GREENHOUSE GASES

AN EDUCATIONAL RESOURCE

This resource was developed by the American Farm Bureau Foundation for Agriculture®
with funding from the Oklahoma Beef Council through the Beef Checkoff.

Food and Agriculture
Center for Science Education

OKLAHOMA BEEF COUNCIL
Funded by Beef Farmers and Ranchers

FOR GRADES 10–12

In this series of high school lessons and labs, students begin by exploring how energy flows in a system by comparing what happens when chocolate is placed under an incandescent lightbulb and a light-emitting diode (LED) bulb. They discover that since the LED bulb intakes less energy than the incandescent bulb that it also emits less heat energy. Students then investigate by exploring and expanding to other energy system inputs and outputs, focusing on cattle, methane emissions, and the biogenic carbon cycle. Students create models to make sense of and explain how various cattle feed (inputs) can alter the quantity of methane (outputs) in the cycling of matter and flow of energy in aerobic and anaerobic conditions through the cattle's digestion system.

Targeted Next Generation Science Standards (NGSS) Performance Expectations

HS-LS2-3

Targeted SEPs

- *Asking Questions & Defining Problems*
- *Developing & Using Models*
- *Constructing Explanations & Designing Solutions*

HS-LS2-4

Targeted DCIs

- LS2.B: Cycles of Matter and Energy Transfer in Ecosystems
- ESS3.D: Global Climate Change

HS-ESS3-6

Targeted CCCs

- *Energy & Matter*
- *Cause & Effect*
- *Systems & System Models*

Table of Contents:

LESSON 1 Engage – Sticky Situations ____ 1

LESSON 2 Explore – What is the Cost of a Burp? ____ 8

LESSON 3 Explain – Beef Cattle Energy Model ____ 15

LESSON 4 Elaborate & Evaluate – One Small Step for Cattle, One Giant Step for Mankind ____ 17

AMERICAN FARM BUREAU FOUNDATION FOR AGRICULTURE®

The American Farm Bureau Foundation for Agriculture® is building awareness, understanding and a positive public perception of agriculture through education.

800-443-8456 | www.agfoundation.org

OKLAHOMA BEEF COUNCIL
Funded by Beef Farmers and Ranchers

The Oklahoma Beef Council's mission is to enhance beef demand by strengthening consumer trust and exceeding consumer expectations.

405-840-3777 | www.oklabeef.org

ENGAGE — STICKY SITUATIONS

Learning Target(s)

Ask questions that arise from careful observation of unexpected results to clarify and seek additional information about how heat caused the chocolate to melt in one system but not the other.

Use data to develop a model based on evidence to explain the flow of energy and cycling of matter in an incandescent bulb and LED lightbulb.

Guiding Question

Why do some lightbulbs melt chocolate and others do not?

Cause & Effect

Energy & Matter

Asking Questions & Defining Problems

Activity

(1–2 days)

Purpose:

Beef cattle require energetic inputs, in the form of nutrients from feed, to survive. Some of this input energy cattle utilize (example: for maintenance and growth), and some they release as waste from their system (example: methane gas). Variations in the input energy provided to cattle in feed impacts the resulting waste energy outputs from their "system" (note: for the sake of the study of energy flow, we are calling one beef animal a "system" into which and from which energy flows). This lab looks at the energy wasted by different types of light bulbs to aid students in making connections between energy inputs and outputs. This information will benefit later lessons where students should connect the concept of conserving energy with methods for reducing waste energy outputs from the beef animal system.

In this Engage lesson, students will analyze the conditions that cause chocolate to melt. They will compare two different light bulbs, one incandescent bulb and one LED bulb, to recognize the differences in energy transfer (heat energy output) resulting from the different bulbs (input). As the chocolate melts, students will see how energy waste results (output) from the different energy inputs for the two bulbs (light bulb type/lux).

Melting Chocolate Lab

Students will work in pairs to observe the differences that occur in the melting chocolate due to the characteristics of the light bulb the chocolate is placed under. Using a "Notice & Wonder" chart (see Activity Worksheet), students will work to make sense of the phenomena to create a model with an explanation later in the lessons.

At their station, students will place a piece of chocolate on a paper towel below each lamp (one lamp with an LED bulb, one lamp with an incandescent bulb). They will then turn on both lamps and record the temperature of each lamp in one-minute increments. For each temperature recorded, students will write their observation of the chocolate under each bulb in the table in their science journal (see table description below). After 10 minutes, the students will write a final observation of what occurred during the lab, including an explanation as to why what they observed happened.

After the lab, students will use their data, observations, and questions to discuss what happened during the lab and why. Gather all of the student's observations and questions to form a question board. Discuss similarities and differences among the observations and questions to move toward a consensus of what they noticed and what they need to learn more about. (Teacher info: Energy flow: the incandescent lightbulb that melts the chocolate releases energy in the form of heat from its system. The LED light bulb does not intake as much energy and does not release as much heat.)

Using a blank Sankey model (with no explanation at this point), the students will complete the diagram to form an explanation of the system on their own for both bulb types. Review the diagrams, discussing similarities and differences between the models. Upon explanation, students will draw two different Sankey diagrams for the two different lightbulbs to demonstrate what they think happened during the lab *(HS-LS2-3)*.

What the Teacher Does
The teacher will introduce the activity, raise questions, and provide background information, as needed, while students conduct the lab. Teachers should allow the students freedom to explore and question the outcomes.

What the Students Do
The students will form hypotheses, ask questions, and conduct the experiment to determine why the outcomes are happening.

Facilitation & Discussion Strategies

- If students seem apprehensive to share, you can have them share in groups first and then report out.
- As students complete the activity, facilitate discussion within the groups by asking your students critical thinking questions. Such questions include (Paul & Elder, 2014):

Clarity

- *Could you elaborate further?*
- *Could you give me an example?*
- *Could you illustrate what you mean?*

Accuracy

- *How could we check on that?*
- *How could we find out if that is true?*
- *How could we verify or test that?*

Precision

- *Could you be more specific?*
- *Could you give me more details?*
- *Could you be more exact?*

Relevance

- *How does that relate to the problem?*
- *How does that bear on the question?*
- *How does that help us with the issue?*

Depth

- *What factors make this a difficult problem?*
- *What are some of the complexities of this question?*
- *What are some of the difficulties we need to deal with?*

Breadth

- *Do we need to look at this from another perspective?*
- *Do we need to consider another point of view?*
- *Do we need to look at this in other ways?*

Logic

- *Does all this make sense together?*
- *Does your first paragraph fit with your last?*
- *Does what you say follow from the evidence?*

Significance

- *Is this the most important problem to consider?*
- *Is this the central idea to focus on?*
- *Which of these facts are most important?*

Fairness

- *Do I have any vested interest in this issue?*
- *Am I sympathetically representing the viewpoints of others?*

Differentiation Strategies

- Students can be placed in groups to create their concept maps (described in detail below).
- Students can be placed in groups to create their Sankey diagrams.
- Together, as a class, you can create the Sankey diagram for the Incandescent bulb and have students create the Sankey diagram for the LED bulb.
- Extension: Have students create a Sankey diagram for another bulb type (e.g., fluorescent).
- Extension: Have students create a Sankey diagram to demonstrate the energy inputs and outputs of humans. This Sankey diagram can be connected to cattle inputs and outputs.

Linking question from Engage to Explore:

Your Sankey diagrams represent energy flow in two different light bulb systems; how might a Sankey diagram represent energy flow in other systems such as a beef animal's system?

Detailed Learning Plan

Materials:

1. Lamps (number depends on how many stations set up)
2. Incandescent bulb (60 Watt) (1 per station)
3. LED bulb (60 Watt) (1 per station)
4. Infrared (IR) thermometer
5. Chocolate
6. Paper towels
7. Science journals
8. Sankey Model Worksheet
9. Activity Sheet

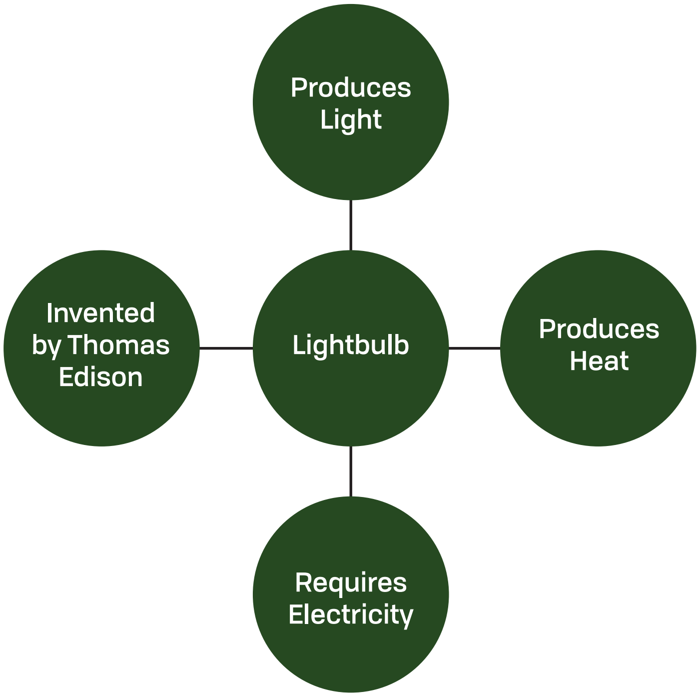
   *Note: Make sure the lightbulbs are the same equivalency (i.e., both 60W).

Lab Set Up:

1. Set stations up around the room before the start of the lab. The number of stations depends on group size.
2. At each station, place a lamp with an LED bulb (sample A), a lamp with an incandescent bulb (sample B), and paper towels. You will hand the chocolate out to the students when they are ready to start the lab.

Introduction:

As class begins, hold up a lightbulb and ask students to create a concept map to highlight what they know about the lightbulb, focusing on energy (5 minutes).

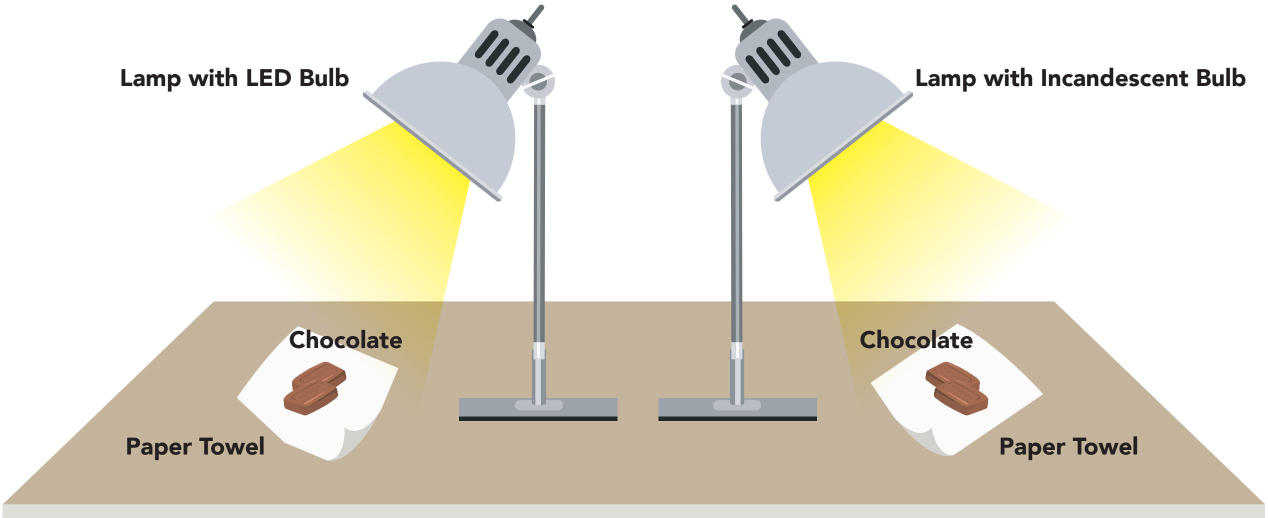


Concept Map Example:

Draw a concept map on the board, and have students share what they recorded on their map to create a class map (10 min). Use this map to guide any misconceptions presented and begin the conversation around inputs and outputs of energy.

Upon completion of the whole class concept map, explain to the students that they will be doing an investigation to further their knowledge on this topic.

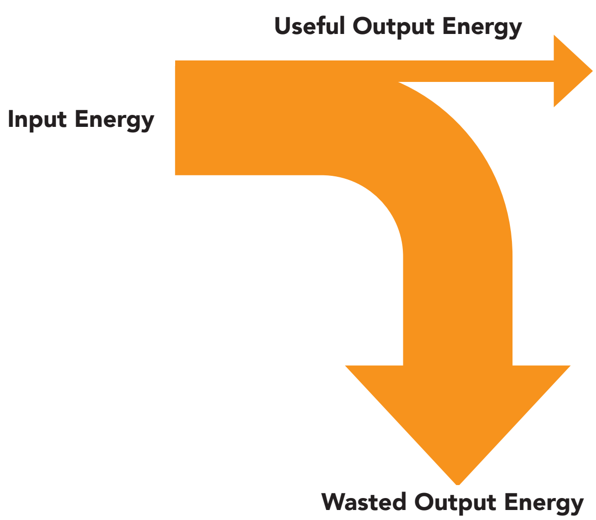
Station Setup



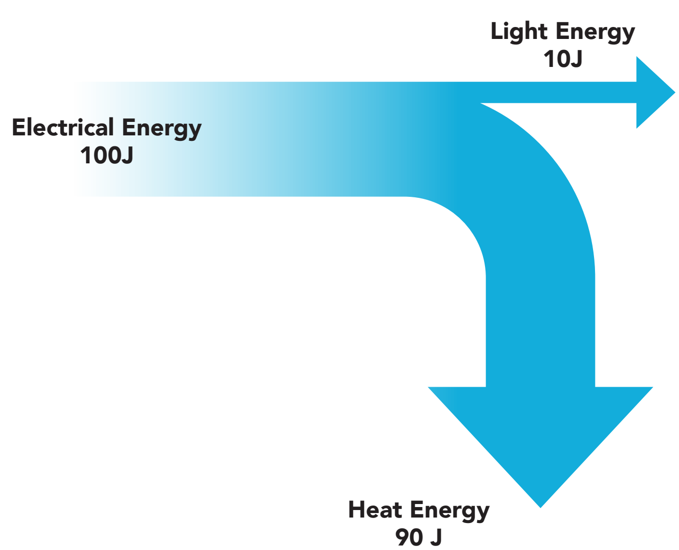
Lab Procedure:

1. Hand out the activity sheet and go over the procedure with your students (10 min).
2. Have the students draw a model in their science journals of what they think will occur during the experiment, labeling their model to aid in their explanation (Part 1 – Activity Worksheet).
3. Provide the lux reading for each bulb for them to record on their activity sheet.
4. Lab Explanation/Review (5 min): Tell the students to come to the teacher to get their chocolate. They will then go to their assigned station to begin the experiment. At their station, they will place a piece of chocolate on a paper towel below each lamp. They will then turn on both lamps, recording the temperature in 1-minute increments. For each temperature recorded, students will write their observations ("Notice") and questions ("Wonder") of the chocolate for each test (A and B) in the table included in the Activity Worksheet. After 10 minutes, the students will write a final observation of what occurred during the lab, including an explanation as to why. Students might choose to include pictures throughout the lab.
5. Divide the class into groups of three or four students each, and they should begin the lab.
6. Students will complete the data collection and conclusions (20 min).
7. After the lab is complete, as a class, discuss what happened during the lab and why with the students using their data, observations, and questions as a guide (20 min). (Teacher info: Energy flow: the incandescent lightbulb that melts the chocolate releases energy in the form of heat from its system. The other (LED) light bulb does not intake as much energy and does not release it as heat.
8. Have students write their observations and questions on Post-it notes and gather all of the student's observations and questions to form a question board (10 min).
9. Discuss similarities and differences among the observations and questions to move toward a consensus of what they noticed and what they need to learn more about (15 min).
10. Discuss reasons for varying amounts of heat generated from the two lightbulbs. Remind students that in some cases, heat is the desired product, such as warming lamps for food, or incubation. However, light bulbs would ideally produce no heat. Also, ask if this is possible. Electromagnetic energy (electricity) is converted into heat and light in a light bulb, which is also an electromagnetic form of energy (potential to kinetic) (15 min).
11. Using a blank Sankey model (see Sankey model worksheet) (with no explanation at this point), the students will complete the diagram to form an explanation of the system on their own for both bulb types. Review the diagrams, discussing similarities and differences between the models (15 min).
12. After reaching a consensus, based upon the students' explanations, create a class Sankey model to explain the melting chocolate (10 min).
13. Show the students an example of a completed Sankey diagram (see below), explaining that Sankey diagrams are used to visually represent how energy flows through a system (5 min), and have students draw two different Sankey diagrams for the two different lightbulbs to demonstrate what they think happened during the lab (20 min — This activity could be for homework if needed due to time constraints).

Sankey Diagram Example:



Possible Incandescent Lightbulb Example:



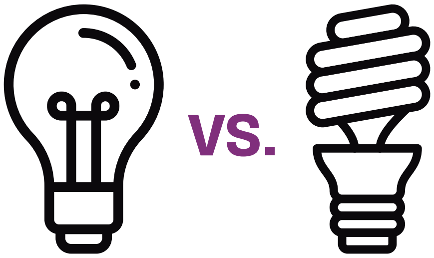
STICKY SITUATIONS

Purpose

Different variables impact different energetic inputs into the beef animal system on energetic outputs from the system. For example, the quality of food we feed cattle impact the resulting energy waste. Lighting accounts for 20-25% of all the electricity used in the United States. On average a household uses 5-10% of its energy for lighting. A commercial industry on the other hand consumes 20–30% of their energy in lighting only. 50% or more of the energy used is wasted by obsolete equipment, inadequate maintenance, or inefficient use.

Equipment

1. Lamps (number depends on how many stations set up)
2. Incandescent bulb (60 Watt) (1 per station)
3. LED bulb (1 per station)
4. Infrared (IR) thermometer
5. Chocolate
6. Paper towels
7. Activity Worksheet (this page)
8. Science journals



Procedure — Part I

1. Have students draw a model in their science journals of what they think will happen during the experiment, labeling their model for further explanation.
2. Break into groups of 3–4 students.
3. Examine your light bulbs. Record the watts consumed by each bulb in the appropriate space on the Data Table (Watts, W).
4. Record room temperature by pointing the IR thermometer at the bulbs before they are turned on. Hold the IR thermometer ~10 cm away from the bulb and point it directly at the center of the bulb surface. This should be the starting temperature for both light bulbs (T_s). Record in Data Table.
5. Turn on both light bulbs.
6. After 1 minute, measure the temperature from 10 cm away from each bulb. Record these final temperatures (T_f) in the Data Table.
7. Continue to measure the temperature in 1-minute increments, recording any changes you observe that occur to the chocolate (3rd column).
8. Calculate the net change in temperature, ΔT ($\Delta T = T_f - T_s$) after 10 minutes.

NAME: ______________________ **DATE:** __________ **CLASS PERIOD:** __________

STICKY SITUATIONS

	Incandescent Bulb	Light Emitting Diode (LED)	Notice (What did you observe?)	Wonder (What do you question based on your observations?)
Watts consumed				
Starting temperature, T_S (°C)				
Temperature at 1 min. (°C)				
Temperature at 2 min. (°C)				
Temperature at 3 min. (°C)				
Temperature at 4 min. (°C)				
Temperature at 5 min. (°C)				
Temperature at 6 min. (°C)				
Temperature at 7 min. (°C)				
Temperature at 8 min. (°C)				
Temperature at 9 min. (°C)				
Final temperature (10 min), T_f (°C)				
Change in Temperature $\Delta T = T_f - T_S$, (°C)				
Light emitted (Lux)				

NAME: ______________________ **DATE:** ____________ **CLASS PERIOD:** ____________

STICKY SITUATIONS

Part II. Conclusions

1. What did you observe during this lab?

2. Explain your observations.

3. Which bulb produces more heat (represented by a change in temperature)?

4. The main purpose of a light bulb is to provide light, not heat. Knowing this, explain the benefits of using LED light bulbs instead of incandescent bulb.

EXPLORE — WHAT IS THE COST OF A BURP?

Learning Target(s)

Part 1: **Observe how "anaerobic digestion" with the production of CO_2 and methane works in nature and engineered systems.**

Investigate and describe the connection existing between energy waste and climate change.

Part 2: **Use data to discuss energy flow into and out of the animal.**

Guiding Questions

Part 1: **What are the energy inputs and energy outputs of the beef animal system?**

Part 2: **How are beef animals able to utilize structural carbohydrates as an energy input?**

Cause & Effect

Energy & Matter

Planning & Carrying Out Investigations

Developing & Using Models

Activity

Part 1: (1 class period set up, 1–2 class period observation)

Purpose:

Anaerobic digestion occurs when microbes break down organic materials in the absence of oxygen. When the organic matter is broken down it is converted to a biogas (among other things), which contains methane that can be used as a fuel source just like propane or natural gas. Anaerobic digestion often happens in nature. The same process occurs in cow stomachs, which causes them to release methane gas. In this lab, students will recognize which general types of organic materials (substrates) produce more biogas than others.

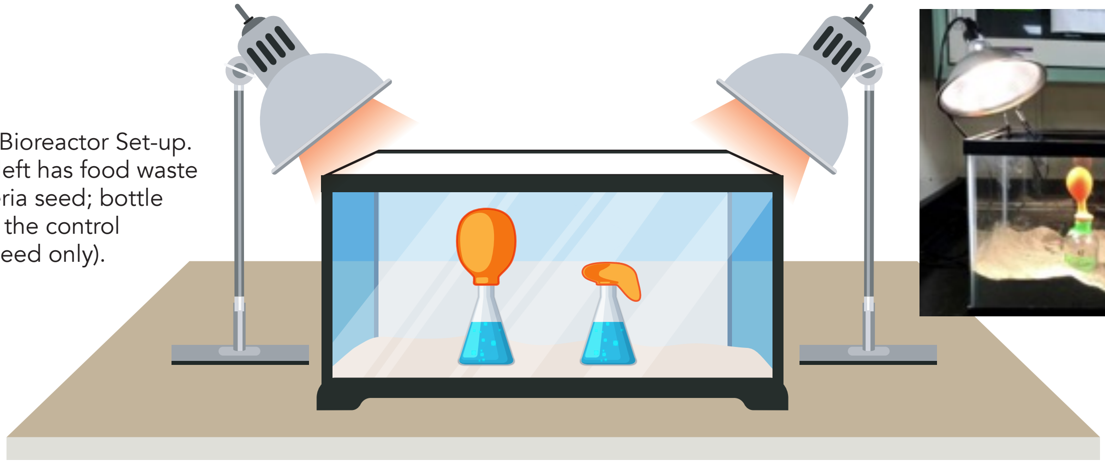
Students will compare types of organic matter to a control (see below) to determine if different general types of organic materials produce more biogas than others.

Bioreactor Bottle Lab

Students will work in pairs to observe the difference that occurs in the balloon inflation resulting from gas production. In a week-long experiment, students gather biogas data from the mini-anaerobic digesters they build to break down different types of organic materials with microbes. The digesters are made from small bottles attached to a gas collection device (see Figure 1).

Students compare biogas production from different organic materials. They can compare food vs. other organic wastes, different food groups (carbohydrates, proteins, fats), or finely chopped vs. whole food wastes. They monitor and measure gas production, then graph and analyze the collected data.

Figure 1. Bioreactor Set-up. Bottle on left has food waste plus bacteria seed; bottle on right is the control (bacteria seed only).



Part 2: (1-2 class periods; conducted simultaneously while observing bottle lab above)

Purpose:

Cattle rumens (one compartment of their four-compartment stomach) have microbes that facilitate anaerobic fermentation while breaking down cellulose (the insoluble fiber in "greens"). The process releases gas (E that is lost from the system). It also releases energy (Volatile Fatty Acids), which cattle can use for their own energetic needs. Students can make connections between the changes they observe in the bottle lab to the energy cattle release during digestion.

Using the table below, walk students through a discussion and exploration focused on the following questions.

1. What do we know about the purpose of certain teeth?
2. Why do cows not have front teeth on their upper jaw?
3. What does this tell us about cattle diets?
4. What is fiber?
5. Do humans need fiber in their diet?
6. What are the differences between ruminant and monogastric animals (cattle versus human digestion types)?

Teeth vs. Digestion

Animal	# of teeth	Type	Digest Fiber?
Cow	32	rumen	Yes
Human	32	monogastric	No
Horse	36–44	monogastric & cecum	Yes
Pigs	44	monogastric	No
Sheep	32	rumen	Yes
Camel	34	rumen	No
Rabbits	28	monogastric & cecum	Yes

What the Teacher Does
The teacher provides vocabulary, background information, and lab materials/procedure based upon student need. The teacher explains to the students how to take qualitative observations and notes in their journals. The teacher also walks the students through a discussion to apply the information they observe in the lab.

What the Students Do
The students use mini-anaerobic digesters to test and observe biogas created from different variables. The students then discuss the lab results, explaining the differences in observations.

Facilitation & Discussion Strategies

Think-Pair-Share

Think: Teachers begin by asking a specific higher-level question about the text or topic students will be discussing. Students "think" about what they know or have learned about the topic for a given amount of time (usually 1-3 minutes).

Pair: Each student should be paired with another student. Teachers may choose whether to assign pairs or let students pick their partners. Remember to be sensitive to learners' needs (reading skills, attention skills, science skills) when creating pairs. Students share their thinking with their partner, discuss ideas, and ask their partner questions about their thoughts on the topic (2-5 minutes).

Share: Once partners have had ample time to share their thoughts and discuss, teachers expand the "share" into a whole-class discussion. Allow each group to choose who will present their thoughts, ideas, and questions they had to the rest of the class. After the class goes through "share," you may choose to have pairs reconvene to talk about how their thinking perhaps changed due to the "share" element.

Affinity Mapping

Give students a broad question or problem that is likely to result in many different ideas, such as "What were the impacts of the Great Depression?" Have students generate responses by writing ideas on Post-it notes (one idea per note) and placing them in no particular arrangement on a wall, whiteboard, or chart paper. Once multiple ideas have been generated, have students begin grouping them into similar categories, then label the categories and discuss why the ideas fit within them, how the categories relate to one another, and so on.

Differentiation Strategies

1. Allow students to do work in groups to aid in understanding.
2. Provide individual copies of the instructions for students who need them.

Linking question from Engage to Explore:

Thinking back to the Sankey diagram you made for the melting chocolate lab (Engage Lesson), what energy inputs and outputs result from digestion in cows?

Detailed Learning Plan

Part 1:

*This activity has been adapted from "My Bacteria has Gas!" developed by Clarkson University as part of their K-12/University Partnership.

Vocabulary/Definitions

Variable: Any component of the experiment that is alterable; in this experiment, the variable will be the "substrate" placed in the reactor to provide food for the microbes (bacteria).

Experimental group: The experimental set-up or group that includes the independent variable being tested.

Control group: The experimental set-up or group that does not have the independent variable. The purpose of the control group is to make sure the independent variable is causing the results.

Substrate: Organic matter that is broken down or digested by bacteria.

Anaerobic: An environment or condition that lacks oxygen

Anaerobic digestion: A process through which bacteria break down organic matter (substrate) — such as manure — without oxygen.

Biogas: A gas mixture produced during anaerobic digestion that contains methane and carbon dioxide. Biogas can be burned as an energy source. Biogas contains 55%-75% methane and 44%- 24% carbon dioxide, with the other gases making up 1% or less of the mixture.

Bioreactor: An artificial environment in which organisms are encouraged to accomplish a particular task, essentially the microbes' workplace.

Digester Effluent: Liquid waste from anaerobic digesters, farms, factories, or households that sometimes flows into bodies of water. [Note that if you do not have access to a digester, you may use muck from the bottom of a pond.]

Manure: Solid wastes from animals (dung).

Organic material: All living or once-living things or items produced by living things. These carbon-based items include food waste, yard scraps, plant material, sugar, animal wastes, human wastes, and animals and people themselves. Also called "organics."

Timeframe:

Day 1: 25-minute setup; pre-lab hypothesis and discussion

Days 2-4: record observations (~5 minutes/day)

Day 5: Final measurement; 40-minute assessment, which includes graphing results and documentation.

Materials:

(Note that materials and procedures are for each student team to set up one reactor vessel each; students setting up similar bottles will work together. It is best to have two students work together to attach the balloon, having one student hold the bottle firmly on the tabletop with both hands while the other student stretches the balloon over the bottle's mouth.)

Per student:

- Lab gloves
- Safety glasses
- Science journal
- Worksheet A

Per group:

- Procedure sheet (1 per group or 1 per station)
- Sharpie or wax marker for labeling reactor bottles
- 1 small-mouthed reactor bottle (500 ml Nalgene bottle, Glass bottle, or other vessel that has a smooth lip small enough to stretch a balloon over)
- 1 large balloon, 5 mL or thicker (test balloons beforehand to make sure they are 100% airtight)
- 200 mL digester effluent (or appropriate substitute for microbial seed)
- 60 grams food sample, or other organic substrate (60 ml liquid substrate such as milk)

  CONTROL GROUPS will NOT add an organic substrate

Additional, for set up:

- Per station (set up one substrate per station): glass beaker or scale, plastic spoons, paper towels
- Glass terrariums (suggest using one 10-gallon tank per variable or substrate being tested or, depending on space, ~6-8 bottles per terrarium)
- 2 heat lamps per terrarium
- Extension cords, if needed
- Sand (enough to fill each terrarium ~3-4 inches)
- Flexible tape measure or other flexible measurement device (e.g., string and straight measuring tape will work)

For data collection:

- Each student group should record their data on their data sheet (in their science journals) and prepare a table where each group can record their quantitative data according to the substrate they are using (see Worksheet A). At the end of the experiment, the class data will be shared so students can calculate average values for each of the substrates.

Have the students set up a table to collect data in their science journals (see below).

Data Table

Group # ______	Circumference of Balloon in Centimeters (nearest 0.1 cm)				
Substance:	Day 1	Day 2	Day 3	Day 4	Day 5
	0.0				
Qualitative Observations					

Lab Procedure:

(print procedures below (included in the supplemental materials) and place at each station)

Preparing the Bottle Reactors — Each team of students will be preparing one bottle. There may be multiple bottles for one substrate.

1. Put on your gloves
2. Using the marker and masking tape, label your reactor bottle to indicate which substrate (or control) you are testing (milk, donut, manure, control) and your initials or class period as instructed by your teacher.
3. Measure 200 mL of digester effluent ("Microbe Source") and carefully add this to your reactor bottle. This material serves as a seed for the microorganisms (MICROBIAL SEED).
4. Measure 60 grams (or 60 ml of liquid) of your substrate (or control) and carefully add this to your reactor bottle. This material is your ORGANIC SUBSTRATE.
5. Once you have both your microbial seed and organic substrate added to your bottle, carefully fit a balloon over your team's bottle. Try not to create any pinholes or rips in the balloon as you do this! Make sure the balloon fits snuggly onto the bottle's lip. This action works best if one person holds the bottle on the table with both hands while the other person carefully stretches the balloon over the bottle's mouth.
6. Wrap tape tightly around the bottle cap area, over the edge of the balloon, to prevent gas leakage for each bottle. The seal must be airtight.
7. Record on your data sheet the start date/time, substance (i.e., what you put into your reactor bottle), and your qualitative observations and notes.
8. Place the bottle in the appropriate tank for your team. Make sure that the reactor bottle contents are at or below the level of the sand. (This helps add more direct heat to the substrates).
9. Clean up your station, remove your gloves, and wash your hands.
10. After lab set up (or finish for homework), have the students answer the following questions in their science journals. Discuss the students' answers as a whole class.
    1. Sketch the bioreactor you constructed. Be sure to label each part (tank, sand, light, bottle, bottle contents, balloon, etc.).
    2. Make a hypothesis: Which organic substrate(s) do you think will produce the most biogas? Why?
    3. What substances are in the control bottle? What purpose does this bottle serve?

*The teacher will place the two heat lamps outside the tank on opposite sides and adjust the lamps to face the bottles after the students have completed the setup.

Suggested Stations:

Station	Substance	mL of Effluent	mL of Milk	g of Donut	g of Manure
A, B, C, D	Control	200	0	0	0
E, F, G, H	Donuts	200	0	60	0
I, J, K, L	Manure	200	0	0	60
M, N, O, P	Milk	200	60	0	0

Observation and Data Recording

- Each day, or as often as possible, observe the bottles and measure the biogas produced by measuring the circumference of the balloon expansion.
    - To take the circumference, wrap the string (round in each terrarium tank) around the widest part of the balloon, hold onto the string at the point where the two ends overlap, then straighten the string out and measure the length to the nearest centimeter. This measurement will be the diameter of the balloon.
- Record your results - Record the date, time, measurement, and any other observations on the datasheet in their science journals.
- At the end of the experiment – when gas production seems to have stopped, or when you must end the investigation due to time constraints, have students measure the final circumference of the balloon and record it on their datasheet.

Safety Notes

- Wash hands after touching anything in this system. Always wear gloves when handling cow manure.
- The gas inside the bottles is flammable. While it does not pose a considerable risk, do not keep open flames near the gas. With the correct safety equipment (gloves, safety goggles), this gas can be flared or released outside once gas collection has been completed.
- Do not fill a reactor bottle to more than 50% of its volume. If large particles clog the tubing, extreme pressures can build up within the reactor. If this happens, place the clogged bottle in a trash bag and unscrew the bottle cap through the bag to prevent the reactor contents from spraying in the classroom.
- The bottles may have an odor, like rotting eggs or cow manure. Be sure adequate ventilation is available when conducting the activity.
- If no noticeable change occurs in a gas measurement bottle, check to ensure that gas is not leaking out of the container. If a leak is found, cover it with hot glue.

Post Lab:

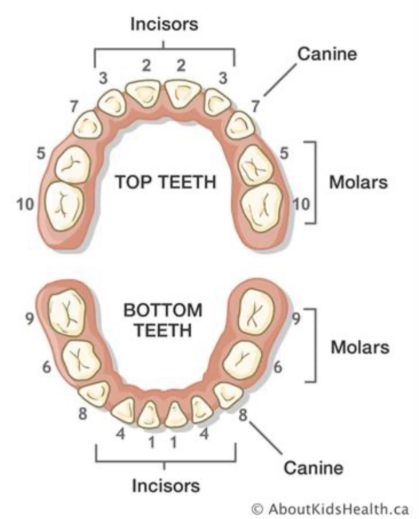
- When students have completed their datasheet, allow them to share their data with the rest of their class, so everyone has a complete set of data showing all the tested variables (Worksheet A).
- Use the class's data to construct a multiple-line graph showing the total change in gas production over time. Be sure to include:
  - o Labels (with units!) for x and y-axis
  - o A key (or labeled line) for each variable
  - o A title
- Tell students, "After completing your graph and analyzing the class's data, state a well-supported claim that answers the question, "What are the energy inputs and energy outputs of the beef animal system?""

*Part 2:

Every day, after students record their observations to Part 1, using the table below, walk students through a discussion and exploration focused on the following questions.

Day 2:

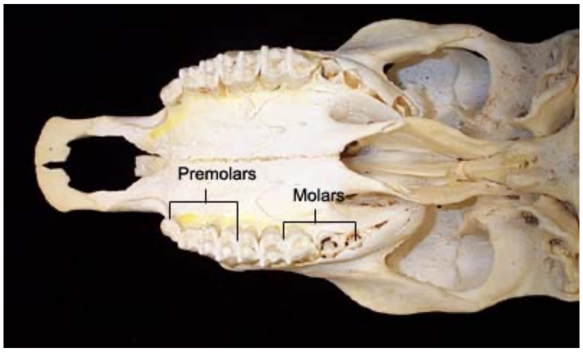
1. What do we know about the purpose of certain teeth?
   a. Show pictures of different teeth (both ruminant and monogastric animals (cattle versus human digestion type)).
2. Why do cows not have front teeth on their upper jaw?
   a. Show cow tooth diagram.
3. What does this information tell us about cattle diets?



Day 3:

1. What is fiber?
2. Do humans need fiber in their diet?

Use Affinity Mapping (see technique above in facilitation and discussion strategies)



Day 4:

1. What are the differences between ruminant and monogastric animals (cattle versus human digestion type)?
2. Why does number of teeth matter?
3. How does number of teeth impact digestion?

Notes & Tips

*The exploration of the physiology of cows' teeth is important in making sense of how cattle digest their food. Teeth in the back of the mouth (known as molars) are located on the top and bottom jaws. Plant materials sometimes contain tough stems, but because a cow chews food in a side-to-side motion, the molars shred the grass into small pieces that are more easily digested. A cow's unique ability to digest human inedible plant matter such as grass make it a valuable "upcycler" of nutrients.

BOTTLE REACTOR (BIOGAS) LAB PROCEDURES

1. Put on your gloves
2. Using the marker and masking tape, label your reactor bottle to indicate which substrate (or control) you are testing (milk, donut, manure, control) and your initials or class period as instructed by your teacher.
3. Measure 200 mL of digester effluent ("Microbe Source") and carefully add this to your reactor bottle. This material serves as a seed for the microorganisms (MICROBIAL SEED).
4. Measure 60 grams (or 60 ml of liquid) of your substrate (or control) and carefully add this to your reactor bottle. This material is your ORGANIC SUBSTRATE.
5. Once you have both your microbial seed and organic substrate added to your bottle, carefully fit a balloon over your team's bottle. Try not to create any pinholes or rips in the balloon as you do this! Make sure the balloon fits snuggly onto the bottle's lip. This action works best if one person holds the bottle on the table with both hands while the other person carefully stretches the balloon over the bottle's mouth.
6. Wrap tape tightly around the bottle cap area, over the edge of the balloon, to prevent gas leakage for each bottle. **<u>The seal must be airtight</u>**.
7. Record on your data sheet the start date/time, substance (i.e., what you put into your reactor bottle), and your qualitative observations and notes.
8. Place the bottle in the appropriate tank for your team. Make sure that the reactor bottle contents are at or below the level of the sand. (This helps add more direct heat to the substrates).
9. Clean up your station, remove your gloves, and wash your hands.
10. After lab set up (or finish for homework), have the students answer the following questions in their science journals. Discuss the students' answers as a whole class.
    1. Sketch the bioreactor you constructed. Be sure to label each part (tank, sand, light, bottle, bottle contents, balloon, etc.).
    2. Make a hypothesis: Which organic substrate(s) do you think will produce the most biogas? Why?
    3. What substances are in the control bottle? What purpose does this bottle serve?
    4. What purpose do the multiple setups for each substance serve?

NAME: ______________________ DATE: ______________ CLASS PERIOD: ______________

WHAT IS THE COST OF A BURP?

Class Data Collection

Circumference of Balloon in Centimeters (nearest 0.1cm)					
	Day 1	Day 2	Day 3	Day 4	Day 5
Control					
Group A	0.0				
Group B	0.0				
Group C	0.0				
Group D	0.0				
Daily Average					
Donuts					
Group A	0.0				
Group B	0.0				
Group C	0.0				
Group D	0.0				
Daily Average					
Manure					
Group A	0.0				
Group B	0.0				
Group C	0.0				
Group D	0.0				
Daily Average					
Milk					
Group A	0.0				
Group B	0.0				
Group C	0.0				
Group D	0.0				
Daily Average					

EXPLAIN — **BEEF CATTLE ENERGY MODEL**

Learning Target(s)

Apply and demonstrate knowledge of changing inputs and outputs in energy flow by creating and explaining a beef cattle model.

Guiding Question

What are the effects of different energetic inputs into the beef animal system on energetic outputs from the system?

Cause & Effect

Energy & Matter

Constructing Explanations & Designing Solutions

Activity

(1 class period)

Purpose:

Students will be able to take the models, data, observations, and questions they have developed thus far to make sense of the changing inputs and outputs in beef cattle's energy flow.

Students will create a Sankey diagram to represent a realistic energy flow of a beef animal. This diagram must show differences in energy outputs due to changes in energy inputs. Students will write an explanation of the animal "system" and the effect of energy inputs versus outputs using their Sankey diagrams as a guide.

Sankey Models

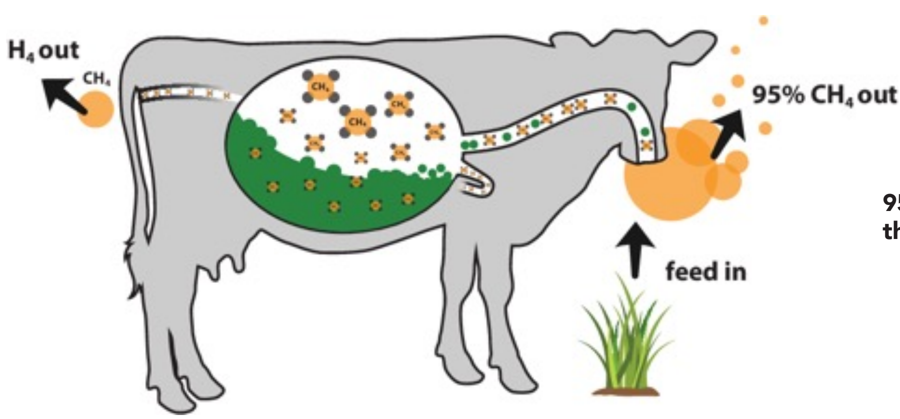
This activity begins with a review of the other Sankey models the students have already created and discussed. Students will discuss what they have observed so far and how this information relates to how energy flows through the system of a beef animal. As a class, elaborate on the group discussions by creating a class model to describe the phenomena thus far. Use your prediction from earlier and modify it based upon what you have learned.

Present the students with the guiding question, "What are the effects of different energetic inputs into the beef animal system on energetic outputs from the system?" As a class, break down the question's meaning (i.e., what is the question asking?), having students annotate the question to understand what is being asked (see below).

Students will then draw and label a cow diagram, using what they understand about Sankey models, to answer the guiding question (see potential example below).

What happened as a result? — What the cow ate — Cow digestive system — manure and gas

What are the effects of different energetic inputs into the beef animal system on energetic outputs from the system?



95% of total CH4 from the system released here.

What the Teacher Does
The teacher facilitates a discussion focused on reviewing what has been learned thus far.

What the Students Do
The students work in groups to apply what they have learned to cows.

Facilitation & Discussion Strategies

Gallery Walk: Gallery walks get students up and out of their chairs and actively engaging with the content and each other. In gallery walks, students might display their computer or tablet screen, a group-made poster, a paragraph they've written, or a collage they've designed. Classmates peruse each other's work, perhaps providing feedback, praising each other, or both.

Differentiation Strategies

Allow students to choose which way they want to create and explain their model (see ideas below in the Detailed Learning Plan).

Instead of having students come up with solutions independently, give groups one of the proposed solutions below and have them research to determine strengths and weaknesses for each solution.

Linking question from Engage to Explore:

Why should we care about the impact of energy inputs and outputs of the beef animal system?

Detailed Learning Plan

The materials for this Explain activity can vary based upon the form of the final model. Students can use large pieces of paper to draw their model, create the models on a computer, create videos to explain their model after it is made, use a voiceover PowerPoint to develop and explain their model, and many other possibilities.

Procedures:

1. Have the students get out their science journals where they have recorded all of their data, observations, and questions up to this point.
2. Put students in groups and prompt them to discuss what they have observed and how this information is connected. Have the students construct an energy mind map to demonstrate the connections they observe (refer to example from the Melting Chocolate Lab).
3. Bring the students back together as a class and allow them to share their mind maps and what they discussed in their groups.
4. Once all groups have shared, use their understanding to create a class model to describe the phenomena thus far, asking students as the model is made if the model accurately reflects their understanding.
5. Transition the students by presenting them with the guiding question, "What are the effects of different energetic inputs into the beef animal system on energetic outputs from the system?"
6. As a class, break down the question's meaning (i.e., what is the question asking?), having students annotate the question to understand what is being asked (see above). Students can annotate independently, in groups, or as a whole class (depending upon student need and time constraints).
7. Once the students have reached an agreement on what the question is asking, task them with drawing and labeling a diagram of a cow (in any form you choose, see ideas above), using what they understand about Sankey models, to answer the guiding question (see potential example above).
8. Display student models with explanations around the room and have students conduct a Gallery Walk (see details above) to review their classmates' work. Give the students Post-it notes so they can leave feedback on the other student-created models as they review.
9. Afterward, ask the groups to reconvene and debrief on what they observed in other models. Follow this with a whole-class discussion so your students can share what questions they might have.

ELABORATE & EVALUATE — **ONE SMALL STEP FOR CATTLE, ONE GIANT STEP FOR MANKIND**

Learning Target(s)

Gather and analyze data to present solutions to decrease the impacts of energy inputs and outputs associated with the beef animal system.

Articulate and evaluate solutions to the methane gas emissions issue based upon obtained knowledge.

Guiding Question

How do the beef animal system's energy inputs and outputs impact social, economic, and environmental realities? What can cattle raisers, scientists, and consumers do to reduce the amount of methane gas produced by cattle?

Cause & Effect

Energy & Matter

Systems & Systems Models

Obtaining, Evaluating, & Communicating Information

Activity

(2–3 class periods)

Purpose:

According to the Food and Agriculture Organization, enteric methane emissions from domesticated ruminants (wild animals excluded) account for 30% of all global human-caused methane emissions. In ruminants, methane is produced mainly by enteric fermentation, where microbes decompose and ferment plant materials, such as celluloses, fiber, starches, and sugars, in their digestive tract or rumen. Enteric methane is one by-product of this digestive process, and it exits the animal through burping. In the United States, beef cattle are responsible for 18% of methane emissions, or 1.8% of total human-caused greenhouse gas emissions. It is not possible to eliminate methane production from ruminants, short of eliminating the rumen. Obviously, this would be an undesirable result. Without ruminant animals, much of Earth's landmass would be unusable for producing food as manure nourishes the soil, thus increasing its fertility.

Further, the ecology of many of our grazing lands depends on large herbivores, and cattle grazing is used to maintain these ecosystems in a productive, healthy state. Emissions of enteric methane are the cost of this unique service that ruminants provide. Rather than eliminating methane, reducing the amount of methane produced during food production is a sustainable goal. Enteric methane accounts for about 47% of the total carbon footprint of beef in the United States when everything from cattle feed production to cooking energy in homes and restaurants is considered.

Elaborate:

With this information in mind, students will research solutions to reducing the impact of energy flow associated with the beef animal system (including improvements internal and external to the beef animal system).

Students will work in groups to determine possible solutions to reduce the amount of methane produced from beef animal systems. While the students should come up with their own solutions, possible solutions to assist with facilitation are included. Possible solutions (as presented by the Society of Biology) include:

1. Plant more trees on farms to offset the livestock carbon footprint. This is called carbon sequestration- when biological compounds accumulate carbon via the capturing of carbon dioxide. Although planting many trees will inevitably increase the total carbon sequestration, there can also be issues with this concept. Planting trees can disturb the soil and release more carbon dioxide, so it is not efficient enough to be a solution in itself. Farmland can also be carefully managed with wildlife in mind.
2. Adopting more productive cattle breeds to produce beef. Some breeds can make more efficient use of food or are more resistant to particular diseases.
3. Selecting for specific genotypes that increase yield can increase beef output relative to the food input, leading to more efficient beef production. Genes that contribute to a greater disease resistance could also be targeted. Desirable genetics can also be targeted that influence body size and structure to reduce wastage of biomass during slaughter.

4. Optimize animal feed further, so beef animals only eat what they need, with the best nutritional value. Pollution from excess nutrients is an issue when the animals are overfed. Animals will often eat more than they need for maintenance, growth, and wellbeing, so measuring this more carefully will allow for less wastage as an animal converts the feed into its own biomass.
5. Improving the nutrient balance of rations provided to cattle may also aid in efficient biomass conversion and lower production costs. Reducing fiber in a cow's diet, in particular, will reduce methane emissions from cattle, in turn reducing their carbon footprint.
6. Use cattle manure more effectively as a fertilizer. Developing and buying equipment that more rapidly applies manure back into the ground as fertilizer reduces nitrous oxide emissions into the atmosphere.
7. Designing new animal concentrate feed that reduces methane emissions. Increasing the digestibility of feed will make energy transfer more efficient. Less fiber content can lead to reduced methane emissions because less fermentation is required.
8. Developing plant breeding programs to improve crops for cattle to eat. Selectively breeding crops for feed could lead to a yield increase, so less land use could be used to make the same amount of feed for a beef animal. Crops can also be developed, which reduces the need for pesticides and fertilizers, again reducing the beef's total carbon footprint.

Evaluate:

After creating with one possible solution, the students will present their solution to their peers. Students will evaluate the presented solutions to determine the most effective based upon their understanding of the beef animal system. Have the students create a list of parameters in which to evaluate the solutions. Possible evaluation parameters include monetary requirements, time restrictions, and overall effectiveness.

What the Teacher Does
The teacher guides each group as they research, ensuring they are on the right track and answering questions that develop. Where possible, students should be directed back to previous data, observations, and questions to assist with their solutions.

What the Students Do
Students will work in small groups to research solutions and create a presentation to share solutions with evidence (from research and what they have learned in class) with their peers. They will then evaluate the solutions to determine the most effective one.

Facilitation & Discussion Strategies

COMPUTER TOUR:

Assignments on laptops or tablets can be engrossing for students, but they can also be isolating. Stopping the individual work, pausing, and asking students to take a quick "tour" around the room to see what others are doing can assist with the learning. In a computer tour, half of the students remain with their devices to give a quick click-through of their work while the other half visit and ask questions—then switch.

Differentiation Strategies

Having an authentic audience can increase student engagement. If possible, find a farmer you could 1. Send the students' suggestions to or, 2. Invite to class to hear the presentations.

For presentations, allow the students to choose how to present their information (orally only, visuals, chart paper, computer-generated, etc.).

Detailed Learning Plan

Materials:

- Chart paper
- Markers
- Computers
- Large Post-it Notes or Index Cards
- Other as necessary for students' presentation method

Procedure:

1. Display the following questions separately on chart paper around the room (you may need to make multiple copies of each question and divide the class to make sure students are not waiting too long to respond).
    - Question #1 – How do the beef animal system's energy inputs and outputs impact social, economic, and environmental realities?

- Question #2 – What can cattle raisers, scientists, and consumers do to reduce the amount of methane gas produced by cattle?

2. Have the students walk around and answer each question based on their knowledge from studying energy inputs and outputs in the beef animal system (20 min).
3. Once all students have had a chance to respond (or they can work in groups), have one student summarize each question's responses (one summary per chart paper) (10 min).
4. At this point, the students will be making educated guesses regarding their answers, as few of their answers/solutions are evidence-based.
5. Tell the students that they are responsible for helping cattle raisers reduce the amount of methane gas produced by cattle to improve the social, economic, and environmental factors affected by the carbon footprint. To complete this task, they will research possible solutions, critically analyzing* the solutions they find, based upon what they have learned, to present the best one to their classmates. If your students need a review of how to critically analyze sources, you can provide the CRAAP test for them to use. The CRAAP test asks:
   a. **C**urrent – When was the source written? Does it need to be up-to-date for your research?
   b. **R**elevant – Does the information relate to your topic? Does it answer your question?
   c. **A**uthoritative – Who is the author of your source? Do they have the authority to write about the topic?
   d. **A**ccurate – Are you able to verify the information in another source? Does the author provide evidence of their findings?
   e. **P**urposeful – What is the reason for publishing this information? Is it fact, opinion, persuasion, or meant to sell a product?
6. Their presentation will include (5 min):

a. A description of the solution they propose as best
b. An explanation of why the solution would be the best
c. Methods for implementing the solution

7. Give the students a timeframe for their research and begin (30-45 min; students may need to finish for homework).
8. About halfway through the class session, stop the students and have them take a computer tour (see above in Facilitation and Discussion Strategies) (15 min).
9. Have the students present their solutions in the manner they choose (see above in Differentiation Strategies for ideas) (timeframe depends on the number of groups).
10. After all groups present, create a class concept map to organize the ideas presented.
11. Have students assist in making connections between solutions, variables (e.g., monetary, time, effectiveness, etc.).
12. Discuss as a class what cattle raisers would be looking for in a solution and add this information to the concept map. If you have a cattle raiser willing to participate, include them in this discussion (20 min).
13. Have each student write a reflection in their journal explaining which presented solution they feel was most effective and why (20 min).
14. Have students summarize their reflection on a large Post-it note or an index card (5 min).
15. Create a large bar graph or table on the board and have students add their summary to the column indicating their choice (see below for an example). If you have a cattle raiser participating, allow them to "vote" as well (5 min).

16. Review the solution most selected, highlighting the reasons the students gave for choosing that solution as most effective (10 min).
17. Discuss the solutions as a whole class, comparing the proposed solutions to the Sankey models they created. Discuss with the students how the process of finding a solution went for them. Was it easy to meet the parameters? Did they have to compromise as they researched solutions?
18. Have the students document their reflections from the whole class discussion in their science journal, making sure to answer the guiding questions: How do the beef animal system's energy inputs and outputs impact social, economic, and environmental realities? What can cattle raisers, scientists, and consumers do to reduce the amount of methane gas produced by cattle?

Notes & Tips

*To help students apply critical thinking and analysis skills to sources, encourage students to access prior knowledge and seek multiple resources to find patterns and construct knowledge. Challenge student assumptions with questions about bias, purpose, and point of view.

1. Ask students to find other resources that offer support or contradiction.
2. Ask for reasons and specific data to support their conclusions.
3. Help students identify their own questions for further investigation.

AMERICAN FARM BUREAU
FOUNDATION
FOR AGRICULTURE®

The American Farm Bureau Foundation for Agriculture® is building awareness, understanding and a positive public perception of agriculture through education.

800-443-8456 | www.agfoundation.org

OKLAHOMA BEEF COUNCIL
Funded by Beef Farmers and Ranchers

The Oklahoma Beef Council mission is to enhance beef demand by strengthening consumer trust and exceeding consumer expectations.

405-840-3777 | www.oklabeef.org

AMERICAN FARM BUREAU
FOUNDATION
FOR AGRICULTURE®

The American Farm Bureau Foundation for Agriculture® is building awareness, understanding and a positive public perception of agriculture through education.

800-443-8456 | www.agfoundation.org

OKLAHOMA BEEF COUNCIL
Funded by Beef Farmers and Ranchers

The Oklahoma Beef Council mission is to enhance beef demand by strengthening consumer trust and exceeding consumer expectations.

405-840-3777 | www.oklabeef.org