What and Where is Carbon

Lesson 1 Overview

Carbon is one of the most abundant elements in the universe and one of the most abundant elements on Earth. Carbon is in the air we breathe, the food we eat, the clothes we wear, and so many more places. Carbon is everywhere, and its structure makes it critical to life and energy on our planet. Carbon makes up 17% of the human body and 40% of plants. Lesson 1 will emphasize the chemical structure and components of carbon, fossil fuels, new and old carbon, and how carbon is harvested and used within the bio-renewable realm.

Lesson 1 consists of three main activities:

Carbon Comparison	Students practice identifying products containing carbon and distinguishing those typically derived from old vs. new carbon.
Carbon in the Energy Cycle	Through discussion and viewing a short video, students learn carbon's role in the energy cycle and how old vs. new carbon affects carbon in the atmosphere.
Fermentation Lab	Students perform a lab experiment illustrating how enzymes effect the rate of fermentation converting plant starches into ethanol and CO_2.

Here are the BIG IDEAS and *Learning Objectives* for Lesson 1

BIG IDEAS		*Learning Objectives (LO)*
1. Carbon is an important resource for living things and our economy	→	Students will define carbon and be able to understand its chemical structure and physical role for life and within the environment
2. Carbon-based energy has many different sources and useful forms	→	Students will categorize energy sources between old carbon and new carbon
3. Energy and fuels that humans use are mostly derived from natural resources	→	Students will be able to identify energy and fuels derived from natural resources

Lesson 1 meets educational standards for both the *Next Generation Science Standards (NGSS)* and the *Agriculture, Food, and Natural Resources Career Cluster Standards (AFNRCCS)*.

See the Educational Standards section at the end of this lesson for a detailed table of how standards apply.

Standards Summary

Carbon Comparison

NGSS

MS-ESS2-1 — *Link*

AFNRCCS

CS.02.02 — *Link*
NRS.02.04 — *Link*
NRS.02.05 — *Link*

Learning Objectives (LO)

LO1
LO2 See BIG IDEAS text box

Carbon in the Energy Cycle

NGSS

MS-ESS2-1 — *Link*

Learning Objectives (LO)

LO1
LO2 See BIG IDEAS text box

Fermentation Lab

NGSS

HS-ESS2-6 — *Link*
MS-LS2-3 — *Link*

AFNRCCS

NRS.02.01 — *Link*

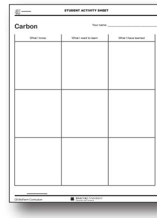
Learning Objectives (LO)

LO3 See BIG IDEAS text box

Lesson 1 Outline *page*

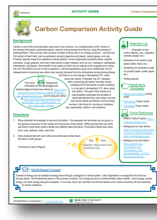
Part A | Complete first two columns of Carbon KWL 3

1. Give each student a copy of Carbon KWL and time to complete the first two columns.
2. Discuss what carbon is based on their KWL work.



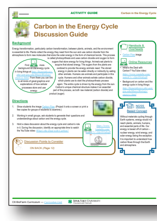
Part B | Complete **Carbon Comparison** activity 5

1. Introduce examples of carbon.
2. Follow Carbon Comparison Activity Guide to facilitate students in developing an understanding of carbon, its significance to humans and life in general, and its sources.
3. Play *What is Carbon*, individually using student tablets or as a group using a projection of the class's computer or tablet screen.
4. Have students organize the knowledge they have gained thus far using Old Carbon and New Carbon Frayer Models.



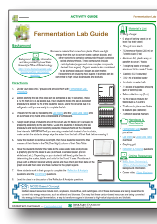
Part C | Complete **Carbon in the Energy Cycle** discussion 11

1. Introduce the visual Carbon Flow in the Global Energy System.
2. Facilitate students' generating questions and developing understanding of the energy cycle.
3. Have students watch the video *What's the Deal with Carbon?* about the carbon cycle.
4. Use the Carbon in the Energy Cycle Discussion Guide to facility a group discussion.



Part D | Complete **Fermentation Lab** and analysis 15

1. Ask students to share what they know about fermentation and carbon's role in it.
2. Use the Fermentation Lab Activity Guide to facilitate students' completion of the Fermentation Lab. *(This takes at least 2, typically 3, meeting periods.)*
3. Work with students to analyze and discuss their results.



Part E | Learners generalize and apply knowledge gained in Lesson 1 . . . 3

1. Have students and instructor complete the remaining column of the Carbon KWL.
2. Hold a group discussion of the Carbon KWL results.
3. Have students complete a summary writing that explains in a Letter to the Editor format why carbon in agriculture is so important to our economy.

Appendix | Detailed table of how Educational Standards apply 21

Time Requirements

(Preparation time does not include the time needed to familiarize yourself with this curriculum.)

Total Preparation: 30 – 90 min
Total Implementation: 3 – 5 hrs

Time Breakdown

Part A |
Preparation: <10 min
Implementation: 15 – 30 min

Part B |
Preparation: < 10 min
Implementation: 30 – 60 min

Part C |
Preparation: 10 – 30 min
Implementation: 30 – 60 min

Part D |
Preparation: 10 – 30 min
Implementation: 60 – 90 min
(over at least two days)

Part E |
Preparation: <10 min
Implementation: 30 – 60 min

Key Words

- Biofuels
- Biomass
- Biorenewable
- Carbohydrates
- Carbon
- Energy cycle
- Fermentation
- New carbon
- Old carbon
- Photosynthesis

Carbon

Your name: ______________________________

KWL Chart

What I know	What I want to learn	What I have learned

Adapted from WorksheetWorks.com

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Carbon Comparison Activity Guide

Background

Carbon is one of the most abundant resources in the universe. It is a building block of life. Carbon is the element that nature, particularly plants, uses for storing energy from the sun, using the process of photosynthesis. There are two main sources of carbon that we use in our energy economy – old and new. Old carbon is fossil fuels, such as petroleum products (gasoline and diesel), natural gases, and coal. Products typically made from petroleum include plastics, human-engineered (synthetic) fibers, asphalt, cosmetics, drugs, gasoline, and more. New carbon is plant material, such as corn, soybeans, switchgrass, strawberries, and leaves. One benefit of new carbon is that it can be regrown when supplies are running low, but if the Earth runs out of coal or gasoline, it will be impossible to grow more. Additionally, the CO_2 released when consuming new carbon was recently removed from the atmosphere during photosynthesis. (So there is no net change in atmospheric CO_2 when using new carbon.) Whereas, the CO_2 released when consuming old carbon has been stored underground for thousands of years (resulting in a net gain in atmospheric CO_2 when using old carbon). The goal of this activity is to help students understand the benefits of using fuels derived from new carbon sources, such as bio-diesel and ethanol, as the energy sources in the future for running our airplanes, cars, spaceships, tractors, and combines.

Find more background information on the advantages and disadvantages of using new carbon at: *www.solarschools.net/resources/stuff/advantages_and_disadvantages.aspx*, and of using old carbon at: *greenliving.lovetoknow.com/Advantages_and_Disadvantages_of_Non_Renewable_Energy*

Directions

1. Show students the examples of new and old carbon. The examples can be shown as one group or two groups (one group of new carbon and one group of old carbon). Without giving them any hints, ask them to write down what is similar and different about the items. Think about where they came from, uses, textures, looks, and more.

2. Have students talk with each other about what was similar about the items in both groups.

Continued on back (Page 6)

Big Idea

- Originally, they all came from something living.

(Student lists will contain more than the big idea)

Material's List

- Examples of new carbon (leaves, corn, soybeans, animals, people, etc.)
- Examples of old carbon (coal, plastic bottle, fossil, etc.)
- Something for students to write on (scratch paper, poster paper, etc.)
- Writing utensils

Handouts & Overheads

- Where is the Carbon? activity sheet
- New Carbon Frayer model
- Old Carbon Frayer model

Online Resources

- What is Carbon? game: *isfair.herokuapp.com/*
- Background on new carbon: *www.solarschools.net/resources/stuff/advantages_and_disadvantages.aspx*
- Background on old carbon: *greenliving.lovetoknow.com/Advantages_and_Disadvantages_of_Non_Renewable_Energy*

NGSS Based Concept

Transfer of energy can be tracked as energy flows through a designed or natural system. Life is dependent on energy flow from the sun through plants. The fundamental player in this process is carbon. Our energy economy is fundamentally carbon-based – wind energy, nuclear energy, and solar energy being the exception. In our lives, food, fuel, and fiber are the foundations of our carbon economy. All are necessary for human existence.

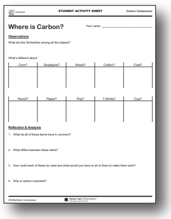
Directions *(continued)*

3. Ask students to discuss what was different about the items.

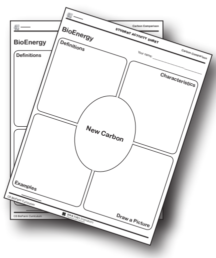
Big Ideas

- The old carbon is from dead [fossil fuels] materials, and the new carbon is from living materials.
- Plastics, synthetic fibers, and fossil fuels are all derived from materials that were once alive, but have undergone transformation over time.

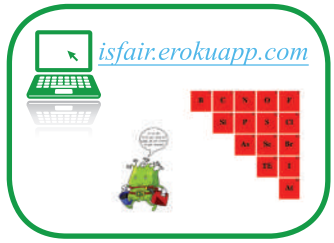
(Student lists will contain more than the big idea)



4. Have students complete the Where is Carbon? activity sheet
5. Ask students to use sticky notes to write down what they know about carbon, one idea for each note. Share these out as a group, allowing for discussion, questions, and group common ideas together.



6. Cluster sticky notes on the board. Generate a summary statement for each cluster. Using summary statements, have the students discuss the difference between old and new carbon.
7. This is a good time to play the online *What is Carbon?* game.
8. Have students complete Frayer models in small groups or individually.
9. Discuss the advantages and disadvantages of old and new carbon from a Central United States perspective?



Discussion Points to Consider

- Talk more about energy from new carbon, focusing on what plants ethanol and bio-diesel come from. You can also talk more about new types of energy are being developed from other new energy sources – miscanthus, switchgrass, etc.
- Why is carbon important? Some reasons to discuss include:
  - * It's in everything we use
  - * It makes up 18% of our body and 40% of plants
  - * It's the 4th most common element in Galaxy, solar system, and on earth, etc.
- Geographically, which carbon source is more available in Iowa? Midwestern United States?
  (Answer – new carbon)

Where is Carbon?

Your name: ______________________________

Observations

What are the Similarities among all the objects?

What's different about:

Corn?	Soybeans?	Wood?	Cotton?	Coal?

Pencil?	Paper?	Pop?	T-Shirts?	Cup?

Reflection & Analysis

1. What do all of these items have in common?

2. What differs between these items?

3. How could each of these be used and what would you have to do to them to make them work?

4. Why is carbon important?

BACK OF SHEET (*blank*)

BioEnergy

Frayer Model

Your name: ______________________________

Definitions

Characteristics

Old Carbon

Examples

Draw a Picture

Adapted from WorksheetWorks.com

BioEnergy

Frayer Model

Your name: ______________________________

Definitions

Characteristics

New Carbon

Examples

Draw a Picture

Adapted from WorksheetWorks.com

Carbon in the Energy Cycle Discussion Guide

Background

Energy transformation, particularly carbon transformation, between plants, animals, and the environment is essential to life. Plants collect the energy they need from the sun and use carbon dioxide from the atmosphere to form new molecules that store the solar energy in the form of chemical bonds. This process is called photosynthesis and uses carbon dioxide and oxygen to form sugars that store energy for living things. Animals eat plants to acquire that stored energy. The sugars from the plants are oxidized to provide the energy animals need. The stored energy in plants can be eaten directly or indirectly by eating other animals. Humans are animals and participate in this cycle. Humans and other animals exhale carbon dioxide, which plants use to start the photosynthesis process again. The entire cycle is driven by the energy from the sun. Carbon's unique chemical structure makes it an essential part of the process, as both raw material (carbon dioxide) and product (sugar).

Find more background on the energy cycle in living things at: *hyperphysics.phy-astr.gsu.edu/hbase/Biology/enercyc.html*. From there you can link to all kinds of great graphics and explanations of how cellular processes store and use energy.

Handouts & Overheads

- Carbon Flow image

Online Resources

- What's the Deal with Carbon? YouTube video: *www.youtube.com/watch?v=2Jp1D1dzxj8*
- Background on carbon and the energy cycle in living things: *hyperphysics.phy-astr.gsu.edu/hbase/Biology/enercyc.html*

Directions

1. Show students the image Carbon Flow. (Project it onto a screen or print a few copies for groups of students to examine.)
2. Working in small groups, ask students to generate their questions and understandings about carbon and the energy cycle.
3. Hold a class discussion about the energy cycle and carbon's role in it. During the discussion, identify an appropriate time to watch the YouTube video: *What's the Deal with Carbon?*

www.youtube.com/watch?v=2Jp1D1dzxj8

Discussion Points to Consider

ON BACK *(Page 12)*

NGSS Based Concept

Without materials cycling through Earth systems, energy would not reach plants, animals, humans, and essential parts of life. Our energy is based off of carbon – nuclear energy, wind energy, and solar energy being the exception. It is important to understand how carbon flows through the Earth and atmosphere.

Discussion Points to Consider

- Ask students where plants get energy? *(Answer: the sun)* What form do they store energy in? *(Answer: Carbon based molecules such as sugars, starches, cellulose, and fats.)*
- What gas do plants release as a by-product of storing the sun's energy in sugar molecules (photosynthesis)? *(Answer: oxygen.)*
- What do animals breathe? *(Answer: oxygen)* What do animals breathe out? *(Answer: carbon dioxide.)* Where do animals get energy from? *(Answer: eating plants and other animals.)*
- As animals, what do humans breathe? *(Answer: oxygen)* What do humans breathe out? *(Answer: carbon dioxide.)* Where do humans get energy from? *(Answer: eating plants and other animals.)*
- Where do plants, animals, and humans get the energy they need to live from? *(Answer: carbon compounds—sugars, starches, oils, fats, etc. that were created originally by plants through photosynthesis.)*
- What impact does the carbon cycles have on climate change? *(Answer: Carbon dioxide in the atmosphere affects climate. Plants remove carbon from the atmosphere through photosynthesis. By lowering the total plant mass, there will be less carbon dioxide removed from the atmosphere. [Deforestation, urban development, drought, etc.])*
- Why is it important to use new carbon as opposed to old carbon? *(Answer: old carbon increases atmospheric carbon.)*
- How can we use less old carbon? What are different sources of energy we can use instead of fossil fuels? Discuss the advantages and disadvantages of each.
- What happens when we run out of fossil fuels?


Global
Atmosphere
Global Warming
Greenhouse Gases
Local
Biomass/ Energy
CO2
Organismal
O2
CO2
Carbon Flow
Part of a Global System

BACK OF SHEET (*blank*)

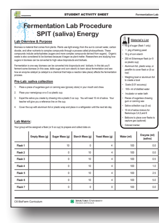
Fermentation Lab Guide

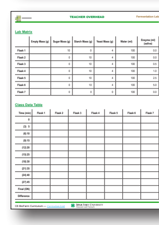
Background

Background information and labs provided by Iowa State University's Office of Biotechnology: *www.biotech.iastate.edu/biorenewables-curriculum-modules/*

Biomass is material that comes from plants. Plants use light energy from the sun to convert water, carbon dioxide, and other nutrients to complex compounds through a process called photosynthesis. These compounds include carbohydrates (sugars and more complex compounds derived from sugars). Organic waste is also considered to be biomass because it began as plant matter. Researchers are studying how sugars in biomass can be converted to high-value bioproducts and biofuels.

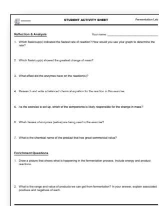
Directions





1. Divide your class into 7 groups and provide them with Fermentation Lab Procedure.
2. Before starting the lab (this step can be competed a day in advance), make a 10 ml mark on a 5 oz plastic cup. Have students follow the saliva collection procedure to collect 10 ml of the students' saliva. Store the covered cup in a refrigerator until you are ready to complete the lab.
3. Prepare for the lab by replicating the Lab Matrix and the Class Data Table onto an overhead or by hand onto a chalkboard or whiteboard.
4. Assign each group of students one of the seven 250 ml flasks (or 9 oz cups) to preparing according to the lab matrix. Guide the students in following the lab procedure and taking and recording accurate measurements at the indicated time intervals. IMPORTANT—if you are using a water-bath instead of an incubator, make certain the students always wipe the water from the bath off their flask before massing it.
5. Allow the reaction to continue overnight, then have students record the final masses of their flasks in the ON (Over Night) column of their Data Table.

6. Have the students transfer their data to the Class Data Table and provide a graphing grid for the class to use (overhead, oversized paper, grid on whiteboard, etc.). Depending on your students' skill level, guide them in determining the scales, labels, and units for the X and Y axes. Provide each group with a different colored writing utensil and have them plot their data on the graph and add their color and flask number to the graph legend.



7. Have students work in their groups to complete the Reflection & Analysis questions and the Enrichment questions.
8. Lead the class in a discussion of the Reflection & Analysis questions.

Material's List

- 10+ g of sugar
- 6 pkgs of baking yeast (or at least 1oz total yeast)
- 50+ g of corn starch
- 7 Erlenmeyer flasks (250 ml) or 7 plastic cups (9 oz)
- Aluminum foil, plastic wrap, or parafilm to cover 7 flasks
- 7 weighing boats or enough aluminum foil to create 7 boats
- Scale(s) (0.01 accuracy)
- 700+ ml of distilled water
- Incubator or water bath
- 7+ pieces of sugarless chewing gum or canning wax
- Saliva collection cup (5 oz)
- 10 ml of saliva mixture for flasks/cups 3,4,5,and 6
- 7 balloons to place over flasks to capture gas (optional)
- 7 different colored markers

Handouts & Overheads

- Fermentation Lab student procedure
- Lab Matrix & Class Data Table overhead
- Graphing grid
- Reflection & Analysis questions

Online Resources

- *Iowa State University's Office of Biotechnology* for background information
- Career video: *Plant Engineer*

NGSS Based Concept

Carbon-based resources include corn, soybeans, miscanthus, and switchgass. All of these biomasses are being researched to convert into energy resources, such as ethanol and biomass. One way that these carbon-based resources are being converted into energy is through fermentation, a way to transform sugars in biomass to high-value bioproducts and biofuels.

Lab Matrix

	Empty Mass (g)	Sugar Mass (g)	Starch Mass (g)	Yeast Mass (g)	Water (ml)	Enzyme (ml) (saliva)
Flask 1		10	0	4	100	0.0
Flask 2		0	10	4	100	0.0
Flask 3		0	10	4	100	0.5
Flask 4		0	10	4	100	1.0
Flask 5		0	10	4	100	2.5
Flask 6		0	10	4	100	5.0
Flask 7		0	0	0	100	0.0

Class Data Table

Time (min)	Flask 1	Flask 2	Flask 3	Flask 4	Flask 5	Flask 6	Flask 7
0							
(3) 5							
(6) 10							
(9) 15							
(12) 20							
(15) 25							
(18) 30							
(21) 35							
(24) 40							
(27) 45							
Final (ON)							
Difference							

Fermentation Lab Procedure SPIT (saliva) Energy

Lab Overview & Purpose

Biomass is material that comes from plants. Plants use light energy from the sun to convert water, carbon dioxide, and other nutrients to complex compounds through a process called photosynthesis. These compounds include carbohydrates (sugars and more complex compounds derived from sugars). Organic waste is also considered to be biomass because it began as plant matter. Researchers are studying how sugars in biomass can be converted to high-value bioproducts and biofuels.

Fermentation is one way biomass can be converted into bioproducts and biofuels. In this lab you'll ferment some biomass (in this case, table sugar and corn starch) to learn about fermentation and see how an enzyme catalyst (a catalyst is a chemical that helps a reaction take place) affects the fermentation process.

Pre-Lab: saliva collection

1. Place a piece of sugarless gum or canning wax (grocery store) in your mouth and chew.
2. Place your name/group on a 5 oz plastic cup.
3. Expel the saliva you create by chewing into a plastic 5 oz cup. You will need 10 ml of saliva. Your teacher will give you a reference line on the cup.
4. Cover the cup with aluminum foil or plastic wrap and place in a refrigerator until the next lab day.

Material's List

- 10 g of sugar (flask 1 only)
- 1 pkg of baking yeast
- 10 g of corn starch
- 250 ml Erlenmeyer flask (or 9 oz plastic cup)
- Aluminum foil, plastic wrap, or parafilm to cover flask or (9 oz cup)
- Weighing boat or aluminum foil to create a boat
- Scale (0.01 accuracy)
- 100+ ml of distilled water
- Incubator or water bath
- Pieces of sugarless chewing gum or canning wax
- Saliva collection cup (5 oz)
- 10 ml of saliva mixture for flasks/cups 3,4,5,and 6
- Balloons to place over flasks to capture gas (optional)
- Colored marker

Lab Matrix

Your group will be assigned a flask (or 9 oz cup) to prepare and collect data on.

	Empty Mass (g)	Sugar Mass (g)	Starch Mass (g)	Yeast Mass (g)	Water (ml)	Enzyme (ml) (saliva)
Flask 1		10	0	4	100	0.0
Flask 2		0	10	4	100	0.0
Flask 3		0	10	4	100	0.5
Flask 4		0	10	4	100	1.0
Flask 5		0	10	4	100	2.5
Flask 6		0	10	4	100	5.0
Flask 7		0	0	0	100	0.0

Lab Procedure

1. Each group of students will be responsible for preparing one of the seven 250 ml flasks (or 9 oz cups) according to the lab matrix. Label your flask/cup with the number you have been assigned.
2. Mass the empty flask/cup and record it on the table.
3. Mass the sugar, starch, and yeast as required for your part of the lab and add it to the flask/cup.
4. Add warm (37^{O}C) water to the flask/cup and enzyme (saliva from the pre-lab prep) to your flask/cup in the amount indicated by the matrix.
5. Cover the flask/cup with parafilm, plastic wrap, or aluminum foil and poke 2 small holes in the cover.
6. Record the mass of your flask/cup on the table below. The class will later combine all the results of the lab for final analysis.
7. Swirl the flask/cup to mix and place the flask/cup in an incubator or water bath set at 37^{O}C.
8. Measure the mass of the flask/cup every 3 or 5 minutes. Swirl the flask/cup occasionally during the incubation. **IMPORTANT** – *Make sure to wipe the excess water from the side of the container if using a water bath.*
9. Continue to measure the mass until the end of class.
10. Let the reaction continue until the next day.
11. Record the final mass the next day in the "ON" (Over Night) column.
12. Combine your data with the class data on the data table provided by your teacher and transfer these results to your table.
13. Follow your teacher's instructions for graphing your data alongside the data from the other groups.
14. Discuss in your group the data and answer the questions under Reflection & Analysis and Enrichment Questions.

Data Table

Time (min)	Flask 1	Flask 2	Flask 3	Flask 4	Flask 5	Flask 6	Flask 7
0							
(3) 5							
(6) 10							
(9) 15							
(12) 20							
(15) 25							
(18) 30							
(21) 35							
(24) 40							
(27) 45							
Final (ON)							
Difference							

Reflection & Analysis

Your name: ______________________________

1. Which flask/cup(s) indicated the fastest rate of reaction? How would you use your graph to determine the rate?

2. Which flask/cup(s) showed the greatest change of mass?

3. What effect did the enzymes have on the reaction(s)?

4. Research and write a balanced chemical equation for the reaction in this exercise.

5. As the exercise is set up, which of the components is likely responsible for the change in mass?

6. What classes of enzymes (saliva) are being used in the exercise?

7. What is the chemical name of the product that has great commercial value?

Enrichment Questions

1. Draw a picture that shows what is happening in the fermentation process. Include energy and product reactions.

2. What is the range and value of products we can get from fermentation? In your answer, explain associated positives and negatives of each.

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Meeting Educational Science Standards Using C6 BioFarm Curriculum: Lesson 1

Next Generation Science Standards

Standard	Description	Students Will...	Activity
Earth's Systems *MS-ESS2-1*	Develop a model to describe the cycling of Earth's materials and the flow of energy that drives this process.	Learn how various forms of energy can be produced from carbon resources	**Carbon Comparison Activity** **Carbon in the Energy Cycle**
Earth's Systems *HS-ESS2-6*	Develop a quantitative model to describe the cycling of carbon among the hydrosphere, atmosphere, geosphere, and biosphere.	Understand the role of carbon in the environment, and how carbon cycles through the environment	**Fermentation**
Ecosystems: Interactions, Energy, and Dynamics *MS-LS2-3*	Develop a model to describe the cycling of matter and flow and energy among living and nonliving parts of an ecosystem.	Understand the role of plants and animals in the carbon cycle	**Fermentation**

AFNRCC Standards on Page 22

Agriculture, Food, and Natural Resources Career Cluster Standards

Standard	Description	Students Will...	Activity
Evaluate the nature and scope of the Agriculture, Food & Natural Resources Career Cluster and the role of agriculture, food and natural resources (AFNR) in society and the economy *CS.02.02*	Examine the components of the AFNR systems and assess their impact on their local, state, national, and global society, and economy.	Learn about how carbon surrounds them and how it impacts our economy	**Carbon Comparison Activity**
Analyze the interrelationships between natural resources and humans *NRS.02.01*	Analyze the interrelationships between natural resources and humans.	Learn how human actions impact the carbon cycles and the overall ecosystem	**Fermentation**
Analyze the interrelationships between natural resources and humans *NRS.02.04*	Examine and explain how economics affects the use of natural resources.	Learn how consumer preferences and markets impact demand and use of various carbon resources	**Carbon Comparison Activity**
Analyze the interrelationships between natural resources and humans *NRS.02.05*	Communicate information to the public regarding topics related to the management, protection, enhancement, and improvement of natural resources.	Be able to share information about best practices for stewardship and use of natural resources	**Carbon Comparison Activity**