11.2 Human Activity and Climate Change

Climate change refers to changes in long-term weather patterns in certain regions. Global warming, an increase in Earth's average global temperature, is one aspect of climate change. The current increase in global temperature is caused by an increase in greenhouse gas emissions, especially carbon dioxide, from the burning of fossil fuels and other human activities. Various regions of Earth are expected to undergo changes in temperature, precipitation patterns, and the amount of ice. Climate change is expected to affect society, economies, and the environment.

Words to Know

climate change
enhanced greenhouse effect
general circulation models (GCMs)
global warming
global warming potential (GWP)
permafrost
precautionary principle

The amount of Arctic sea ice is shrinking by 2 percent to 3 percent every decade. The average sea level is rising at about 3 mm per year. Since the 1970s, the average global temperature has risen by about 0.55°C. Few people doubt that Earth is undergoing a change in climate. But are these climate observations related? And if so, how? What are the natural processes that influence climate and what role do humans play? In this section, you will investigate possible answers to these questions.

Global Warming

The term "climate change" can be misleading because it suggests that the entire climate of the planet changes all at once. Instead, **climate change** refers to changes in long-term weather patterns in certain regions, such as regions of the northern hemisphere. These changes affect the redistribution of thermal energy around Earth.

One aspect of climate is temperature. Paleoclimatologists have evidence that Earth has undergone many cycles of cooling and warming (Figure 11.14). Several ice ages have occurred in the past 1 million years alone. Over the past century, in particular, scientists have noted a definite warming trend (Figure 11.15 on the next page).

The increase in global average temperature is known as **global warming**. Average global temperature can be measured in different ways, but it often refers to the combined average temperatures of ocean surface waters and air over land and oceans.

Did You Know?

Global warming is causing sea level to rise—but not only because of melting ice in Greenland, the Arctic, and Antarctica, as scientists once believed. The major reason for the increasing sea levels is the thermal expansion of seawater as temperatures increase.

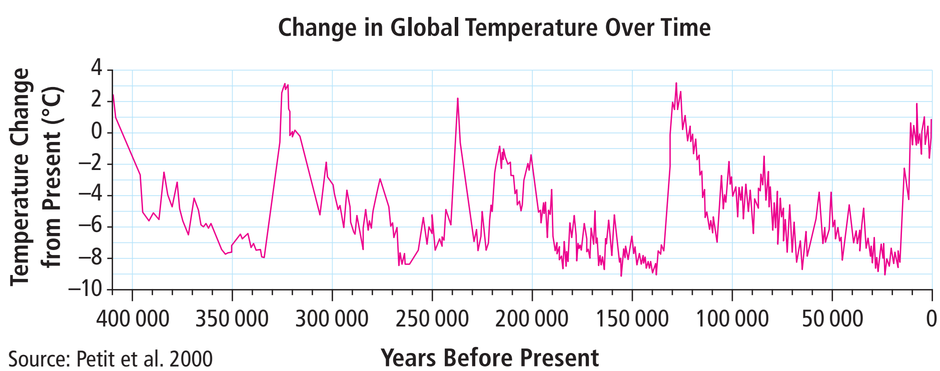
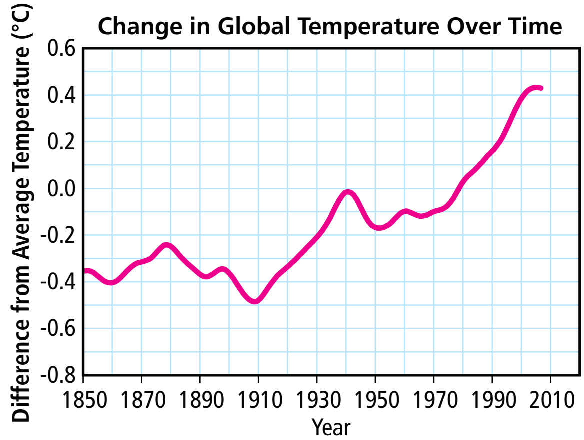


Figure 11.14 Estimated change in average global temperature at Earth's surface over the past 400 000 years

The average global temperature increased by about 0.74°C from 1906 to 2005. Predictions based on computer models suggest that the average global temperature could increase by 1°C to 2.5°C in the next 50 years and by as much as 6°C in the next 100 years. A few degrees may seem insignificant when viewed on a local scale. However, when Canada was covered with ice 21 000 years ago, the average global temperature was only 3-5°C cooler than today.

It is difficult to anticipate the effects of global warming on a system as large as Earth and its atmosphere. Most scientists agree that global warming will affect climates around the world. To what extent natural processes and human activities influence global warming has been the subject of much debate.



Sources: Climatic Research Unit and Hadley Centre, 2008

Figure 11.15 Change in global average temperature since 1850. Data from other research teams also show a trend of increasing temperatures.

11-2A What's All the Hot Air About CO_2? Find Out ACTIVITY

With the Industrial Revolution of the late 19th century came large factories and the first automobiles. The new technologies ran on fossil fuels, which release carbon dioxide when they burn. In this activity, you will track the carbon dioxide emissions from human activities since the Industrial Revolution. You will also track the amount of carbon dioxide in the atmosphere and the global temperature increase over time.

Carbon Dioxide and Average Global Temperature

Year	Industrial CO_2 Emissions (Gigatonnes)*	CO_2 Concentration in the Atmosphere (parts per million per volume)	Temperature Increase Since 1861 (°C)
1861	0.67	285	0.00
1880	1.15	292	0.00
1900	2.63	298	0.05
1920	3.42	303	0.29
1940	4.95	307	0.46
1960	9.98	318	0.35
1980	20.72	340	0.41
2000	23.42	365	0.63

Source: Carbon Dioxide Information Analysis Center (CDIAC)
* 1 gigatonne = 1 billion tonnes

Materials

- graph paper
- coloured pencils or pens

What to Do

1. Use the data from the table to make the following three line graphs. Draw a best-fit line for each graph.
   (a) Year versus Industrial CO_2 Emissions
   (b) Year versus CO_2 Concentration in the Atmosphere
   (c) Year versus Temperature Increase Since 1861
2. Using a different colour, extend each of the line graphs to 2020. This technique is known as extrapolating the data.

What Did You Find Out?

1. Describe the shape of each of graph.
2. Describe the trends since 1861 for each of the following:
   (a) industrial CO_2 emissions
   (b) CO_2 concentration in the atmosphere
   (c) average global temperature increase
3. What connections can you make among the graphs?
4. What might affect the accuracy of the extrapolated data?

Did You Know?

In 2003, people in Europe endured what was very likely the hottest summer in the region since 1500.

The Enhanced Greenhouse Effect

The **enhanced greenhouse effect** is the increased capacity of the atmosphere to absorb and emit thermal energy because of an increase in greenhouse gases. The scientific community is concerned about the role of human activities in the enhanced greenhouse effect. Other than water vapour, the principal gases in the atmosphere are nitrogen (78 percent) and oxygen (21 percent). The remaining percentage is made up of trace gases, which occur in very small concentrations, including certain greenhouse gases.

Scientists have identified several important greenhouse gases produced by human activities and the gases' global warming potentials (Table 11.1). **Global warming potential (GWP)** describes the ability of a substance to warm the atmosphere by absorbing and emitting thermal energy. CO_2 is assigned a GWP of 1. The GWP of every other greenhouse gas expresses the warming ability of that gas compared to the warming ability of CO_2 over the same timeframe. Nitrous oxide, for example, has about 298 times the warming ability of CO_2 over 100 years.

Although Figure 11.16 shows water vapour is an important greenhouse gas, it is not included in the table because human activities have very little direct effect on the amount of water vapour in the atmosphere. Ozone is not included in the table because it is continually broken down and reformed in the atmosphere, and so it is very difficult to determine its GWP.

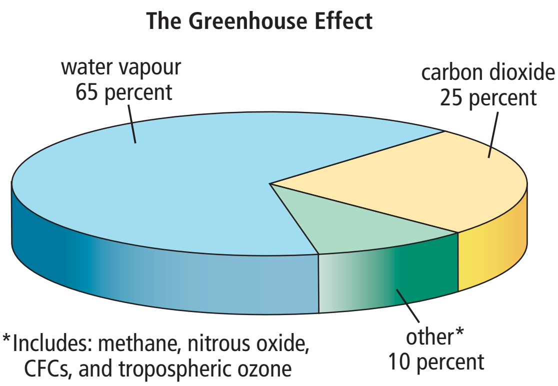


Figure 11.16 The approximate contribution of greenhouse gases to the greenhouse effect

Table 11.1 Greenhouse Gases and Global Warming Potential

Greenhouse Gas	Chemical Formula	Atmospheric Lifetime (years)	Source from Human Activity	Global Warming Potential (GWP)
carbon dioxide	CO_2	variable	• combustion of fossil fuels • deforestation	1
methane	CH_4	about 12	• processing of fossil fuels • livestock agriculture • waste dumps • rice paddies	25
nitrous oxide	N_2O	114	• production of chemical fertilizers • burning waste • industrial processes	298
chlorofluorocarbons (CFCs)	various	45	• liquid coolants • refrigeration • air conditioning	4750–5310

Source: Intergovernmental Panel on Climate Change 2007

Carbon dioxide

Before the 19th century, levels of CO_2 in the atmosphere remained in balance because of the carbon cycle. The start of the increase in CO_2 levels has been linked to the Industrial Revolution. The Industrial Revolution was so named because it marked explosive growth of industry, manufacturing, and transportation. With this expansion came an increase in the use of fossil fuels. Fossil fuels, such as coal, oil, and gas, form when the remains of ancient organisms are compressed. Fossil fuels contain large amounts of carbon, which is released when the fuels are burned (Figure 11.17). Fossil fuel combustion is the greatest carbon source resulting from human activity.

Deforestation also converts major carbon sinks—forests—into carbon sources. This adds to the amount of CO_2 going into the atmosphere.

Many people are making an effort to reduce CO_2 emissions by reducing their energy use and purchasing electric energy from wind farms and other alternative energy sources. Another possible strategy is to plant more trees in order to remove CO_2 from the atmosphere. A number of countries have tree planting projects to expand forested areas.

Figure 11.17 Idling automobiles produce greenhouse gases and air pollution that directly affects human health.

internet connect

A carbon offset is an emission reduction credit that people buy to help make up for their greenhouse gas emissions. Organizations that work to reduce CO_2 emissions sell carbon offsets. A wind farm, for example, might sell carbon offsets to a touring musical group to help make up for the greenhouse gas emissions produced by air travel. Find out more about carbon offsets. Begin your search at **www.bcscience10.ca.**

Methane

Methane (CH_4) is a gas that is very efficient at absorbing and emitting thermal energy. Although it is less abundant than CO_2 and water vapour, CH_4 is 25 times more powerful than CO_2 at absorbing and emitting the heat radiating from Earth's surface. In oxygen-free environments, bacteria break down waste materials, releasing CH_4. A major source of CH_4 is decomposing garbage in landfills. One solution is to collect and burn the CH_4 for fuel, although this process releases CO_2.

Other sources of CH_4 are also important. CH_4 is released during the process of animal digestion (Figure 11.18). Like natural wetlands, rice paddies are a source of CH_4. In northern regions, when frozen swampland (muskeg) thaws, it releases CH_4. In addition, extracting, producing, and burning fossil fuels can release CH_4. Since 1750, the amount of CH_4 in the atmosphere has increased more than 150 percent. The increase is thought to be related to rapid growth in the human population since that time.

Figure 11.18 Livestock produce 18 percent of the total amount of the methane in the atmosphere.

Nitrous oxide

Although present in small amounts, nitrous oxide (N_2O or dinitrogen oxide) is the third-largest contributor to the enhanced greenhouse effect. N_2O is formed from biological processes of bacteria in ocean water, soil, and manure. Humans produce large amounts of N_2O from the use of nitrogen-rich chemical fertilizers in farming and the improper disposal of human and animal waste. Automobile exhausts also release N_2O.

Ozone

Ozone (O_3) is a molecule that occurs naturally in the stratosphere at altitudes between 10 km and 50 km. At this level, it forms the ozone layer, which filters out harmful ultraviolet radiation from the Sun. However, close to Earth's surface, O_3 occurs naturally in only trace amounts. And yet, over the last few decades, scientists have recorded a steady climb in the amount of surface O_3. In the upper Fraser Valley of British Columbia, for example, high surface levels of O_3 have been affecting the quality and quantity of some crops grown.

O_3 results from chemical reactions between sunlight and air pollution from the burning of fossil fuels, mainly in cars and trucks. Much of the ozone-producing pollution in the Fraser Valley comes from traffic in the Greater Vancouver Regional District. The pollution includes hydrocarbons and nitrogen oxides. As the global use of fossil fuels increases, so does the quantity of surface ozone.

Chlorofluorocarbons

Chlorofluorocarbons (CFCs) are a group of human-made greenhouse gases with powerful global warming potential. CFCs are made up of chlorine, fluorine, and carbon. The main use of CFCs is as coolants for refrigerators and air conditioners.

Many nations have signed an agreement called the Montreal Protocol to ban the use of CFCs. In addition to being greenhouse gases, CFCs are thought to be the main cause of the depletion of Earth's protective ozone layer (Figure 11.19). In the 1970s, scientists discovered that the CFCs commonly used in aerosol spray cans (such as hair spray and spray paint cans), air conditioners, refrigerators, and even fire extinguishers were getting into the atmosphere in large quantities. When CFCs reach the atmosphere, the chlorine atoms are released and break apart O_3 molecules. Not only has stratospheric ozone been thinning in many places, but scientists also think that CFCs are the main reason for the massive hole in the ozone layer over Antarctica. The ozone hole could potentially increase global warming by allowing more solar radiation to reach Earth's surface.

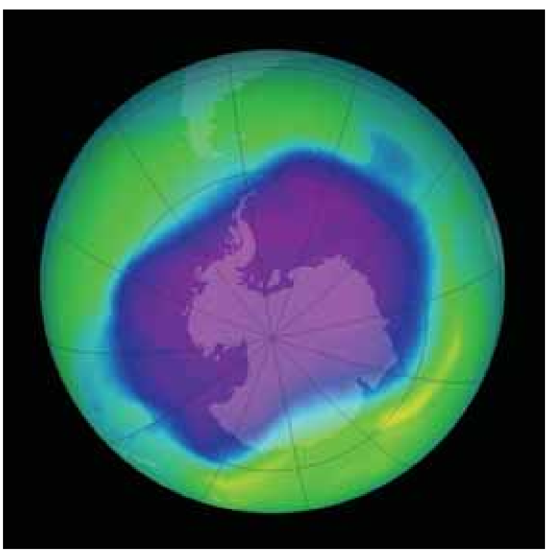


Figure 11.19 A satellite image of the ozone hole over the Antarctic observed September 21–30, 2006. Although ozone-depleting CFCs have been banned in most developed nations, these chemicals last a long time in the atmosphere. It may take decades before the full effect of reducing CFCs is seen.

Albedo and Climate

The albedo at Earth's surface affects the amount of solar radiation that a region receives. As Figure 11.20 shows, different materials have very different albedos. Changes in albedo at Earth's surface could affect the climate in various ways. Figure 11.21 shows the variation in albedo around Earth. If large stretches of Arctic sea ice were to melt, for example, the albedo in the Arctic would drop. This region would then absorb more solar radiation. Would this cause more sea ice to melt? Or would some other consequence result? It is difficult to predict what might happen.

Evidence does suggest that the low albedo of some types of forests plays an important role in regulating climates. Boreal forests have low albedo and so they absorb solar radiation. Deforestation increases albedo, causing more solar radiation to be reflected back into space. Forests are an important carbon sink, but do they affect the average global temperature in other ways? Scientists try to answer questions like this using a variety of methods.

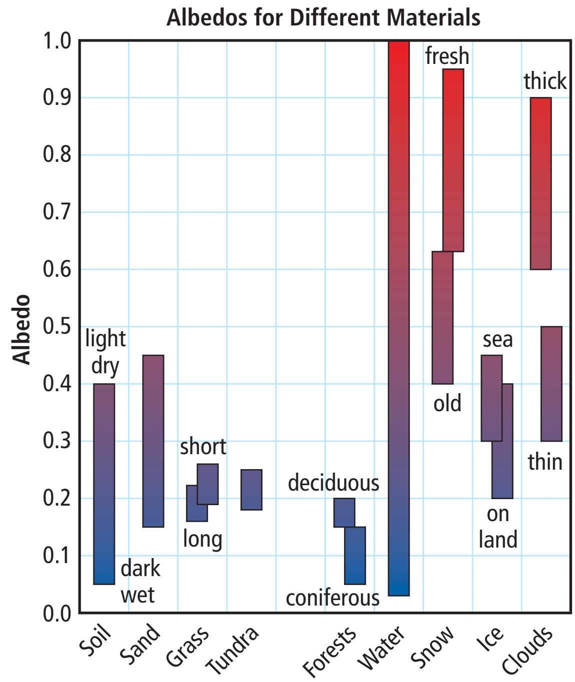


Figure 11.20 Albedos for different surfaces vary widely

Reading Check

1. What is the difference between the natural greenhouse effect and the enhanced greenhouse effect?
2. What does GWP describe?
3. List three greenhouse gases that are released when fossil fuels are burned.
4. Name a greenhouse gas that does not occur naturally.
5. Which has a higher albedo: sea ice or soil?

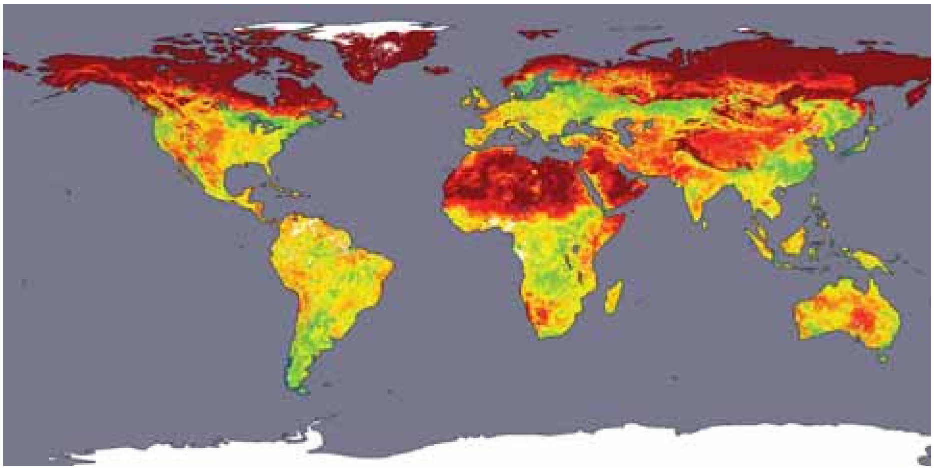


Figure 11.21 A satellite image of global albedo. Red areas have the highest albedos, yellow and green areas have intermediate albedos, and blue and purple areas have the lowest albedos. No data are shown for the white areas and oceans.

The Role of Science in Understanding Climate Change

Suggested Activity

Find Out Activity 11-2B on page 497

Research and analysis of climate data require cooperation and commitment from people around the world. It would be extremely difficult and inaccurate to base conclusions about global climate change on single observations made at specific locations. To increase reliability, many measurements must be taken. By compiling multiple measurements from around the world and over time, researchers have noticed trends. These trends can be analyzed by using computer models.

General circulation models (GCMs) are computer models designed to study climate. GCMs take into account multiple factors, such as changes in greenhouse gas concentrations, albedo, ocean currents, winds, and surface temperatures. GCMs are used for weather forecasting, climate analysis, and climate change predictions. The models are very sophisticated and factor in the properties of fluids, chemical reactions, and how organisms affect their environment. The goal of scientists who use GCMs is to better understand the complex nature of climate and the effects of human activities on it (Figure 11.22).

As technology and scientific understanding improve through better satellite analysis, more observation tools in the ocean, and increased knowledge among researchers, the accuracy of the computer models increases. Computer models have successfully reproduced the climate of the past 100 years, and simulations have also matched temperature changes over the past 1000 years. Currently, GCMs provide the best predictions of future conditions of our atmosphere and global climate.

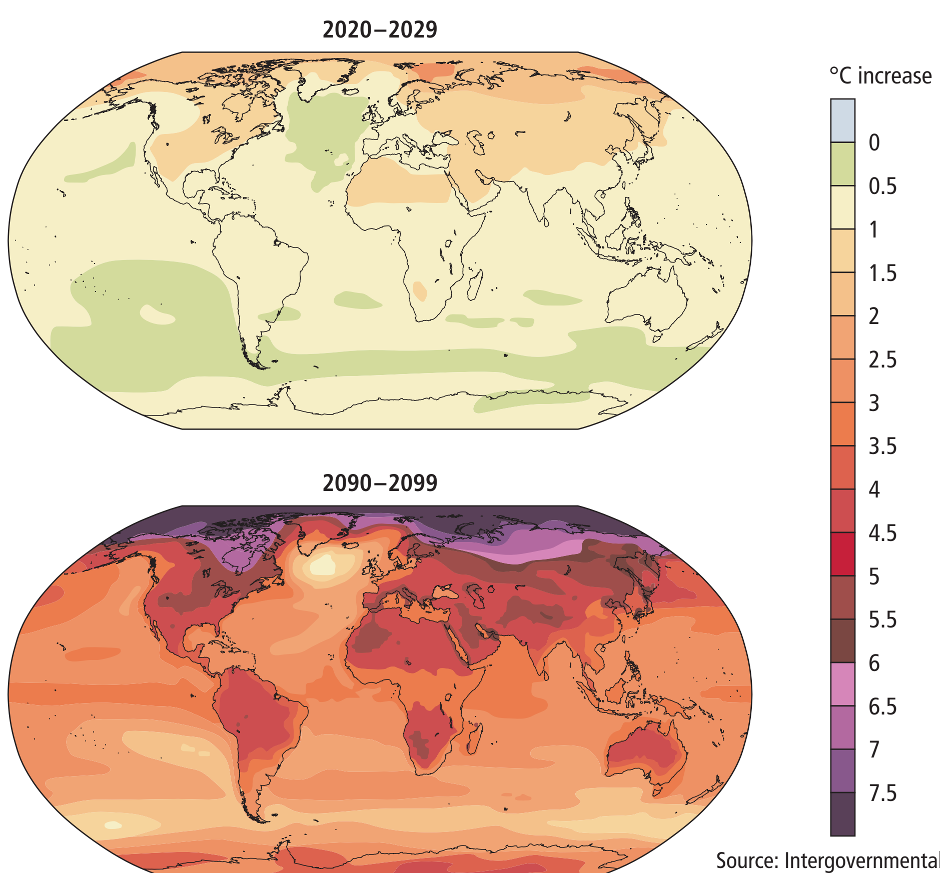


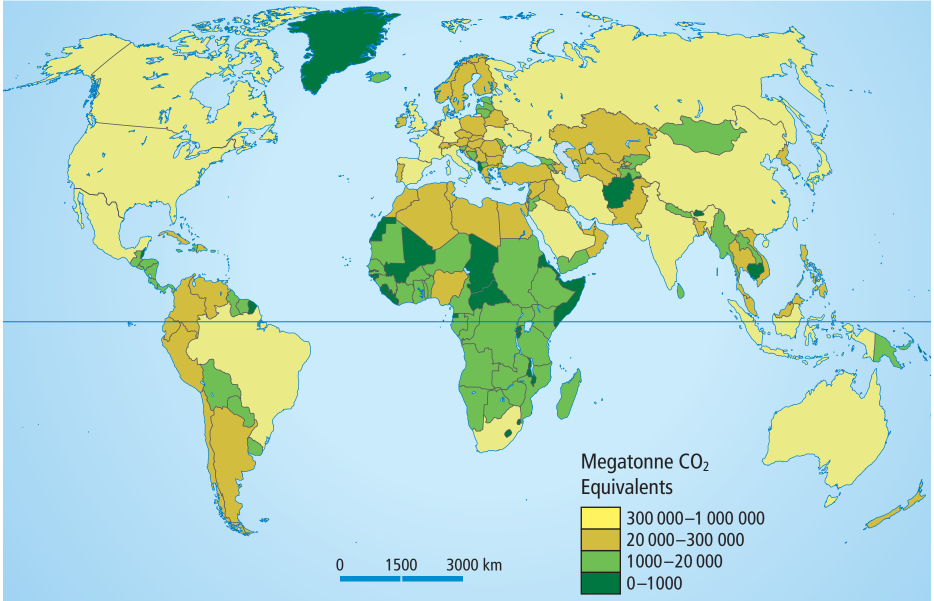
Figure 11.22 These maps of projected global temperatures were based on predictions from GCMs. The maps represent a worst-case scenario of increasing greenhouse gas emissions.

Source: Intergovernmental Panel on Climate Change

The Role of International Cooperation in Dealing with Climate Change

Paleoclimatologists think that Earth's climate has been relatively stable for thousands of years. Only in your parents' generation and in your own have major climate changes thought to be caused by human activities been observed. To address the global concern about climate change and global warming, the United Nations Environmental Programme (UNEP) and the World Meteorological Organization (WMO) formed the Intergovernmental Panel on Climate Change (IPCC). The IPCC was established in 1988 and includes experts from about 130 countries around the world. The goal of the IPCC is to assess evidence of the human influence on climate change and possible ways to respond. The IPCC looks at the social and economic issues related to climate change as well as the environmental issues.

In addition, the United Nations has set up an international environmental treaty called the United Nations Framework Convention on Climate Change (UNFCCC). The treaty is designed to encourage countries around the word to reduce greenhouse gas emissions in order to reduce the rate of global warming (Figure 11.23). The treaty does not set binding rules. Instead, countries meet to determine what the greenhouse gas emission limits should be.



Source: Adapted from Globalis 2003

Figure 11.23 The total emissions of greenhouse gases for various countries. The developed nations of the world contribute the most greenhouse gas emissions.

Global Impacts of Climate Change

Current climate change models predict that temperatures will increase more in arctic regions than in equatorial regions and more on land than in the oceans. Some models predict a temperature rise of 6°C in northern regions and a sea level rise of almost 88 cm within the next 100 years. Predicting the exact effects of these changes on particular locations is very difficult. Figure 11.24 on the next page lists some potential global effects of climate change, assuming that greenhouse gas emissions continue to rise.

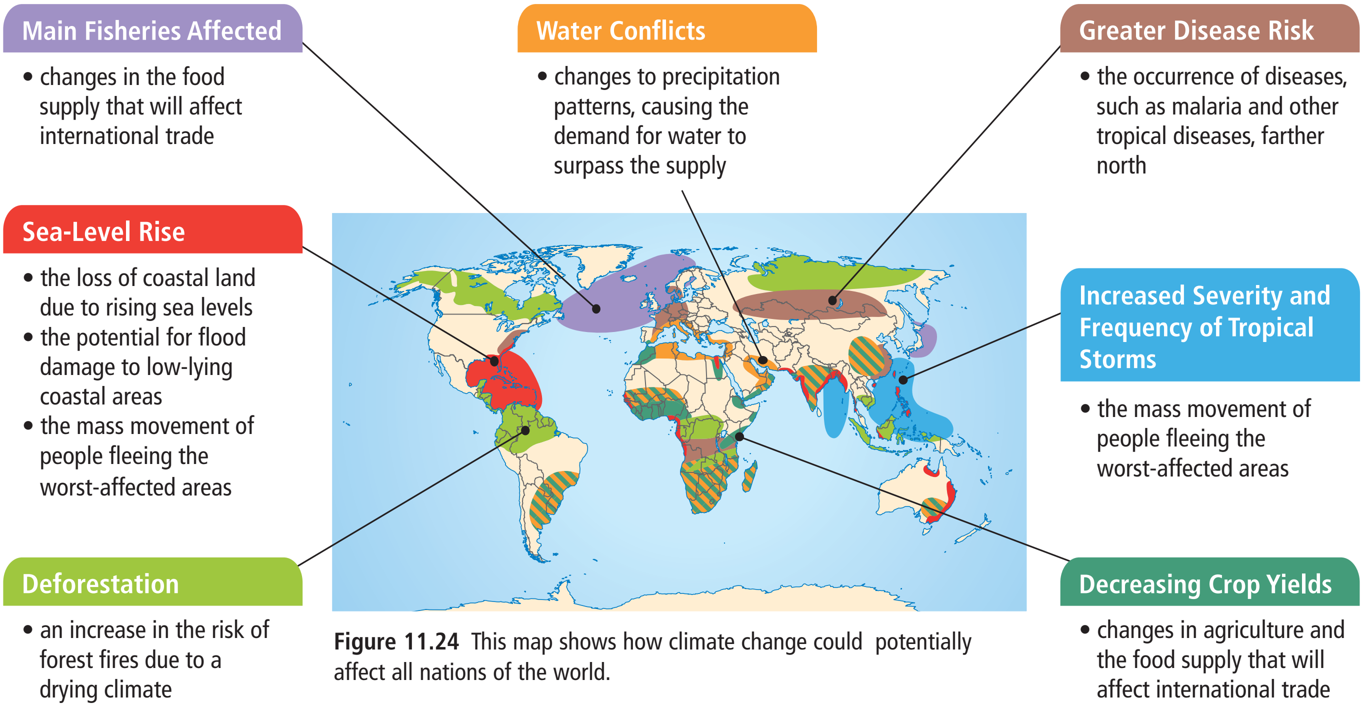


Figure 11.24 This map shows how climate change could potentially affect all nations of the world.

Impacts of Climate Change on Canada

As a country located in the northern hemisphere, where the effects of global warming could be most severe, Canada may be one of the most affected nations. Statistics Canada reports that, in some areas of the country, 22 out of 23 recent winters have had temperatures above normal. Surface temperatures have increased between 0.5°C and 1.5°C in parts of southern Canada, with the greatest warming occurring in the west. Temperatures have been rising in northern Canada as well, especially in the arctic regions. Areas of permafrost are melting. **Permafrost** is ground that usually remains frozen year-round. The ice cover in the Arctic Ocean is rapidly shrinking.

Climate change will affect weather patterns, such as winter and summer temperatures and the amount and location of rainfall. Satellite data have shown that the growing seasons are already becoming longer each year. Aspen trees in Alberta bloom a full 28 days sooner than they did a century ago. In the past decade, total precipitation over Canada has increased by 12 percent, with the greatest increase over Nunavut (25 percent to 45 percent).

Scientists suggest that, in future, we can expect heavier spring rains and longer heat waves in some parts of the country (Figure 11.25). These changes will affect biomes across Canada (Figure 11.26). Continuing changes in the patterns of precipitation will also affect the quantity and the quality of water available for people's homes, agriculture, and industrial uses, such as obtaining oil. One of the most important industries in Canada is the fisheries. Changes to the temperature, water quality, and currents in oceans, lakes, and streams could have devastating effects on fish populations.

Forestry is another important industry across Canada. An increase of CO_2 in the atmosphere might help the forests to grow. However, warmer temperatures will create better conditions for forest fires, for the insects that harm trees, and for a variety of different plants.

The general health of Canadians could also be affected by climate change. High summer temperatures would worsen the health effects of air pollution. Warm winters would allow disease-carrying insects to survive farther north than in the past. More violent storms that could interrupt power supplies and damage roads are also possible, making it difficult for hospitals and other essential services to function.

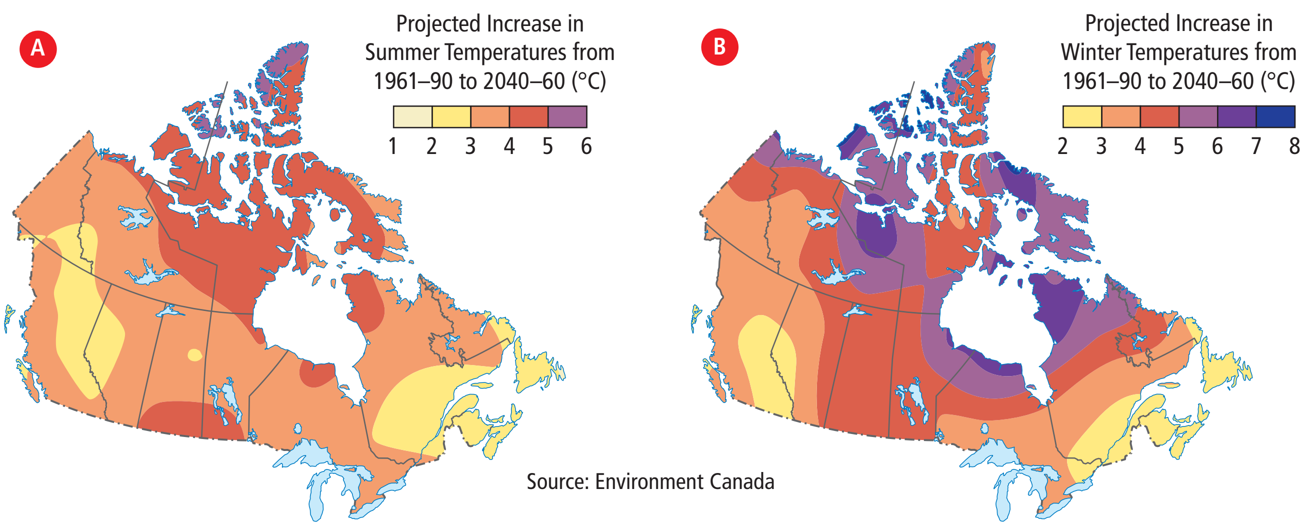


Figure 11.25 Projected temperature change for Canada in 2050, summer (A). Projected temperature change for Canada in 2050, winter (B). The maps are based on the Coupled Global Climate Model developed by Environment Canada.

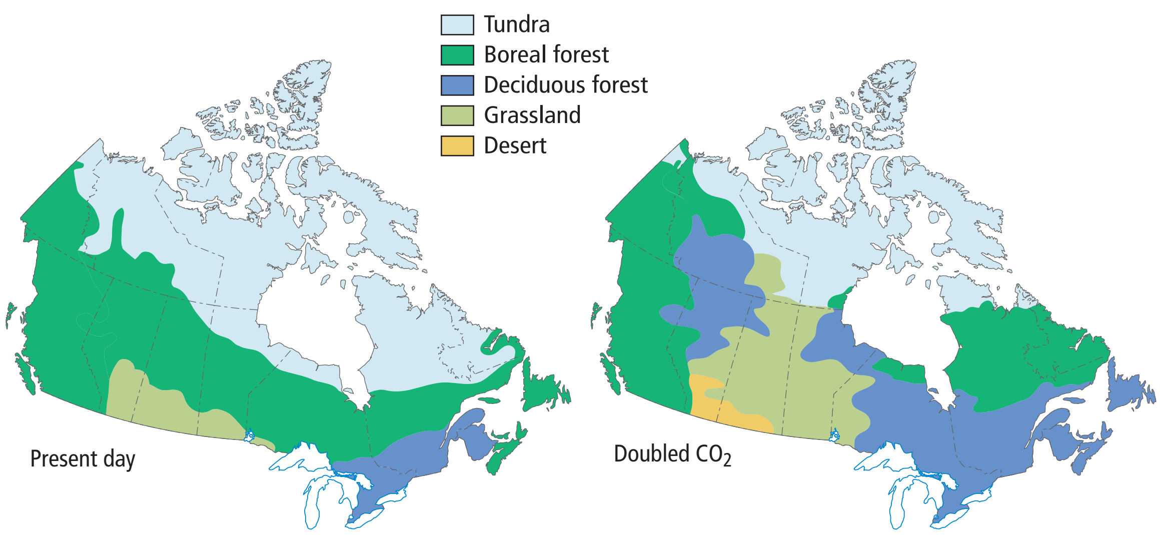


Figure 11.26 Changes projected for Canada's biomes if the concentration of CO_2 doubles from what it was before the Industrial Revolution.

Impacts of Climate Change on British Columbia

In future, most regions of British Columbia will be warmer. The amounts and effects of greenhouse gases on the global climate system will influence how great the temperature change will be. Figure 11.27 shows projections for increases in temperature.

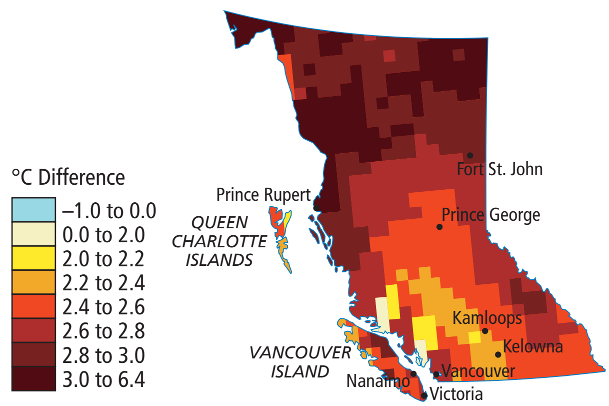
The effects of climate change and global warming on British Columbia may be significant. Some computer models suggest an almost 30 cm rise in the sea level along the northern coast of British Columbia over the next century. A rise in sea level would pose a serious flood threat to some coastal communities and low-lying areas as well as to port facilities and docks. In addition, a change in weather patterns could bring more rain to some areas and drought to others (Figure 11.28).

Freshwater glaciers are an important source of drinking water in British Columbia. These glaciers have been shrinking since the 1980s and will continue to shrink because of global warming (Figure 11.29 on the next page).

Table 11.2 on the next page summarizes some of the possible effects of climate change on the province.

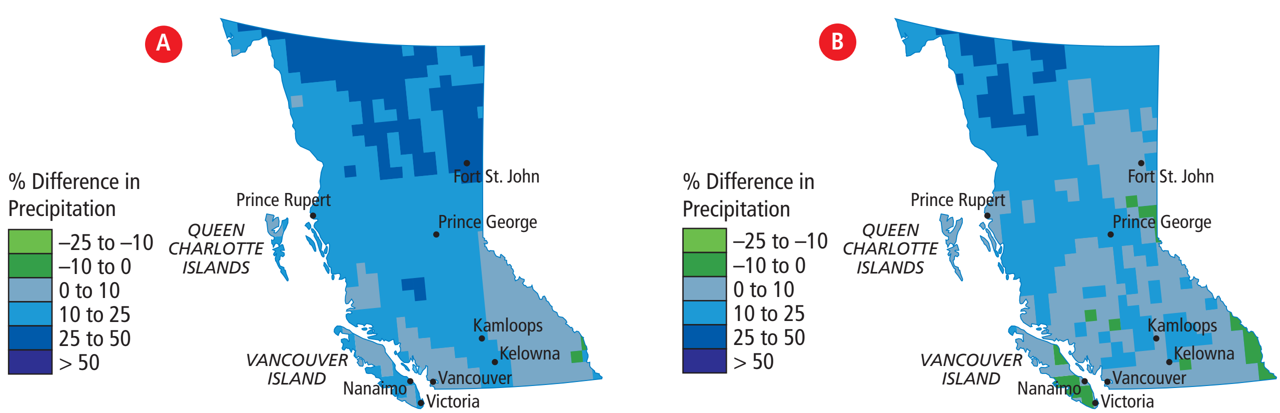
internet connect

What will the climate be like where you live in 20 years? In 100 years? Go to **www.bcscience10.ca** to link to online climate modelling programs.



Source: Adapted from Rodenhuis et al. 2007

Figure 11.27 The projected change in average annual temperatures in British Columbia for 2041–2070 from historical temperatures.



Source: Adapted from Rodenhuis et al. 2007

Figure 11.28 The projected change in precipitation in British Columbia for 2041–2070 from historical amounts. The projected changes for winter (A) and summer (B) precipitation are shown in separate maps.

Table 11.2 Predicted Effects of Climate Change on British Columbia

Segment Affected	Effects of Climate Change
Fisheries	• Changes in ocean life could occur; for example, warm water species, such as tuna and mackerel, may replace cold water species, such as salmon. • Salmon may migrate northwards to find colder water.
Forestry	• Northern regions will become warmer, extending the range of some tree species. • Droughts will affect many species of trees and favour the spread of grasslands. • Drought will increase the risk of fire in the forests. • Incidence of disease and insect infestations will increase.
Wetlands	• Current flood-prevention measures may not be able to contain floods along the coast and in interior British Columbia. • Ecosystems in wetlands, estuaries, and deltas will be affected by a rise in water levels.
Water	• A change in weather patterns will affect the supply and, therefore, the demand for water. • Spring thaws will arrive earlier, and droughts will happen more often and last longer. • Rising sea levels could mean saltwater flooding of low-lying farming areas.
Wildlife	• Changing temperatures will alter habitats, food supplies, and shelter for many species of wildlife. • An increase in the amount of CO_2 dissolved in the ocean will make ocean water more acidic, which could harm ocean life and even result in the loss of some species.

Figure 11.29A Helm Glacier in British Columbia (A)

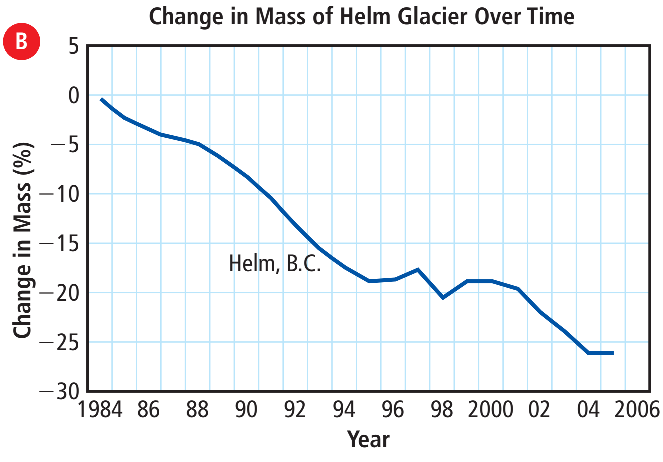


Figure 11.29B The mass of Helm Glacier has changed from year to year, and has decreased overall. The glacier loses more ice in summer than it gains in winter.

Reading Check

1. What is a general circulation model?
2. Why was the IPCC formed?
3. List a possible social impact of global climate change.
4. Describe one possible effect of global warming on Canadian biomes.
5. List three possible environmental effects of climate change on British Columbia.

Table 11.3 Likelihood Terminology used by the IPCC

Term	Probability of Event Occurring
Virtually certain	> 99 percent
Extremely likely	> 95 percent
Very likely	> 90 percent
Likely	> 66 percent
About as likely as not	33–66 percent
Unlikely	< 33 percent
Very unlikely	< 10 percent
Extremely unlikely	< 5 percent

Uncertainty and Decision

Predictions about climate change cannot be certain. For this reason, scientists use specific terms when discussing the likelihood of their predictions coming true. As shown in Table 11.3, the term "virtually certain" means that a prediction will probably be correct. The term "extremely unlikely" means that a prediction probably will not come true. Considering the likelihood of specific predictions about climate change can help people decide how to respond.

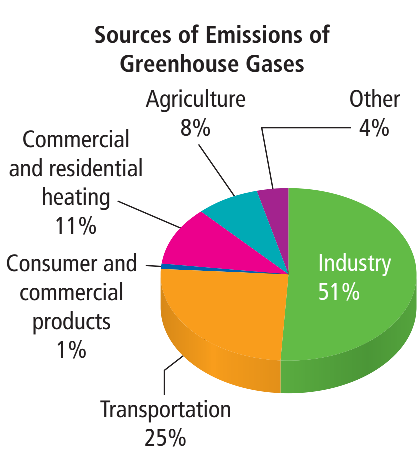
The response to climate change will affect society, the economy, and the environment. One of the greatest barriers to limiting greenhouse gas emissions is the cost. People in developed countries are concerned that the cost of implementing changes will be overwhelming. People in developing countries are reluctant to slow their economic growth. Figure 11.30 shows the amount of greenhouse gas emissions from a variety of sources in Canada. To reduce greenhouse gases from any one source, we would have to change the way we live. What changes could we make? Would these changes be worth it? For example, the manufacturing industry produces large amounts of greenhouse gases but we rely on manufactured goods such as clothing, electronics, and cars. Some people argue that it makes sense to buy manufactured goods that will last as long as possible, even if they cost more, and to charge a fee to companies for products that do not last very long.

One way to think about the response to climate change is to consider two extreme scenarios:

(1) Climate change will not greatly affect our lives or the environment.

(2) Climate change will cause drastic changes in weather patterns that will greatly affect our lives and the environment.

We cannot be sure which scenario will occur. One response would be not to act. Another response would be to make changes that might influence the course of climate change or help people to adapt to changing climates. What would be the consequences of not taking action if the first scenario is correct and climate change does not greatly affect people or the environment?



Source: Adapted from Environment Canada

Figure 11.30 Sources of emissions of greenhouse gases in Canada

The United Nations suggests that governments should use the precautionary principle to guide their responses to climate change. The **precautionary principle** is the principle that a lack of complete scientific certainty should not be used as a reason to postpone cost-effective measures to prevent serious environmental damage.

An Action Plan for the Global Community

Our ability to deal with climate change will not come from the actions of one individual, one corporation, or even one country. Decreasing overall greenhouse gas emissions will require global cooperation.

In a recent report on climate change, the IPCC suggests that major polluters should be taxed based on the type, impact, or amount of greenhouse gas emissions. The report adds that employing different, healthier strategies could eventually enhance economic growth.

Table 11.4 on the next page shows the key components of the IPCC action plan for addressing global warming and climate change.

Suggested Activity

Think About It 11-2C on pages 498–499

Canada's Response to Climate Change

Industry and transportation account for about 75 percent of the total greenhouse gases produced by Canada (Figure 11.31). These sectors are the focus of plans that the Canadian government has implemented to reduce our greenhouse gases:

- reducing greenhouse gas emissions from cars and trucks
- introducing policies requiring major greenhouse gas-producing industries to reduce emissions
- increasing the types of energy-efficient products available
- setting guidelines for improving indoor air quality

The use of consumer goods accounts for about 12 percent of all greenhouse gas emissions in Canada. Switching to energy-efficient lights, dishwashers, refrigerators, and air conditioners would lower the per person emissions of greenhouse gases. In addition, green building codes outline how to construct new energy-efficient buildings and update existing buildings to improve their energy efficiency.

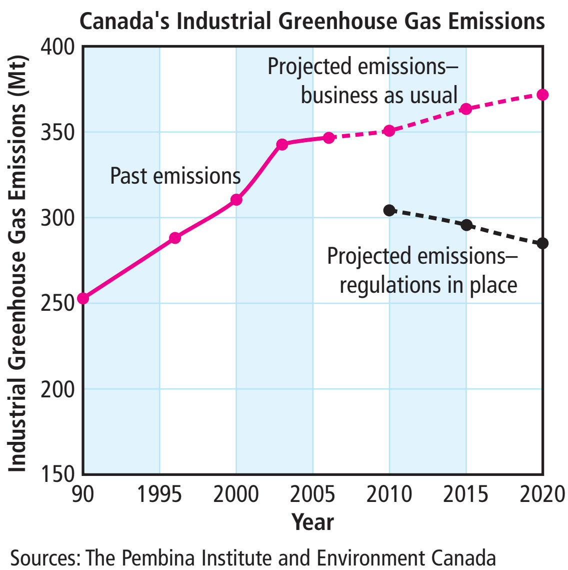
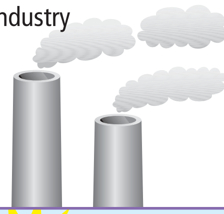
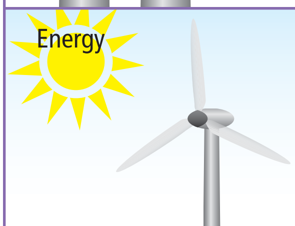
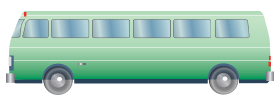
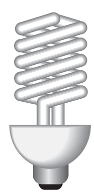
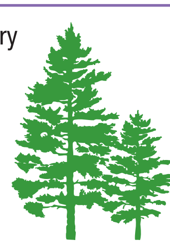


Figure 11.31 Two scenarios for Canada's projected greenhouse gas emissions: if business continues as usual, or if emissions are reduced to meet specific targets

Explore More

Imagine spraying perfume into the air and then trying to put the perfume back in the bottle. This is what it would be like trying to capture CO_2 from the atmosphere once it has been released during industrial processes. However, new techniques are being used to capture CO_2 at the source and store the gas underground. Known as carbon capture and storage, the technologies prevent large amounts of CO_2 from entering the atmosphere. Find out more about carbon capture and storage and Canada's leading role in developing these technologies. Begin your search at **www.bcscience10.ca**.

Table 11.4 Strategies for Addressing Climate Change

Sector	Strategy for Reduction of Greenhouse Gas Emission
Industry 	• Switch to more energy-efficient electric equipment, heat, and power sources. • Increase the amount of recycling. • Monitor and control non-CO_2 greenhouse gas emissions.
Energy 	• Develop more efficient ways of producing energy. • Research renewable energy sources (hydroelectric, wind, solar, biofuels, and geothermal power). • Store CO_2 underground after it is removed from natural gas.
Transportation 	• Improve fuel efficiency for vehicles. • Introduce hybrid vehicles, which do not rely on fossil fuels alone. • Introduce alternative fuels, such as hydrogen or biofuels. • Shift from road transport to rail. • Improve and promote the use of public transportation.
Construction 	• Switch to high-efficiency lighting. • Use energy-efficient appliances, heating systems, and air conditioning systems. • Improve insulation of buildings. • Use solar and geothermal heating and cooling.
Agriculture 	• Improve fertilizer (nitrogen) use. • Specify crops used for energy purposes (i.e., corn, soybeans). • Increase use of soil carbon storage. • Improve management of livestock waste. • Improve techniques for cultivating rice crops. • Reclaim and reuse lands damaged by agriculture.
Forestry 	• Promote worldwide planting of trees and reforestation. • Encourage efficient use of forest products for energy. • Encourage better forest-management strategies.
Waste management 	• Promote recycling, composting, and minimizing waste. • Encourage the burning of waste for energy recovery. • Recover methane gas from decomposition in garbage dumps and landfills.

11-2B Calculating Carbon Emissions

Find Out ACTIVITY

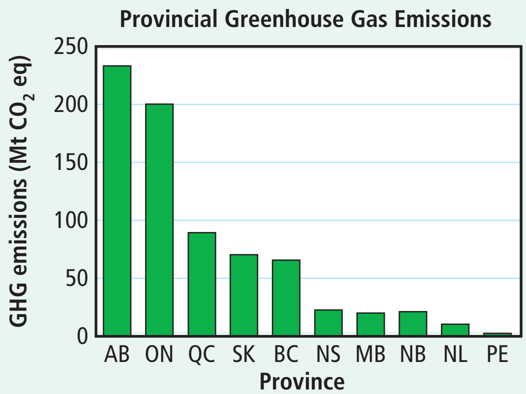
Everyone adds some CO_2 to the atmosphere, but the more fossil fuels we use, the more CO_2 we produce. What is British Columbia's contribution? In this activity, you will calculate, compare, and contrast the per capita (per person) carbon dioxide emissions for each province in Canada.

Materials

- calculator

What to Do

1. Examine the bar graph and table shown below. The graph shows the total amount of greenhouse gas emissions for each province of Canada. The table gives the population of each province.



Source: Environment Canada 2005

2. Copy the table into your notebook. Read the graph and fill in the CO_2 emission values in the third column of the table in your notebook. Amounts are given in megatonnes of equivalent CO_2.
(**HInt:** 1 Mt = 1 000 000 tonnes)
3. Before making any calculations, predict which provinces you think will have the greatest per capita CO_2 emissions.
4. Divide the total CO_2 emission values by the population numbers to calculate the per capita CO_2 emissions.

What Did you Find Out?

1. Did your calculated results match your prediction? Explain.
2. (a) Which three provinces have the highest CO_2 emission values?
   (b) Why do you think these three might have the highest values?
3. Some regions of Canada are especially rich in fossil fuels. Obtaining and processing fossil fuels produces greenhouse gases. How might the distribution of fossil fuel sources in Canada relate to the per capita CO_2 emission values that you calculated?

Canadian Population

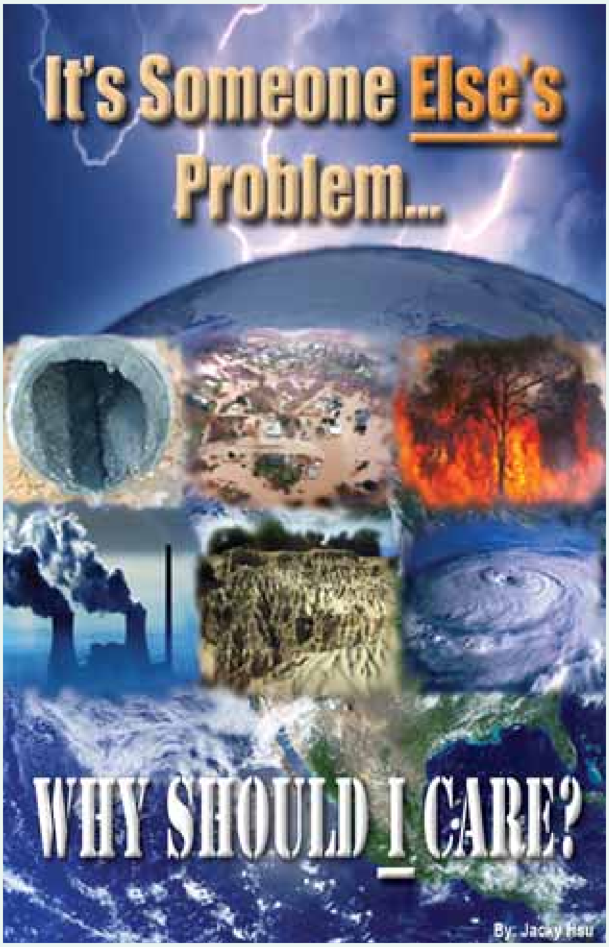
Region	Population, 2006	CO_2 Emissions (millions of tonnes)	CO_2 Emissions Per Capita (tonnes)
Canada	31 612 897	739	
Ontario	12 160 282		
Quebec	7 546 131		
British Columbia	4 113 487		
Alberta	3 290 350		
Manitoba	1 148 401		
Saskatchewan	968 157		
Nova Scotia	913 462		
New Brunswick	729 997		
Newfoundland and Labrador	505 469		
Prince Edward Island	135 851		

11-2C Pondering Posters

The terms "climate change" and "global warming" can evoke emotional debate about the nature and extent of a looming international crisis. Each poster shown here was created by one or more high school students as a project on climate change and global warming. In this activity, you will analyze the students' responses to each term.

What to Do

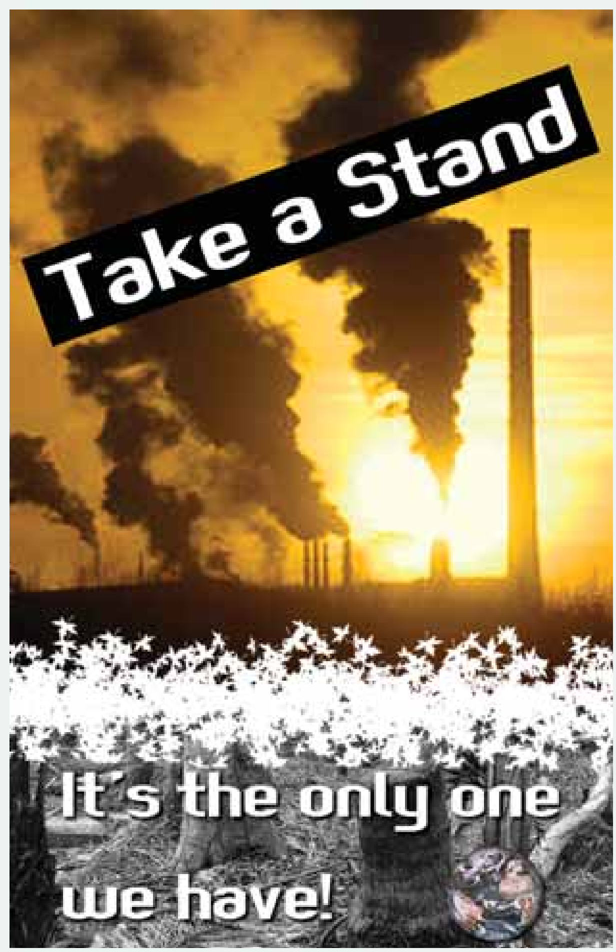
1. Look at the students' posters. For each one, write down the title and write a brief paragraph explaining your interpretation of the poster. Address the following in your interpretation:
   - the artists' personal responses to the issue
   - an explanation of any symbolism used
   - the scientific basis for the information presented
   - the clarity and impact of the statement being made
2. After you have finished, share your interpretations of the posters with your classmates. Explain whether you feel that each poster conveyed the students' message well or whether the message was vague.



Posters courtesy of Mr. Pahal's Fraser Heights Secondary Information Technology class


This is a Global Warning
We Are Being Cooked
Our Power?
2001
START
1 2 3
4 5 6
7 8 9
0

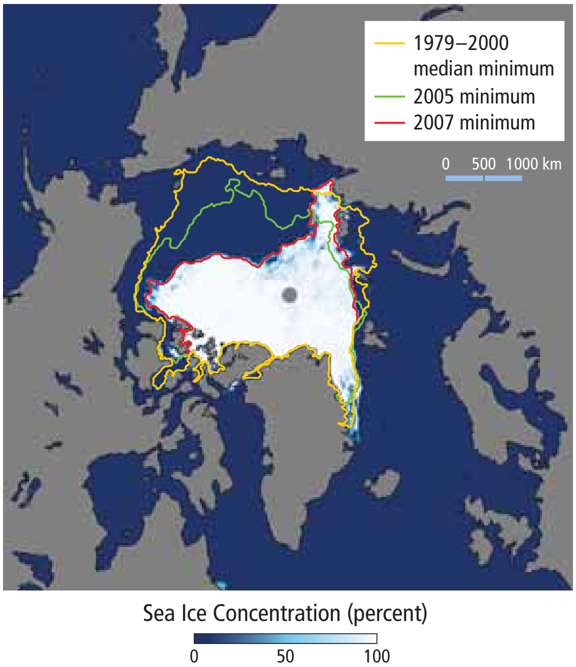

We could all go up
in smoke.


Take a Stand
It's the only one
we have!

Science Watch

Sea Ice Melt in the Arctic

The Arctic is warming about twice as fast as most of the world. One of the most visible effects of Arctic warming is melting sea ice, which brings both problems and opportunities. On September 15, 2007 the amount of Arctic sea ice reached a record low. The satellite image below shows the extent of Arctic sea ice on that day compared to the maximum amount of sea ice and minimum amount of sea ice recorded in 2005. The average amount of sea ice from 1979 to 2000 is also shown. White areas of the image show high concentrations of ice, turquoise areas are broken sea ice, and dark blue areas are open water.



Sea ice has a regulating effect on ocean water temperatures. Sea ice also keeps temperatures cool at Earth's surface by reflecting much of the solar radiation that reaches it. Without large sheets of ice, this cooling effect would be lost. Rapidly melting ice could also affect the balance of salt water to fresh water and alter ocean currents and weather patterns.

Arctic sea ice provides habitat for a rich ecosystem. Animals that rely on the sea ice include Arctic foxes, polar bears, seals, and walruses. Algae attached to the bottom of sea ice is food for marine animals such as beluga, narwhal, char, and cod. Biologists estimate that, by 2050, the polar bear population could drop by $\frac{2}{3}$ due to the shrinking amount of sea ice. In contrast, there has been an influx of animals to the Arctic that are uncommonly seen in the far north, such as robins, finches, and dolphins.

For the people who live in the Arctic, the loss of the sea ice could mean the loss of a traditional way of life. For thousands of years, the Inuit have travelled across the Arctic sea ice to hunt and fish. The sea ice is becoming increasingly unstable, however, and too dangerous to travel across.

The rapid loss of the Arctic sea ice has also marked a turning point in the history of ocean travel in the North. For as long as people have explored global trade routes, they have sought a waterway across "the top of the world." Known as the Northwest Passage, this route directly connects the Atlantic Ocean and Pacific Ocean, although, historically, ships have not been able to push through the barrier of Arctic sea ice. In 2007, the sea ice shrank enough that a ship could travel through. The direct route from ocean to ocean cuts travel by thousands of kilometres, saving time and reducing production of greenhouse gases.

Questions

1. Describe two ways in which the loss of Arctic sea ice could affect climate.
2. Identify the importance of sea ice in:
   (a) Arctic ecosystems
   (b) the traditional Inuit lifestyle
3. What are some possible results of increasing travel through the Arctic?

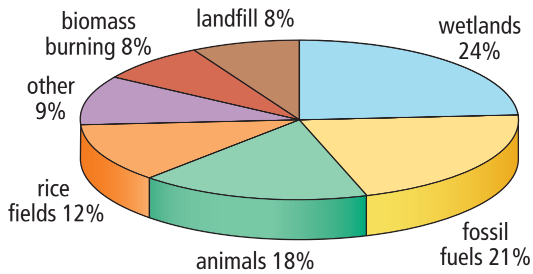
Checking Concepts

1. What does the term "climate change" mean?
2. List three observations that indicate that climate change is occurring.
3. What is the effect of greenhouse gases on heat radiated from Earth's surface?
4. Define "enhanced greenhouse effect."
5. What is global warming?
6. What is the most abundant greenhouse gas?
7. (a) What does GCM refer to?
   (b) How are GCMs used to study climate change?
   (c) List three factors that GCMs take into account.
8. (a) What does the term "carbon source" mean?
   (b) What is the largest carbon source resulting from human activity?
9. Name a source of the greenhouse gas nitrous oxide (N_2O).

Understanding Key Ideas

10. A change in room temperature of only 1°C to 2.5°C would be barely noticeable. Explain why scientists are alarmed at the potential for the same increase in the average global temperature of Earth in the next 50 years.
11. The global warming potential (GWP) of sulfur hexafluoride (SF_6) is 23 900. Compare the ability of SF_6 to absorb and emit thermal energy with that of CO_2.
12. Ozone in the stratosphere protects life on Earth from the Sun's harmful ultraviolet radiation. Why is ozone in the troposphere considered harmful?
13. Describe at least one way that global warming could affect each of the following in British Columbia.
   (a) water supplies
   (b) fisheries
   (c) wildlife
   (d) forestry
   (e) coastal ecosystems
14. Study the graph below of methane sources.
   (a) If you were going to start a program to reduce methane emissions, which source would you target and why?
   (b) Briefly explain how your program would help to reduce methane emissions.

Methane Sources



Source: Environment Canada, 2000

15. Some people have calculated that everyone could produce about 2 tonnes of CO_2 per year without disrupting the natural greenhouse effect. The average car produces about 4.3 tonnes of CO_2 each per year.
   (a) As more people in developing countries start using cars, what might happen to global CO_2 emissions?
   (b) What other factors could change your answer to (a) above?

Pause and Reflect

The table below shows examples of industries in British Columbia, the problems related to climate change for one industry, and some strategies for solving the problems. Copy the table into your notebook, and complete the other rows in your table.

Industry	Problem	Strategy for Solution
Manufacturing	• High energy use • Air pollution • Waste material	• Use energy-efficient equipment. • Monitor air quality and emissions. • Recycle material.
Construction		
Forestry		

Chapter Review

Prepare Your Own Summary

In this chapter, you investigated how climate change is caused by natural processes and human activities. Create your own summary of the key ideas from this chapter. You may include graphic organizers or illustrations with your notes. (See Science Skill 11 for help with using graphic organizers.) Use the following headings to organize your notes:

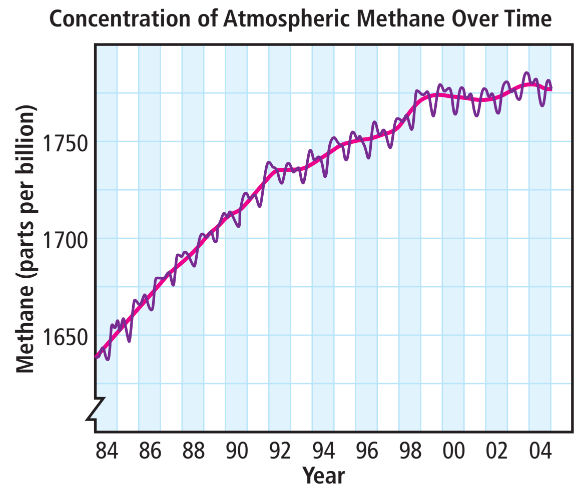
1. Studying Past Climates
2. Natural Processes that Affect Climate
3. Signs of Climate Change
4. The Enhanced Greenhouse Effect
5. Effects of Climate Change
6. Responding to Climate Change

Checking Concepts

1. Is "weather" the best term to describe the conditions of the atmosphere over a large region for many years? Explain your answer.
2. What do paleoclimatologists study?
3. Describe how the angle of incidence of the Sun's rays affects climates on Earth.
4. List two biogeoclimatic zones in British Columbia.
5. Briefly describe the role of oceans in the global climate system.
6. What is the importance of the natural greenhouse effect to living organisms?
7. What is meant by the term "climate change"?
8. What are two signs, other than increasing temperatures, that indicate that climates on Earth are changing?
9. Has Earth ever gone through global cooling? Explain.
10. Draw a Venn diagram comparing the natural greenhouse effect with the enhanced greenhouse effect. Note where human activities are involved.
11. What is the effect of carbon sources on Earth's atmosphere?
12. List three gases that are important in the enhanced greenhouse effect.

Understanding Key Ideas

13. What would happen to the seasons in British Columbia if the North Pole tilted away from the Sun in June and toward the Sun in December?
14. Describe how each of the following natural events could affect global climate.
    (a) a major volcanic eruption
    (b) a large meteor impact
    (b) a warming of ocean water
15. How does an El Niño event at the equator affect weather in northwest Canada?
16. (a) Briefly describe two effects of massive forest fires on the atmosphere.
    (b) Explain how massive forest fires could affect climates.
17. Study the graph shown below of methane in the atmosphere over time. The red line shows the average. The blue line shows seasonal variations.



Source: National Oceanic and Atmospheric Administration, Earth System Research Laboratory

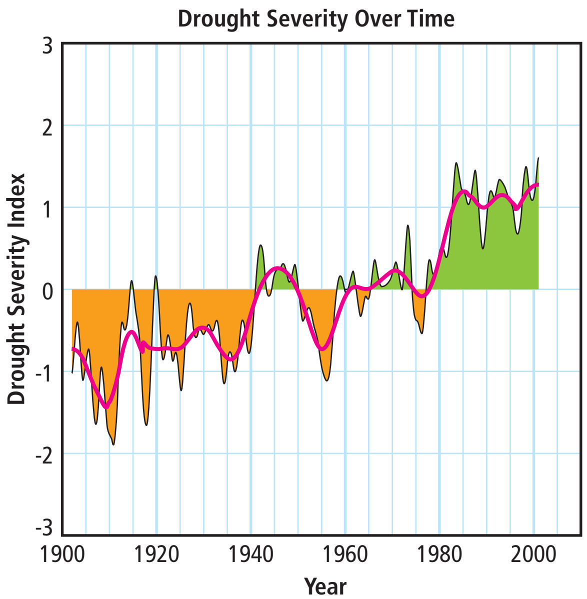
    (a) Describe the trend shown in the graph.
    (b) Is there a link between the levels of atmospheric methane and human activities? Explain.
    (c) Explain the connection between buying a hamburger at a fast-food restaurant and levels of methane in the atmosphere.

18. Without the natural greenhouse effect, Earth would be too cold for much of life as we know it to survive. Why, then, are scientists around the world so concerned about the enhanced greenhouse effect?

19. For each activity listed below, describe one strategy that could be used to reduce greenhouse gas emissions:
    (a) generating electric energy
    (b) transporting consumer goods
    (c) deforestation

Applying Your Understanding

20. Scientists with the United States' National Center for Atmospheric Research have calculated the extent of droughts over the last century. They determined the amount of surface land moisture for large regions and how surface land moisture has changed over time. Overall, they found that droughts became more severe from about 1970 to 2000. The graph below can be used to track drought severity (or wetness) in different regions. For most of Africa, southwestern Australia, and the prairies of North America, positive values on the graph indicate when these regions were drier than average. Negative values on the graph indicate when these same regions were wetter than average. The pink line shows how the amount of moisture has varied from decade to decade.



—Adapted from figures created by Dr. A. Dai of the National Center for Atmospheric Research, Boulder, Colorado, U.S.A.

(a) When did the most severe droughts occur in Africa?
(b) What can you conclude about changes in drought severity in most of Africa, southwestern Australia, and the prairies of North America?
(c) Can you conclude that more droughts occur every year? Explain your answer.

Pause and Reflect

Consider the following quotation: "You should never talk about a problem without talking about a solution." This statement was often made by Dr. Dixon Thompson, a founder of the environmental movement in western Canada and a professor of environmental science. How do you interpret his statement? Review the chapter, listing five or more possible problems. For each problem, suggest a solution.