

**Teacher’s Guide**

**Cow Power!**

***April 2020***

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Activate students’ prior knowledge and engage them before they read the article.

[Reading Comprehension Questions](#_Student_Reading_Comprehension) 3

These questions are designed to help students read the article (and graphics) carefully. They can help the teacher assess how well students understand the content and help direct the need for follow-up discussions and/or activities. You’ll find the questions ordered in increasing difficulty.

[Graphic Organizer 5](#_Graphic_Organizer)

Thishelps students locate and analyze information from the article. Students should use their own words and not copy entire sentences from the article. Encourage the use of bullet points.

[Answers 6](#_Answers_to_Reading)

Access the answers to reading comprehension questions and a rubric to assess the graphic organizer.

[Additional Resources 8](#_Additional_Resources_1)

Here you will find additional labs, simulations, lessons, and project ideas that you can use with your students alongside this article.

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# Anticipation Guide

Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Directions: *Before reading the article*,** in the first column, write “A” or “D,” indicating your **A**greement or **D**isagreement with each statement. Complete the activity in the box.

As you read, compare your opinions with information from the article. In the space under each statement, cite information from the article that supports or refutes your original ideas.

|  |  |  |
| --- | --- | --- |
| **Me** | **Text** | **Statement** |
|  |  | 1. Burning biogas produces CO2, but the process is considered carbon neutral. |
|  |  | 1. Methane (CH4) has a higher global warming potential than CO2. |
|  |  | 1. Dairy farms and livestock account for about 50% of all methane released into the atmosphere in the U.S. due to human activities. |
|  |  | 1. Greenhouse gases absorb infrared radiation from Earth’s surface. |
|  |  | 1. Cows release methane only when they burp. |
|  |  | 1. Cow manure is a good natural fertilizer. |
|  |  | 1. Both CO2 and CH4 are produced in anaerobic digesters. |
|  |  | 1. Dairy farmers can save money by generating electricity from methane to power their farms and heat their homes. |
|  |  | 1. Food scraps cannot be used to generate methane. |
|  |  | 1. Almost all dairy farms in the U. S. now have anaerobic digesters. |

# Student Reading Comprehension Questions

Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Directions**: Use the article to answer the questions below.

1. How many biogas systems were in operation in the U.S. in 2017?
2. How much manure do the cows at Noblehurst Farms produce each day?
3. What is the approximate monthly reduction in carbon dioxide production by Noblehurst Farms after implementing a methane digester?
4. Which two industries account for 10% of the methane generated by human activities in the U.S.?
5. How much money does Noblehurst Farms save by using methane digesters?
6. How do cows contribute to the production of greenhouse gases?
7. Which elements combine to make methane?
8. Define global warming potential.
9. Aside from dairy farms, list three other potential sources of biogas.
10. What is enteric fermentation?
11. Explain how a methane digester functions.

**Student Reading Comprehension Questions, cont.**

**Questions for Further Learning**

***Write your answers on another piece of paper if needed.***

1. Burning methane releases CO2, which is also a greenhouse gas. Explain why burning methane is better than releasing it into the atmosphere.
2. Explain how greenhouse gases raise global temperatures.
3. Compare and contrast the chemical formulas for the reaction that takes place in a digester and the combustion of methane.
4. Do you think farms should be required to implement methane digesters? Why or why not?
5. California passed a law requiring dairy farms to reduce their production of methane, so many farms have begun using a digester. What could other industries or organizations do to reduce their methane production? Be creative yet reasonable.

# Graphic Organizer

Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Directions**: As you read, complete the graphic organizer below to describe the role of dairy farms and livestock production in producing and removing greenhouse gases from the atmosphere.

|  |  |
| --- | --- |
|  | **Describe the process and greenhouse gases involved** |
| **Burning biogas** |  |
| **Enteric fermentation** |  |
| **Anaerobic digester** | *Describe temperature, chemicals, and overall process.* |
| **Burning methane (generator)** | *Include chemical equation and advantages.* |

**Summary:** In the space below, or on the back of this paper, write a one-sentence summary (18 words or less) of the information in the article.

# Answers to Reading Comprehension Questions & Graphic Organizer Rubric

1. **How many biogas systems were in operation in the U.S. in 2017?**

*The US had 2,200 biogas systems in operation in 2017.*

1. **How much manure do the cows at Noblehurst Farms produce each day?**

*The cows produce 40,000 gallons of manure each day.*

1. **What is the approximate monthly reduction in carbon dioxide production by Noblehurst Farms after implementing a methane digester?**

*They have reduced carbon dioxide emissions by approximately 409 tons per month.*

1. **Which two industries account for 10% of the methane generated by human activities in the U.S.?**

*The two industries that account for 10% of the methane generated by human activities in the United States are dairy farms and livestock operations.*

1. **How much money does Noblehurst Farms save by using methane digesters?**

*Noblehurst Farms saves around $100,000 a year on electricity.*

1. **How do cows contribute to the production of greenhouse gases?**

*Cows release methane as a part of their digestive process and methane is a greenhouse gas.*

1. **Which elements combine to make methane?**

*Methane is made of carbon and hydrogen.*

1. **Define global warming potential.**

*Global warming potential is a greenhouse gas’s ability to trap extra heat in the atmosphere over time as compared to CO2.*

1. **Aside from dairy farms, list three other potential sources of biogas.**

*Hog farms, poultry farms, and wastewater treatments plants are potential sources of biogas.*

1. **What is enteric fermentation?**

*Enteric fermentation is part of the digestive process for ruminants, such as cows. It is when microbes in the stomach of a ruminant break down food. The cow receives energy from the process and produces methane.*

1. **Explain how a methane digester functions.**

*Farmers place manure into anaerobic digesters where bacteria use enzymes to break the manure into smaller components and produce carbon dioxide and methane. The digester captures the methane so it can be burned to release thermal energy that can power a generator.*

**Questions for Further Learning**

1. **Burning methane releases CO2, which is also a greenhouse gas. Explain why burning methane is better than releasing it into the atmosphere.**

*Burning methane releases CO2, but the negative impact of methane is much higher than the negative impact of CO2. Methane has a GWP of 28 while CO2 has a GWP of 1.*

1. **Explain how greenhouse gases raise global temperature.**

*Greenhouse gases absorb radiation from the sun and transfer the energy to nearby atmospheric gases through bond vibrations increasing the level of average thermal energy.*

1. **Compare and contrast the chemical formulas for the reaction that takes place in a digester and the combustion of methane.**

*Digester formula: C6H12O6 – 3CO2 + 3CH4*

*Combustion of methane: CH4 +2O2 – CO2 + 2H2O + energy*

*Both formulas contain methane. One formula contains methane as a reactant while the other contains it as a product. Carbon dioxide is also present in both reactions.*

1. **Do you think farms should be required to implement methane digesters? Why or why not?**

*Student answers will vary but should include an explanation for the response.*

1. **California passed a law requiring dairy farms to reduce their production of methane, so many farms have begun using a digester. What could other industries or organizations do to reduce their methane production? Be creative yet reasonable.**

*Student answers will vary and should include information about the production of methane.*

**Graphic Organizer Rubric**

If you use the Graphic Organizer to evaluate student performance, you may want to develop a grading rubric such as the one below.

|  |  |  |
| --- | --- | --- |
| **Score** | **Description** | **Evidence** |
| 4 | Excellent | Complete; details provided; demonstrates deep understanding. |
| 3 | Good | Complete; few details provided; demonstrates some understanding. |
| 2 | Fair | Incomplete; few details provided; some misconceptions evident. |
| 1 | Poor | Very incomplete; no details provided; many misconceptions evident. |
| 0 | Not acceptable | So incomplete that no judgment can be made about student understanding |

# Additional Resources

**Labs and demos**

Food to Energy: This website includes instructions for a variety of laboratory activities to help students understand anaerobic digestion and how digesters function.  
<https://sites.clarkson.edu/foodwaste/for-teachers/>

In this lab, students will create two simulations of the Earth’s atmosphere. They will compare a control model with a one that has an increased presence of carbon dioxide gas in order to analyze how this effects temperature. They will also complete research in order to learn more about the makeup of the Earth’s atmosphere.

<https://teachchemistry.org/classroom-resources/greenhouse-gas-simulation>

**Simulations**

Carbon Tracker – CH4: This NOAA website explains the ways that methane impacts the environment and includes an animation of global methane.  
<https://www.esrl.noaa.gov/gmd/ccgg/carbontracker-ch4/>

Greenhouse Gas Inventory Data Explorer: Students can use this interactive tool to explore EPA data about Greenhouse Gas Emissions and Sinks and includes information about agriculture.  
<https://cfpub.epa.gov/ghgdata/inventoryexplorer/#iagriculture/allgas/source/all>

**Lessons and lesson plans**

Carbon Hoofprints: Cows and Climate Change: In this lesson students learn about the digestive systems of ruminants and how the methane produced by cattle impacts the environment.  
<https://www.agclassroom.org/teacher/matrix/lessonplan.cfm?lpid=707>

Turning Waste into Energy: This lesson includes a video and student workbook designed to help students understand how methane impacts the environment and how methane digesters can help reduce that impact.   
<https://www.pbslearningmedia.org/resource/kqedcl11.sci.ess.turningwasteintoenergy/turning-waste-into-energy/support-materials/>

**Other Resources**

The Park Spark Project: This page describes how one community implemented a digester in a dog park.  
<https://parksparkproject.com/artwork/1206505.html>

Create an infographic: Using web-based tools, students will use principles of energy to describe the greenhouse effect (or another real-world cycle of their choice).

<https://teachchemistry.org/classroom-resources/thermochemistry-infographic>

# Chemistry Concepts, Standards, and Teaching Strategies

**Connections to Chemistry Concepts**

The following chemistry concepts are highlighted in this article:

* Chemical Reactions
* Energy and Thermodynamics
* Kinetics: catalysts
* Reactions & Stoichiometry

**Correlations to Next Generation Science Standards**

This article can be used to achieve the following performance expectations and dimensions of NGSS:

**HS-LS2-3**

Construct and revise an explanation based on evidence for the cycling of matter and flow of energy in aerobic and anaerobic conditions.

**HS-ETS1-3**

Evaluate a solution to a complex real-world problem based on prioritized criteria and tradeoffs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

**Disciplinary Core Ideas:**

* LS2.B: Cycles of Matter and Energy Transfer in Ecosystems
* ETS1.C: Optimizing the Design Solution

**Crosscutting Concepts:**

* Systems and System Models
* Scale, Proportion, and Quantity
* Energy and Matter

**Science and Engineering Practices:**

* Constructing explanations and designing solutions
* Obtaining, evaluating, and communicating information

**Nature of Science:**

* Science is a human endeavor.

Student Reading Comprehension Questions – connections to NGSS Crosscutting Concepts:

* Q6: Cause and Effect
* Q10 + Q11: Energy and Matter
* Questions for Further Learning Q2: Stability and Change

**Correlations to Common Core State Standards**

See how *ChemMatters* correlates to the[**Common Core State Standards**](https://www.acs.org/content/acs/en/education/resources/highschool/chemmatters/teachers-guide.html)  at www.acs.org/chemmatters.

**Teaching Strategies**

Consider the following tips and strategies for incorporating this article into your classroom:

* **Alternative to the Anticipation Guide** provided: Before reading, ask students what they have heard about cows contributing to the greenhouse effect and what questions they have about how dairy farmers can reduce the environmental impact of their farms. As they read the article, students should look for answers to their questions.