengthening existing solutions to mitigate negative impacts on GHG emissions of methane could make a difference in decreasing global temperatures. This computational model has a few limitations, as there are other policy assumptions that are not built into this system for comparison. It also does not give specifics on what "high" and "low" mean quantitatively, so it is up for interpretation by people who are using the scenarios it generates to develop policy.
How to Achieve This Level	Student completes 0 out of 3 Look Fors	Student completes 1-2 out of 3 Look Fors	Student completes 3 out of 3 Look Fors

To Provide Additional Support for Students:

As students are working, move around the room to see their progress. If students are struggling, consider providing the following prompts:

- Why are we using this computer model?
- What are the different things we can change in the computer simulation?
- How easy or difficult would it be to change these different things in society?
- According to this simulation, what would happen if we did nothing?
- What things in the simulation increase greenhouse gas emissions? How do you know?
- What things in the simulation decrease greenhouse gas emissions?
- What choices do you think we as a society could change to reduce greenhouse gas emissions? Why would some changes be harder than others to implement?
- What were the strengths of this model? What were its limitations?

After successfully achieving the 2°C goal, students should reflect on what they found and explain how this model was useful to understand and describe different industrial systems' contributions of GHGs to the atmosphere and how the different variables can influence future global temperature changes. They can record this on their Lesson 13 Student Guide Part 3: Using a Computation Model to Make Predictions.

Hold a whole-class discussion to have students share their reflections on using the model. Use a Random Reporter routine to make sure you hear from a representative from each student pair. Build off student contributions to conclude:

- The model was useful in visualizing how different changes to different variables can potentially affect future changes to global temperature.
- The model has many strengths, including how you can manipulate many variables.
- It is limited in that there are likely many more variables that influence future climate change that the model does not take into account.