Section 8.2 Greenhouse Gases and Human Activities

(Student textbook pages 323 to 332)

Specific Expectations

- **D2.1** use appropriate terminology related to climate change, including, but not limited to: *albedo*, *anthropogenic*, *atmosphere*, *cycles*, *heat sinks*, and *hydrosphere*
- **D2.2** design and build a model to illustrate the natural greenhouse effect, and use the model to explain the anthropogenic greenhouse effect
- **D2.3** analyse different sources of scientific data for evidence of natural climate change and climate change influenced by human activity
- **D2.4** investigate a popular hypothesis on a cause-and-effect relationship having to do with climate change
- **D3.1** describe the principal components of Earth's climate system and how the system works
- **D3.3** describe the natural greenhouse effect, explain its importance for life, and distinguish it from the anthropogenic greenhouse effect
- **D3.4** identify natural phenomena and human activities known to affect climate, and describe the role of both in Canada's contribution to climate change
- **D3.5** describe the principal sources and sinks, both natural and/or anthropogenic, of greenhouse gases
- **D3.6** describe how different carbon and nitrogen compounds influence the trapping of heat in the atmosphere and hydrosphere
- **D3.7** describe, in general terms, the causes and effects of the anthropogenic greenhouse effect, the depletion of stratospheric and tropospheric ozone, and the formation of ground-level ozone and smog

In this section, students will learn about how greenhouse gases absorb and radiate solar energy. They will also explore how the greenhouse effect works. Students will consider human activities in context of increasing greenhouse gases, and differentiate the natural greenhouse effect from the anthropogenic greenhouse effect.

Common Misconceptions

- Students often believe the greenhouse effect is bad; however, they need to understand that the greenhouse effect occurs naturally and keeps Earth warm enough to sustain life. The anthropogenic (human-caused) greenhouse effect is causing global warming because of the addition of greenhouse gases that are increasing at very high rates as a result of human activity. Have a class discussion about how the atmosphere has warmed and cooled at intervals in the past. Explain that current warming is a problem because it is being driven by human activity and will have a huge impact on how Earth's systems work.
- Some students may believe that human activity is not impacting the greenhouse effect. Encourage them to refer to graphs showing the relationship between carbon dioxide levels and the industrial era. Remember that there is still a significant amount of controversy, even in the scientific community, about climate change. The dispute is not about whether global warming is occurring (it clearly is), but rather what is causing it and how long and severe it will be. There are many people who believe the climate change issue to be propaganda put forth by governments to increase regulations on how humans live. Students must be allowed to do research and come to their own supported positions.
- Students may believe that the hole in the ozone layer is fixed because it is not in the news as much anymore. Have students consider that there is more than one problem in the atmosphere, and ozone depletion, though under control, is still a problem.

Background Knowledge

To determine if a gas is a greenhouse gas, scientists must test the ability of the gas to absorb infrared radiation. First, a cylinder is filled with the gas to be tested. Then an infrared light is shone at the tube. Scientists measure the amount of light that passes through the tube, compared to the amount of light that entered the tube. The test is based on the theory that the bonds between atoms in a molecule stretch and bend like springs, a process known as vibration. Infrared radiation will cause gas molecules to vibrate. If the molecules vibrate a certain way—at the same frequency as the infrared radiation—then the molecules will absorb the energy of the infrared radiation. Oxygen and nitrogen, the most abundant gases in the atmosphere, do not absorb infrared radiation.

The Moon, Mars, and Venus, like Earth, are all located within the zone around the Sun where sunlight is strong enough for water to exist as a liquid. These other bodies are excellent examples of the impact the greenhouse effect has on climate. The Moon does not have an atmosphere. Temperatures range from a high above the boiling point of water to a low of −173°C. Although Mars has an atmosphere that comprises mainly carbon dioxide and water vapour, it is further from the Sun than is Earth. Ground-level temperatures range from a daytime high of about 27°C near the equator to a low of about −122°C at the poles. Venus is at the other extreme. Its atmosphere is extremely dense and comprised primarily of carbon dioxide. Venus is nearer the Sun than Earth is. The temperature is 450°C at the surface.

Concentrations of carbon dioxide have increased by 36 percent above pre-industrial levels. Methane has increased by 148 percent and nitrous has increased by 18 percent. These levels that are now present appear to be unprecedented in the past 650 000 years.

Human activities have created new greenhouse gases. Some of these are very long-lived, such as halocarbon gases and sulphur hexafluoride. Adding 1 kg of these gases to the atmosphere has the same effect as the emission of more than 10 000 kg of carbon dioxide.

Humans release more than 26 billion tones of carbon dioxide per year into the atmosphere from burning fossil fuels, and that number is rising.

Ultraviolet radiation from the Sun breaks the chemical bonds in O_2 (oxygen). These bonds reform as O_3 (ozone), releasing heat during the reaction. The ozone molecules then absorb ultraviolet radiation, providing protection to the surface of Earth (and humans who get sunburned). The Montreal Protocol on Substances that Deplete the Ozone Layer was signed on September 16, 1987. The protocol gives a timetable for reduction and ultimate elimination of ozone depleting substances (for example, chlorofluorocarbons).

Literacy Support

Using the Text

- The subject of this section is commonly discussed in the general media, but typically poorly understood. Encourage students to turn each heading within the section into a question, and then make notes about facts and details that help answer the question. Encourage students to use Key Terms in their notes.

Before Reading

- ELL Preview the Key Terms with English language learners before reading. Draw students' attention to words they already know that share prefixes with the Key Term *biogeochemical cycle*. Have students make connections to predict the meaning of each Key Term.
- Have students look at the headings to determine the main ideas in the section and help them identify the most important information in the text. Students can use this information to organize their learning.

During Reading

- ELL Pause the reading at any time to direct students to record an important point, to discuss a point, to ensure that English language learners understand a complicated sentence or new term, or to redirect the reading.
- Encourage students to make a web to help them organize their understanding. They can begin their web based on headings in the section, and develop the content as they progress through the material. Provide students with **BLM G-44 Main Idea Web**.

After Reading

- Ask each student to write a short two-sentence summary of the main points of the section. You can then have students work in groups to compare their summaries and agree on one. The summaries can be shared with the class and recorded so they can be used as a review.

Using the Images

- DI Encourage spatial learners to summarize the illustrations throughout the section as a preview to the material.
- Combine the images in this section with the associated text headings. Students can use this to organize their work as they progress through the section.

- After reading gather students in groups and have them look through the photographs and illustrations in the section. Have students summarize the section based on what is presented in the visuals. Each student can record the group's summary and use it as a study tool later.

Assessment FOR Learning		
Tool	**Evidence of Student Understanding**	**Suppporting Learners**
Learning Check, pages 326, 330	Students explain why greenhouse gases are measured in parts per million.They explain how the percentage increase in gases is related to climate change.Students explain the term carbon sink and how water vapour and carbon dioxide interact in a positive feedback loop.Students identify sources of nitrous oxide. Human activities that cause methane to accumulate in the atmosphere. Students describe how halocarbons and ozone interact to change the atmosphere, and the sources of greenhouse gases that contribute to the anthropogenic greenhouse effect. Answers to question 2 on page 326 should explain that sinks are where carbon is stored, both for the long and short term. There are many answers to question 4. Ensure students explain their choices.	Students can work in pairs or groups to provide peer support if they are having difficulty. You may also wish to split the questions among the class and have students present their findings verbally. Students can use **BLM 8-7 Where Does the Carbon Go?** to help them explain carbon sinks. **BLM 8-8 The Greenhouse Gases** can be used to help students summarize all the major sources of greenhouse gases mentioned in the student textbook. Students' summaries for question 8 can be presented in an alternative format they choose (for example, a song, skit or poster). Provide students with **BLM G-43 Flowchart** to help them answer question 3.
Activity 8-3 Graphing Changes in Carbon Dioxide	Students create and describe graphs based on data provided. They identify trends in carbon dioxide emissions and concentration, and average global temperature increase. Students use results to identify a relationship between increases in industrial processes, carbon dioxide, and average global temperature.	Students may benefit from referring to the Math Skills Toolkit 3 in the student textbook.
Section 8.2 Review questions, page 332	Students explain the greenhouse effect and describe different greenhouse gases. They explain why scientists measure the concentration of gases in the atmosphere and identify different anthropogenic sources of greenhouse gases. Students describe factors that determine the global warming potential of greenhouse gases.	**BLM 8-9 Global Warming Potentials** can be used to support some of the questions.

Instructional Strategies

- ELL Some students may need to read the text aloud in order to capture the information. Provide a space for these students that will not distract other students. Alternately, read the headings throughout the section aloud to the class and have them discuss the content.
- ELL Some students may be interested in pursuing work on a topic of particular interest. Provide the opportunity for these students to work independently. This may be especially valuable for students who do not believe in human-caused global warming. You may wish to dedicate space to collect research. Provide students with **BLM G-18 How to Do a Research-Based Project** and **BLM G-20 Research Worksheet** for support. Use **BLM A-21 Project Self-Assessment Checklist** and **BLM A-44 Research Project Rubric** for assessment.
- Create a word wall that includes pictures or other visual aids to introduce and support the vocabulary in this section. Have English language learners create first language translations so the word wall will support their vocabulary as well.
- Use a variety of concrete and visual aids to help with this material. Models and manipulatives may be helpful to all students.

- Encourage students who are having difficulty to ask for assistance from peers. You may want to structure formal peer-tutoring groups, or develop a system to pair students needing support with other students.
- Pre-assess what students know about greenhouse gases by having a class discussion. Ensure that all students participate with a show of hands to determine understanding.
- Encourage students to make models that show the relative global warming potentials of difference greenhouse gases, or to use models and manipulatives. Provide students with **BLM G-17 Using Models and Analogies in Science**.
- Have students work in teams and develop a detailed answer to the questions in **BLM 8-10 Life Affecting Climate**. Ensure students are clear on the difference between the natural and enhanced greenhouse effect.
- Use **BLM A-14 Events Chain or Flowchart Checklist** to assess students' answers to Learning Check question 4.
- Use **BLM A-6 Developing Models Checklist** to assess students' models where appropriate.

Activity 8-3 Graphing Changes in Carbon Dioxide

(Student textbook page 329)

Pedagogical Purpose

Students track the changes in carbon dioxide levels in the atmosphere that have occurred since the Industrial Revolution. As students graph the data provided, they see a clear relationship between increases in industrial processes, increases in carbon dioxide, and increases in average global temperature.

Planning		
Materials	Graph paper	Coloured pencils or pens
Time	20–30 min	

Background

Ice core data indicate the atmospheric concentration of carbon dioxide did not exceed 300 ppm in the past 650 000 years (the extent of the data). The concentration has remained at rates of 260 to 280 ppm during the interglacial period measured over the last 10 000 years. In 2005, atmospheric carbon dioxide had increased to 379 ppm and most of that increase has been seen in the last 50 years.

Activity Notes and Troubleshooting

- This activity is straightforward, but be aware that some students may have difficulty designing their own graphs to represent the three different data sets. Have them refer to Study Toolkit 4 Organizing Your Learning: Using Graphic Organizers on page 565 of the student textbook before beginning.
- The line students extrapolate is considered to be the "business as usual" or BAU line. Many climate-change strategies commit to reduce emissions by a certain percent and then graph those scenarios to show how big a difference can be made.

Additional Support

- DI Logical-mathematical and spatial learners may enjoy this activity. If they, or other students, want a challenge, have them graph future scenarios where emissions increase or decrease. For example, have them calculate emissions reduced by 10 percent or 20 percent over 2000 levels (a 2000 baseline). The lines can then be extrapolated to predict what future emissions may be.
- ELL Check for comprehension of the instructions by having students read them back to you. Have students engage in discussion or questioning about the graphing activity.
- Use **BLM A-19 Graph from Data Checklist** and **BLM A-33 Interpreting Data Rubric** for assessment.

Answers

1. These graphs show exponential growth. Students will be familiar with exponential, linear, and quadratic curves from math class.
2. All three lines rise in a similar fashion, though they are not exactly the same as each other. The graph shows a similar trend in rising industrial carbon dioxide emissions, carbon dioxide concentration and average global temperature increase.
3. Students' answers will vary, but should reflect an understanding that there is a relationship between emissions, carbon dioxide levels, and increasing temperature.

Learning Check Answers (Student textbook page 326)

1. The concentration of many molecules is quite low, so the actual number of molecules in a particular volume is very small. The unit ppm or ppb allows these to be counted or referenced more easily.
2. A sink is a place where matter or energy is stored, keeping that material out of circulation until released. A carbon sink is a place where carbon is stored (for example, in a plant). The carbon is not released until the plant dies.
3. Increases in carbon dioxide in the atmosphere would lead to global warming, which would increase the rate of evaporation and thus increase the amount of water vapour in the atmosphere, which would cause global temperature to rise and the rate of evaporation to get even higher.
4. Agriculture and the raising of livestock result in increasing levels of methane in the atmosphere.

Learning Check Answers (Student textbook page 330)

5. Most natural production of nitrous oxide comes from damp tropical soils and the oceans. Important human sources are chemical fertilizers, manure and sewage treatment, and vehicle exhausts.
6. Carbon dioxide +37%, methane +149%, nitrous oxide +16%; increases in chlorofluorocarbons are impossible to calculate because these greenhouse gases did not exist before the Industrial Revolution. Increased greenhouse gases are related to the anthropogenic greenhouse effect, which is the increased capacity of the atmosphere to absorb and prevent the escape of thermal energy.
7. Halocarbons chemically react with ozone, breaking apart the ozone and causing the ozone "hole."

8. Most of the increase in carbon dioxide has come from the burning of fuels needed for transportation, manufacturing, and energy production. Deforestation and the spread of agriculture have added carbon dioxide, methane, and nitrous oxide. Industrial activities have produced ozone, chlorofluorocarbons, and other pollutants that affect the climate system.

Section 8.2 Review Answers (Student textbook page 332)

1. Scientists measure the concentrations of gases in the atmosphere to determine how they have changed over time.
2. The greenhouse effect is needed to keep Earth warm enough to support life as we know it. The friend is likely referring to the anthropogenic greenhouse effect, which is the enhanced greenhouse effect caused by humans adding greenhouse gases to the atmosphere.
3. Example: The amounts that humans add is small compared to the amount that is already there. There is no evidence that human activity has caused the concentration of water vapour in the atmosphere to change.
4. Three major anthropogenic sources of methane are decomposing garbage, raising livestock, and processing coal and natural gas. To reduce methane from livestock, scientists have proposed feeding cattle clover and alfalfa instead of corn and grain. Reducing human consumption of food from livestock would also reduce the methane. Conserving electricity reduces methane released from the processing of coal and natural gas. Reducing, re-using, and recycling reduces the methane released because less garbage will build up in landfills and less processing will be required to make new products.
5. Chlorofluorocarbons are manufactured chemical compounds that contain chlorine, fluorine, and carbon. When released into the atmosphere they may cause depletion of the ozone layer, which means that more ultraviolet radiation reaches Earth's surface.
6. Chlorofluorocarbons and fluorinated gases are made entirely by human activity. Human activity has some effect on the concentration of carbon dioxide, methane, nitrous oxides, and ozone. Human activity has a negligible impact on the concentration of water vapour in the atmosphere.
7. The three factors that determine the global warming potential of different greenhouse gases are the concentration of the gas in the atmosphere, the ability of the gas to absorb heat, and the length of time the gas remains in the atmosphere.
8. Example: The agriculture sector would cause more global warming than the energy sector would. Because methane's global warming potential is 25 times higher than that of carbon dioxide, the percentage of methane emitted could have the potential to trap roughly twice as much thermal energy as the carbon dioxide emitted by the energy sector does.

Section 8.3 Cycling of Matter and the Climate System

(Student textbook page 333 to 340)

Specific Expectations

- **D2.1** use appropriate terminology related to climate change, including, but not limited to: *albedo*, *anthropogenic*, *atmosphere*, *cycles*, *heat sinks*, and *hydrosphere*
- **D2.4** investigate a popular hypothesis on a cause-and-effect relationship having to do with climate change, using simulations and/or time-trend data that model climate profiles
- **D3.4** identify natural phenomena known to affect climate, and describe the role of both in Canada's contribution to climate change
- **D3.5** describe the principal sources and sinks, both natural and/or anthropogenic, of greenhouse gases
- **D3.7** describe, in general terms, the causes and effects of the anthropogenic greenhouse effect, the depletion of stratospheric and tropospheric ozone, and the formation of ground-level ozone and smog
- **D3.8** identify and describe indicators of global climate change

In this section, students will learn about the natural cycles of carbon, nitrogen, and water. Students will explore the capacity of these cycles to store carbon and nitrogen. They will learn how human activity has released stored carbon and nitrogen.

Common Misconceptions

- Students may believe that plants take in food from the outside environment (only true for carnivorous plants) and/or plants get their food entirely from the soil via roots. They may also have misconceptions about carbon dioxide, believing it is a source of energy. (It is used in photosynthesis. Plants respire for energy like all other organisms, breaking down oxygen into carbon dioxide).
- Students may not see plants as a source of carbon dioxide because plants are carbon sinks. Plants respire just as other organisms do.
- Students may believe that oxygen and carbon dioxide create a carbon dioxide cycle. This does not occur. Carbon dioxide is created and destroyed in other cycles (the carbon cycle).
- Students may believe it is undesirable to have bacteria in soil. In fact, bacteria present in soil make it possible for plants to use nitrogen, which they require.

Background Knowledge

Nutrients cycle through the ecosystem, in and out of terrestrial and aquatic stores, and in and out of organisms. All living things require carbon and nitrogen. These elements are incorporated into carbohydrates, fats, DNA, RNA, and proteins that make up cells in living things. Animals obtain their nutrients by eating plants or by eating animals that ate plants. Plants obtain nutrients in two ways. Carbon is obtained through plant leaves in the process of photosynthesis. Nitrogen is obtained through their roots with the help of bacteria in the soil. The elements are recycled through the ecosystem from living organisms to dead organisms to decomposers and then into the environment where the cycle repeats.

The carbon cycle is actually the interconnections between the four major reservoirs of carbon. In general, the reservoirs are plants, the terrestrial biosphere, oceans and rocks (or sediments). Forests are reservoirs containing 86 percent of Earth's above-ground carbon and 73 percent of the carbon in soils.

The global carbon budget balances the increases and decreases (the exchanges) of carbon between reservoirs. Carbon budgets can also be used on a regional scale, to measure the exchange of carbon and determine if the area is a carbon sink or a carbon source.

The supply of nitrogen is a critical factor that drives the types and diversity of plants, interactions of grazing animals and their predators, and the productivity of plants. By increasing the amount of nitrogen cycling, humans are indirectly affecting many natural systems. These effects include increasing the global concentrations of nitrous oxide in the atmosphere and increasing regional concentrations of other forms of nitrogen that form smog. As well, in some regions, soils and bodies of water are becoming acidified. Biodiversity that depends on low-nitrogen soil is being lost, in turn reducing populations of organisms that depend on this biodiversity.