

ChemMatters[®]

Demystifying Everyday Chemistry

Teacher's Guide

APRIL 2020

<u>Cow Power</u>	2
<u>Clearing the Air</u>	11
<u>Capturing Carbon</u>	20
<u>Why Avocados Are So Appealing</u>	33
<u>About the Teacher's Guide</u>	42



Teacher's Guide

Cow Power

April 2020

Table of Contents

<u>Anticipation Guide</u>	3
Activate students' prior knowledge and engage them before they read the article.	
<u>Reading Comprehension Questions</u>	4
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.	
<u>Graphic Organizer</u>	6
This helps 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.	
<u>Answers</u>	7
Access the answers to reading comprehension questions and a rubric to assess the graphic organizer.	
<u>Additional Resources</u>	9
Here you will find additional labs, simulations, lessons, and project ideas that you can use with your students alongside this article.	
<u>Chemistry Concepts, Standards, and Teaching Strategies</u>	10

Anticipation Guide

Name: _____

Directions: *Before reading the article*, in the first column, write “A” or “D,” indicating your Agreement or Disagreement 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 CO ₂ , but the process is considered carbon neutral.
		2. Methane (CH ₄) has a higher global warming potential than CO ₂ .
		3. Dairy farms and livestock account for about 50% of all methane released into the atmosphere in the U.S. due to human activities.
		4. Greenhouse gases absorb infrared radiation from Earth’s surface.
		5. Cows release methane only when they burp.
		6. Cow manure is a good natural fertilizer.
		7. Both CO ₂ and CH ₄ are produced in anaerobic digesters.
		8. Dairy farmers can save money by generating electricity from methane to power their farms and heat their homes.
		9. Food scraps cannot be used to generate methane.
		10. 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 CO_2 , 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	<i>Describe temperature, chemicals, and overall process.</i>
Burning methane (generator)	<i>Include chemical equation and advantages.</i>

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.
- 2. How much manure do the cows at Noblehurst Farms produce each day?**
The cows produce 40,000 gallons of manure each day.
- 3. 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.
- 4. 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.
- 5. How much money does Noblehurst Farms save by using methane digesters?**
Noblehurst Farms saves around \$100,000 a year on electricity.
- 6. 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.
- 7. Which elements combine to make methane?**
Methane is made of carbon and hydrogen.
- 8. 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.
- 9. Aside from dairy farms, list three other potential sources of biogas.**
Hog farms, poultry farms, and wastewater treatments plants are potential sources of biogas.
- 10. 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.
- 11. 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

- 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.
- 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.
- Compare and contrast the chemical formulas for the reaction that takes place in a digester and the combustion of methane.**
*Digester formula: $C_6H_{12}O_6 - 3CO_2 + 3CH_4$
Combustion of methane: $CH_4 + 2O_2 - CO_2 + 2H_2O + \text{energy}$
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.*
- 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.
- 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/#agriculture/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](http://www.acs.org/chemmatters) 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.

Teacher's Guide

Clearing the Air

April 2020

Table of Contents

<u>Anticipation Guide</u>	12
Activate students' prior knowledge and engage them before they read the article.	
<u>Reading Comprehension Questions</u>	13
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.	
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<u>Additional Resources</u>	18
Here you will find additional labs, simulations, lessons, and project ideas that you can use with your students alongside this article.	
<u>Chemistry Concepts, Standards, and Teaching Strategies</u>	19

Anticipation Guide

Name: _____

Directions: *Before reading the article*, in the first column, write “A” or “D,” indicating your Agreement or Disagreement 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. Smoke always rises.
		2. The Clean Air Act was enacted in 1960 in the U.S.
		3. There are two types of ozone, one harmful and one very important for life on Earth.
		4. Ozone is colorless.
		5. In 2015, all counties in the U.S. were in compliance with the national ozone standard to limit atmospheric ozone.
		6. Ozone levels rise in the winter.
		7. Normally, air temperature increases with altitude.
		8. Catalytic converters in cars and trucks lower ozone-producing chemicals in exhaust.
		9. Modern catalytic converters carry out three chemical reactions at the same time.
		10. The ozone hole over Antarctica has improved since 1987.

Student Reading

Comprehension Questions

Name: _____

Directions: Use the article to answer the questions below.

1. Briefly explain how ozone can both be harmful and critical to life.
2. Explain how harmful ground level ozone is produced.
3. What efforts have been made to control ground level ozone production, particularly in urban areas?
4. Explain one major obstacle we are facing in reducing the amount of ground level ozone produced globally.
5. How have humans impacted the “good” ozone in the stratosphere and what efforts have been made to repair the damage to the ozone layer.
6. Explain how a catalytic converter works and classify the three chemical reactions seen in the table on page 11 titled “Cleaner Cars.”
7. The coronavirus pandemic of 2019-2020 began in December of 2019. The amount of cases began to increase dramatically worldwide in March of 2020 when the weather was beginning to warm up. The virus is particularly dangerous to those with respiratory issues. Based on the info in this article, what additional dangers may be present for people fighting the coronavirus in urban areas as the weather begins to heat up?
8. On a separate sheet of paper, write a short opinion editorial (OP-ED) piece on whether you agree that human activities have influenced global temperatures on the planet. Be sure you to use facts and evidence, not politics, when you write your piece.

Student Reading Comprehension Questions, cont.

Questions for Further Learning

Write your answers on another piece of paper if needed.

1. Observe the map of the United States titled “8-Hour Ozone Nonattainment Areas (Jan. 2020)” on page 11. Dangerous levels of ozone can be found predominantly in areas with a high population density. Create an argument based on evidence as to why California contains the greatest amount of land area with extreme levels of ground level ozone. There are many areas in the United States with high population density such as the Northeast U.S. What factor or factors may be causing the increased levels in California?

2. Suppose you were in charge of creating an updated Clean Air Law. What amendments would you make to reduce the amount of ground level ozone produced?

3. Use one of the many free infographic websites available online and create an infographic explain what ozone is and how ground level ozone is produced, the dangers of ground level ozone, and simple things everyone can do to help minimize ground level ozone production.

Graphic Organizer

Name: _____

Directions: As you read, complete the graphic organizer below to describe issues related to air pollution and ozone.

	Ground-level Ozone	Stratospheric Ozone
Sources		
Equations for how it is formed		
Effect on human health		
Solutions to problems		

Summary: On the back of this sheet, write one thing you can do to reduce the amount of ground-level ozone, and why your choice would help.

Answers to Reading Comprehension Questions & Graphic Organizer Rubric

- 1. Briefly explain how ozone can both be harmful and critical to life.**
Ozone in the stratosphere protects life on Earth by absorbing dangerous solar radiation. Ground level ozone is a pollutant and causes health problems.
- 2. Explain how harmful ground level ozone is produced.**
VOCs and NO_x gases undergo a chain reaction, in the final steps a single oxygen atom is split from a VOC or NO_x gas, which combines with an oxygen molecule (O_2) producing ozone (O_3)
- 3. What efforts have been made to control ground level ozone production, particularly in urban areas?**
Major improvements in reducing ground level ozone production can be contributed to legislation introducing strict emission standards for cars and trucks and the evolution of the catalytic converter in cars.
- 4. Explain one major obstacle we are facing in reducing the amount of ground level ozone produced globally.**
Ozone can travel long distances in global air currents. Therefore, ozone created in one county, state, country, or continent can travel to another. Reducing ground level ozone must be a national and global effort with everyone doing their part to control emissions in their state or country.
- 5. How have humans impacted the “good” ozone in the stratosphere and what efforts have been made to repair the damage to the ozone layer.**
The emissions of chlorofluorocarbons (CFCs), which produces free radical chlorine atoms when exposed to radiation from the sun in the atmosphere catalyze the depletion of the ozone layer in the stratosphere. The UN adopted the Montreal protocol which limits or bans the emissions of gases that deplete the ozone layer.
- 6. Explain how a catalytic converter works and classify the three chemical reactions seen in the table on page 11 titled “Cleaner Cars.”**
Decomposition Reaction: NO_x gases are reduced to oxygen and nitrogen gas
Synthesis reaction: carbon monoxide is combined with oxygen to produce carbon dioxide
Combustion Reaction: unburned hydrocarbons are combined with oxygen to produce carbon dioxide and water vapor
All three reactions convert harmful gases to less harmful products.
- 7. The coronavirus pandemic of 2019-2020 began in December of 2019. The amount of cases began to increase dramatically worldwide in March of 2020. The virus is particularly dangerous to those with respiratory issues. Based on the info in this article, what additional dangers may be present for people fighting the coronavirus in urban areas as summer approaches in the northern hemisphere.**
Summer months typically bring stronger and more prevalent sunshine to areas in the northern hemisphere, which will increase ground level ozone production. If individuals with respiratory issues are exposed to high levels of ground level ozone it could cause complications for their body trying to fight the virus or even worsen the symptoms of the virus.
- 8. On a separate sheet of paper, write a short opinion editorial (OP-ED) piece on whether you agree that human activities have impacted global temperatures on the planet. Be sure to use facts and evidence, not politics, when you write your piece.**
Answers will vary, remind students to use data and evidence in their piece.

Questions for Further Learning

1. **Observe the map of the United States titled “8-Hour Ozone Nonattainment Areas (Jan. 2020)” on page 11. Dangerous levels of ozone can be found predominantly in areas with a high population density. Create an argument based on evidence as to why California contains the greatest amount of land area with extreme levels of ground level ozone. There are many areas in the United States with high population density such as the Northeast U.S. What factor or factors may be causing the increased levels in California?**

Answers may vary. Due to the topography of California with a large number of mountains adjacent to low level valleys, temperature inversions are very common. Temperature inversions cause the air to become stagnant, thus not allowing the smog or pollutants to diffuse. California also has a very high population density and very little rain. Rain has the ability to “wash” out some the air pollutants and clear the air, the lack of rain in the area may also contribute to the high levels of ground level ozone.

2. **Suppose you were in charge of creating an updated Clean Air Law. What amendments would you make to reduce the amount of ground level ozone produced?**

Answers may vary. Things to consider: Car emissions, clean energy solutions, global collaboration.

3. **Use one of the many free infographic websites available online and create an infographic explain what ozone is and how ground level ozone is produced, the dangers of ground level ozone, and simple things everyone can do to help minimize ground level ozone production.**

Venngage.com, pitkochar.com, and canva.com are examples of some of the free infographic making websites. Answers will vary.

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.
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0	Not acceptable	So incomplete that no judgment can be made about student understanding

Additional Resources

Lessons and lesson plans

Catalysis & Catalytic Converters: In this lesson, students will be introduced to catalysts while expanding their knowledge of chemical reactions and stoichiometry. They will first learn about catalytic converters and then be challenged to create the best “catalytic converter” of hydrogen peroxide to oxygen gas in an inquiry-based activity.

<https://teachchemistry.org/classroom-resources/catalysis-catalytic-converters>

The Downside to Catalysts - An Exploration of CFC's on the Ozone Layer: In this lesson students will make observations of a colorful homogenous catalyst and intermediate in a reaction demonstration that will spark their interests.

<https://teachchemistry.org/classroom-resources/the-downside-to-catalysts>

The Ozone Layer: In this lesson, students will develop an explanation for the consequences of ozone depletion on Earth by planning and carrying out an investigation. Students will use analysis and interpretation of data to develop a model to explain the cause and effect of Ozone depletion on the planet Earth.

<https://teachchemistry.org/classroom-resources/the-ozone-layer>

Videos

Catalytic Converters Video: This video investigates the role of a catalytic converter and its corresponding chemical reactions within a vehicle. Students will learn about both oxidation and reduction reactions and how they, in combination with a catalyst, can impact the molecules released in a car's exhaust.

<https://teachchemistry.org/classroom-resources/catalytic-converters-video>

Chemistry Concepts, Standards, and Teaching Strategies

Connections to Chemistry Concepts

The following chemistry concepts are highlighted in this article:

- Gases: Density
- Reactions & Stoichiometry

Correlations to Next Generation Science Standards

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

HS-ESS3-4

Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.

HS-ETS1-3

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

Disciplinary Core Ideas:

- ESS3.c: Human Impacts on Earth Systems
- ETS1.B: Developing Possible Solutions

Crosscutting Concepts:

- Cause and Effect: Mechanism and explanation.
- Scale, Proportion, and Quantity
- Systems and System Models
- Stability and Change

Science and Engineering Practices:

- Analyzing and interpreting data
- Constructing explanations and designing solutions

Nature of Science:

- Scientific knowledge assumes an order and consistency in natural systems.

Correlations to Common Core State Standards

See how *ChemMatters* correlates to the [Common Core State Standards](http://www.acs.org/chemmatters) at www.acs.org/chemmatters.

Teaching Strategies

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

- Alternative to Anticipation Guide: Before reading, ask students about their ideas about smog, and if they have ever seen it. Ask what pollutants are found in smog, and what problems they think smog might cause (health and otherwise). As they read, students can find information to confirm or refute their original ideas.
- After they read, ask students what weather and pollutant conditions promoted the deadly smog in Donora, Pennsylvania in 1948.

ChemMatters™

Demystifying Everyday Chemistry

Teacher's Guide

Capturing Carbon

April 2020

Table of Contents

<u>Anticipation Guide</u>	21
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Anticipation Guide

Name: _____

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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. The challenge we have in capturing greenhouse gases is to scale them quickly.
		2. By weight, CO ₂ accounts for most of the greenhouse gases released into the atmosphere annually.
		3. Technologies to remove CO ₂ from the atmosphere can eliminate the need for other measures to reduce greenhouse gas emissions.
		4. When CO ₂ is captured from the air, it is trapped on a sorbent where it can be released later as a raw material for new products.
		5. Bioenergy systems capture CO ₂ in plants and other agricultural products, then burn the biomass to produce electricity and heat.
		6. Carbonate-containing minerals are toxic.
		7. Carbon dioxide can be injected underground as a solid.
		8. Coastal wetlands hold vast amounts of carbon in their soils and plants.
		9. The first Earth Day was held more than 60 years ago.
		10. A shift toward a plant-based diet could significantly reduce greenhouse gases in the agricultural sector.

Student Reading

Comprehension Questions

Name: _____

Directions: Use the article to answer the questions below.

1. What are NETs and how do they reduce the carbon dioxide in the atmosphere?
2. The UN Environment Program recommends that we reach net zero emissions by 2050. What is the difference between “zero emissions” and “net zero emissions”?
3. You have likely heard of the terms *carbon footprint* and *carbon emissions*. The title of this article is *Capturing Carbon*. Carbon is a general term used by scientists and the general population to discuss some of the gases in the atmosphere that have effects on climate change.
 - a. What are some more specific names of these gases in the atmosphere?
 - b. Why can the word carbon be used as a generalization for these chemicals?
4. Extraction of CO₂ from air requires the use of a sorbent.
 - a. What is the difference between absorption and adsorption?
 - b. Why would a low-temperature desorption method be an improvement to the air extraction technology design?
5. What must be true of a bioenergy technology to claim that it “captures carbon twice”?
6. Earth does a pretty good job of making rocks and minerals. Humans are experimenting with the idea of reacting CO₂ from the air with certain metal oxides naturally found in the earth to create similar kinds of minerals, thus capturing CO₂.
 - a. Write the balanced chemical equations that show this process for each of the main metal oxides found in basalt rock. (The equation for the reaction with CaO is given in the article.)
 - b. Why is this process classified as negative emissions?

Student Reading Comprehension Questions, cont.

7. How does planting trees address the goal of capturing carbon?

Study the graph showing the phase diagram on page 14 and answer the remaining questions.

8. If normal atmospheric conditions are about 25 °C and 1 atm, what is the state of matter in which CO₂ exists in our atmosphere?
9. What conditions must be applied to CO₂ so it becomes a supercritical fluid?
10. Considering the goal of NETs, why would you want to avoid applying heat to CO₂ to assist in this transition to supercritical fluid?

Questions for Further Learning

Write your answers on another piece of paper if needed.

1. Choose one NET. Identify the advantages and disadvantages of using this technology. Then explain how scientists and engineers should weigh the pros and cons to decide whether this technology should be used on a large scale.
2. The graphic on page 12 contains a quote that says: “We have technologies to remove greenhouse gases from air, but it’s less clear whether we can scale them fast enough to make a difference.”
 - a. What does it mean to scale these technologies?
 - b. Why would it be difficult to scale the technologies?
3. You may have seen advertisements for the Impossible Burger, which is described as the meatless burger or meat made from plants. This company’s mission begins with the goal, “To drastically reduce humanity’s destructive impact on the global environment by completely replacing the use of animals as a food production technology.” How does meat production increase our carbon footprint?

Graphic Organizer

Name: _____

Directions: As you read, complete the graphic organizer below to describe each type of carbon capture described in the article.

NET	How it works	Possible Problems
Extracting from Air		
Burning New Fuels		
Making Rocks		
Burying Underground		
Growing Plants		

Summary: On the back of this paper, write a tweet (280 characters or less) describing one of the technologies to remove carbon from the atmosphere.

Answers to Reading Comprehension Questions & Graphic Organizer Rubric

- 1. What are NETs and how do they reduce the carbon dioxide in the atmosphere?**
Negative Emission Technologies. They are technologies that take CO₂ out of the atmosphere in a variety of ways. They are called negative emission because they are attempting to take away the emitted molecules, thus subtracting them from total emissions.
- 2. The UN Environment Program recommends that we reach net zero emissions by 2050. What is the difference between “zero emissions” and “net zero emissions”?**
Zero emissions means that we are not allowing any greenhouse gases into the atmosphere from our various human endeavors. Net zero emissions means that we will take out as much greenhouse gas from our atmosphere as we have put in, making the sum total of emissions zero.
- 3. You have likely heard of the terms carbon footprint and carbon emissions. The title of this article is *Capturing Carbon*. Carbon is a general term used by scientists and the general population to discuss some of the gases in the atmosphere that have effects on climate change.**

 - a. What are some more specific names of these gases in the atmosphere?**
Carbon dioxide (CO₂) and methane (CH₄)
 - b. Why can the word carbon be used as a generalization for these chemicals?**
They are both carbon-containing compounds that have an impact on energy transfer in our atmosphere.
- 4. Extraction of CO₂ from air requires the use of a sorbent.**

 - a. What is the difference between absorption and adsorption?**
Absorption is when a substance mixes into another substance. Adsorption is when a substance adheres to another substance, either on the surface or in pores.
 - b. Why would a low-temperature desorption method be an improvement to the air extraction technology design?**
Using a high temperature would require energy, which would use some kind of technology that generates emissions, thus lowering the impact of the negative emission technology.
- 5. What must be true of a bioenergy technology to claim that it “captures carbon twice”?**
Its first capture is when it is growing. It is capturing carbon dioxide through photosynthesis. If the biomass is used for burning, then its emissions must be captured in order for the technology to capture the carbon dioxide a second time.
- 6. Earth does a pretty good job of making rocks and minerals. Humans are experimenting with the idea of reacting CO₂ from the air with certain metal oxides naturally found in the earth to create similar kinds of minerals, thus capturing CO₂.**

 - a. Write the balanced chemical equations that show this process for each of the main metal oxides found in basalt rock. (The equation for the reaction with CaO is given in the article.)**
MgO(s) + CO₂(g) → MgCO₃(s)
CaO(s) + CO₂(g) → CaCO₃(s)
FeO(s) + CO₂(g) → FeCO₃(s)

b. Why is this process classified as negative emissions?

It is taking carbon dioxide from the air and storing it in the earth. This process does not require an input of energy, so it is only reducing emissions that were already present.

7. How does planting trees address the goal of capturing carbon?

Increasing the number of plants growing on earth increases the amount of CO₂ taken out of the atmosphere due to photosynthesis.

Study the graph showing the phase diagram on page 14 and answer the remaining questions.

8. If normal atmospheric conditions are about 25 °C and 1 atm, what is the state of matter in which CO₂ exists in our atmosphere?

Gas

9. What conditions must be applied to CO₂ so it becomes a supercritical fluid?

Increase pressure to at least 73 atm. The work done to increase the pressure will provide energy to heat up the sample enough to reach the minimum 31°C that will push it into the supercritical phase.

10. Considering the goal of NETs, why would you want to avoid applying heat to CO₂ to assist in this transition to supercritical fluid?

Applying heat would require energy. This would work against the goal of negative emissions because the energy applied would likely come from an emission source. It would also require energy to pressurize the sample, but that is one of the disadvantages that has to be weighed. If it takes too much energy to do that, this will not be an effective technology.

Questions for Further Learning

1. Choose one NET. Identify the advantages and disadvantages of using this technology. Then explain how scientists and engineers should weigh the pros and cons to decide whether this technology should be used on a large scale.

The chart on page 15 is a good starting point. Students should discuss that most technologies will have positives and negatives that must be evaluated in order to determine efficiency and usefulness.

2. The graphic on page 12 contains a quote that says: “We have technologies to remove greenhouse gases from air, but it’s less clear whether we can scale them fast enough to make a difference.”

a. What does it mean to scale these technologies?

Scaling is a process of taking a system that works in one setting and making it work in a much larger or smaller setting.

b. Why would it be difficult to scale the technologies?

Due to bulk properties of materials and unavoidable conditions, processes and chemical reactions don’t always work the same in different scales. When testing the ideas, scientists and engineers likely experimented with small-scale versions of the technologies and processes. In order for them to be useful, they would have to be scaled up by several orders of magnitude, which could affect their efficiency and negate their usefulness.

3. You may have seen advertisements for the Impossible Burger, which is described as the meatless burger, or meat made from plants. This company's mission begins with the goal, "To drastically reduce humanity's destructive impact on the global environment by completely replacing the use of animals as a food production technology." How does meat production increase our carbon footprint?

As mentioned in the Carbon Footprint textbox, the processing associated with animal food production is quite high, due to a large amount of water and land use. The link from the textbox,

<https://earthday.org/foodprint>, is a good source of information on the impact of a variety of different kinds of food and why some have higher or lower impacts.

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

Greenhouse Gas Simulation: This laboratory activity can be used to simulate greenhouse gases.

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

Finding CO₂ Mass in your Breath: A lab activity to trap carbon dioxide from your breath in a limewater solution. This connects to the mineralization technology.

<https://teachchemistry.org/classroom-resources/finding-co2-mass-in-your-breath>

Alka-Seltzer & Gas Solubility: A lab activity about the solubility of CO₂ in water. This can be used as a connection to the idea of carbon storage, as oceans are a large CO₂ sink.

<https://teachchemistry.org/classroom-resources/alka-seltzer-gas-solubility>

Lessons and lesson plans

Calculating Your Carbon Footprint: This lesson ties very nicely to the article. It addresses climate change and guides students toward calculating their carbon footprint.

<https://teachchemistry.org/classroom-resources/calculating-your-carbon-footprint>

Carbon, Carbon Everywhere: This lesson on the carbon cycle is geared for middle school, but can be implemented with high school students.

<https://teachchemistry.org/classroom-resources/carbon-carbon-everywhere>

Ideal Gas Law using Carbon Dioxide: A lesson that uses CO₂ to teach the ideal gas law.

<https://teachchemistry.org/classroom-resources/ideal-gas-law-using-carbon-dioxide>

Finding Chemistry Connections in Climate Change: Article from *Chemistry Solutions* that suggests several ways to link chemistry and climate change in lessons.

<https://teachchemistry.org/periodical/issues/may-2017/finding-chemistry-connections-in-climate-change>

Projects and extension activities

- Construct an argument to propose funding for one NET you think has the potential for greatest success. This can be done by assigning students to different regions of the country or the world to allow for various types of arguments.
- Hold a debate, town meeting, or board meeting to develop a plan for implementing one or more NET with different kinds of parameters, such as: using a specific budget, considering a specific region, as a board member of a national or international industrial company, or as an environmental activist.
- Design an industrial scale plan or prototype for one NET. This is a great opportunity to use the Design Cycle to meet NGSS Science & Engineering Practices. Students need to study the technology enough to understand its limitations and requirements to make the design.
 - In a chemistry class, it might be easier to select one technology that best matches a given unit, so studying the technology goes with studying the unit concepts.
 - Chemical reactions for the mineralization method
 - Phases of matter or gases for the geological sequestration
 - Chemical reactions with thermochemistry for bioenergy or plant growth
 - Structure of matter or materials with air capture

Chemistry Concepts, Standards, and Teaching Strategies

Connections to Chemistry Concepts

The following chemistry concepts are highlighted in this article:

- Chemistry Basics – physical properties
- Reactions & Stoichiometry – chemical change; conservation of matter
- States of Matter – phase changes; phase diagram; sublimation

Correlations to Next Generation Science Standards

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

HS-ESS3-4

Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.

HS-ESS3-5

Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth's systems.

HS-ESS3-6

Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.

Disciplinary Core Ideas:

- PS1.A: Structure and Properties of Matter
- ESS3.C: Human Impacts on Earth Systems
- ESS3.D: Global Climate Change

Crosscutting Concepts:

- Systems and System Models
- Cause and Effect: Mechanism and explanation
- Stability and Change

Science and Engineering Practices:

- Analyzing and interpreting data
- Constructing explanations (for science) and designing solutions (for engineering)
- Engaging in argument from evidence

Nature of Science:

- Scientific knowledge is based on empirical evidence.
- Scientific investigations use a variety of methods.

Student Reading Comprehension Questions – connections to NGSS Crosscutting Concepts:

- Q4: Structure and Function
- Q5: Systems and System Models + Stability and Change + Cause and Effect
- Q6: Patterns + Systems & System Models
- Q7: Structure and Function
- Q4: Structure and Function
- Q8: Energy and Matter-Flows + Cycles and Conservation
- Questions for Further Learning Q1: Q7: Scale, Proportion, and Quantity

Correlations to Common Core State Standards

See how *ChemMatters* correlates to the [Common Core State Standards](http://www.acs.org/chemmatters) 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: Before reading, have a discussion and ask students for their ideas about removing CO₂ from the atmosphere. Ask what problems might be encountered in removing CO₂. As they read, students can compare their original ideas with information in the reading.
- After reading, ask students what they found most interesting or surprising from reading article.
- Chemical reactions: This article can start off a unit of chemical reactions using mineralization as a way of introducing synthesis reactions.
- Gases or covalent bonding: This article can be the anchor for a series of lessons on small molecules, what they are made of, how they bond, and effects they have in the atmosphere.
- Phases: This can be a good transition between lessons on liquids/solids and lessons on gases, with the phase diagram linking the topics together and showing why it is difficult to simply collect the CO₂ from the air.
- Do the puzzle on the next page with your students for a fun way to “capture” carbon.

Carbon Capture

Twelve carbon dioxide molecules have been captured in the matrix below. Find all 12 (not all the “carbon”s and “dioxides” are adjacent). Enter the remaining letters into the spaces below to find out how green chemists get around.

C	A	R	B	O	N	D	I	O	X	I	D	E
C	D	I	O	X	I	D	E	T	D	H	D	C
A	I	C	C	A	R	B	O	N	I	E	I	A
R	O	A	Y	R	C	A	R	B	O	N	O	R
B	X	R	I	D	E	T	H	E	X	I	X	B
O	I	B	C	A	R	B	O	N	I	R	I	O
N	D	O	S	D	I	O	X	I	D	E	D	N
D	E	N	D	I	O	X	I	D	E	O	E	C
I	C	D	I	O	X	I	D	E	D	I	U	A
O	A	M	O	C	A	R	B	O	N	B	I	R
X	R	K	X	E	D	I	O	X	I	D	E	B
I	B	A	I	R	B	C	A	R	B	O	N	O
D	O	O	D	D	I	O	X	I	D	E	N	N
E	N	A	E	T	E	S	C	A	R	B	O	N

Answer

T H E Y R I D E T H E I R S O D I U M
B I K E - A R B O N A T E S .

ChemMatters™

Demystifying Everyday Chemistry

Teacher's Guide

Why Avocados Are So Appealing

April 2020

Table of Contents

<u>Anticipation Guide</u>	34
Activate students' prior knowledge and engage them before they read the article.	
<u>Reading Comprehension Questions</u>	35
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.	
<u>Graphic Organizer</u>	37
This helps 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.	
<u>Answers</u>	38
Access the answers to reading comprehension questions and a rubric to assess the graphic organizer.	
<u>Additional Resources</u>	40
Here you will find additional labs, simulations, lessons, and project ideas that you can use with your students alongside this article.	
<u>Chemistry Concepts, Standards, and Teaching Strategies</u>	41

Anticipation Guide

Name: _____

Directions: *Before reading the article*, in the first column, write “A” or “D,” indicating your Agreement or Disagreement 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
		11. Avocado is a berry.
		12. One avocado contains more potassium than a medium-sized banana.
		13. Avocados contain mostly saturated fats.
		14. Unsaturated fats can lower “bad” cholesterol levels and decrease the risk of heart disease.
		15. Avocados contain only insoluble dietary fiber.
		16. Free radicals produced by oxidation in the body can damage stable molecules your body needs to function.
		17. Avocados contain high levels of antioxidants.
		18. The U.S. production and use of avocados has been steadily declining for the past 20 years.
		19. Avocados brown faster than apples because they contain more of an enzyme that catalyzes oxidation.
		20. When avocados turn brown, you should not eat them.

Student Reading Comprehension Questions

Name: _____

Directions: Use the article to answer the questions below.

1. What are minerals?
2. What are the differences among saturated, monounsaturated, and polyunsaturated fats?
3. For those who ingest a high fat diet, what are some effects to their bodies?
4. You typically hear that eating foods containing fat is unhealthy. Why do people actually need some fats in their diet?
5. What is a free radical? How do free radicals harm the body?
6. What state of matter (solid, liquid, gas) are saturated fats at room temperature? Unsaturated fats? Why, based on their molecular structure, do they exist in these states?
7. What are some differences between soluble and insoluble fibers? Where would you find each type of fiber? How does each type affect your body?
8. How has the demand for avocados in the U.S. changed over the years? Has the U.S. been able to keep up with the demand? What would we need to do to keep pace with the demand?
9. What is hydrogenation of fats? Why is it done, and for what types of foods? How does it affect the nutritional value of foods?
10. State some effects on the environment that are caused by the increase in demand for avocados.
11. How has the cost of avocados changed over the years? What are some reasons for these changes?

Student Reading Comprehension Questions, cont.

Questions for Further Learning

1. Take a poll of your classmates: How many like avocados? Approximately how often do they eat them per week/month? In (or with) what types of foods are the avocados found?
2. Look up the U.S. Recommended Daily Allowance (RDA) for fats, especially saturated and unsaturated fats. What are your favorite foods, and what is the fat content in them? How could you adjust your diet to meet the RDA better, or are you already within range? Explain.

Graphic Organizer

Name: _____

Directions: As you read, complete the graphic organizer below to describe the healthy chemistry of avocados.

	Examples	Benefits
Minerals		
Fats		
Antioxidants		

Summary: In the space below, or on the back of this paper, write a short email to a friend describing the health benefits of avocados.

Answers to Reading Comprehension Questions & Graphic Organizer Rubric

1. What are minerals?

Minerals are elements that perform essential functions in organisms. They include calcium, magnesium, phosphorus, sodium and other ions.

2. What are the differences among saturated, monounsaturated, and polyunsaturated fats?

The differences between saturated and unsaturated fats are based on their structure and types of bonds. Saturated fats have all single bonds in them, and this gives them a linear structure. Unsaturated fats have carbon-carbon double bonds. These bonds will give the molecule a more bent, non-linear shape. Monounsaturated fats have one carbon-carbon double bond, while polyunsaturated fats have multiples of these bonds.

3. For those who ingest a high fat diet, what are some effects to their bodies?

A diet high in fats could cause an increase in cholesterol in the bloodstream. This can cause high blood pressure, heart attacks, or strokes.

4. You typically hear that eating foods containing fat is unhealthy. Why do people actually need some fats in their diet?

The body needs some fat to stay healthy. Fats help generate energy and maintain cell growth.

5. What is a free radical? How do free radicals harm the body?

When the body reacts with amino acids, sugars, and fatty acids, electrons are removed from these chemicals (this is called oxidation). These newly oxidized products are called free radicals and are unstable--they readily react with other healthy, necessary, stable molecules in the body (i.e., proteins, DNA, lipids).

6. What state of matter (solid, liquid, gas) are saturated fats at room temperature? Unsaturated fats? Why, based on their molecular structure, do they exist in these states?

Saturated fats are solids, as opposed to unsaturated fats, which are liquids. Saturated fats are linear in structure, which results in larger surface area and therefore increases the capability of intermolecular forces (LDFs) between molecules. The bends in the unsaturated fats decreases the area where the molecules can attract, so they molecules are held together as tightly by LDFs, so they are liquid.

7. State the difference between soluble and insoluble fibers. Where would you find each type of fiber? How does each type affect your body?

Soluble fiber dissolves in water, forming a gel in your stomach. Insoluble fiber does not dissolve and passes through the body. Both types can control your appetite, but insoluble fibers helps with digestion.

8. How has the demand for avocados in the U.S. changed over the years? Has the U.S. been able to keep up with the demand? What would we need to do to keep pace with the demand?

The demand for avocados has increased dramatically over the past 20 years, after being constant the previous 20 years (see graph in article). The U.S. production has remained constant, while the imports have increased greatly to keep up with the demand. If we do not want to depend on other country's production, the U.S. must grow more. This however, will have a large impact on the environment.

9. What is hydrogenation of fats? Why is it done, and for what types of foods? How does it affect the nutritional value of foods?

Hydrogenation is the reaction of organic compounds (i.e., fats) with hydrogen. Hydrogen atoms bond with carbons that were double bonded to each other in the fat. That makes the unsaturated fats into saturated fats. This is done in foods (such as margarine) to keep the fats stable (longer shelf life) and to preserve its flavor. This lowers the nutritional value of the food because there is more “bad” fat in the food.

10. State some effects on the environment that are caused by the increase in demand for avocados.

With the increase in demand of avocados, there are a lot of environmental issues. More forests have to be cut down to grow avocado trees. Other ecosystems would be interrupted by these avocado trees. Also, avocado trees require a lot of water to grow.

11. How has the cost of avocados changed over the years? What are some reasons for these changes?

The costs of avocados has increased dramatically. The cost of growing, harvesting, and transporting affect the cost. Because the U.S. gets most of its avocados from other countries, that has an effect on the cost as well (transportation, import tax/tariffs).

Questions for Further Learning

Student answers will vary.

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

Activity: Keep avocados from turning brown. Students answer the question: What is the best way to keep a used avocado fresh?

<https://edu.glogster.com/glog/avocado-experiment/1st019imij9?=glogpedia-source>

Saturated and unsaturated fats: An organic chemistry demonstration. In this activity, students can distinguish between saturated and unsaturated fats using NaOH and potassium permanganate.

<https://pubs.acs.org/doi/abs/10.1021/ed062p320>

Activity: Analyzing fat content. In this activity, students analyze the fat content in several food items and identify foods that contain one day's worth of calories from healthy fat.

https://www-tc.pbs.org/wgbh/nova/teachers/activities/pdf/3401_01_nsn.pdf

Other Resources

YouTube Video – Saturated vs. unsaturated fats: <https://youtu.be/Uspq--iGuUw>

A Guide to the Different Types of Fat Infographic: <https://www.compoundchem.com/2015/08/25/fat/>

Why Do Avocados Turn Brown? – The Chemistry of Avocados Infographic:

<http://www.compoundchem.com/2014/08/03/why-do-avocados-turn-brown-the-chemistry-of-avocados/>

Chemistry Concepts, Standards, and Teaching Strategies

Connections to Chemistry Concepts

The following chemistry concepts are highlighted in this article:

- Chemistry basics – Chemical and Physical changes
- Kinetics - catalysts
- Organic Chemistry – molecular structure; saturated vs. unsaturated
- Reactions & Stoichiometry

Correlations to Next Generation Science Standards

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

HS-PS2-6

Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.

Disciplinary Core Ideas:

- PS1.A: Structure and Properties of Matter
- PS1.B: Chemical Reactions

Crosscutting Concepts:

- Cause and Effect: Mechanism and explanation
- Structure and Function

Science and Engineering Practices:

- Constructing explanations (for science) and designing solutions (for engineering)

Nature of Science:

- Scientific knowledge assumes an order and consistency in natural systems.

Correlations to Common Core State Standards

See how *ChemMatters* correlates to the [Common Core State Standards](http://www.acs.org/chemmatters) 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: Before reading, ask students if they like avocados, and why. Also ask them if they think avocados are healthy, and why they think so. As they read, students should record information they find interesting, as well as specific information describing the good chemistry of avocados.
- After they read the article, show (or ask students to watch) the 3-minute video clip referenced in the article to learn more about avocados. As they watch the video, they should record new information that was not in the article.
- Ask students what they found most interesting from reading article.

About the Teacher's Guide

Teacher's Guide team editors Dusty Carroll, Scott Hawkins, Matt Perekupka, and Jennifer Smith created the Teacher's Guide article material. Susan Cooper prepared the anticipation, reading guides, and connections to standards.

Christine Suh (Managing Editor), Emily Abbott (Administrative Editor), and Lis Gallegos (Production Editor) coordinated the production and development of the Teacher's Guides.

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