

## PERMAFROST IS A SINK

### Overview:

Methane and carbon dioxide are released from thawing permafrost. Both are potent greenhouse gases that could contribute to continued warming of the climate.

### Objectives:

The student will:

- interpret graphs and charts to determine some properties of greenhouse gases; and
- explain a positive feedback loop generated by thawing permafrost and how it could impact climate change.

### Targeted Alaska Grade Level Expectations:

*Science*

- [9] SA1.1 The student demonstrates an understanding of the processes of science by asking questions, predicting, observing, describing, measuring, classifying, making generalizations, inferring, and communicating.
- [10] SA1.1 The student demonstrates an understanding of the processes of science by asking questions, predicting, observing, describing, measuring, classifying, making generalizations, analyzing data, developing models, inferring, and communicating.
- [10] SC3.1 The student demonstrates an understanding that all organisms are linked to each other and their physical environments through the transfer and transformation of matter and energy by relating the carbon cycle to global climate change.

### Whole Picture:

Alaska Natives long ago recognized the dangers of carbon dioxide and methane seeps, even if they weren't aware of the reason for the danger. Native people were warned against sleeping near such areas because they might not wake up again. Then it was thought such places were burial grounds for shamans or places where spirits dwelt. Now it is known that escaping gases can pool, especially if there is no wind, and poison someone sleeping nearby.

So where does the gas come from? One source is thawing permafrost. Permafrost is often laden with organic material that froze before it had a chance to decompose. When permafrost thaws, that organic material immediately begins the decomposition process. Two compounds produced as a result of decomposition are methane and carbon dioxide, both of which are greenhouse gases.

#### Greenhouse Gases

Greenhouse gases are atmospheric gases that effect the radiant heat cycle of the planet. Such gases are necessary in the atmosphere, and properly balanced, play a vital role in regulating the temperature of the planet. Scientists are concerned that such gases, if out of balance, may contribute to climate change.

Greenhouse gases cause what is known as the greenhouse effect. Solar radiation penetrates Earth's atmosphere and reaches the ground, where it warms the surface, then is radiated back through the atmosphere and away from the planet. Greenhouse gases absorb some of that reflected energy and act as a barrier to this process, creating a shield that traps the heat next to the planet. If there are too many greenhouse gases, too much heat is trapped, and the temperature of the planet may increase.

#### Carbon Dioxide

Plants and animals, including humans, give off carbon dioxide when they extract energy from their food during cellular respiration. Carbon dioxide bubbles out of the earth in natural springs, explodes out of volcanoes, and is released when organic matter burns (such as during forest fires).

Anything that releases carbon dioxide into the atmosphere (living or non-living) is considered a source. Anything that absorbs and holds carbon dioxide from the air or water is considered a sink. Over geologic time,

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sources and sinks generally balance. In today's atmosphere, however, levels are climbing in a dramatic and easily measurable fashion, providing evidence that there are now more sources than sinks. The burning of fossil fuels by humans is thought to be primarily responsible for the observed increases.

### **Methane**

Methane is capable of holding more than 20 times the heat of carbon dioxide but is often overlooked as an important greenhouse gas because relatively small amounts exist in the atmosphere. Because it degrades in the atmosphere its effects are hard to predict, but methane can exert a powerful influence on temperature.

While the concentration of methane in the atmosphere is considerably less than that of carbon dioxide, it has more capacity to increase temperature, and thus affect climate change. Methane is naturally produced by anaerobic decomposition of biomass in wetlands and animal wastes, and through the aid of anaerobic bacteria in the stomachs of ruminants. It is commonplace to see methane bubbling to the surface of Arctic lakes.

### **Vocabulary:**

**anaerobic** – occurring or living in the absence of oxygen

**anthropogenic** – caused or produced by humans

**carbon** – a naturally abundant, non-metallic element that occurs in all organic compounds and can be found in all plants and animals; diamonds and graphite are pure forms, and carbon is a major part of coal, petroleum, and natural gas; symbol is C on the periodic table of elements

**carbon cycle** – the continuous process by which carbon is exchanged between organisms and the environment; carbon dioxide is absorbed from the atmosphere by plants and algae and converted to carbohydrates, passed into the food chain and returned to the atmosphere by respiration and decay; the burning of fossil fuels also releases carbon dioxide into the atmosphere

**carbon dioxide** – a colorless, odorless gas that is present in the atmosphere and is formed when any fuel containing carbon is burned; it is exhaled from animals' and humans' lungs during respiration, produced by the decay of organic matter and used by plants in photosynthesis

**climate** – the 30-year average weather conditions of a certain region, including temperature, rainfall, and wind

**decomposition** – the process of decaying or rotting brought about by the activity of certain bacteria or the feeding of fungi

**feedback loop** – a circular pathway of cause and effect; related to climate feedback loops, can be positive (adding to the rate of warming) or negative (reducing it)

**greenhouse effect** – the trapping of the sun's radiation in Earth's atmosphere due to the presence of greenhouse gases

**greenhouse gas** – any of the atmospheric gases that contribute to the greenhouse effect; includes carbon dioxide, water vapor, methane, and nitrous oxide

**methane** – chemical compound with the formula CH<sub>4</sub>; the principal component of natural gas

**organic** – matter derived from plants and animals; relating to chemical compounds containing carbon

**ruminant** – a mammal that digests plant-based food by initially softening it within the animal's first stomach, known as the rumen, then regurgitating the semi-digested mass, now known as cud, and chewing it again; the process of re-chewing the cud to further break down plant matter and stimulate digestion is called ruminating; ruminating mammals include cattle, goats, sheep, giraffes, bison, yaks, water buffalo, deer, camels, alpacas, llamas, wildebeest, and antelope

**seep** – to pass gradually or leak through small openings; become diffused gradually

**sink** – a natural or manmade reservoir that absorbs and stores chemical compound (such as carbon or methane) for an indefinite period

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### Materials:

- VIDEO: "Methane Bubbles to the Surface of an Arctic Lake"
- VIDEO: "Hunting for Methane with Katey Walter Anthony"
- VIDEO: "Climate Change in the Arctic: Greenhouse Gases"
- VISUAL AID: "Don't Sleep There"
- STUDENT INFORMATION SHEET: "Greenhouse Gases and the Greenhouse Effect"
- STUDENT INFORMATION SHEET: "How Does Permafrost Fit In?"
- STUDENT WORKSHEET: "Greenhouse Gas Scavenger Hunt"

### Activity Procedure:

1. Ask students if they have ever been sitting near a pond or lake and noticed bubbles rising from the bottom. These are gases escaping from the lakebed. Ask students where the gas is originating? (*The decomposition of organic matter releases carbon dioxide and methane.*) Explain some areas, called seeps, release large quantities of trapped gases. Show students VISUAL AID: "Don't Sleep There." Explain people recognized areas with seeps even before the gas was identified. Show VIDEO: "Methane Bubbles to the Surface of an Arctic Lake" which documents a large methane seep.
2. Recount a story told by Elder Robert Charlie:
 

*"There is what Athabaskan people call a 'bear den experience.' No one should try and sleep in a bear den because they might go to sleep and stay asleep all winter, like the bear. It was thought that sleeping in the closed space with no fresh air is what made the bear's body slow down and would do the same to people."*

*The thought behind the lore is that sleeping in a small space led to decreased available oxygen, which triggered the hibernation. Carbon dioxide poisoning does lead to reduced neural activity and lethargy (among other things) and eventually death. Scientists now understand there are many biological "tricks" that contribute to a bear's state of hibernation, but lack of fresh air is not one of them. In reality, an abandoned bear den could provide shelter in an emergency situation. It's the ones that aren't abandoned you need to be careful of! While it is possible to run out of air in a tightly closed space, and suffer from carbon dioxide poisoning, it is unlikely a bear den provides such an environment.*
2. Explain carbon dioxide is a well-known greenhouse gas released during the decomposition of organic material; methane is another. Methane is produced during anaerobic decomposition. Anaerobic means decomposition that occurs without the presence of oxygen. Microbes (decomposers that break down dead plants and animals) metabolize the organic material and release methane as a byproduct. When organic material is frozen in permafrost, the process of decomposition is stopped. The organic material can remain the same for thousands of years – frozen in time. When the permafrost thaws, however, the microbes go to work.
3. Show VIDEO: "Hunting for Methane with Katey Walter Anthony." Katey Walter Anthony explains how thawing permafrost and warming temperatures will release up to 10 times the amount of methane currently present in the atmosphere.
4. Hand out STUDENT INFORMATION SHEET: "Greenhouse Gases and the Greenhouse Effect" and STUDENT INFORMATION SHEET: "How Does Permafrost Fit In?" Choose a reading strategy appropriate for the class.
5. Hand out STUDENT WORKSHEET: "Greenhouse Gas Scavenger Hunt." Explain students will access VIDEO: "Climate Change in the Arctic: Greenhouse Gases" to complete part one of the worksheet. They will refer to the information sheets read in class for part two of the worksheet. Ask students to complete the worksheet.

### Extension Ideas:

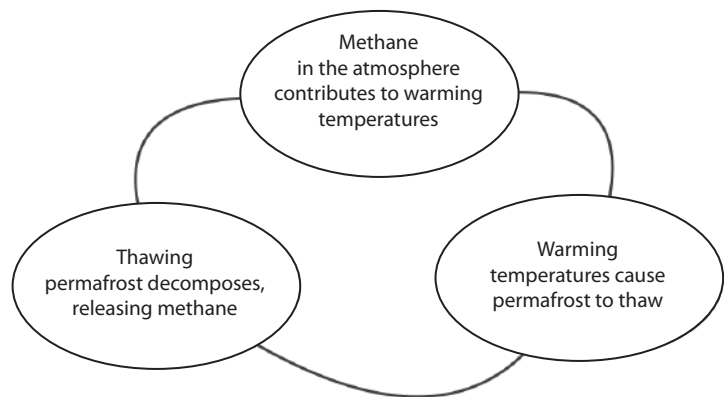
1. Research the Lake Nyos disaster. On August 21, 1986 Lake Nyos suddenly emitted a large cloud of CO<sub>2</sub>, which suffocated 1,700 people and 3,500 animals in nearby villages.

## PERMAFROST IS A SINK

- If you have access to methane, research experiments that ignite methane bubbles using a soapy solution. Students find this very engaging! You can find directions on the Internet, as well as video examples on YouTube™.
- Ask students to research the viability of capturing methane from seeps to use as a community energy source. Students could complete a design that could harness the methane and pipe it to homes.

### Answers:

- nitrogen and oxygen
- water vapor
- Any three of the following: burning of fossil fuels, respiration from animals and/or humans, forest fires, erupting volcanoes, organic soil decay
- B. absorbs
- deep ocean
- soil decay
- Methane – 12 years  
Carbon Dioxide – 50-200 years  
Nitrous Oxide – 120 years
- Methane and carbon dioxide
- See figure (right)
- anaerobic
- B. caused by humans
- Carbon Dioxide: naturally occurring through respiration, decomposition, volcanoes, forest fires; also occurs through burning of oil and gas, cement manufacturing, and deforestation  
Methane: occurs naturally from anaerobic decomposition and from livestock digestion  
Nitrous Oxide: burning of oil, gas, coal, wood; fertilizers, coal mining; also occurs naturally
- Answers will vary.



## DON'T SLEEP THERE



# GREENHOUSE GASES AND THE GREENHOUSE EFFECT

## Greenhouse Gases

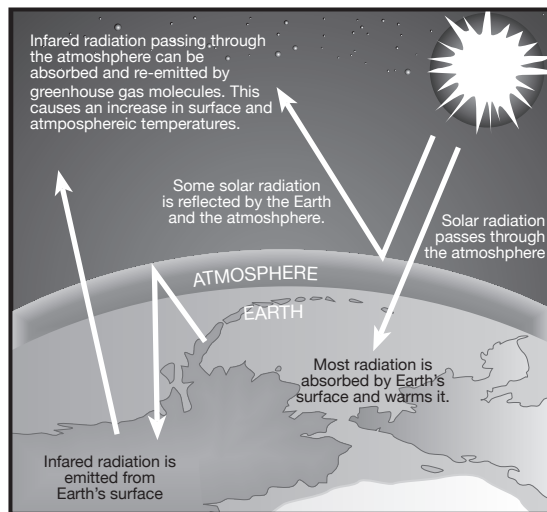
Earth's atmosphere is a natural shield that protects the planet and keeps it hospitable to life. About one percent of the atmosphere is made up of gases referred to as greenhouse gases. These gases absorb radiant heat from Earth and keep the planet warm. Without them, Earth would be inhospitable.

Greenhouse gases:

- include water vapor, carbon dioxide, ozone, methane and nitrous oxide
- absorb and reflect heat back to Earth
- are naturally occurring and play a vital role in regulating the planet's climate

*The balance of greenhouse gases in the atmosphere keeps the climate stable. When the balance changes, the climate changes.*

## Greenhouse Effect



A greenhouse traps the sun's energy. Short wavelengths of visible light energy pass through the windows and are absorbed by the soil. The warm soil then radiates heat, but that heat energy has a longer wavelength and cannot pass back through the window. More and more heat is trapped over time and the greenhouse heats up.

A similar process takes place on Earth. Sunlight penetrates the atmosphere and warms the planet surface then the planet radiates the heat. Some radiant energy escapes the atmosphere, but greenhouse gases absorb some radiant energy. The trapped heat energy warms the lower atmosphere. (The upper atmosphere is actually colder because the layer of gases keeps the heat from reaching it.)

### Carbon Dioxide (CO<sub>2</sub>)

Carbon dioxide, or CO<sub>2</sub>, is a significant greenhouse gas; it traps infrared energy and is important in maintaining global average temperature, which is about 59° Fahrenheit (15° Celsius). Without water vapor, CO<sub>2</sub>, and methane (CH<sub>4</sub>) (the three most important naturally produced greenhouse gases), Earth's surface would be about 0° Fahrenheit (-18° Celsius). At this temperature, the planet would be a much different place.

The level of CO<sub>2</sub> in the atmosphere has increased nearly 30 percent since the 1750s, when the burning of fossil fuels became an important part of the industrialized world. Scientists are monitoring this increase to see how it might be contributing to global climate change.

### Methane - The Other Greenhouse Gas (CH<sub>4</sub>)

Carbon dioxide tends to dominate the greenhouse gas spotlight, but methane is a formidable competitor. In fact, methane is a very potent greenhouse gas. A molecule of methane is up to 25 times stronger than carbon dioxide. In other words, it has the ability to hold 25 times more heat and radiate it back to Earth.

Methane, or CH<sub>4</sub>, is a principal component in natural gas – a highly sought-after fossil fuel and also a critical component in the world's energy supply. It is a naturally occurring by-product of anaerobic (without oxygen) decomposition. One way methane is produced is through the digestive process of ruminants. Another is when microbes in thawing permafrost begin to decompose the organic material.

## GREENHOUSE GASES AND THE GREENHOUSE EFFECT

### Comparing Greenhouse Gases

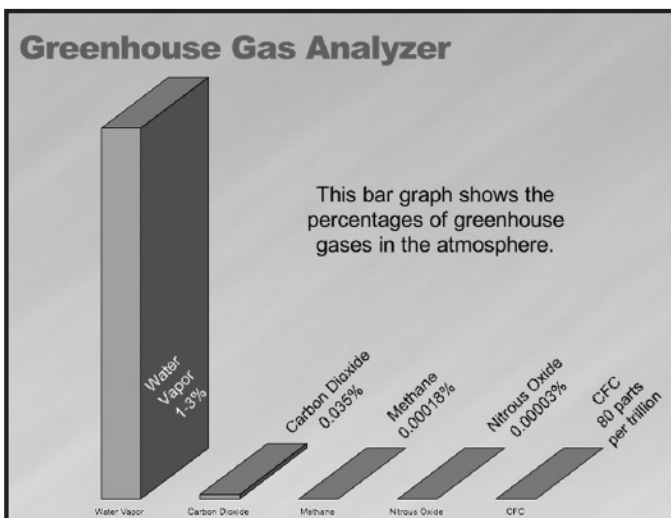
Different types of blankets keep in different amounts of heat, and greenhouse gases work the same; some keep in more heat than others. If you think of one volume of carbon dioxide as being one blanket, then the same volume of methane would equal 25 blankets and nitrous oxide would equal 296 blankets.

Without greenhouse gases, Earth would be a much colder planet, dropping at least 33° Celsius (59° Fahrenheit) colder than current temperatures. Too many greenhouse gases could overheat the planet.

*About  
80-90 percent of  
Earth's natural greenhouse  
effect is due to water vapor.  
The remainder is due to  
carbon dioxide, methane,  
and a few other  
trace gases.*

GHG (Greenhouse Gas)	How long does it stay in the Atmosphere?	Warming Potential	Percent of Total Atmosphere	Where does it come from?
Carbon Dioxide	50 - 200 years	1	0.039%	Naturally occurring through respiration, volcanic activity, and forest fires; a byproduct of burning fossil fuels, of cement manufacturing, deforestation and other land uses
Methane	12 years	25	0.000179%	A natural byproduct of anaerobic decomposition and from livestock digestion; a byproduct of oil and gas production, coal mining, rice paddies, dams and landfills
Nitrous Oxide	120 years	296	0.00003%	A byproduct of burning fossil fuels; a byproduct of fertilizer manufacturing and coal mining; also occurs naturally

*About 99 percent of Earth's atmosphere is made up of nitrogen (78%) and oxygen (21%). The remaining are trace gases. Greenhouse gases are among the trace gases.*



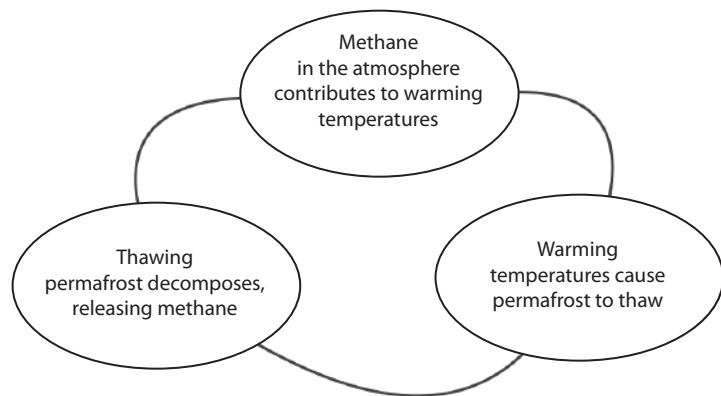
## GREENHOUSE GASES AND THE GREENHOUSE EFFECT

### Permafrost and Greenhouse Gases

Permafrost is often filled with dead plants, trees and animals that froze before they had a chance to be broken down. When permafrost thaws, that **organic** material immediately begins to **decompose**. As it does **methane** and **carbon dioxide** are released. Both are **greenhouse gases**. As the climate of the Arctic gets warmer, those warmer temperatures might thaw more permafrost. That will release more carbon dioxide and methane, which, in turn, could contribute to warmer temperatures. This self-feeding cycle is called a **positive feedback loop**.

As the process of decomposition occurs, methane is continually released from millions of seeps across Alaska. The decomposition that occurs in thawing permafrost is also a major contributor to the amount of methane in the atmosphere.

This diagram at right describes a positive feedback loop involving thawing permafrost and methane.



**Carbon** is a natural element that is found in all organic (living) compounds. The **carbon cycle** is the continuous process by which carbon is exchanged between organisms and the environment. Plants combine carbon dioxide from the air with water from the soil to create another compound called carbohydrates. When the plant dies, decomposers break down the plant and respire the carbon back into the air. When decomposers can't complete the job, because geologic or weather processes bury the organic material, the carbon is out of carbon cycle in a carbon **sink**. Frozen permafrost is a carbon sink.

**Carbon Dioxide:** a colorless, odorless gas that is present in the atmosphere and is formed when any fuel containing carbon is burned; it is exhaled by animals and humans during respiration, produced by the decay of organic matter and used by plants in photosynthesis

**Methane:** chemical compound with the formula CH<sub>4</sub>; the principal component of natural gas

### Vocabulary

**anaerobic** – decomposition occurring in the absence of oxygen (think underground)

**anthropogenic** – caused or produced by humans (burning fossil fuels and raising cattle add greenhouse gases)

**decomposition** – the process of decaying or rotting when certain bacteria feed on organic matter

**greenhouse gas** – any of the atmospheric gases that contribute to the greenhouse effect, trapping the sun's radiation in Earth's atmosphere; greenhouse gases help regulate Earth's climate

**organic** – matter from plants and animals; relating to chemical compounds containing carbon

**positive feedback loop** – a self-feeding cycle

**ruminant** – a mammal that digests food by softening it within the first stomach then regurgitating the semi-digested mass and chewing it again, called ruminating (cows, moose, sheep, bison, etc.)

**seep** – to pass gradually or leak through small openings

**sink** – a device, system or process responsible for taking some extensive entity out of circulation (such as a carbon sink)



**NAME:** \_\_\_\_\_  
**GREENHOUSE GAS SCAVENGER HUNT**

**PART ONE Directions:** Access the VIDEO: "Climate Change in the Arctic: Greenhouse Gases." Navigate through the information to answer the questions below.

1. 99% of Earth's atmosphere is composed of these two gases:  
\_\_\_\_\_
  
2. Which greenhouse gas is the most common in Earth's atmosphere? \_\_\_\_\_
  
3. List three sources of carbon dioxide.  
\_\_\_\_\_, \_\_\_\_\_, and \_\_\_\_\_
  
4. A gas in the atmosphere is a greenhouse gas if it \_\_\_\_\_ the heat radiated off Earth's surface.  
A. reflects                      B. absorbs                      C. dissolves                      D. cools
  
5. Which carbon reserve holds the most carbon? \_\_\_\_\_
  
6. What process releases the most carbon dioxide? \_\_\_\_\_

**PART TWO Directions:** Use STUDENT INFORMATION SHEET: "Greenhouse Gases and the Greenhouse Effect," and STUDENT INFORMATION SHEET: "How Does Permafrost Fit In?" to answer the remaining questions.

7. Match the gas to the length of time it remains in the atmosphere.
 

Methane	12 years
Carbon Dioxide	120 years
Nitrous Oxide	50 – 200 years
  
8. What two greenhouse gases are released when permafrost thaws?  
\_\_\_\_\_ and \_\_\_\_\_
  
9. Draw a positive feedback loop that describes the relationship between thawing permafrost, methane, and warming temperatures.

**NAME:** \_\_\_\_\_  
**GREENHOUSE GAS SCAVENGER HUNT**

10. **Circle one.** Methane is produced by the anaerobic / aerobic decomposition of organic matter.

11. Anthropogenic means:

- A. genetic anthropology
- B. caused by humans
- C. caused by ruminants

12. Match the greenhouse gas with its source.

- Carbon Dioxide                      occurs naturally from anaerobic decomposition and from livestock digestion
- Methane                                burning of oil, gas, coal, wood; fertilizers, coal mining; also occurs naturally
- Nitrous Oxide                        naturally occurring through respiration, decomposition, volcanoes, forest fires; also occurs through burning of oil and gas, cement manufacturing, and deforestation

**Critical Thinking**

**Directions:** Read the following definition of the carbon cycle, then respond to the question below.

**Carbon Cycle**

Carbon, found in all organic material, is the building block of life. The carbon cycle is highly complex, but, in simple terms, it is the continuous process by which carbon is exchanged between organisms and the environment. Carbon dioxide is absorbed from the atmosphere by plants and algae and converted to carbohydrates. When the plants are eaten, the carbon enters the food chain and is returned to the atmosphere by respiration. When the animal dies, its body decays, returning stored carbon. Plants that aren't eaten, decay after they die. The burning of fossil fuels also releases carbon dioxide into the atmosphere.

13. Permafrost is a carbon "sink" because it holds carbon in a frozen state, keeping it out of the carbon cycle. Explain how thawing permafrost could affect the carbon cycle and contribute to climate change.

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