# Life Cycle Assessment and Renewable Energy from an Indigenous Perspective

ND EPSCoR Lesson Plan

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**Lesson Title:** Life Cycle Assessment and Renewable Energy from an Indigenous Perspective

**Lesson Overview:** This lesson focuses on ways of reclaiming sustainability as an in Indigenous way of knowing and focuses on the western science concepts of energy from wastes and life cycle assessment. Students will explore how chemical engineering concepts allow for us to take the idea of converting food (traditional corn ethanol) into fuel and how we should be looking at converting waste materials into fuel. Using concepts within traditional engineering along with chemical engineer's ability to use biochemical means to break down waste and generate a fuel. The second part of this lab will compare our current food system and look at all of the inputs of the lunch we just had and compare it to our ancestors' food systems'. What energy went into the walleye we caught and ate, what energy goes into the manoonim we harvested and prepared, what energy comes from the picking of berries or the drying of sage?

The first part of the lesson focuses on how engineering can be used to help make use of "waste" sources. We will have discussion of the bison or the deer (depending on tribes) and how all parts were used. There was no such thing as waste in indigenous culture. We will discuss the effects of traditional fuels and how scientist came up with using our food as a fuel. Students will be asked to brainstorm other ways in which we can get fuel and help reduce waste. Students will perform a demo using a food source. Students will then preform a second demo where we use a waste material to form a biofuel and then using chemical engineering concepts, we will apply enzymes to our waste and watch as fuel is formed. This process takes a while, so may need to be wrapped up in a different period.

This second part of the lesson introduces students to life cycle assessment. In this lesson, students will consider what raw materials and energy that went into our lunch. In addition, students are tasked with considering ways in which these resources can be reduced using indigenous knowledge. Following a discussion of the life cycle of our foods, students are asked to compare and contrast our lunch we had with how our ancestors ate.

**Lesson Objectives:**

1) To recognize how indigenous knowledge and ways of knowing are already embedded within engineering.
2) To understand where the resources and energy we consume everyday come from within in a life cycle assessment context
3) To understand that in proper LCA design mentality there is no such thing as waste, engineers can come up with creative solutions using engineering principles to use earth's resources sustainably

**NSF Subject Classification:** Environmental Engineering and Chemical Engineering

**National Next Gen Standards:**

- HS-PS3-3. Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy

- HS-LS2-4. Use mathematical representations to support claims for cycling of matter and flow of energy among organisms in an ecosystem

**North Dakota Standards:**

- HS-PS3-3. Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy
- HS-LS2-4. Use mathematical representations to support claims for cycling of matter and flow of energy among organisms in an ecosystem
- ET1.A: Defining and Delimiting Engineering Problems
- ET1.C: Optimizing the Design Solution Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (tradeoffs) may be needed.

**Grade or Grade Band:** 8-12

**Time Needed (estimate):** 2 50-minute class periods

**Lesson Author:** Jessi Kjemhus
Teaches 7-12 science at Northwood Public School since 2015 and 9-12 science at North Border Public School prior. She graduated in 2012 with a Composite Chemistry degree from Mayville State University and then with her Master's from Valley City State University in 2015. She can be contacted at jessi.kjemhus@northwoodk12.com

**Scientist/K12 Collaborator & University:** Bethany Klemetsrud, University of North Dakota

**Scientist Bio:** Dr. Bethany Klemetsrud is an assistant professor in Chemical Engineering at the University of North Dakota. Bethany grew up on the White Earth Nation and is excited to be able to work close to her home and family. She received her undergraduate degree from the University of Minnesota Duluth and completed her PhD at Michigan Technological University in 2016. Her dissertation is titled "EXPERIMENTAL AND THEORETICAL INVESTIGATION OF SUSTAINABLE FAST PYROLYSIS BIOFUELS FROM WOODY BIOMASS". Her passions include advocating for the broadening participation of Native students in STEM, developing technologies that can convert waste into useful products or energy. Beth's primary form of research within the chemical engineering department looks at using fast pyrolysis to thermochemically convert waste materials into use chemicals and energy dense products. Bethany comes from a large family and is committed that her younger siblings and niece and nephews be able to see themselves at Scientists and Engineers if that's what path they choose.

**Summary of Research and/or Problem Being Studied:** This work focuses on developing renewable or sustainable energies from materials from agriculture and municipal wastes. This work employs biochemical and thermochemical solutions. Due to the dangers of thermochemical in a high school setting we will focus on biochemical conversion. All renewable/sustainable energy must be evaluated in terms of its ability to solve climate issues. This can be done mathematically with life cycle assessment. Measuring all of the inputs and outputs of a system from extraction to final use and disposal of that product or process. This work looks at novel solutions for turning waste into energy and evaluating it at a much larger scale of sustainability. Life cycle assessment will be used to quantify environmental impacts however the use of stakeholder and community participations will look at the larger question of sustainability and if these sources of energy are beneficial to communities in terms of social and economic impacts.

**Preparation/Materials**

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**Background knowledge students must have to be successful**
Students need to know that environmental impact from everything we do including eating. Whether it is harvesting, processing or transporting the food, we are using fossil fuels which are increasing greenhouse gases into our atmosphere. The goal is to minimize out greenhouse gas footprint and live sustainably.

**Essential Terminology**
Biofuels-
Greenhouse gases (GHG)-
Enzyme-
Sustainability-

**Resources:**

- North Dakota Established Program to Stimulate Competitive Research STEM page
- Food Emission Calculator
- Food Wastage Calculator
- YouTube Video explaining carbon footprint
- YouTube Video ways to reduce carbon footprint
- Green Eatz website
- Carbon Footprint calculator website
- Carbon Cycle Gizmo- could be used as an introduction or extension
- Greenhouse Effect Gizmo- could be used as an introduction or extension

**Websites:**

- https://www.ndepscor.ndus.edu/ndep/nature/sunday-academy/stem-module-topics/
- https://www.foodemissions.com/Calculator
- http://www.stopwaste.co/calculator/
- https://www.youtube.com/watch?v=8q7_aV8eLUE
- https://www.youtube.com/watch?v=KdiA12KeSL0
- http://www.greeneatz.com/foods-carbon-footprint.html
- https://www.carbonfootprint.com/
- https://www.explorelearning.com/

**Materials needed:**

- Balloons
- Corn syrup or sugar
- Corn flakes
- Yeast
- Spoon
- 1 teaspoon

- Flask
- Stopwatch
- Beaker
- Water
- Computer
- Pencil/pen

*PowerPoint – found as separate attachment*

**Procedure/Activities**

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## Lesson 1:

- Slides 2 - 5
- Go over biofuel vocab
- Slides 6 - 12
- Hand out activity 1 worksheet and go over materials needed and what to do; slide 13
    - Give students a chance to discuss questions after first experiment; slide 14
    - Talk through what they will do for the second experiment; slide 15
    - Give students a chance to discuss questions after doing the second experiment and discuss everything as a group; slide 16
- Slides 17 - 19
- Go over enzyme vocab
- Slides 20 - 22

## Lesson 2:

- Optional introduction (or extension for later): Carbon Cycle Gizmo or Greenhouse Effect Gizmo-takes about 20-40 minutes depending on the Gizmo and students' speed
- Review from previous lesson
- Go over greenhouse gas and sustainability vocab words
- Slides 23 - 26
- YouTube Video explaining carbon footprint
    - https://www.youtube.com/watch?v=8q7_aV8eLUE
- Slides 27 – 28, explain activity two and hand out sheet
    - Show how to use the calculator website and explain what to do. Maybe go through a sample one together, especially help those students who need more guidance.
- Discuss what was discovered

## Lesson 3: *depending on time left, this lesson may be combined with lesson 2

- Review what was found out about yesterday's activity
- Slide 29, explain activity three and hand out sheet
    - Show how to use the calculator website and explain what to do. Maybe go through a sample one together, especially help those students who need more guidance.
- Discuss what students discovered, found interesting, etc.
- Ways to reduce carbon footprint video
    - https://www.youtube.com/watch?v=KdiA12KeSL0
- Slides 30 - 32
    - Optional extension: http://www.greeneatz.com/foods-carbon-footprint.html
        - Goes through in more detail about amount of carbon dioxide is released by getting these food people and then goes through ways we can reduced our carbon footprint
- Slides 33 - 38

- Go over ways we could reduce our carbon footprint, research different ways that we could implement in our rural or city lifestyles
    - Have students pick 2 or 3 changes that they are willing to implement in their lives, share together
- Optional extension if needed
    - Students calculate their carbon footprint
        - https://www.carbonfootprint.com/

**Extensions for above average students:**

- Calculate personal carbon footprint
    - Analyze what could be done to minimize their use of carbon dioxide
    - https://www.carbonfootprint.com/
- Cycle Gizmo or Greenhouse Effect Gizmo-takes about 20-40 minutes depending on the Gizmo and students' speed

**Mediation/Support for students that need it:**

- Step by step instruction
- Frequent check-ins
- Gizmos can be modified to meet support needs of some students

**Lesson Outline (for research-based lessons)**

1) Observe Phenomena
2) What questions should we be able to answer?
3) Write a Hypothesis
4) Come up with a Research Plan
5) Carry out investigation
6) Revisit the Background Research
7) Construct Explanations. (TASKS-Publish/Communicate Findings)

**Standards Alignment**

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**ND Science Standard(s):**

- HS-PS3-3. Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy
- HS-LS2-4. Use mathematical representations to support claims for cycling of matter and flow of energy among organisms in an ecosystem
- ET1.A: Defining and Delimiting Engineering Problems
- ET1.C: Optimizing the Design Solution Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (tradeoffs) may be needed.

**Disciplinary Core Idea: e.g.** Chemistry and Environmental Science

Analyzing the cycling of energy and how our environment is effected by it.

**North Dakota DPI Standards:**

**ND ELA**

W.7 Conduct short as well as more sustained research projects to answer questions (including self-generated questions) or solve problems.

a. Develop a research question.

b. Narrow or broaden the inquiry when appropriate.

c. Synthesize multiple source

**Next Gen Standards:**

- HS-PS3-3. Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy
- HS-LS2-4. Use mathematical representations to support claims for cycling of matter and flow of energy among organisms in an ecosystem

**Science and Engineering Practices**

- Developing and Using Models

**Cross Cutting Concepts**

- Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system.
- Modern civilization depends on major technological systems. Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks.
- Energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems.

**Unit Objectives**

- Students will be able to recognize how we effect our environment and ways we can live a sustainable life through reduce, reuse, and recycle.

**Assessment**

- Through activities, students will see how we can reuse energy but also see how we waste it. Through analyzing their lives, they will find ways to reduce their carbon footprint by brainstorming and group discussion.

**Daily Plans and Assessments**

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**Learning Target for each day/activity**

- Lesson 1/Day 1- Students will carry out yeast experiment to see what yeast needs to carry out its reaction to generate carbon dioxide.

- Lesson 2/Day 2- Students will analyze how much carbon dioxide output is due to their lunch.

- Lesson 3/ Day 3- Students will analyze carbon dioxide output is from food waste and what changes they could make to reduce their carbon footprint.

**Criteria for Success/Assessment for each activity**

- Lesson 1- Students will see how energy cycles through from a yeast reaction but its byproduct is carbon dioxide; natural form of carbon dioxide being released.

- Lesson 2- Students recognize how much carbon dioxide is added to our atmosphere due to just eating lunch.

- Lesson 3- Students recognize that food wastage leads to carbon dioxide output and evaluate what can they do to reduce their carbon dioxide impact on Earth.

**Additional Lesson Resources / Materials**

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**References:**

Klemetsrud, B. “Biofuels + Sustainability”. 19 July, 2020. https://www.ndepscor.ndus.edu/ndep/ nature/sunday-academy/stem-module-topics/

**Websites for purchasing materials**

General Lab supplies:

Nasco

https://www.enasco.com/c/Education-Supplies/Science

Flinn

https://www.flinnsci.com/

Carolina

https://www.carolina.com/lab-supplies-and-equipment/science-lab-supplies/science-lab-classroom-supplies/10300.ct

School Specialty

https://www.schoolspecialty.com/science-supplies-and-products

Amazon

www.amazon.com

Retailers such as Target or Walmart

# Activity 1 – Exploring Yeast

**Purpose**

To determine which materials have what yeast needs to react and form ethanol.

**Background information**

Yeast plays an important role in food we eat every day and in some drinks. Yeast is the reason why bread rises. Without it, bread would have minimal holes and be very dense. Yeast carries out an essential chemical reaction that results in the dough rising for bread

**Testable Question**

Yeast needs _____ to react and in the process it creates _____ helping the dough to rise.

**Materials:**

- Balloon
- Corn syrup or sugar
- Corn flakes
- Yeast
- Spoon
- 1 teaspoon
- Flask
- Stopwatch
- Beaker
- Water

**Direction**

- Measure 2 spoonfuls of corn syrup or 2 spoonfuls of sugar into the flask
- Measure 1 teaspoon of yeast into the flask
- Fill the flask to the 150 mL mark with warm water
- Place balloon on top of flask
- Swirl the flask for approximately 1 minute until contents appear well mixed

Stop. Record your observations.

1. Why is the balloon expanding? What gas do you think is causing this?

2. What's the purpose of the yeast?

3. Where else do you use yeast? Why does it work?

Now switch up the experiment a bit and compare the balloon size from the previous experiment to the next experiment.

- Measure 2 spoonfuls of corn flakes into another flask
- Measure 1 teaspoon of yeast into the flask
- Fill the flask to the 150 mL line with warm water
- Place balloon on top of flask
- Swirl the flask for approximately 1 minute until contents appear well mixed

Post Lab Questions

1. Why is the balloon not expanding?

2. What is causing this?

3. What makes corn flakes different than corn syrup?

# Activity 2 – GHG Emissions for Food Production

**Purpose**

To determine the amount of inputs and GHG emissions from today's Lunch

**Background Information**

Everything that we consume and dispose of comes from the environment and ultimately ends up in the environment. The food in which we consume has emissions from the creation of farmlands, growing of food, harvesting of food, transporting of food and disposing of food. The same steps occur in the raising of cattle and livestock, the food we feed them has the same steps.

**Testable Question**

The lunch from today emitted _____ of $CO_2$ eq.

## Direction

1. List out the items that went into today's lunch
2. Determine as a group the total amount/mass that went into today's lunch
3. Use the calculator to determine production and transportation emissions https://www.foodemissions.com/Calculator

| List of Ingredients in Today's Lunch | Total mass (lbs) | Production (kg of CO2) | Transportation (kg of CO2) |
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| Total Emissions | | | |

# Activity 3 – GHG Emissions for Disposed Products

**Purpose**

To determine the amount of inputs and GHG emissions generated from the waste today.

**Background Information**

Everything that we consume and dispose of comes from the environment and ultimately ends up in the environment. The food in which we consume has emissions from the creation of farmlands, growing of food, harvesting of food, transporting of food and disposing of food. The same steps occur in the raising of cattle and livestock, the food we feed them has the same steps.

**Testable Question**

The waste from today's lunch emitted _____ of $CO_2$ eq.

## Direction

1. List out the items that went into today's trash
2. Weigh out those items
3. Use the calculator to determine the amount of emissions that could be avoided. http://www.stopwaste.co/calculator/

| List of Disposed Items from Today's Lunch | Total mass (lbs) | Emissions Avoided | |
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| Total Emissions | | | |

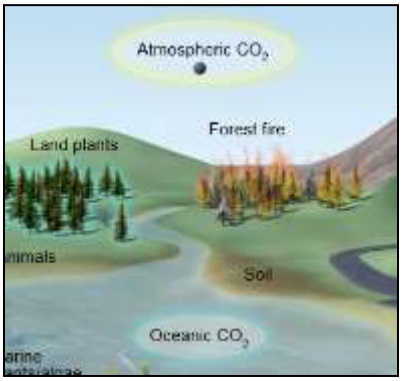
Name: _____ Date: _____

# Student Exploration: Carbon Cycle

**Vocabulary:** atmosphere, biomass, biosphere, carbon reservoir, carbon sink, fossil fuel, geosphere, greenhouse gas, hydrosphere, lithosphere, photosynthesis

**Prior Knowledge Questions** (Do these BEFORE using the Gizmo.)
In the process of **photosynthesis**, plants take in carbon dioxide ($CO_2$) from the atmosphere and water ($H_2O$) from the soil. Using the energy of sunlight, plants build molecules of glucose ($C_6H_{12}O_6$) and oxygen ($O_2$).

1. How do plants on Earth affect the amount of carbon in Earth's atmosphere? _____
   _____
2. Animals eat plants and produce carbon dioxide and water. How do animals affect the amount of carbon in Earth's atmosphere? _____




**Gizmo Warm-up**
The *Carbon Cycle* Gizmo allows you to follow the many paths an atom of carbon can take through Earth's systems. To begin, notice the black carbon atom in the **Atmospheric $CO_2$** area, highlighted in yellow. The glowing blue areas represent possible locations the carbon atom could go next.

1. From Earth's atmosphere, where can the carbon atom go next? ____
2. Click on **Land plants** and read the description. How did the carbon atom get from the atmosphere to a plant? _____
   _____
3. Select **Land animals**. How did the carbon atom get from land plants into the animal?

   _____
4. Select **Atmospheric $CO_2$**. How did the carbon atom get from land animals back to the atmosphere? _____
   _____

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| **Activity A:**<br>**Carbon pathways** | Get the Gizmo ready:<br>• Click **Reset**. |  |

**Introduction:** Earth can be divided into four systems. The **atmosphere** is the air above Earth's surface. The **hydrosphere** is composed of all of Earth's water. The **geosphere** is the rocky, non-living part of Earth. The **biosphere** consists of all living things, including people. Some scientists use the term "anthroposphere" to describe everything made or modified by humans.

**Question: How does carbon move between the atmosphere, hydrosphere, biosphere, and geosphere?**

1. Explore: Use the Gizmo to create a path for carbon that begins and ends in the atmosphere. Fill in the steps in the path below. Then, label each location with the system it represents. Finally, summarize very briefly how the carbon atom got to that location.

| Carbon path | System | How it got there |
|---|---|---|
| Atmospheric $CO_2$ ↓ | Atmosphere | nospheric $CO_2$ comes from volcanoes, burning fossil fuels, and other sources. |

2. Create: Click **Reset**. Use the Gizmo to create a path in which the carbon atom goes from the atmosphere to the hydrosphere, biosphere and geosphere. Describe each transition briefly.

| Atmosphere | Hydrosphere | Biosphere | Geosphere |
|---|---|---|---|
| Atmospheric $CO_2$ → | → | → | |
| lcanoes, burning fossil fuels, and other sources. | | | |

**(Activity A continued on next page)**

**Activity A (continued from previous page)**

3. Explore: Use the Gizmo to create three more carbon paths, each starting and ending in the atmosphere. Label each location with A for atmosphere, B for biosphere, G for geosphere, or H for hydrosphere. (You can also use P for anthroposphere if you like, or just include it in the biosphere.)

Path 1:

Path 2:

Path 3:

4. Explain: Based on the Gizmo, explain how the following transitions might take place:

   A. Describe at least two ways that carbon can get from a land plant to the atmosphere.

   B. Describe at least two ways that carbon can get from the atmosphere to the hydrosphere.

   C. Can you find two ways that carbon can get from the ocean to the **lithosphere**? (The lithosphere is the rigid layer of the Earth, including the crust and part of the mantle.)

   D. Describe at least two ways that carbon can get from seashells to the atmosphere.

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|---|---|---|
| **Activity B:**<br>**Human activities** | Get the Gizmo ready:<br>• Click **Reset**. |  |

**Introduction: Fossil fuels**, such as coal, oil, and natural gas, formed over millions of years from the remains of ancient plants and animals. The burning of fossil fuels, as well as other human activities, increases the amount of carbon dioxide in the atmosphere.

**Question: How does human activity affect the carbon cycle?**

1. Describe: Using the Gizmo, determine how coal and petroleum (oil) are formed. Describe the steps required to form each fuel from atmospheric $CO_2$.

Coal: _____

_____

Petroleum: _____

_____

2. Explore: Natural gas is a mixture of methane ($CH_4$), ethane ($C_2H_6$), and other gases. Find two ways that natural gas forms. List the steps of the two carbon pathways below:

Path 1:

Path 2:

How is the formation of natural gas related to the formation of coal and petroleum? _____

_____

3. Describe: Fossil fuels are used in many ways. Using the Gizmo, describe the main use for each fuel.

Coal: _____

Petroleum: _____

Natural gas: _____

In each case, what is the end product of burning the fossil fuel, and where does it go?

_____

**(Activity B continued on next page)**

**Activity B (continued from previous page)**

4. Explore: Another major contribution to atmospheric carbon dioxide is the cement industry. Using the Gizmo, find a carbon atom path from the atmosphere to the cement plant. (Hint: One of the ingredients in cement is limestone.)

Path:

How is carbon dioxide produced in a cement plant? _____

_____

5. Analyze: Click **Reset**, then navigate to the **Land animals**. Select **Atmospheric $CH_4$**.

   A. How do land animals create methane? _____

   _____

   B. Humans raise large numbers of cattle for food. How will these herds of cows affect Earth's atmosphere? ____

   _____

   _____

6. Analyze: In many tropical rainforests, people clear land by cutting down trees and burning them. After a few years, the soil runs out of nutrients and cannot be farmed any longer. How does this practice of "slash and burn agriculture" affect Earth's atmosphere?

_____

_____

_____

_____

7. Draw conclusions: In general, how do many human activities influence the carbon cycle?

_____

_____

| **Activity C:**<br><br>**Modeling the carbon cycle** | Get the Gizmo ready:<br>• Select the MODEL tab. |  |
|---|---|---|

**Introduction:** Humans have been burning fossil fuels rapidly for the past 250 years. As a result, the amount of atmospheric $CO_2$ has increased by about 40% since the year 1800. By measuring how much carbon moves into and out of the atmosphere, scientists can predict the change in the amount of atmospheric carbon dioxide every year.

**Question: How can we model changes in atmospheric carbon over time?**

1. Observe: The MODEL tab shows a simplified model of the carbon cycle. The ovals represent **carbon reservoirs**, where carbon is stored. The unit "GtC" stands for gigatonnes of carbon, where one GtC is equal to one trillion kilograms of carbon. The arrows represent how much carbon moves from one reservoir to another each year, in gigatonnes per year.

    A. Look at the arrows pointing toward atmospheric $CO_2$. What are the two major sources of atmospheric carbon? _____

    B. A **carbon sink** is a location that stores carbon for a long period of time. Which two carbon sinks remove carbon from the atmosphere? _____

    C. Without changing the Gizmo, list the carbon reservoirs from largest to smallest.

    _____

    Note: The largest carbon reservoir is actually Earth's lithosphere, which contains about 80,000 GtC. However, there is not much exchange between the lithosphere and the other reservoirs on short time scales.

2. Experiment: If necessary, click **Return to original settings**. These settings approximate present-day conditions, but should not be taken as exact values.

    A. What is the total amount of carbon removed from the atmosphere each year by the ocean and land plants? _____

    B. What is the total amount of carbon added to the atmosphere from soil and the burning of fossil fuels? _____

    C. How much will atmospheric carbon change in one year? _____

    In 10 years? _____ In 100 years? _____

**(Activity C continued on next page)**

**Activity C (continued from previous page)**

3. Calculate: Carbon dioxide is a **greenhouse gas** that helps to trap heat in Earth's atmosphere. We need some $CO_2$ in the atmosphere to maintain a warm planet, but excess carbon can cause considerable warming of the planet.

   A. What fossil fuel usage will result in no change in atmospheric $CO_2$ each year? _____

   B. What percentage decrease in fossil fuel usage is required to achieve this goal? _____

4. Experiment: Using the Gizmo model, explore the following questions:

   A. How does increasing plant **biomass** (amount of plants) affect atmospheric $CO_2$?

   _____

   B. How does increasing oceanic $CO_2$ intake affect atmospheric $CO_2$ and oceanic $CO_2$?

   _____

   As carbon dioxide is absorbed by the ocean, the ocean becomes slightly more acidic. This could make it harder for many organisms to build their shells and skeletons. The consequences of ocean acidification are not yet fully understood.

5. Infer: Click **Reset** and **Return to original settings**. Suppose we completely stopped burning fossil fuels immediately. How many years would it take to return to atmospheric $CO_2$ levels from the year 1800, about 600 GtC? Use the Gizmo to find the answer.

_____

6. Think about it: Since hard-shelled organisms evolved about 550 million years ago, billions of tons of limestone rock have been produced from their shells. Limestone is made of calcium carbonate, with the formula $CaCO_3$.

Based on this, how do you think the amount of atmospheric $CO_2$ has changed in the last 550 million years, and how has this affected Earth's climate? Explain your answer.

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_____

_____

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_____

Name: _____ Date: _____

# Student Exploration: Greenhouse Effect

**Vocabulary:** global warming, greenhouse effect, greenhouse gas, heat flow

**Prior Knowledge Questions** (Do these BEFORE using the Gizmo.)

1. What do you notice when you get into a car that has been sitting in the Sun for a while?

   _____

2. Why is the inside of the car so hot? _____

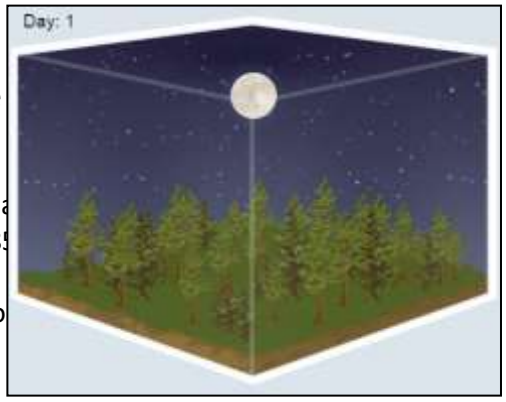
   _____

3. How would things be different if the car's windows were left open? _____

   _____

**Gizmo Warm-up**

Like the windows of a car, **greenhouse gases** play a major role regulating Earth's climate. Without the gases that trap heat in atmosphere, Earth would be a frigid desert like Mars (average temperature -55°C, or -67°F). Too much greenhouse gas and Ea be a fiery inferno like Venus (average temperature 450°C, or 8



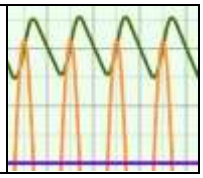

On the *Greenhouse Effect* Gizmo, set the **Greenhouse gases** to **Simulation speed** to **fast**.

1. Click **Play** ( ) and view the BAR CHART tab. The temperature will go up and down every day, but try to look at the overall trend. What happens to the temperature over time?

   _____

2. Now set the **Greenhouse gases** to 100% and let the simulation run for a while. How does a maximum amount of greenhouse gas affect the temperature?

   _____

| | | |
|---|---|---|
| **Activity:**<br><br>**Heat in, heat out** | Get the Gizmo ready:<br>• Click **Reset** ( ).<br>• Set **Simulation speed** to **slow**.<br>• Set the **Greenhouse gases** level to 10%. |  |

**Question: How do greenhouse gases affect Earth's climate?**

1. Observe: Select the BAR CHART tab and click **Play**. After about 24 simulated hours, click **Pause** ( ). What do you notice about the **heat flow** into and out of Earth's atmosphere?

   _____

   _____

2. Analyze: Select the TABLE tab.

   A. At what time of day is heat flow into the atmosphere ($H_{in}$) greatest? _____

   B. At what time of day is heat flow into the atmosphere ($H_{in}$) least? _____

   C. Does heat flow out of the atmosphere ($H_{out}$) change during a day? _____

   D. At what time of day is surface temperature highest? _____ Lowest? _____

3. Predict: Click **Reset**. When you change the amounts of greenhouse gases in the atmosphere, which factor(s) do you expect to change? (Circle your answer/answers.)

   Heat flow in  Heat flow out  Temperature

4. Experiment: Select the BAR CHART tab, and click **Play**. While the simulation is playing, move the **Greenhouse gases** slider back and forth. What do you notice?

   _____

   _____

5. Experiment: Click **Play**, and this time observe the GRAPH tab as you change the **Greenhouse gases**. What do you notice?

   _____

   _____

**(Activity continued on next page)**

**Activity (continued from previous page)**

6. Draw conclusions: The influence of greenhouse gases on temperature is called the **greenhouse effect**. Based on what you have seen, how do greenhouse gases affect the heat flow into and out of Earth's atmosphere?

   _____

   _____

   _____

   _____

7. Extend your thinking: Atmospheric concentrations of greenhouse gases such as carbon dioxide have risen dramatically in the past century. Most scientists agree that this has begun to result in **global warming**, a slow increase in average temperature worldwide.

   What are the possible consequences of global warming?

   _____

   _____

   _____

   _____

   _____

   _____

   _____

*Note: The reason greenhouse gases raise the temperature of Earth's atmosphere is similar to, but not identical to, the way that the glass in a greenhouse raises the temperature inside.*

*In a greenhouse, sunlight passes through the transparent glass and is absorbed by the plants and soil below. Heat is then radiated from plants and soil, which heats the air inside the greenhouse. The hot air is trapped by the glass. If the glass were not there, the hot air would mix with the colder air outside, and the result would be similar temperatures inside and outside the greenhouse.*

*In Earth's atmosphere, greenhouse gases are transparent to visible light but absorb heat that is emitted from Earth's surface. Some of this heat is then reflected back to Earth. If the greenhouse gases were not present, all of the heat would radiate into space instead.*