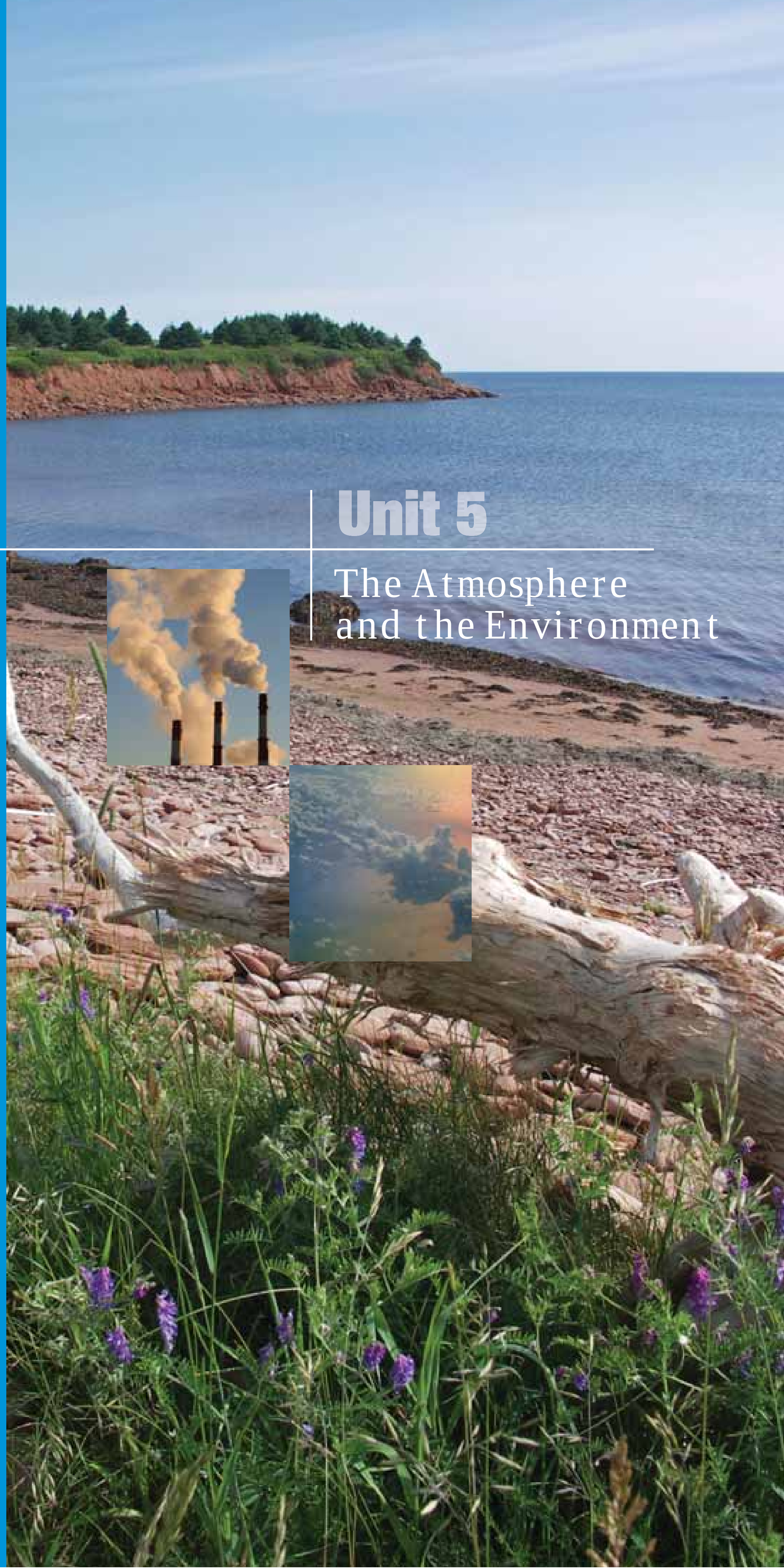
# TOWARD A SUSTAINABLE FUTURE

Challenges
Changes
Choices

## Unit 5

The Atmosphere and the Environment



# Chapter 17: The Atmosphere and Atmospheric Issues

## INTRODUCTION TO ATMOSPHERIC SCIENCE

**Figure 17.1:** The atmosphere is very thin relative to the size of Earth. All life depends on this fragile zone of gases.

The atmosphere is a dynamic collection of gases that constantly move and change. These gases form several layers around Earth that are loosely defined by composition and temperature. Working from the surface of the Earth outward, the layers are:

- the **troposphere**, which extends to an altitude of about 8 kilometres in polar regions and 17 kilometres at the equator;
- the **stratosphere**, which extends to about 50 kilometres from Earth's surface;
- the **mesosphere,** which extends to 80 or 90 kilometres from Earth's surface; and
- the **thermosphere** (also called the ionosphere), which gradually diminishes and forms a fuzzy border with outer space.

There is relatively little mixing of gases between layers.

### Did You Know?

At 30 kilometres above Earth's surface, the 'sky' above you is black.

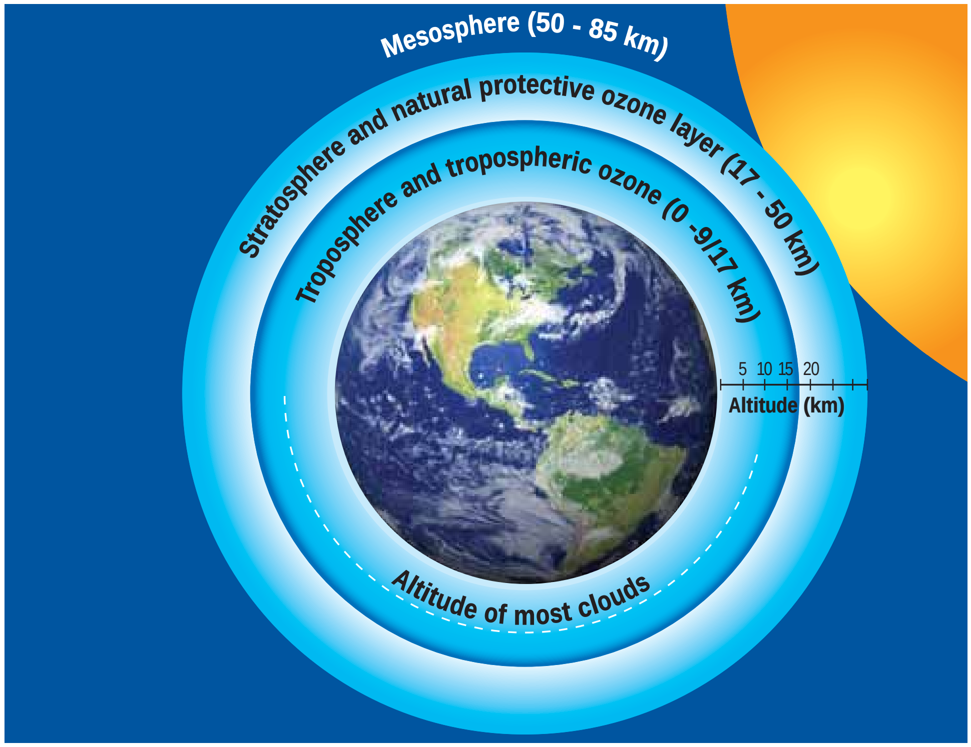



**Figure 17.2:** Layers of the atmosphere (not to scale).
*Photo courtesy Canada Space Agency/International Day for the Preservation of the Ozone Layer*

The atmosphere is a soup of chemicals. About seventy-eight per cent of the soup is nitrogen and twenty-one per cent is oxygen. The remaining one per cent is a mix of the other gases, which play an important role in the health of the ecosystem. We move through this gaseous soup every day, pushing aside or breathing in billions of its molecules. These molecules are not static—they are constantly interacting with each other in ways that can create new chemicals, and they are also interacting with the land, the sea, plants, and animals.

## Did You Know?

The stratosphere is the layer of the atmosphere where jet aircraft fly.

How the Atmosphere is Important to Life on Earth

1. It protects life forms from harmful solar radiation.
2. It traps heat close to the planet's surface.
3. It provides an energy circulation system (through wind and pressure systems).
4. It maintains the gases that support life on Earth.

## Atmospheric Interactions

Many natural processes affect, or are affected by, chemicals in the atmosphere. For example, plants take in carbon dioxide and give off oxygen. **Nutrient cycling** is the process by which nutrients move around in the ecosystem during growth or decay. For example, when plants decay, they release nutrients into the soil and some chemicals, such as methane and carbon dioxide, into the atmosphere. If the wind carries these gases away, another process comes into play: **physical transport**.

Like wind, water can also transport chemicals throughout the atmosphere. An example of this is when nitric oxide molecules (expelled as exhaust from a car's tailpipe) combine with water droplets in the atmosphere to form nitric acid, which becomes part of the water cycle. The acid can be carried in the atmosphere and may eventually fall as acid rain.

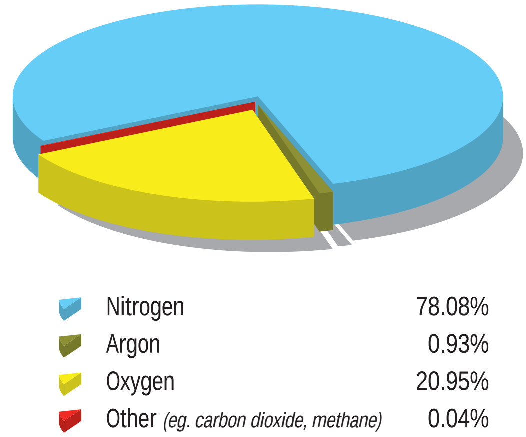



**Figure 17.3:** The proportion of gases in Earth's atmosphere. *Courtesy of Michael Pidwirny, University of British Columbia (Okanagan)*

In addition to the natural processes that are constantly stirring up the atmosphere, humans also impose change. We both alter the amount of naturally occurring compounds in the air and add compounds that do not naturally occur in the atmosphere. We impose change when we burn wood or oil to heat our homes, use propane for cooking, burn fossil fuels to generate electricity, and burn gasoline or diesel in motorized vehicles. The burning (combustion) of these fuels and other materials releases not only carbon dioxide into the atmosphere, but also many potentially harmful airborne pollutants that can spread around the world.

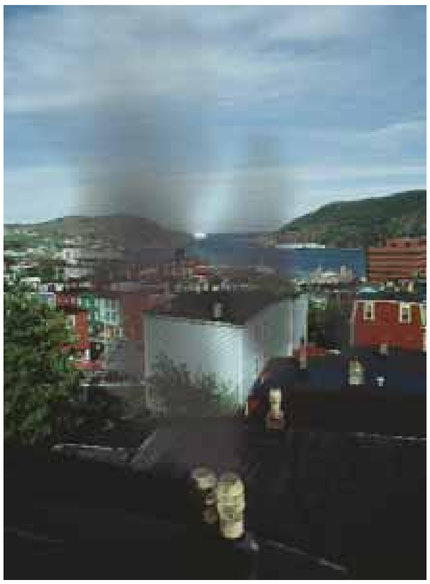


**Figure 17.4:** The smoke from wood-burning homes can introduce significant quantities of more than a hundred pollutants to indoor and outside air.

The uneven heating of Earth's surface and atmosphere constantly changes the balance of warm and cool air, which in turn creates wind. **Prevailing winds** are those that blow in regular patterns in the troposphere. For the most part, the prevailing winds in Newfoundland and Labrador blow from the west. Because many densely populated and industrialized areas are located in that direction, these prevailing winds also bring pollutants into the province.

### The Importance of Understanding the Atmosphere

What takes place in the atmosphere has an immense impact, one that is felt by all species on Earth. This unit is about the atmosphere—what it is, how we are causing it to change, and how those changes are affecting life as we know it. It also examines what people can do to take care of the air (which takes care of us). Severe weather, air quality, airborne pollutants, and climate change are closely intertwined issues—so they are all discussed throughout the unit. By understanding the connections between issues, we can identify opportunities to address them simultaneously with wisely chosen behaviours and policies.

## CHECK your Understanding

1. List the four layers of the atmosphere. In what layer are most living things found?
2. How does the atmosphere support life on Earth?
3. The atmosphere is dynamic. What are four things that are responsible for the dynamics of the atmosphere?

For Further Discussion and/or Research:

4. In table format, document visible evidence of the dynamic nature of the atmosphere.

## AIRBORNE POLLUTANTS AND AIR QUALITY

Atlantic Canada has been called the "tailpipe of North America" because prevailing winds carry pollutants into the region from industrial areas to the west. But the region also makes its own contributions to air pollution. Together, these pollutants cause significant health, environmental, and economic issues in Atlantic Canada, and they also have an impact after they fall to the ground.

This chapter introduces you to some air pollutants, and explains both how they affect the quality of the air we breathe and how they affect human health, ecological health, and the economy. It also highlights actions that individuals, industries, and governments can take to reduce the emission of air pollutants.

"Air quality" is measured locally according to the presence and quantity of five common pollutants that can potentially affect the health of Canadians: sulphur dioxide, nitrogen dioxide, carbon monoxide, suspended particulates (such as dust and pollen), and ground-level ozone. The quality of the air we breathe depends upon the level of each of these pollutants at a particular time.

**Figure 17.5:** Emissions from smoke stacks going out into the atmosphere.

### Categories of Air Pollutants

Some definitions of air pollution include only substances that make air smelly, discoloured, or hazardous to breathe. A broader definition of air pollution includes any chemical, physical (for example, dust), or biological substance that changes the natural characteristics of the atmosphere.

Every air pollutant has unique characteristics that define and determine both what it is and what kind of harm it can do. Although each air pollutant is unique, those that share similar characteristics can be grouped into general categories: criteria air contaminants, heavy metals, persistent organic pollutants, toxics and ozone-depleting substances and greenhouse gases. Here is what these terms mean:

1. **Criteria air contaminants** are the major cause of smog and acid rain. Criteria air contaminants come from similar (and sometimes identical) sources, including the burning of fossil fuels.

2. **Heavy metals** are metal elements such as mercury and lead. This group of pollutants can be transported by the air and contaminate water and food sources. Although our bodies need trace amounts of some metals, heavy metals can accumulate in body tissues and be poisonous even in low concentrations.

3. **Persistent organic pollutants** are organic pollutants that do not break down easily and remain in the environment for a long time. Persistent organic pollutants can travel great distances. Like heavy metals, they are of particular concern because they can enter the food supply, accumulate in body tissue, and have significant impacts on human health and the environment, even in low concentrations.

4. **Toxics** are pollutants that are poisonous to humans and the environment. Some criteria air contaminants, heavy metals, and persistent organic pollutants can also be listed in this category. "Toxic" can also refer to pollutants listed in the regulations of the *Canadian Environmental Protection Act*. If a pollutant is listed as a toxic in these regulations, the Government of Canada has the legal authority to prevent or control its use and/or release.

5. **Ozone-depleting substances** are compounds that contribute to the depletion of ozone in the stratosphere. Depletion of stratospheric ozone allows more ultraviolet light to reach the surface of Earth. Ultraviolet light causes skin cancer and cataracts, and damages some marine organisms, plants, and plastics.

6. **Greenhouse gases** trap heat in the atmosphere by absorbing long-wave infrared radiation.

**Did You Know?**

You breathe in approximately 15, 000 litres of air each day.

### Criteria Air Contaminants

Criteria air contaminants—and their interactions with one another and the atmosphere—are the main cause of smog and acid rain. Criteria air contaminants indicate overall air quality; higher levels mean lower air quality.

In Canada, "criteria air contaminants" include:

- nitrogen oxides ($NO_x$)
- sulphur oxides ($SO_x$)
- volatile organic compounds (VOCs)
- carbon monoxide (CO)
- ammonia ($NH_3$)

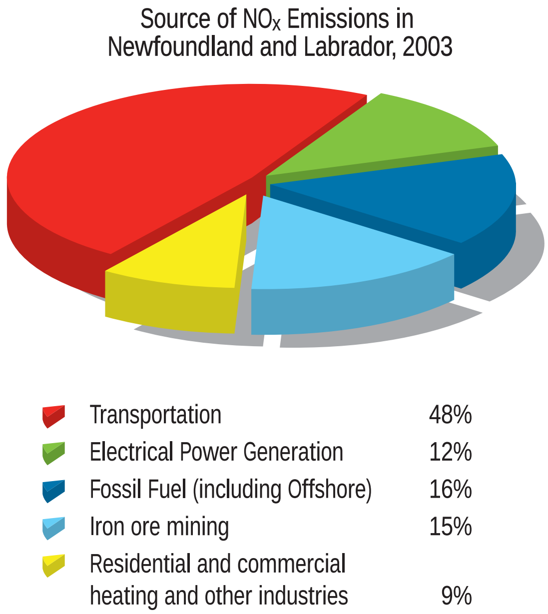



**Figure 17.6:** Sources of $NO_x$ emissions in Newfoundland and Labrador (2003).
*Courtesy of Environment Canada*

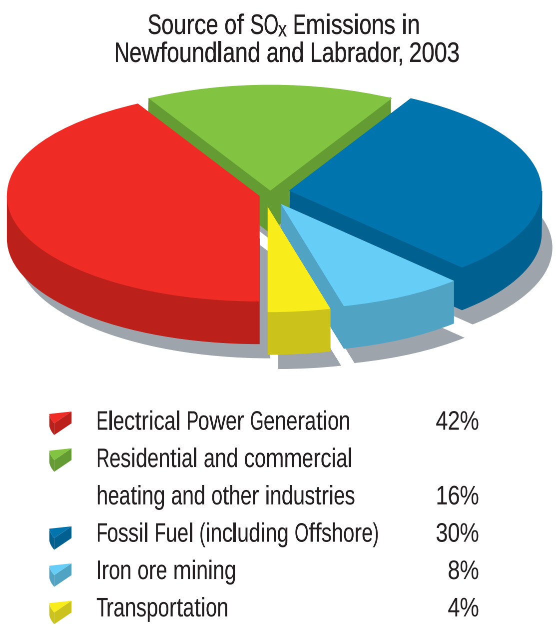



**Figure 17.7:** Sources of $SO_x$ in Newfoundland and Labrador (2003). *Courtesy of Environment Canada*

### Nitrogen Oxides

Nitrogen oxides ($NO_x$) contain one atom of nitrogen and different numbers of oxygen atoms. The gases that result include nitric oxide—also known as nitrogen monoxide (NO)—and nitrogen dioxide ($NO_2$).

$NO_x$ is released into the air when fossil fuels—natural gas, gasoline, diesel, oil, and coal—are burned. Transportation (use of vehicles fuelled by gas or diesel) is the largest source of $NO_x$ emissions in Newfoundland and Labrador.

### Sulphur Oxides

Sulphur oxides ($SO_x$) are a family of gases that contain a sulphur atom and different numbers of oxygen atoms. The presence of sulphur dioxide ($SO_2$) can cause major air-quality concerns. This gas is formed when the sulphur in raw materials such as coal, oil, and metal-containing ores combines with oxygen during the combustion and refining processes. Sulphur dioxide can react with oxygen in the atmosphere and form sulphur trioxide ($SO_3$). It can also dissolve in water vapour in the air to form sulphuric acid ($H_2SO_4$). These compounds can further interact with other gases and particles in the air and form sulphates (a source of secondary particulate matter) and other products that can be harmful to people and the environment.

Newfoundland and Labrador is a relatively high emitter of sulphur dioxide (per capita). Ontario, for example, emits about half the $SO_2$ per capita that this province does. Most sulphur dioxide emissions in Newfoundland and Labrador come from the generation of electricity and the production of fossil fuels. The largest single source of sulphur dioxide emissions in the province is the Holyrood Thermal Generating Station owned by Newfoundland and Labrador Hydro. The next largest sources are the refinery at Come By Chance and the Iron Ore Company of Canada operation in Labrador City.

### Volatile Organic Compounds

Volatile organic compounds (VOCs) are organic compounds that evaporate easily into the atmosphere. Thousands of compounds meet this definition, but when discussing pollutants, attention is focused on 50 to 150 of the most abundant compounds that have two to twelve carbon atoms. Some small-scale sources of VOCs include gasoline, oil paint, some glues, and nail polish.

In the presence of the sun's ultra-violet rays and warm temperatures, volatile organic compounds and nitrogen oxides react together to

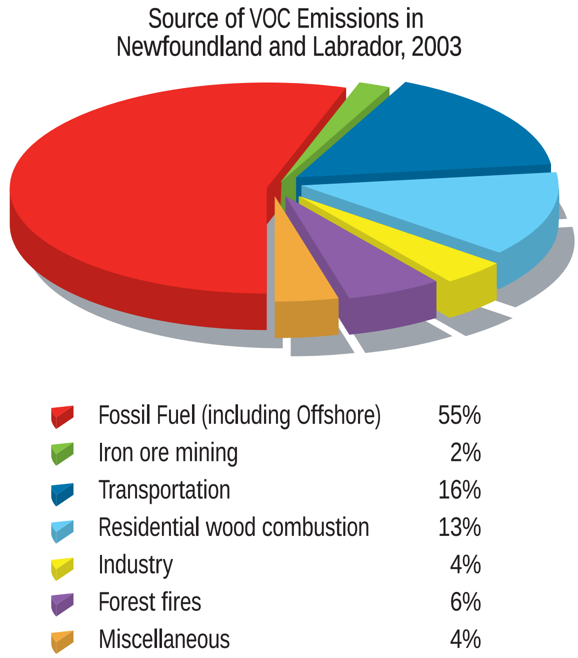



**Figure 17.8:** Sources of volatile organic compound emissions in Newfoundland and Labrador (2003). *Courtesy of Environment Canada*

produce ground-level ozone, a key component of smog. Because many VOCs occur in higher concentrations indoors than outdoors, they also cause indoor air-quality problems. VOCs have direct toxic effects on people, which range from cancer and damage to the nervous system to headaches and nausea.

The major sources of VOCs in Newfoundland and Labrador include fossil fuel production, vehicles, wood stoves, and forest fires (Figure 17.8).

### Ammonia

Atmospheric ammonia is increasingly being recognized as a pollutant of key environmental concern. Ammonia is a colorless alkaline gas which is released into the atmosphere by evaporation and emissions from industrial processes. Every living creature—including humans—releases wastes that include ammonia. In low concentrations, it has a penetrating pungent sharp odour.

In high concentrations, it causes a smothering sensation when inhaled. Ammonia contributes to several environmental problems, including direct toxic effects on vegetation. It reacts with other air-borne substances to produce substances such as ammonium sulfate and ammonium nitrate which then form secondary particulate matter, which have negative effects on human health, atmospheric visibility, and reduces the amount of incoming solar radiation. Ammonia emissions are increasing rapidly in many parts of the world and as a result, these environmental concerns are expected to grow in future.

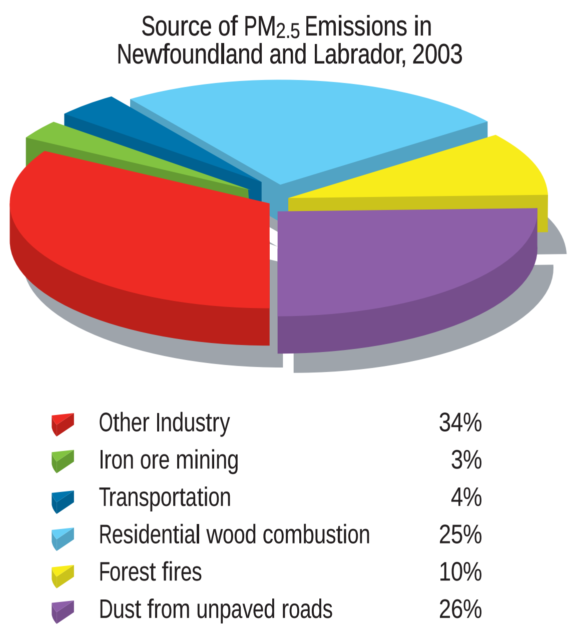



**Figure 17.9:** Sources of primary $PM_{2.5}$ emissions in Newfoundland and Labrador, 2003. *Courtesy of Environment Canada*

### Particulate Matter

Particulate matter (PM) refers to tiny solid or liquid particles that are small enough to remain suspended in the air. Particulate matter is a key component of smog.

Particulate matter has an upper size limit of about 100 micrometres (µm), which is equivalent to one-tenth of a millimetre. Particulates this size and smaller are referred to as Total Suspended Particulate (TSP). TSP is divided into categories based on the size of the particulate matter:

- $PM_{10}$ – coarse particles that have diameters of less than 10µm, which is roughly one-eighth the diameter of a human hair; and
- $PM_{2.5}$ – fine particles that have diameters of less than 2.5µm, which is smaller than a single particle of flour.

The major sources of primary $PM_{2.5}$ in Newfoundland and Labrador are road dust, wood stoves, industry, and forest fires.

## Ground-level Ozone

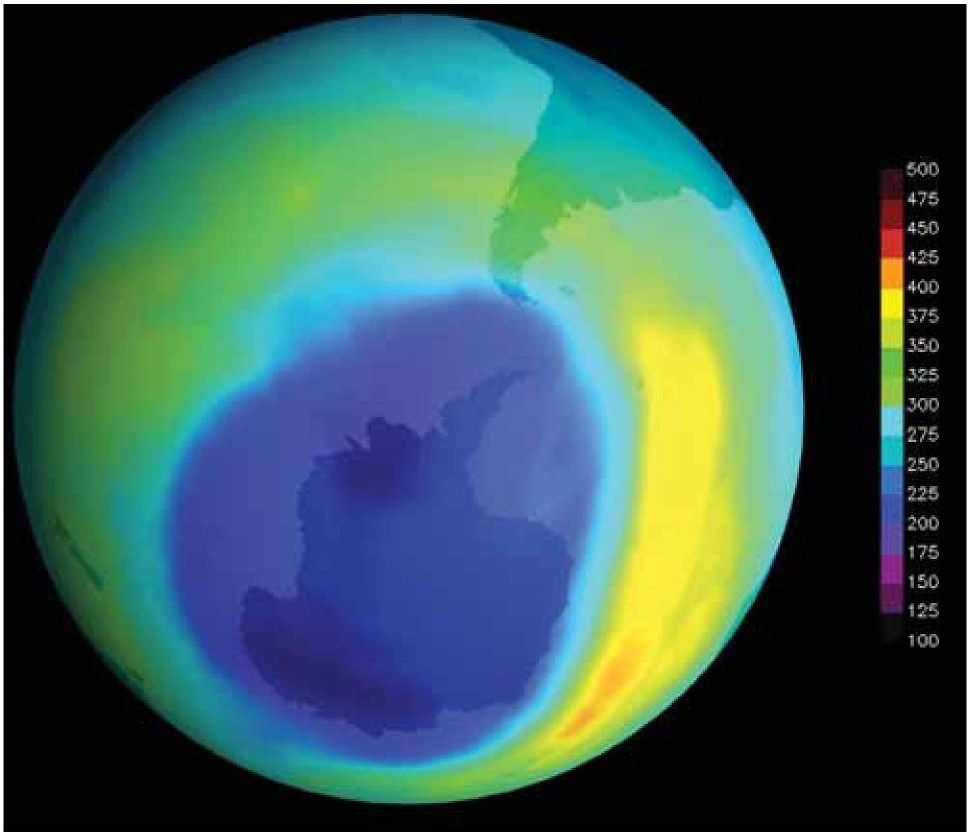



**Figure 17.10:** The hole in the ozone layer (blue oval).
*Photo courtesy Weatherstock/W. Faidley*

Three oxygen atoms bonded together form an ozone molecule ($O_3$). Oxygen molecules ($O_2$) are two atoms of oxygen bonded together. In the stratosphere, naturally occurring ozone ("good ozone") shields Earth from ultraviolet rays. But when ozone occurs in the troposphere (at ground-level) where we can inhale it, it is harmful to our health, the health of the environment, and to some economic activities.

Most ground-level ozone is a secondary pollutant—that is, it is produced when two primary pollutants (VOCs and $NO_x$) react chemically (in this case, in warm temperatures and sunlight). A small amount of ground-level ozone is released directly into the atmosphere by processes such as lightning and sparking in electrical equipment (in motors, for example).

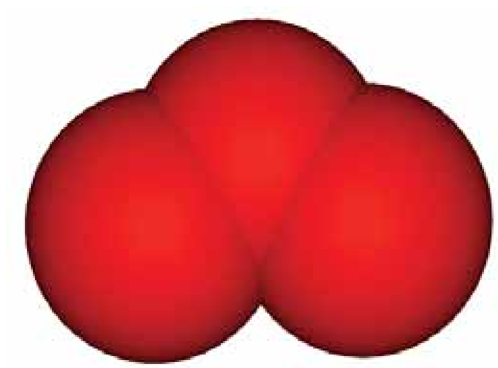


**Figure 17.11:** An ozone molecule.

VOC + $NO_x$ + sunlight = ground-level ozone
A chemical reaction that requires light is called a photochemical reaction.

**Figure 17.12:** Incinerator belching air pollution. *Photo courtesy Department of Environment and Conservation/G. Dawe*

### Long-range Transport of Air Pollutants

Air pollution is a global problem because it doesn't just blow away—there is always someone downwind of the emissions. In Newfoundland and Labrador, the air pollutants that cause smog, acid rain, and other air-quality issues can be emitted far away and transported here in weather systems. Prevailing winds bring pollution north eastward from southern Ontario, southern Quebec, and the eastern United States.

Air pollutants can travel long distances in a single day. During this travel, they may undergo chemical changes (such as forming ground-level ozone), or they may be deposited on the ground, on a building, or in water. These two events—chemical reactions and deposition—are the ways that pollutants leave the atmosphere.

**CHECK your Understanding**

1. Air quality is measured by the presence and quantity of five common pollutants. What are these pollutants?
2. What is the primary source of each of the common pollutants listed above? Focus on sources in or around your community.
3. In table format, list the categories of air pollutants. Next to each write one note on each and give an example of a local source to that pollutant.
4. What is the largest source of nitrogen oxides? How might nitrogen oxide levels be reduced without any significant changes in technology? What significant changes in technology would lead to significant changes in levels of nitrogen oxides?
5. List sources of volatile organic compounds in your home.
6. What is the primary source of ground-level ozone?

## Smog

The term "smog" originally referred to a mixture of smoke and fog in the air. Smog has now become a generic term for a noxious (harmful) mixture of gases and particles in the air. Smog can often be seen, especially over heavily populated areas, as a brownish-yellow or greyish-white haze in the air.

### Sources of Smog

Many pollutants are found in smog, but the two key ones most often associated with it are ground-level ozone and particulate matter. Other pollutants that are often present include sulphur dioxide, carbon monoxide, and hydrogen sulphide.

Smog comes from the same sources that produce ground-level ozone and particulate matter. Activities that emit smog-forming pollutants include (but are not limited to) running cars and trucks (gas or diesel), generating electricity, and burning wood.

The air quality in Newfoundland and Labrador varies according to geographic location and time of year. Although smog, or air pollution, happens at any time of the year, ground-level ozone concentrations are highest in the spring and summer, when the increased sunlight and warmer temperatures necessary for smog formation occur. In summer, the prevailing southwest winds carry smog's precursors and ozone from more heavily industrialized areas to southwestern Newfoundland. During the winter months, however, the prevailing winds are generally from the northwest, a less industrialized area. The production of ground-level ozone is also minimized in winter because of reduced sunlight and colder temperatures.

Winter smog in this province is more likely to be caused by local sources. More residents use their wood stoves during the late fall and winter months, for example. This wood combustion produces particulate matter, nitrogen oxides, volatile organic compounds, and other pollutants. During times of stagnant weather (when there are light or no winds), these pollutants can remain in an area for extended periods of time and negatively affect local air quality. This can be of particular concern in communities where the use of household woodstoves is widespread.

### The Effects of Smog

The pollutants in smog cause serious damage to human health and well-being and directly affect the health of natural ecosystems. Higher health-care costs, lower employee productivity because of increased sick days, and damage to forests, crops, structures, and man-made materials produce significant economic costs to society. To reduce these negative effects requires decreasing the amount of pollution released into the air.

**Figure 17.13:** The serious health effects of smog include respiratory problems. *Photo courtesy Environment Canada*

### Effects on Human Health

Scientific evidence suggests that there is no completely safe level of exposure to ground-level ozone or fine particulate matter, the principle components of smog. The effects of exposure to ground-level ozone include reduced lung function and inflammation and damage to cells that line the airspaces in the lungs. Recent studies suggest that exposure to high levels of ozone can cause irreversible lung damage. This can cause difficulty in breathing, or coughing and wheezing, and can aggravate the symptoms of cardiac and respiratory conditions such as asthma.

Government of Canada studies indicate that approximately 5,900 premature deaths a year occur in Canada as a result of exposure to air pollution. In addition, thousands more require medical attention. The degree of harm corresponds to the type and amount of air pollutants in the smog mix, the length of time a person is exposed to the chemicals, and personal characteristics such as age, activity level, and health status. Exposure to smog puts the health of the elderly and those with pre-existing respiratory or cardiac conditions at further risk. Children and people who exercise outdoors take more breaths over an equivalent amount of time than an average adult, which increases their risk of suffering from poor air quality.

**Figure 17.14:** Researcher checking for the effects of sulphur dioxide on potato plants.

### Effects on the Environment

Many studies of vegetation show that high concentrations of ground-level ozone reduce photosynthesis, and cause leaf damage and stunted growth. Ground-level ozone can harm flowers and shrubs and may be contributing to forest decline in some parts of Canada. The ground-level ozone and particulate matter that are harmful to human respiratory systems can cause similar health effects in domestic and wild animals. Animals can also be affected when poor air quality causes changes in vegetation that upset their normal food supply and habitat. The direct impacts of smog may vary by species, but it is important to remember that its effect on one species can disrupt the complex relationships among members of the food web, and significantly affect an entire ecosystem.

### The Economic Costs of Smog

A recent study conducted for the Ontario Medical Association on the health-related costs of air pollution estimates that poor air quality costs billions of dollars a year. The costs include increased emergency room visits, premature deaths, and the expense of treating increased pain and suffering from illness. The study also found links between increased levels of air pollution and the number of days missed at work or school.

In addition to these costs, smog can also adversely affect revenues from natural resources and agricultural crops. The impacts of ground-level ozone on agriculture are well-documented—they cost Canadian farmers millions of dollars in lost production and increased fertilizer costs each year. The annual cost of the damage caused by ozone on forests is not as well researched, but is likely also to be in the millions of dollars.

Smog can damage buildings and other human-made structures and materials, which is also a cost. Specifically, ground-level ozone can attack synthetic materials (such as plastic and vinyl), cause cracks in rubber, accelerate the fading of dyes, speed deterioration of some paints and coatings, and damage textiles such as cotton, acetate, nylon, and polyester.

CHECK your Understanding

1. Define the term "smog".
2. List the effects of smog on human health.

For Further Discussion and/or Research

3. "There is no smog in Newfoundland and Labrador". Write a one page argument that supports or does not support this statement.

## Heavy Metals and Persistent Organic Pollutants

There are many types of heavy metals and persistent organic pollutants. This chapter discusses mercury, a heavy metal, and dioxins and furans, two groups of persistent organic pollutants.

Heavy metals and persistent organic pollutants have two shared characteristics: they can be carried by air currents over great distances, and they are not easily destroyed. As a result, they can build up in the tissues of living organisms through the processes of bioaccumulation and biomagnification.

### The Grasshopper Effect

Heavy metals and persistent organic pollutants spread from southern to northern regions in a distinctive form of long-range transport called **the grasshopper effect**.

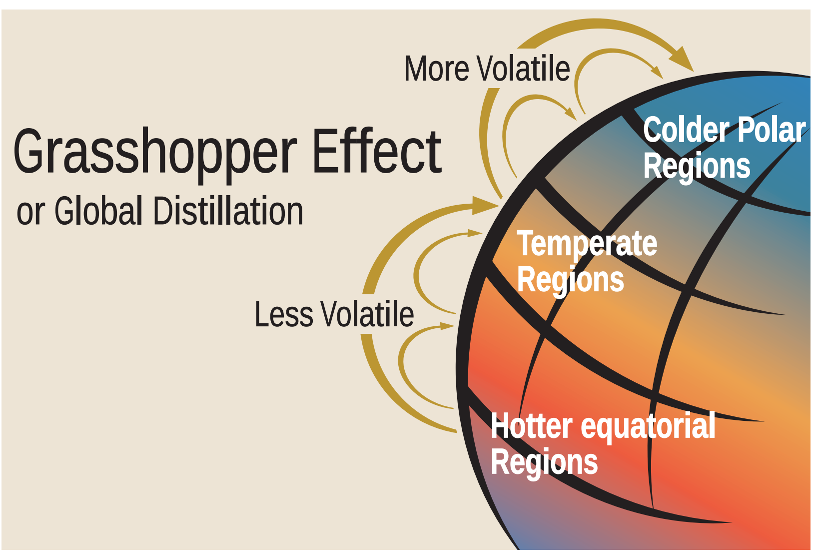



**Figure 17.15:** An illustration of how heavy metals and persistent organic pollutants travel (the grasshopper effect). *Image courtesy Environment Canada*

This is how the grasshopper effect works: when heavy metal and persistent organic pollutants are released as gases in areas with a warm climate, prevailing winds can carry them farther north into areas with a cooler climate. Colder temperatures will cause them to condense out of the air there and be deposited on the ground or in water. In the warmer summer season, these pollutants can be reheated into a gaseous state and returned to the atmosphere. Some will then be carried further north into areas with an even cooler climate, and re-deposited. In this way, the pollutants make hops from warmer to cooler climates.

Eventually these pollutants reach areas where temperatures are unlikely to be high enough to transform them into a gas, and so they remain and accumulate in the soil and water. This is why heavy metal and persistent organic pollutants can be found in areas with cool climates, such as Labrador and the polar regions, far from where they were produced.

## Bioaccumulation and Biomagnification

The most serious environmental concerns related to heavy metals and persistent organic pollutants are the processes of bioaccumulation and biomagnification.

Organisms that inhale pollutants, or consume food that is contaminated with pollutants, will store some of them in their bodies, usually in fatty tissue. This build-up is known as **bioaccumulation**.

**Biomagnification** is the term for the increased concentrations of these substances in organisms that are higher up in the food chain (the substances travel, for example, from micro-organisms to fish, and then to fish-eaters such as otters, loons, and humans). When predators consume the contaminated fatty tissues of animals lower on the food chain, they ingest all the accumulated chemicals. If everything they eat is contaminated, they end up with even higher concentrations of these substances. Even when these consumers use up their energy stores (fat), the pollutants remain in their tissue. Every time a consumer eats contaminated food, more of the pollutant is added to its tissues, which gradually increases the concentration.

### The Bioaccumulation of Methyl Mercury

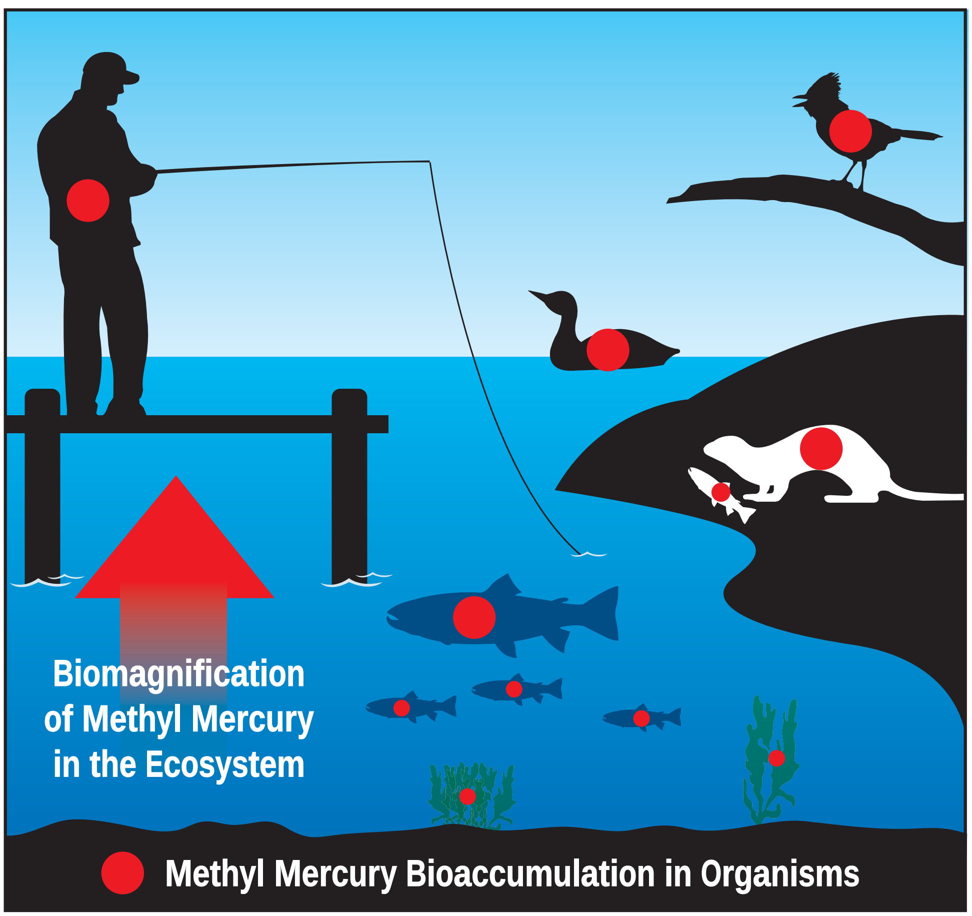



**Figure 17.16:** The size of the red dot on each species indicates how much methyl mercury is bioaccumlating. *Image courtesy Environment Canada/Mercury and the Environment*

## The Heavy Metal Mercury

**Figure 17.17:** Mercury in liquid form.

Mercury exists in three forms:

1. Elemental mercury – a silvery, shiny liquid at room temperature that gives off a colourless and odourless vapour.
2. Inorganic mercury compounds –formed when elemental mercury combines with other elements including sulphur, chlorine, or oxygen.
3. Organic mercury compounds – formed when elemental mercury combines with organic substances (an example is methyl mercury).

## Sources of Mercury

The element mercury exists naturally all around the world in extremely tiny amounts in rocks, soil, air, and water. Natural sources of mercury in the environment include volcanic eruptions, the natural weathering of soil and rock, and underwater vents in the ocean.

Human activity has increased the amount of mercury found in the environment. The level is now two to four times greater than in the period before industrialization. This increase is due largely to industrial processes such as smelting (the fusing or melting of ores), garbage incineration, medical and hazardous waste disposal, and power generation (especially from coal- and oil-fired stations).

**Figure 17.18:** Tuna can contain dangerous levels of heavy metals such as mercury.

In Newfoundland and Labrador, mercury is emitted into the air mainly from burning waste at municipal incinerators and from the Holyrood generating plant. On a national scale, Newfoundland and Labrador facilities emit relatively small amounts of mercury. This is partly because most of our electricity is produced by hydro-electric (rather than coal-or oil-fired) plants. Hydro-electric power developments can also cause some mercury contamination. This occurs because mercury is leached from flooded soil at new hydroelectric dam sites and can end up in the tissues of the organisms in the local food webs.

Mercury is used in a variety of consumer products, including thermometers, barometers, batteries, thermostats, incandescent and fluorescent light bulbs, sump pumps, and the switches in furnaces and other appliances. When these products are disposed of in landfill sites or burned in a waste incinerator, the mercury in them enters the natural environment.

### Dioxins and Furans

Two major groups of persistent organic pollutants are dioxins and furans. Both have chlorine atoms as part of their chemical composition. More than 200 different dioxins and furans are produced globally. These pollutants move around the world through long-range transport.

### Sources of Dioxins and Furans

Natural sources of dioxins and furans include forest fires and volcanic eruptions. These pollutants are also added to the atmosphere through human activities—they are unintentional by-products created when objects that contain chlorine are burned.

In Canada and around the world, the biggest source of dioxins and furans is the combustion of municipal and medical waste. Burning some seemingly inoffensive household materials (such as plastics and glossy magazines) can produce extremely toxic compounds. Thus, even backyard burn barrels are a source of dioxins and furans.

**Figure 17.19:** Burning household material in a backyard burn barrel is a common source of dioxins and furans in Newfoundland and Labrador.

Dioxins and furans are also introduced into the environment from these major sources:

- iron and steel production;
- chemical and pesticide manufacturing;
- pulp and paper bleaching;
- power generation by burning fossil fuels;
- heating buildings by burning fossil fuels;
- burning wood (especially chemically treated wood);
- motor vehicle exhaust; and
- tobacco smoke.

### The Effects of Dioxins and Furans

Dioxins and furans can affect human health. The severity of the impact is influenced by the type of pollutant, as well as the amount and the frequency of a person's exposure to it. Inhaling dioxins and furans is considered "minor exposure" and has minimal effects.

More than ninety per cent of our exposure to dioxins and furans comes from the food we eat. Dairy products, fish, and eggs are the primary sources of exposure to these pollutants. Ingesting contaminated soil on the food we eat and absorbing dioxins and furans through the skin are two additional ways these pollutants can enter the human body.

Scientists have studied the effects of dioxins and furans on laboratory animals and on people exposed to dioxins through industrial accidents, contaminated food, and through exposure in their workplace. The studies show that dioxins and furans have the potential to produce a range of health effects which include:

- skin disorders, such as chloracne;
- liver problems;
- impairment of the immune system, the endocrine system and reproductive functions;
- effects on the developing nervous system; and
- certain types of cancers.

**CHECK your Understanding**

1. Heavy metals are found in the tissues of animals that live in Canada's far arctic regions. How is this possible?
2. Your friend, who is an avid trout fisherperson, tells you that you shouldn't worry about eating trout with low levels of mercury in their tissue. Are they correct in what they say?
3. What are the primary sources of dioxins and furans?

**For Further Discussion and/or Research**

4. It is recommended that users of woodstoves should not burn driftwood that is collected from ocean beaches. Why might this be?

## Actions to Improve Air Quality

The following actions can help reduce the emission of air pollutants:

- using less fuel—through conservation, improved energy efficiency, and reliance on renewable energy sources;
- burning cleaner fuels—natural gas instead of coal, for example;
- cleaning fossil fuels (removing impurities and chemicals) before they are burned; and
- using technologies that capture some emissions before they are released into the atmosphere ("end-of-pipe technologies").

In today's world, fuel combustion is part of everyday life. By taking a closer look at our actions, however, we can reduce their effects on the environment.

Examining the combustion processes and determining whether fuels contain pollutants or create them during combustion is a good place to start. This knowledge provides clues about how to reduce emissions of that pollutant. For example, fuel oil contains sulphur, which is released into the air during combustion. Reducing the amount of sulphur in the fuel oil through better oil refining or by "scrubbing" the sulphur dioxide out of the exhaust gases after the fuel is burned decreases the amount of pollutants released into the atmosphere. Similarly, we know that volatile organic compounds are added to the atmosphere through evaporation or incomplete combustion (when a fire's temperature is too low or it does not receive enough oxygen). To minimize VOC emissions, we need to handle gasoline and other solvents properly (to minimize evaporation), and create the right conditions during combustion so that the fuel burns completely.

**Did You Know?**

Approximately one quarter of Canada's greenhouse gas emissions are generated by means of transportation; all of which involve fossil fuel combustion.

Ultimately, the best way to improve air quality is to avoid creating air pollutants in the first place. By reducing the use of fossil fuels, for example, we will not only improve air quality, but will also address some of the underlying causes of climate change.

### Individual Action – Personal Choices

There are a number of personal choices that we can make to reduce emissions of air pollutants—both in our daily actions, and when we make bigger, longer-term decisions such as the purchase of a home or car.

We can use less fossil fuel and help protect air quality every day if we follow these practices:

1. Reduce how far and how often we drive.
2. Make informed choices about home and water heating—such as how we operate our wood stove or furnace, and how much hot water we use.
3. Use energy more efficiently.

**Did You Know?**

Fine air-borne particles can move hundreds or thousands of kilometres to sicken or even kill people.

Being a wise consumer can also help air quality. When you shop, think about all the energy required to make, package, store, ship, and dispose of your purchases. Wise consumers:

1. Avoid excessive packaging (which will have to be thrown out and eventually incinerated).
2. Choose and encourage eco-wise packaging (which can be recycled).
3. Buy items that can be used more than once.
4. Recycle.
5. Buy locally (which reduces transportation costs).

### Reducing Air Pollution: Motor Vehicle Use

The best way to avoid creating transportation-related emissions is to drive less. To decrease the amount they drive, people can choose to live close to common destinations, and combine errands into one trip. If these solutions aren't viable, you can still minimize emissions (and save on fuel) by adopting the following practices:

- Maintain your vehicle properly.
- Make sure its tires are inflated correctly.
- Do not let it idle for more than ten seconds when you are not in traffic.
- Do not exceed the speed limit.
- When purchasing a vehicle be aware of fuel consumption and avoid "gas guzzlers".

### Reducing Air Pollution: Residential Wood Combustion

In some areas, burning wood is an important source of home heating, yet wood smoke also contributes to air pollution (both indoor and outdoor). Wood smoke is a complex mixture of pollutants. It includes particulate matter, volatile organic compounds, carbon monoxide, nitrogen oxides, and other hazardous air pollutants (including some persistent organic pollutants).

During periods of calm, cool weather, pollutants from wood smoke (especially the fine particulate matter and VOCs) can become concentrated at ground level, resulting in poor local air quality. In effect, poor wood-burning practices at one home can pose health risks for an entire neighbourhood.

Reducing emissions is a matter of using a clean-burning, efficient wood stove in a way that achieves optimum heat with minimal air emissions. To reduce air pollution from wood stoves you can:

1. Burn only dry, seasoned wood. Get firewood in late winter or early spring and store it where it is sheltered from the weather for at least six months before burning it.
2. Adjust the air supply. Starting a fire, or adding new wood, requires more air during the first ten to fifteen minutes. After the wood is charred, less air is required to keep it burning. Loosely packed pieces burn faster because air can reach all the pieces. As a result the wood burns cleaner and more efficiently.
3. Do not reduce the air supply to dampen or hold the fire overnight. This creates excessive emissions and promotes the formation of creosote, a common cause of chimney fires.

**Did You Know?**

During winter, combusting wood in stoves can produce up to seven times as much particle pollution as combusting gasoline in cars.

In addition, when purchasing a new wood stove, choose one that meets the standards set by the Canadian Standards Association (CSA) or the U.S. Environmental Protection Agency (EPA). Both agencies have set mandatory emission limits, resulting in the development of improved combustion technologies for wood stoves. As of 2008, only those wood stoves, fireplace inserts, and factory-built fireplaces that meet the CSA or EPA standards will be allowed to be sold or manufactured in Newfoundland and Labrador.

### Reducing Air Pollution: Electricity Use

In Newfoundland and Labrador, reducing the amount of electricity we use provides the best opportunity for large-scale reduction of air pollutants, including those that cause smog, acid rain, and climate change. Even though the island of Newfoundland generates about three-quarters of its electricity using hydro-electric power (which is virtually emission-free), the other one-quarter must be supplied by the oil-fired generating plant at Holyrood. Any reduction in demand for electricity helps to reduce the amount that must be produced at Holyrood.

**Figure 17.20:** The oil-fired electricity generating station at Holyrood. *Photo courtesy Newfoundland and Labrador Hydro*

In addition, constant improvements in technology provide more and more convenient ways to be energy-efficient at home and at work. By developing energy-wise habits and choosing energy-wise electronics and appliances, you can reduce energy use and save money.

### Reducing Air Pollution: Heavy Metals and Persistent Organic Pollutants

To protect yourself and the environment from mercury exposure, you must learn about the issue, reduce your use of mercury-containing products, and properly dispose of these products when you do use them. Ask your municipality about where to bring waste items that contain mercury. Reducing electricity use is also important. It will help both to reduce the amount of mercury emitted into the atmosphere and address other air-quality and climate-change issues.

To reduce your exposure to the heavy metals and persistent organic pollutants that have bioaccumulated in food sources, follow these precautions:

1. Before you eat meat or fish, trim the visible fat, which is where these pollutants accumulate, and drain excess fat.
2. Read and follow *Canada's Food Guide to Healthy Eating*, which recommends consuming vegetables, fruit, and grains, which have fewer dioxins and furans than meat, milk products, and fish.
3. Follow government advisories about the amount of certain types of fish to eat.

Reducing the amount of dioxins and furans released into the environment involves taking a few simple actions at home:

1. Do not burn garbage, especially construction materials that might contain wood preservatives or plastic.
2. Adopt wood-burning techniques that release fewer dioxins.
3. Reduce, reuse, recycle, and recover.
4. Do not smoke and keep your family away from second-hand smoke.

### Industry Emission-control Technologies and Techniques

Several technologies and techniques are available to industry to reduce their air polluting emissions. These emission-control technologies continue to improve, but in many cases they still do not completely eliminate the release of all air pollutants—and they do not reduce greenhouse gas emissions. In fact, most emission-control technologies slightly increase emissions of greenhouse gases.

### Pre-combustion and Combustion Techniques for Fossil Fuels

One strategy to reduce the emission of pollutants is to use a fossil fuel that is as clean as possible. It is possible, for example, to buy coal that is naturally low in sulphur. Alternatively, coal can be "cleaned" or "washed" before combustion to remove some of its sulphur content. Improved oil-refining techniques can similarly reduce the amount of sulphur in fuel oil.

In addition, some mitigation of the nitrogen oxides in fossil fuels is possible depending on how the oxides were formed. Thermal $NO_x$ can be reduced by controlling combustion conditions (such as the peak temperature in the area of combustion), the amount of time gases spend at peak temperature, and the mixture of fuel and air in the combustion chamber.

### End-of-Pipe Technologies

Traditionally, air pollution issues have been addressed individually by using technologies designed to control the emission of a particular pollutant. These "end-of-pipe" technologies capture or destroy the targeted pollutant just before it is released into the atmosphere. Examples of this technique are catalytic converters on the tailpipes of vehicles, and scrubbers installed at coal- or oil-fired power plants.

Catalytic converters, located between the engine and tailpipe, reduce the amount of carbon monoxide, VOCs and $NO_x$ released into the atmosphere. The converter rips apart the nitrogen and oxygen molecules in nitrogen oxides, releasing nitrogen and oxygen gases (which exist naturally in the atmosphere and are harmless). It also oxidizes residual VOCs and carbon monoxide, forming carbon dioxide. While a catalytic converter is critically important for reducing pollutants that cause smog and acid rain, it does not eliminate them completely. Also, catalytic converters increase emissions of carbon dioxide, a key greenhouse gas that contributes to climate change.

**Figure 17.21:** Ambient air is sampled at three to five metres above ground level and sent to an ozone analyzer. *Photo courtesy Environment Canada*

In power plants that burn fossil fuels, scrubbers (or flue-gas desulphurization units) can remove particles and acid gases such as sulphur dioxide and hydrochloric acid from the exhaust stream. They inject a basic compound into the exhaust that reacts with the acid gases to form neutral compounds, which are then separated from the remaining exhaust. The most efficient scrubbers can remove more than ninety per cent of sulphur dioxide content from flue gas.

Some power plants also use baghouses and electrostatic precipitators to reduce the amount of particulate matter they release. A baghouse is a fabric filter collection system—essentially it's a "house full of bags". Dusty gas flows through the fabric, leaving the dust on the inside of the bag. The particles then either fall into a collection bin (called a "hopper") or are cleaned out of the bags.

Since the 1930s, coal-fired power plants have been using electrostatic precipitators to catch "fly ash"—the fine particles suspended in combustion gases after coal is burned. Electrostatic precipitators operate on the principle that opposite electrical charges attract. Combustion gases are forced through a highly charged electrical field, which gives the particulate matter a negative or positive charge. The charged particulate matter is drawn to metal plates that have the opposite charges. The particles are then knocked or washed off the plates and collected in a hopper.

End-of-pipe pollution control technologies cannot completely eliminate pollutants. In fact, some options actually increase emissions of one type of pollutant while decreasing their target pollutant. For example, though sulphur scrubbers reduce sulphur dioxide emissions, they slightly increase carbon dioxide emissions. Similarly, wood- or biomass-burning can reduce carbon dioxide emissions but increase emissions of other air pollutants. In addition to these drawbacks, sulphur scrubbers, electrostatic precipitators, and bag houses are expensive to install, and do not reduce greenhouse gases or help conserve fossil fuel.

With the exception of hydro-power generation, all electricity production creates some air pollution. The primary pollution-reducing action individuals can take to reduce emissions is to lower their overall energy consumption. On a larger scale, the best action for reducing emissions depends on local circumstances and available technology. If a big reduction in emissions can be achieved at an existing coal- or oil-fired plant for a relatively low implementation cost, then end-of-pipe technologies are a viable choice. In other situations, switching to renewable energy sources—hydro, wind, or nuclear—should be considered.

## CHECK your Understanding

1. What actions can you and your family take to improve air quality in your own community?
2. What can you do with your firewood to maximize the amount of energy it releases and to reduce emissions?
3. Heavy metals and persistent organic pollutants accumulate in food. What can you do to reduce your exposure to heavy metals and organic pollutants in food?
4. Explain how electrostatic precipitators and filters are used to reduce air pollutants from industrial and power plants.

For Further Discussion and/or Research

5. If your family uses a wood stove find out if it is CSA/EPA approved.
6. How are CSA/EPA approved woodstoves different from traditional wood stoves in terms of emissions and efficiency?
7. Through research, find out how baffles and catalysis are used to reduce emission from CSA/EPA approved residential woodstoves.
8. Find out how your municipality gets rid of materials that contain mercury.

### Did You Know?

More than half of the acid deposition in eastern Canada originates from emissions in the United States.

## ACID PRECIPITATION

Pure water is neutral—neither base (alkaline) nor acid, its pH level is 7. Clean rain is naturally slightly acidic (pH of 5.6): it contains acids formed when carbon dioxide reacts with moisture in the atmosphere. When the pH level of rain falls below 5.6, it is considered acid rain.

Figure 17.22 shows the pH values of some common substances. Note that only a small change in the acidity level of rain makes it acid rain.

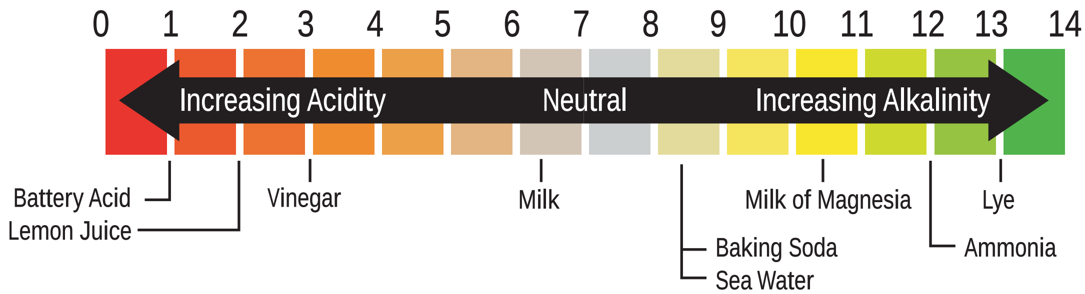



**Figure 17.22:** The pH levels of some common substances. *Courtesy of Environment Canada*

Acid rain is created when sulphur dioxide gas or nitrogen oxide gas undergo a chemical transformation in the atmosphere—the gas combines with airborne water droplets to form either sulphuric acid or nitric acid. These acids can then be deposited back on the ground and on surface water as acid rain, acid snow, or acid fog (which are collectively referred to as acid precipitation or acid deposition).

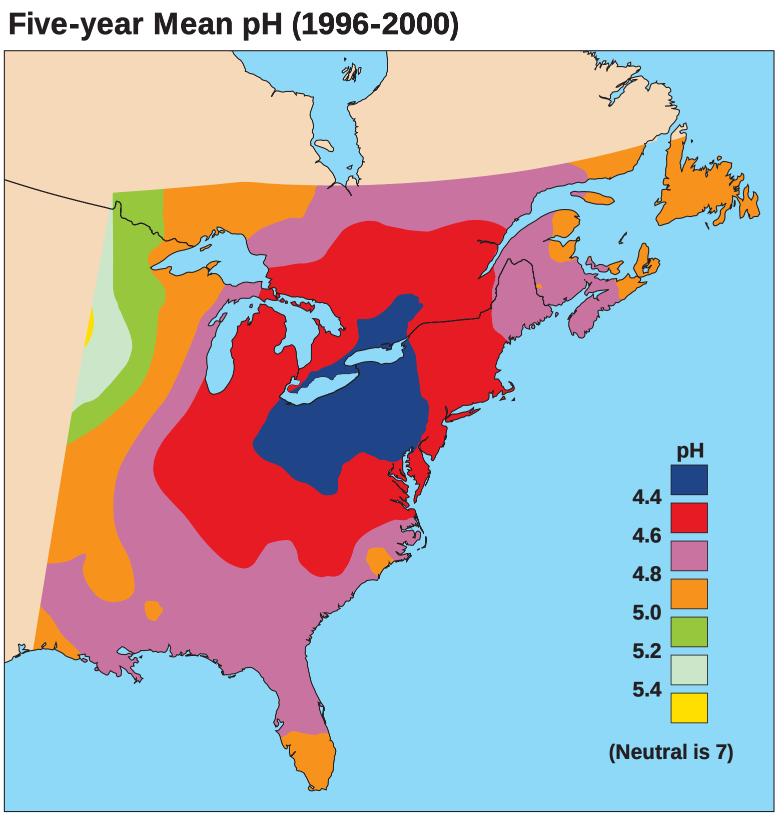



**Figure 17.23:** The mean pH levels of rain that fell in eastern North America from 1996 to 2000. White areas were not included in the study. *Courtesy of Environment Canada*

### Sources of Acid Precipitation

The two key pollutants that form acid precipitation (sulphur dioxide gas and nitrogen oxides) arrive in Newfoundland and Labrador by long-range transport or are produced in the province. Most of the $SO_2$ emitted here—and in the Atlantic region as a whole—comes either from fossil-fuel electricity generation or petroleum refining. Nitrogen oxides are mainly a product of the transportation and electric-power generation sectors.

### The Effects of Acid Precipitation

Like smog, acid precipitation can significantly harm ecosystems, which, in turn, will inevitably affect economic activities. As much as three-quarters of eastern Canada receives levels of acid via precipitation that cause damage to ecosystems and infrastructure (such as building exteriors)—and we are just beginning to learn how acid precipitation can affect human health.

#### Effects on Human Health

Recent health studies have found small but significant relationships between liquid acidic particles suspended in the air (which are called "aerosols"), and human health. People with asthma or allergies may be particularly sensitive to short-term exposure to these acid aerosols, or to long-term exposure to sulphuric acid and ozone.

### Effects on the Environment

Acid precipitation has a negative impact on lakes, rivers, soils, plants (including trees), wildlife, and aquatic species. Over time, its effects on each of these natural components diminish biodiversity.

How severely an ecosystem is affected by acid precipitation depends on the buffering capacity of the soil, which is determined by the underlying bedrock. Bedrock that consists mainly of limestone can largely neutralize the effects of acid precipitation. Unfortunately, more than half of Canada and most of Newfoundland and Labrador have a hard rock base that does not neutralize acid precipitation.

The soil in our province is naturally acidic. Because it lies over hard bedrock, acid precipitation simply adds to its acidity. Some areas of western Newfoundland are an exception to this situation because they have a bedrock layer that is predominately limestone and dolomite.

In addition to increasing the acidity of soil or water in an ecosystem, acid precipitation can cause side effects when it reacts with other pollutants such as heavy metals. The rate of leaching increases as the pH of soil or water is lowered by acid precipitation. This can further elevate concentrations of heavy metals in the soil.

How does acidity affect aquatic ecosystems? As water gradually approaches a pH of 6, small organisms such as insects and plankton begin to disappear. As it becomes more acidic, and approaches a pH of 5, major changes in the plankton population occur, other less desirable species increase, and some fish populations diminish. When the pH level goes below 5, the aquatic ecosystem collapses and all fish disappear.

The collapse of an aquatic ecosystem affects the terrestrial ecosystems that depend on it. For example, an animal that feeds on fish would face the loss of its food source and changes in habitat. In essence, acid rain alters all food webs. Furthermore, it removes essential nutrients such as calcium (which is a base) from soils, and harms the growth and overall health of trees and other plants.

### Effects on Economic Activities

Salmon and other members of the *salmonidae* fish family (including trout) are particularly vulnerable to acidic waters. When increased acidity causes more metals to be leached into the salmon's habitat, these substances accumulate in the fish, especially in their gills. This puts stress on their health, and reduces their reproductive ability. Their eggs are also vulnerable to acidity—embryos may die before they hatch—and fry may not reach maturity. Not only is the loss of viable salmon habitat in freshwater rivers an environmental problem, it also affects both tourism activities and recreational fishing by residents.

The natural acidity of the soil in most of Newfoundland and Labrador poses challenges to the growth of both forests and agricultural crops. The effects of acid precipitation in the forest can be seen as non-uniform growth at the treetop—an effect that reduces the value of the wood as timber. Current levels of acid precipitation results in more than half a million cubic metres of wood in Atlantic Canada being lost each year. Translated to economic terms, the impact is hundreds of millions of dollars annually. In the agricultural sector, acid rain adds operational costs. To neutralize acidic soil, farmers and gardeners must buy and apply lime to their fields and gardens.

Human-made structures are also affected by acid precipitation. The corrosive nature of the acids particularly affects older stone buildings and monuments. Because the stone is basic, acid precipitation can corrode its outer surface. Electrical towers are also affected—acid precipitation can reduce the life expectancy of a tower by half, which greatly increases the frequency of repairs and the maintenance cost per tower.

**Figure 17.24:** A wet-only precipitation collector collects only rain or snow. The samples are taken to a laboratory for chemical analysis.
*Photo courtesy Environment Canada*

## Monitoring Acid Precipitation

From 1983 to 2004, the Newfoundland Environment Precipitation Monitoring Network (NEPMoN) monitored acid precipitation across this province. It collected different forms of precipitation (rain, snow, and hail) and measured them for excess sulphates and nitrates. The network discovered that, generally, the largest acid depositions occurred on the southwest corner of Newfoundland, and diminished to the north and east.

Currently, the Canadian Air and Precipitation Monitoring Network (CAPMoN) maintains two sites in the province, one at Bay d'Espoir on the Island and the other at Goose Bay in Labrador. The goal of CAPMoN is to monitor non-urban sites in order to determine acid rain and smog trends and patterns. These sites also allow further study of long-range transport and other atmospheric processes.

## CHECK your Understanding

1. Why is "acid precipitation" a better term than "acid rain"?
2. What are the main sources of acid precipitation in Newfoundland and Labrador?
3. Discuss the effects of acid precipitation on human health, the environment, and the economy.
4. Why are some ecosystems more affected by acid precipitation than others?

### For Further Discussion and/or Research

5. Levels of acid precipitation are very high in the southwest areas of the island of Newfoundland. Account for these high levels.

## STRATOSPHERIC OZONE

Oxygen molecules in the stratosphere interact with ultraviolet rays from the sun to form ozone gas. The result is the atmosphere's "ozone layer". Under normal circumstances, the ozone layer is continuously depleted and regenerated, which causes variations in its thickness.

Ozone in the troposphere (ground-level ozone) degrades air quality. The ozone layer in the stratosphere, however, protects us from high levels of UV-B radiation. UV-B is the type of ultraviolet radiation that causes sunburns. It can disrupt important biological processes and break down many human-made materials.

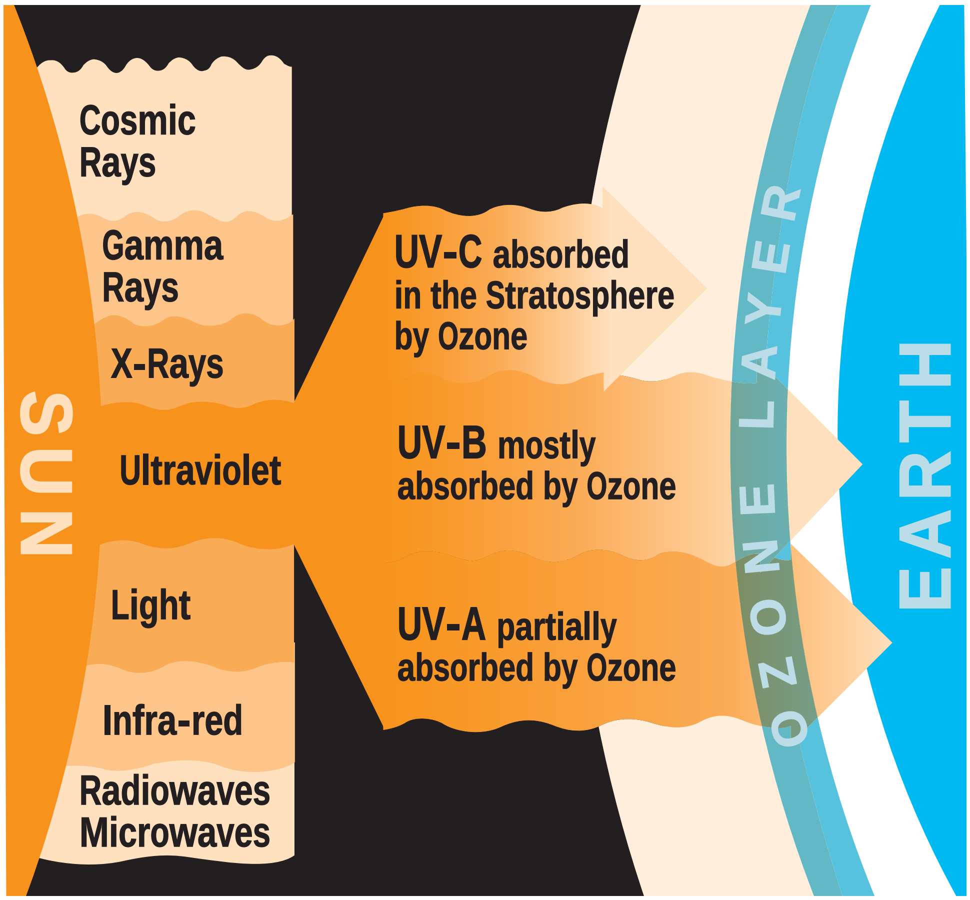



**Figure 17.25:** Three categories of UV radiation. *Source: The 1991 report of the United Nations Environmental Program (UNEP) Environmental Effects Assessment Panel. Environmental Effects of Ozone Depletion: 1991 Update, Panel Report Pursuant to Article 6 of the Montreal Protocol on Substances that Deplete the Ozone Layer Under the Auspices of UNEP, November 1991.*

Some pollutants speed up the depletion of ozone and their presence in the atmosphere has caused the ozone layer to thin. Extreme depletion of this protective stratospheric ozone has created the ozone "hole"—a large area over the Antarctic continent and tip of South America in which up to seventy percent of the ozone (with seasonal variations) has been lost. In a second hole over the Arctic, up to forty percent of the ozone has been lost. Stratospheric ozone has also thinned over non-polar regions, but to a lesser extent. Over southern Canada, for example, the ozone layer is about four percent thinner than normal, with greater losses of six to eight percent in the early spring.

## Sources of Ozone Depleting Chemicals

Most of the chemicals that destroy stratospheric ozone contain chlorine and/or bromine. They do not break down easily in the troposphere so they survive when carried up into the stratosphere. Ozone-depleting substances include chlorofluorocarbons (CFCs) and hydro-chlorofluorocarbons (HCFCs). Many of these ozone depleting substances are also powerful greenhouse gases.

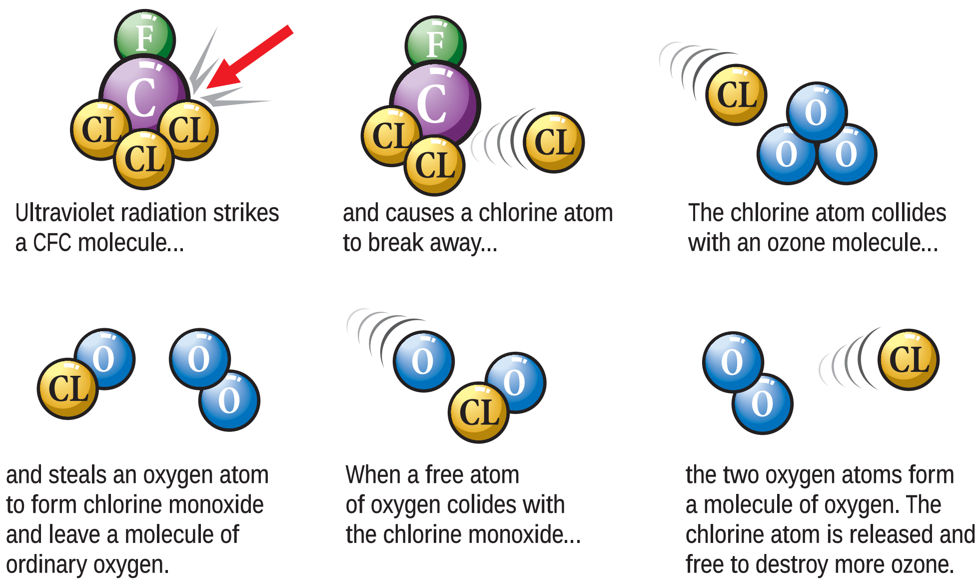



**Figure 17.26:** How stratospheric ozone is destroyed by CFCs.

CFCs are wonderful refrigerants and aerosols propellants. They were common in manufactured products throughout most of the twentieth century. When their ozone-depleting qualities were discovered, however, many governments (including Canada's) began to phase out their use. In their place, completely safe alternatives are now used—and where this is not possible, HCFCs (which have only a fraction of the ozone-depleting potential of CFCs) are used. HCFCs are also set to be phased out and replaced with hydrofluorocarbons (HFCs), which do not have ozone-depleting characteristics. Unfortunately, HFCs are also greenhouse gases that contribute directly to climate change. So their use, too, is regulated, and they will be phased out if possible.

Halons, another group of ozone depleting chemicals, are used primarily in fire suppression systems. They are also being phased out, although in this case the process is more challenging because no substitute exists for them in specialized fire-fighting situations.

## The Effects of Increased UV-B Exposure

When the atmospheric ozone layer thins, more UV-B radiation can reach the surface of Earth. Increased UV-B exposure can degrade building materials—wood and plastic can discolour and become weakened. In addition, UV-B radiation is a factor in the production of ground-level ozone, a key ingredient in smog. It seems likely that a thinner ozone layer will lead to more smog.

Perhaps the greatest impact that increased UV-B penetration will have is on life forms. Current research in Canada, Europe, and Australia has confirmed a link between UV-B radiation and an increased risk factor for skin cancer and cataracts. Many plant species around the world—both in the wild and planted for agriculture—are sensitive to UV-B, though not all in the same way. Increased UV-B levels can cause more weeds to grow in agricultural fields or grazing pastures. Because UV-B radiation can damage cell membranes and the DNA in the nucleus of a cell, UV-B can harm crops and diminish our ability to grow and produce food. UV-B radiation can also alter chloroplasts—the part of the cell that converts carbon dioxide into sugar and oxygen.

Damage also occurs in aquatic environments. Experiments indicate that increased UV-B causes severe disruption of both saltwater and freshwater communities. It harms bacteria, algae, phytoplankton, and zooplankton, the foundation of aquatic food webs. Altering aquatic resources can have devastating effects for all species that rely on them—including humans: more than thirty percent of the protein people consume comes from the sea.

## Actions to Address Stratospheric Ozone Depletion

### Personal Action

Properly disposing of appliances that contain CFCs is one of the best things you can do to prevent the release of ozone-depleting chemicals. Many municipalities have waste-disposal programs to recover refrigerants before they reach a landfill. Even if your refrigerator, freezer, or air conditioner just needs to be repaired, call a certified technician who will recover and recycle the refrigerant rather than release it into the atmosphere.

Environment Canada's UV Index was created to help people adequately protect themselves from exposure to the sun's UV rays. It uses a numerical scale: one indicates low risk of damage from UV-B radiation; eleven or higher warns of extreme risk. The UV Index is available online and is also part of local weather forecasts on the days when the UV-B may reach moderate levels.

### Government and Industry Action

The *Montreal Protocol on Substances that Deplete the Ozone Layer*, an international agreement signed by developed countries, is designed to eliminate the production and importation of the most damaging ozone-depleting substances. Although some ozone-depleting chemicals have been phased out already in developed countries, others (such as HCFCs and methyl bromide) are still being used. Meanwhile, many developing nations have less stringent rules regarding the release of ozone-depleting chemicals, including the most damaging: CFCs.

Overall, developed nations have made significant progress in reducing the emissions of ozone-depleting substances mainly by creating strong control measures such as the *Montreal Protocol*. Changes in technologies and voluntary action by industry are also helping to protect the ozone layer.

As a signatory to the *Montreal Protocol*, Canada has developed several domestic strategies, including a national action plan and a plan for accelerated phase-out of CFCs and halons. Newfoundland and Labrador has been involved in this process through a federal - provincial working group.

## Summary

Molecules in the atmosphere are constantly moving and changing as part of natural processes. Human activities also change the makeup of the atmosphere—we alter the amount of naturally occurring chemicals in the air and add new ones that do not occur naturally.

Human-induced changes to the atmosphere are caused in large part by burning fossil fuels, and also by the creation and use of industrial chemicals. They reduce air quality and cause smog, acid rain, toxic emissions of heavy metals and persistent organic pollutants, and the loss of stratospheric ozone.

The health of all living things is at risk because of poor air quality. So too, is our economy. Tax dollars must be spent to compensate for poor air quality, as expenses for treating related human illness. We also lose healthy natural resources, such as forests and fish-filled streams.

We can use technologies to decrease the amount of air pollution we emit, but they either cannot capture all the air pollutants of concern, or they can increase certain greenhouse gases. People can take individual actions to improve air quality by becoming wise consumers (reduce, reuse, recycle and recover), reducing the use of fossil fuels, and adopting smart wood-burning practices. Industry can play a major role by investing in technologies that reduce and control emissions.

## CHECK your Understanding

1. What type of weather can cause pollutants from wood smoke to be more concentrated at ground level?
2. What type of person is at risk for smog-related health problems? Are some more affected than others? Why?
3. What can people do to minimize air pollution? What can municipalities do?
4. How is acid rain created?
5. What is ozone?
6. Is all ozone in the atmosphere bad for our health? Explain your answer.

### For Further Discussion and/or Research

7. Explain how overfilling your gas tank and spilling gasoline can cause ozone formation (and hence smog) in the troposphere?
8. What is nutrient leaching? How does it relate to the issue of acid rain?
9. Would it be difficult to develop a catalytic converter or other device to remove carbon dioxide from the tailpipe of a conventional car with a gasoline engine? Briefly explain your reasoning.
10. Determine the health hazards of the criteria air contaminants carbon monoxide and ammonia. What are the major sources of these chemicals?

# Chapter 18: Human Impacts on Climate

**Figure 18.1:** The burning of fossil fuels to run automobiles is a major contributer to climate change.

## GREENHOUSE GASES AND HUMAN-CAUSED CLIMATE CHANGE

Climate change is defined as a change in "average weather" that a geographic region experiences over time. Many natural phenomena contribute to climate change, including volcanic activity, solar variability, changes in Earth's orbit and tilt, plate tectonics, and the evolution of organisms that use carbon dioxide and produce oxygen.

Earth's climate is now experiencing changes that cannot be attributed to these natural forces alone. Human activities, primarily the burning of fossils fuels, are changing the chemistry of the atmosphere, which, in turn, is changing climates all around the world.

Some trace gases in the atmosphere absorb long-wave radiation from the sun instead of letting that radiation escape back out into space. These gases are called greenhouse gases because they trap heat around the Earth the same way the glass of a greenhouse keeps heat inside the building. The warming of global temperatures caused by greenhouse gases is called "the greenhouse effect".

Greenhouse gases and the greenhouse effect are natural phenomena. If there were no greenhouse gases in the atmosphere, climates around the world would be far colder. Natural greenhouse gases exist in the atmosphere in trace amounts and their presence is critical to maintaining climates that support life on Earth (not too cold and not too hot). Recently, however, human activities have increased the amount of greenhouse gases in the atmosphere. This increase has thickened the insulation around the planet, which has caused Earth's overall average surface air temperature to increase and is believed to be the cause of more severe weather events.

**Relationship of Human Caused Greenhouse Gas Emissions to Climate Change Impacts**

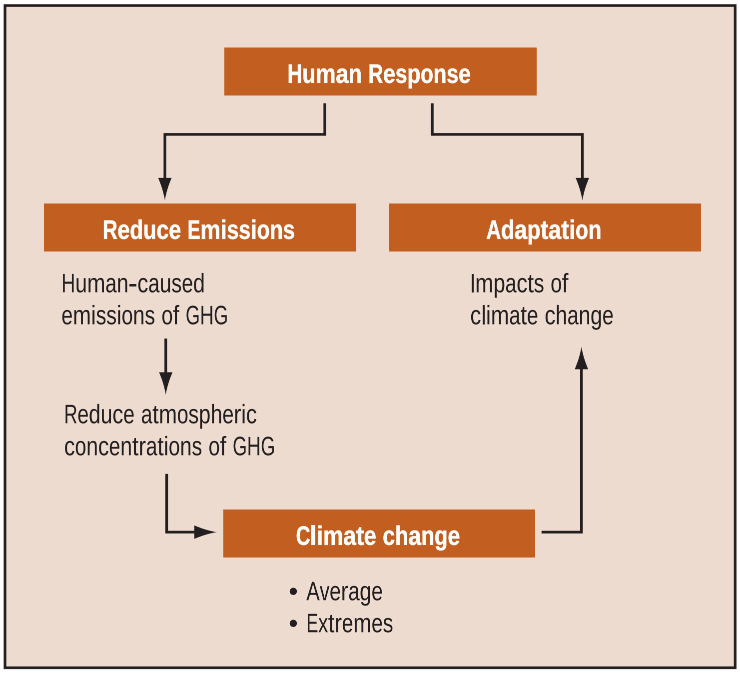



**Figure 18.2:** The relationship between human-caused greenhouse gas (GHG) emissions and climate change impacts. *Courtesy of Environment Canada/Henry Hengeveld*

Burning fossil fuels—coal, oil, natural gas, gasoline, and diesel fuel—is the major human cause of increased greenhouse gases in the atmosphere. Human and natural processes affect each other: human-caused (anthropogenic) emissions raise atmospheric greenhouse gas concentrations, which leads to changes in climate averages and extremes. These climate changes affect natural ecosystems and also human health, economies, and society.

People can address climate change in two ways. The first is to reduce greenhouse gas emissions in order to slow or reduce their build up in the atmosphere and reduce their warming effects. The second is to devise steps to help people cope with the potential impacts of climate change. The second approach, referred to as "adaptation", includes strategies such as building away from shorelines to reduce vulnerability to rising sea levels. Many municipalities in Canada are taking climate-change impacts into consideration as they make plans for new infrastructure, such as storm-water drains, sewers, and roads.

## Sources of Greenhouse Gases (GHGs)

Different types of fuel emit different types and amounts of greenhouse gases. Burning coal emits considerably more kilograms of carbon dioxide ($CO_2$)—a primary greenhouse gas—for each unit of energy it produces than any other energy source. This is because coal is almost pure carbon. Burning coal to create energy causes the carbon to combine with oxygen to form $CO_2$.

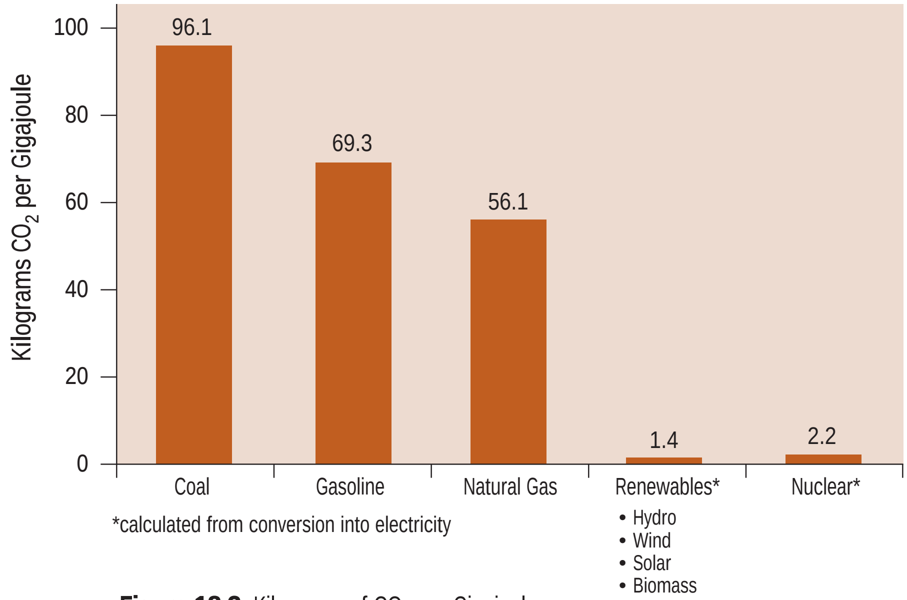



**Figure 18.3:** Kilograms of $CO_2$ per Gigajoule.
*Courtesy of Environment Canada/Atlantic Climate Change Unit*

## Did You Know?

The combustion of fuel that occurs when using motorized transportation is Newfoundland and Labrador's largest source of greenhouse gas emissions. It is responsible for thirty-eight percent of the province's total GHG emissions. In fact, what comes out of vehicle tailpipes is the first or second largest source of GHG emissions in most provinces.

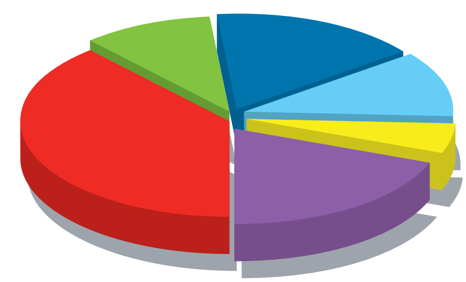
Liquid petroleum, such as oil or gasoline, has about two hydrogen atoms for each carbon atom. When this fuel is burned to create energy there are fewer carbons available to combine with oxygen. As a result, less carbon dioxide is produced than from the same amount of coal.

While the combustion of oil and gasoline ($C_{25}H_{52}$) emits less carbon dioxide than burning coal, it emits more than natural gas. Natural gas, which is mostly methane ($CH_4$), emits the least $CO_2$ of the three forms of fossil fuel (solid, liquid, gas) because it contains the fewest carbon atoms to join with the oxygen.

Creating energy from hydro, wind, solar, and nuclear sources emits virtually no carbon dioxide because these sources are carbon free. For the same reason, biomass (plant material) can also be referred to as a "carbon neutral" energy source because the new plants that grow to replace those that are burned use the $CO_2$ to make food.

The list of each province's major sources of greenhouse gas emissions is shaped in part by how it generates electricity. For example, in Nova Scotia and New Brunswick, power generation is a much greater source of GHG emissions than in Newfoundland and Labrador because those provinces rely more on fossil fuels to create electricity than we do. Electricity production is the second largest source of GHG emissions (nineteen percent) in Newfoundland and Labrador (figure 18.4).

Greenhouse Gas Sources in Newfoundland and Labrador



Total: 9.55 Megatonnes $CO_2$ equivalent

| | |
|---|---|
| Transportation | 38% |
| Buildings (Includes Residential, Commercial & Institutional sectors - almost entirely space heating & hot water) | 10% |
| Fossil Fuel Industry (Includes fugitive sources) | 16% |
| Industry | 11% |
| Non-energy | 5% |
| Electricity | 19% |

**Figure 18.4:** Greenhouse gas sources in Newfoundland and Labrador.
*Courtesy of Environment Canada/Canada's Greenhouse Gas Inventory 1990-2001*

The category "fossil fuel industry", which is Newfoundland and Labrador's third largest source of GHG emissions, includes offshore operations (such as Hibernia) and the refining of crude oil at Come By Chance. The "industry" sector includes energy used in mining, construction, forestry, and agriculture. Oil furnaces and hot-water boilers in homes and commercial and institutional buildings also contribute to greenhouse gases emissions.

## ECO SPOTLIGHT:

### Four Factors in Environmental Decision-making

When a person, industry, or government makes an informed decision on any important matter, they often consider four factors:

- likelihood;
- consequences;
- co-benefits; and
- costs.

Justifying actions to reduce greenhouse gases involves all four of these factors.

#### 1. Likelihood

At issue here are the ideas of "proof" and "scientific uncertainty". Scientists often aim to prove outcomes to ninety or ninety-five percent certainty, but people make decisions every day based on much lower certainty levels. In this case, we do not fully understand the effects that all variables will have on climate change. However, in Canada and around the world, the immense amount of climate-change research now allows most scientists to be confident in asserting that human-caused climate change *is* occurring.

#### 2. Consequences

The second consideration in making decisions about climate change is the magnitude of the consequences of doing nothing. A familiar example of action taken to avoid incidents that have huge consequences is the purchase of fire insurance—most people buy it because the consequences of a loss are great, not because they expect to have a fire. Climate change can potentially produce immense negative consequences, including rising sea levels, species and ecosystem loss, and drought. Some scientists believe it is possible that climate change will have even more disastrous effects on the environment than these.

#### 3. Co-benefits

Many actions to reduce greenhouse gas emissions have benefits in addition to reducing the risk of climate change. For example, switching to fuel-efficient cars will also save money and reduce acid rain and smog. Another approach—providing effective mass transit in large cities—reduces both greenhouse gas emissions and congestion.

### 4. Costs

There are financial costs to reducing greenhouse gases. Some technologies are expensive to operate such as capturing carbon dioxide and pumping it underground for permanent storage. Other approaches are considered expensive because of lost business opportunities—foregoing development of the Alberta oil sands would be an example of an expensive lost business opportunity. On the other hand, some means of reducing greenhouse gases, such as improving home insulation (which reduces energy use), are initially costly but have economic benefits over the long term.

### Consider All Factors

Applying these four factors can help guide our choices and courses of action on the issue of climate change. Since increased greenhouse gases clearly contribute to climate change, and climate change has serious consequences, we should act quickly in areas with the least cost and most benefit. It seems that taking further action, however, will require much debate and social will.

### Who Me?

Climate change is the type of problem that can seem too large and complex to deal with. Yet society has faced wide-scale issues before and people have risen to the challenge by changing how they think. Widely held attitudes about drinking and driving or smoking, as examples, have changed dramatically over the last few decades. A similar change in public belief is needed (and possible) when it comes to climate change. Such a change would lead to wiser energy use (thus fewer harmful emissions) and to improved building and planning strategies.

Whose responsibility is it to address climate change? Everyone has a role to play. Governments react and respond to public concerns. Individuals can make a difference.

### The Climate-change Debate

There are many views on the subject of climate change, and people do not always agree about its seriousness or what can be done about it. Some people believe that reducing energy consumption will depress the economy, eliminate jobs, and constrain personal lifestyles. Others believe that there are many no-cost or low-cost ways to reduce greenhouse gas emissions such as using renewable energy (hydro, wind, solar), using energy efficiently, and taxing energy use instead of income.

CHECK your Understanding

1. List some sources of greenhouse gas emissions in your community.
2. People can respond to climate change in two ways—either by reducing their consumption of natural resources or by adapting their lifestyle. Which of these responses is more ecologically sustainable? Explain your answer.
3. Contrast opposing viewpoints on climate change.

For Further Discussion and/or Research

4. There are more taxes on energy and fewer taxes on income in Europe than in Canada, and Europeans consume less energy than Canadians. What would be the positive and negative effects of implementing the European approach in Canada?
5. Harmful practices can continue for years before they are deemed unacceptable. List three activities that are now considered inappropriate or illegal that were commonplace just a few decades ago. Do you see any similarities between these behaviours and our current use of fossil fuels?
6. Are the costs associated with reducing GHG acceptable when you consider the consequences? Explain.

CORE LABORATORY ACTIVITY

Greenhouse Gases from Human Activity

Purpose:
To compare the amount of carbon dioxide ($CO_2$) in four different sources of gases: ambient air, human exhalation, automobile exhaust, and nearly pure $CO_2$.

Hypothesis:
Create a hypothesis that predicts which gases might contain the most or the least $CO_2$.

Materials
- Five test tubes or glass vials
- Bromothymol blue
- Clay
- Straws
- Balloons containing gas samples (prepared by your teacher)
- Retort stand, clamp and titration apparatus
- Ammonia solution (prepared by your teacher)

Procedure:
1. Label the vials/test tubes A, B, C, D, and Control. Add 15 ml of water and 10 drops of bromothymol blue indicator solution to each vial/test tube.

2. Obtain four balloons containing different gas samples to be tested:
   Sample A – ambient air
   Sample B – human exhalation
   Sample C – automobile exhaust
   Sample D – nearly pure $CO_2$
3. Soften the clay and wrap it around one end of the straw forming a cone-shaped, airtight collar that will fit into the neck of a balloon. The straw should be centred in the middle of the cone and the cone should be large enough to plug the neck of the balloon.
4. Without removing its tie, slip the neck of the Sample A balloon over one of the clay collars and press to make an airtight seal. Place the other end of the straw into the vial labelled A (and right into the solution of water and bromothymol blue). Hold the straw while your lab partner removes the tie and slowly untwists the balloon. Gently squeeze the balloon so the gas slowly bubbles into the solution. You can control the flow of gas by pinching the neck of the balloon.
5. Repeat Step 4 with Samples B, C, and D. In some cases, the colour of the bromothymol blue solution will change from blue to yellow. This indicates the presence of carbonic acid, which was formed from $CO_2$ reacting with the bromothymol blue indicator.
6. Analyze each sample by titrating it with dilute ammonia, which will neutralize the carbonic acid. The bromothymol blue will turn blue again when all the acid has reacted. Count the drops of ammonia you add to each yellow sample to restore it to the same colour as your control vial. Note the results.
7. Make a table like the one below in your record book and record your group's results. Give the table an appropriate title.

### Results

Title:

| Gas Solutions | Bromothymol Blue Colour Change | Drops of Ammonia Added to Match Control |
|---|---|---|
| Sample A: ambient air | | |
| Sample B: human exhalation | | |
| Sample C: car exhaust | | |
| Sample D: pure $CO_2$ | | |

### Analyze and Conclude

1. Based on the number of drops required to restore the colour of the Control Sample, which gas samples contained the most and the least carbon dioxide?
2. Which sample could cause an increase in atmospheric $CO_2$ as a result of daily human activity?

Extensions

3. Why does the bromothymol blue turn yellow? Why didn't Sample A cause this colour change?
4. Why is automobile exhaust a concern?
5. How can you reduce the amount of $CO_2$ you create?
6. How can a city reduce the amount of $CO_2$ it emits?
7. What alternative energy sources could be used to power cars?
8. Why might it be difficult for the public to begin using alternative energy sources?

## CLIMATE CHANGE SCIENCE

*Climate is what you expect, but weather is what you get!*

The science of climate change is a dynamic discipline and research in the field is constantly revising and improving what we know. Climate change is a complex issue, but understanding it is essential to helping us prepare for anticipated changes and extreme weather, and for the effects of both on people and ecosystems—both regional and globally. Natural climate systems, the effects human activity has on them, the greenhouse effect, and some of the changes we may experience in the coming years are all explored in this section.

### Climate versus Weather

Climate: A geographical area's climate is its average pattern of weather measured over a period of time (season to season, year to year). Climate is described in statistical quantities.

Weather: Weather is the state or condition of the atmosphere at a specific time with respect to heat or cold, calm or storm, wetness or dryness, and clearness or cloudiness.

Regional climates can be further influenced by latitude, altitude, topography, proximity to large bodies of water, and ocean currents.

## Components of the Climate System

The major elements that influence climate include:

- the sun and its output;
- Earth's rotation;
- sun/Earth geometry and Earth's slowly changing orbit;
- land and ocean distribution;
- the geographic features of the land;
- the topography of the ocean bottom;
- the mass and basic composition of the atmosphere, oceans, and sea ice; and
- vegetation cover.

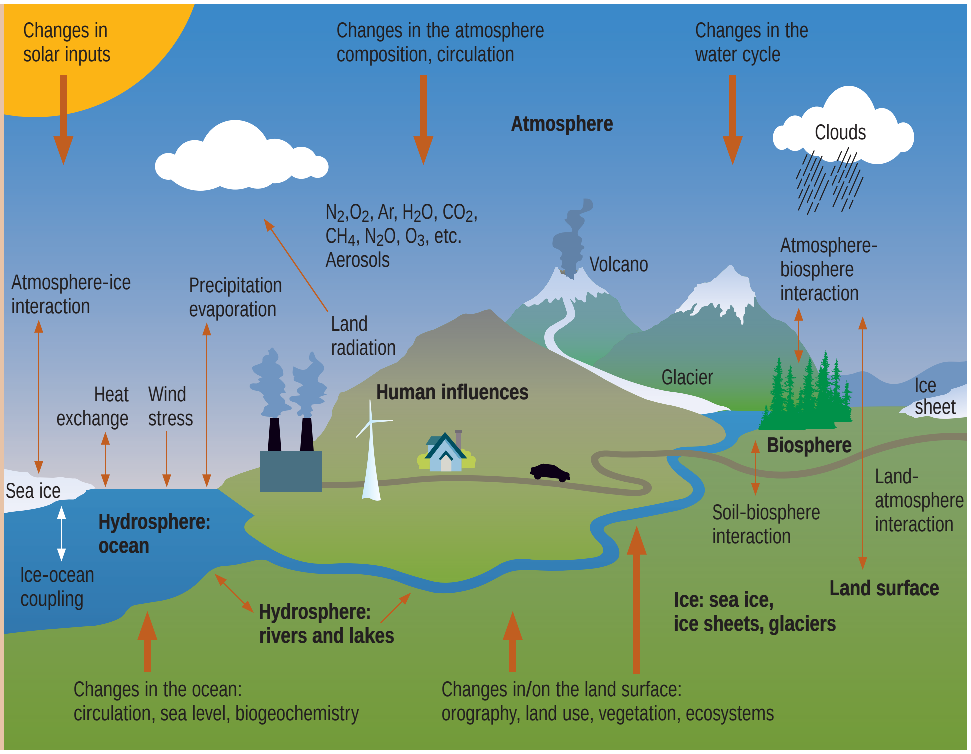



**Figure 18.5:** The global climate system. *Courtesy of Environment Canada/A Matter of Degrees*

## The Atmosphere's Energy Balance and the Greenhouse Effect

Solar energy is constantly entering and leaving Earth's atmosphere. When it enters and leaves at the same rate, the climate system is balanced and the annual average global temperature remains relatively constant.

If either of these rates change or if the global distribution of energy shifts, the climate balance is upset. The annual global average temperature will change and other inter-related weather elements—such as precipitation or wind patterns—will also be altered.

### Solar Radiation

The sun emits radiation in a wide range of wavelengths, including high-energy short-wave radiation (visible light). Earth's surface absorbs about half (forty-nine percent) of all of the incoming solar radiation. The rest is reflected back into space by clouds and surface ice, scattered by dust and water vapour, or is absorbed by the atmosphere. The solar energy that Earth absorbs is converted to heat and warms the planet. Earth then re-radiates long-wave infrared radiation back out towards space.

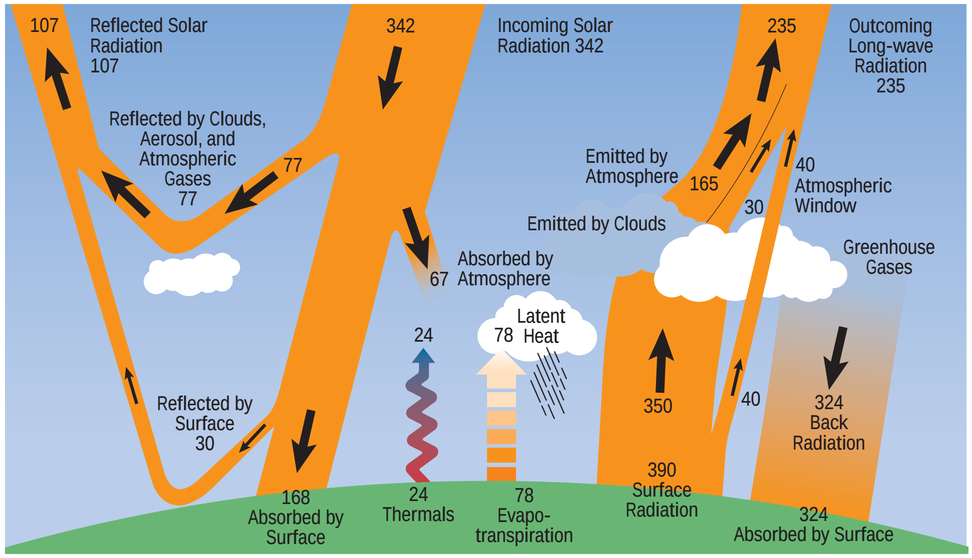



**Figure 18.6:** Earth's annual and global mean energy balance. *Courtesy of Environment Canada/A Matter of Degrees*

**Key:** Watts/square metre (figures) • Direction of solar energy (arrows)

Some long-wave radiation is absorbed by greenhouse gases in the atmosphere. This absorbed radiation is then re-radiated in all directions. The radiation that returns to Earth raises the temperature of Earth's surface. Without this natural greenhouse effect, the average temperature on Earth's surface would be -18°C—thirty-three degrees colder than the current average of 15°C.

A change in any component of the energy balance can lead to dramatic changes in climate.

**Figure 18.7:** Mount St. Helens erupting on May 18, 1980. *Photo courtesy United States Geological Survey/Photo and Image Collections*

## Natural Sources of Climate Change

Most of the natural processes that influence climate take place over thousands or millions of years, but some sudden changes in climate have also occurred. Natural sources of climate change are:

- volcanic activity;
- solar variability;
- changes in Earth's orbit and tilt;
- changes in ocean circulation;
- plate tectonics; and
- biological evolution.

1. Volcanic Activity

   Debris and gases shoot into the atmosphere during all major volcanic eruptions such as the 1980 eruption of Washington State's Mount St. Helens volcano. They block sunlight from reaching Earth, which generally causes a short-lived (five or fewer years) cooling of Earth's climate.

2. Solar Variability
   The energy output of the sun varies slightly over time. Satellite measurements have shown that the total output can vary both throughout the day and during the solar cycle. These variations can directly affect Earth's climate, but the exact role that solar variability plays is still a controversial topic.

3. Ocean Circulation
   Local climates are influenced by the circulation of both deep and surface ocean currents. Evidence suggests that ocean currents have changed over time.

4. Earth's Orbit and Tilt
   Earth's orbit changes over a 100,000-year cycle, shifting from almost circular to elliptical. Changes in the tilt of Earth's axis (between 21.8 and 24.4 degrees) occur on a 40,000-year cycle. Both of these factors affect the planet's solar energy budget and the amount of solar radiation that different areas of the Earth receive. The northern hemisphere is now closer to the sun in winter and farther away in summer (and receives five percent less sunlight in summer) than 12,000 years ago. More tilt leads to greater seasonal variations.

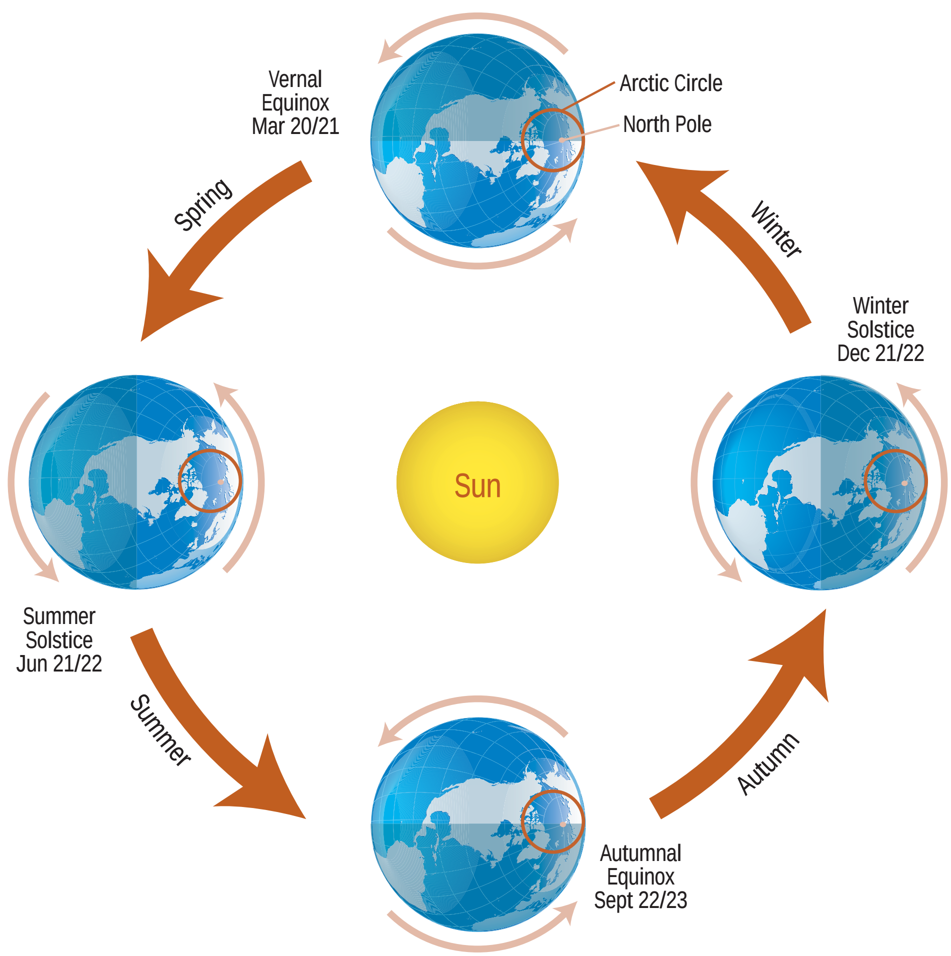



**Figure 18.8:** The change in the position of Earth during its annual revolution around the sun. (Note: drawing is not to scale.)
*Courtesy of Dr. Michael Pidwirny*

5. Plate Tectonics

   Millions of years ago most of Earth's land mass was a single continent. Over time, portions of it drifted apart, gradually forming the continents and ocean basins existing today. The redistribution of land mass and ocean area has had a major effect on global climate.

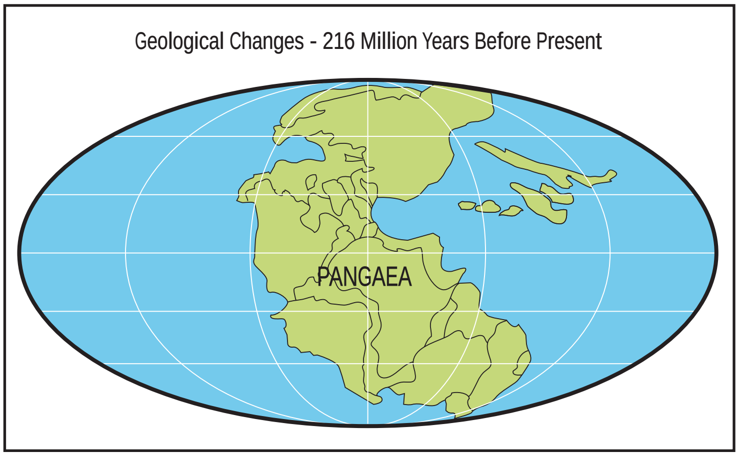



**Figure 18.9:** The arrangement of land on Earth about 216 million years ago. *Courtesy of Dr. Michael Pidwirny*

6. Biological Evolution

   Several billion years ago Earth's pre-life atmosphere—which was mainly carbon dioxide and methane—became predominantly nitrogen and oxygen. The gradual shift in the atmospheric concentrations of the gases occurred during the evolutionary emergence of photosynthetic organisms, which consumed carbon dioxide and generated oxygen.

## The Effect of Human Activity on Earth's Atmosphere

Human activities account for the emission of six major greenhouse gases into the environment. Three of them—carbon dioxide ($CO_2$), methane ($CH_4$), and nitrous oxide ($N_2O$)—also occur naturally. The other three—the hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphahexfluoride ($SF_6$)—are produced only from human sources (thus they are termed "anthropogenic"). Although found in much smaller in concentrations than the others, HFCs, PFCs and $SF_6$ have a major impact because they are powerful and long-lasting.

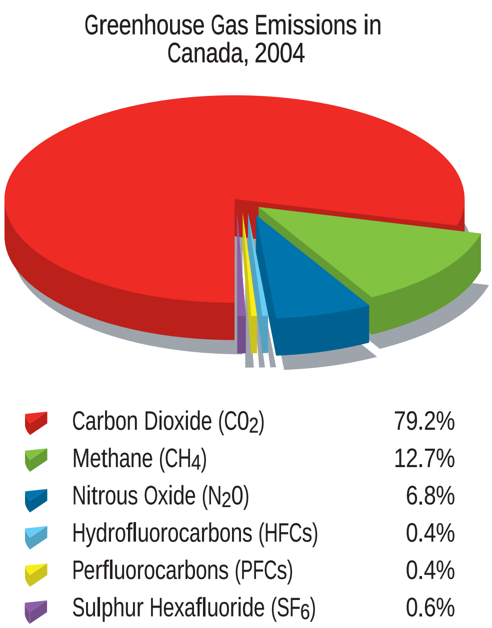



**Figure 18.10:** Canada's 2004 greenhouse gas emissions, expressed as a percentage of the Canadian global warming potential. *Courtesy of Environment Canada*

**Global warming potential** (GWP) is a way of comparing the relative effects that different greenhouse gases will have on climate. The GWP values for different gases are listed in Figure 18.11. Carbon dioxide, the reference gas, has a GWP value of one. Methane has a GWP of 23 which means that if the same volumes of carbon dioxide and methane were released into the atmosphere, the methane gas would have a greenhouse effect that would be twenty three times greater than that of carbon dioxide.

A gas's global warming potential indicates both its potency as a greenhouse gas and its probable lifetime in the atmosphere. This measurement system also allows direct comparisons of greenhouse gas effects. The value is not the only indicator to take into account. The overall contribution of each greenhouse gas also depends on:

- the amount of it that is released into the atmosphere each year; and
- the secondary effects that its presence will have on atmospheric chemistry.

**Atmospheric Lifetime and Global Warming Potential of Major Greenhouse Gases**

**Gases emitted solely from human sources*

| | |
|---|---|
| **Carbon dioxide ($CO_2$)** | |
| Atmospheric Lifetime in Years | Approx. 100 |
| Global Warming Potential | 1 |
| **Methane ($CH_4$)** | |
| Atmospheric Lifetime in Years | 12 |
| Global Warming Potential | 23 |
| **Nitrous oxide ($N_2O$)** | |
| Atmospheric Lifetime in Years | 120 |
| Global Warming Potential | 310 |
| **Hydrofluorocarbons (HFCs)** | |
| Atmospheric Lifetime in Years | 1.5 to 264 |
| Global Warming Potential | 140 to 11,700 |
| **Perfluorocarbons (PFCs)** | |
| Atmospheric Lifetime in Years | 3,200 to 50,000 |
| Global Warming Potential | 6,500 to 9,200 |
| **Sulphur hexafluoride ($SF_6$)** | |
| Atmospheric Lifetime in Years | 3,200 |
| Global Warming Potential | 23,900 |

**Figure 18.11:** Atmospheric lifetime and global warming potential of six greenhouse gases.
*Courtesy of Climate Change 1995: The Science of Climate Change*

## Sources and Characteristics of Major Greenhouse Gases

**Carbon dioxide** (Global Warming Potential, GWP: 1): Carbon dioxide ($CO_2$) is formed naturally by respiration, by the decomposition of organic matter, and by the combustion of biomass (such as lightning-sparked forest fires). Humans have added—and continue to add—significantly to those contributions by burning fossil fuels. Carbon dioxide has a low global warming potential value, but it is the major human-induced contributor to atmospheric warming because it is emitted in such large quantities.

**Methane** (GWP: 23): Produced when organic materials break down in the absence of oxygen, methane ($CH_4$) is emitted naturally by wetlands. Significant human-related sources are municipal dumps, fermentation in the stomachs of cattle raised in large numbers for food, and fossil-fuel production.

**Nitrous oxide** (GWP: 310): Lightning emits nitrous oxide ($N_2O$) naturally; other natural sources are biological and chemical processes in soil. Human-related sources are chemical fertilization and the combustion of biomass and fossil fuels.

**Hydrofluorocarbons** (GWP: 140 to 11,700): HFC gases are commonly used as refrigerants in air conditioners, dehumidifiers, freezers, and refrigerators. They cause little harm when contained in appliances but contribute to global warming and depletion of Earth's ozone layer when they are released into the atmosphere.

**Perfluorocarbons** (GWP: 6,500 to 9,200): PFC gases are used in refrigeration and "clean" fire extinguishers. They cause little harm when contained in appliances but contribute to global warming when released into the atmosphere.

**Sulphur hexafluoride** (GWP: 23,900): This is the most potent greenhouse gas that scientists have ever evaluated. Sulphur hexafluoride ($SF_6$) is used in the electricity industry in high-voltage circuit breakers, switch gear, and other electrical equipment, often replacing polychlorinated biphenyls (or PCBs, which—as persistent organic pollutants—have their own harmful side effects).

## Changes in Greenhouse Gas Concentrations and Temperature over Time

Examining the long-term historical climate record, especially the temperatures before industrialization, shows a rapid increase in atmospheric carbon dioxide. This provides a framework for understanding the climate changes that are happening today.

### Temperature Varies with $CO_2$ Concentration

Ice cores drilled into the Antarctic ice sheet, which extend three kilometres deep and cover a time span of six ice ages, provide long-term data about climate as far back as 650,000 years. Snow falling on the Antarctic continent tends not to melt, but slowly builds up, layer upon layer over thousands of years. As it accumulates, it is compressed by the weight of the layers above it, and air bubbles are trapped. Surrounding ice prevents these bubbles from escaping or mixing with other air bubbles. When analyzed, this "fossil air" can reveal the qualities of the atmosphere at the time the original snow fell.

Analysis of ice cores in the Antarctic shows that, over time, the south polar temperatures have varied consistently with atmospheric concentrations of carbon dioxide. During warmer periods, more $CO_2$ was present in the atmosphere, and during cooler periods less $CO_2$ was present.

Like the fossil air in ice cores, pollen that has been trapped in layers of sediment can also provide clues about climates long ago. Every plant species has a preference for specific temperatures and precipitation patterns—it can only survive in certain types of climates. As a region's climatic conditions change over time, the mix of plant species also changes. Pollen analysis of core samples of soil and sediments can reveal information on two points about climate change. First, examining changes over time indicates how quickly plants migrated into or out of an area as a response to natural changes in climate. This can provide clues to whether plant communities will be able to adapt fast enough to survive at the present pace of human-induced climate change. Second, determining which plants were able to survive in climates that are warmer than today's allows experts to predict which types of plants may thrive, and where, as the climate warms.

### Today's Unprecedented High Levels of Carbon Dioxide

Using ice core, pollen, and other data, we can say with certainty that today's atmospheric concentrations of greenhouse gases are outside the natural range of the last 650,000 years.

During the previous 150 to 200 years, atmospheric $CO_2$ concentrations have increased by thirty percent, from a stable range of 260 to 280 parts per million (ppm) prior to the start of the industrial age (the mid-1800s) to today's levels of more than 380 parts per million. If current trends continue, concentrations are expected to reach an alarming 675 ppm by the end of the twenty-first century.

**Figure 18.12:** Snowmobiles, like all other vehicles that are powered by gasoline, contribute to carbon dioxide emissions. *Photo courtesy Sheldon Marsh*

**Projected carbon dioxide levels by the end of the twenty-first century**

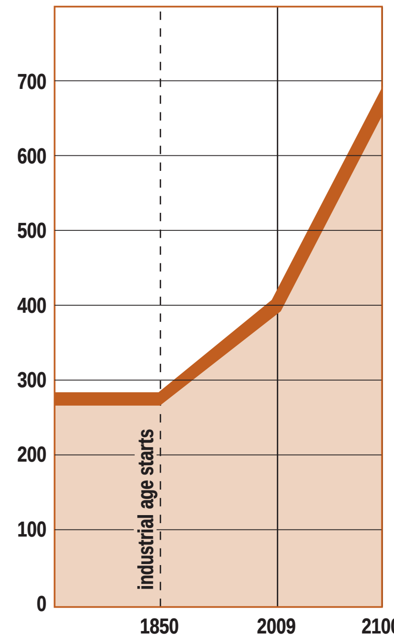



**Figure 18.13:** Carbon dioxide levels have been increasing since the mid 1800's and are expected to increase at a much faster rate if current trends continue.

The increases of the last two centuries are almost entirely due to human activities. The current and predicted atmospheric conditions are unprecedented, and the potential impact of this dramatic release of global warming gases is not fully predictable.

## CHECK your Understanding

1. Distinguish between weather, climate, and climate change.
2. What is solar radiation and what happens to it when it reaches the Earth?
3. Identify the natural causes of climate change.
4. List the common greenhouse gases. Which has the greatest and the least greenhouse potential?
5. Based on the greenhouse potential of the various greenhouse gases, which would have the greatest impact on reducing global warming, cutting carbon dioxide emissions in half or cutting methane emissions in half? Why?

### For Further Discussion and/or Research

6. Limestone deposits along the west coast of the island of Newfoundland suggest that the climate was similar to that of Bermuda when the deposits were laid down. Account for this.
7. Through research, find out what animals remove carbon dioxide from the atmosphere.

## Did You Know?

From analyzing the data, we know that global annual temperature has increased by about 0.6°C since the late 1800s. The ten warmest years on record (to date) were in the 1990s and early years of the twenty-first century. In fact, 2005 was the twenty-seventh straight year during which global mean surface temperatures were higher than the long-term (1880-2004) average.

### Historic Temperature Trends

The climate trends of the past century-and-a-half can be accurately studied by using the large body of scientifically collected weather records.

Temperatures are now measured daily around the world and can be used to tabulate a global mean surface air temperature. These conventional temperature observations are supplemented by satellite-based data. The records show a gradual rise in global temperature over the last 120 years. In Canada, the annual mean temperature has increased by about 1°C during the past half-century.

This overall rise in global and Canadian mean annual temperatures is a general trend, and temperature change also varies by season and region. For example, warming has been more pronounced in western Canada, especially during winter and spring. In Atlantic Canada, trends vary depending on which area you examine. From 1950 to 2003, most of the Maritimes experienced a warming trend, but Newfoundland and Labrador experienced either no trend or cooling temperatures (especially over the Labrador Sea).

**Global Temperature Change 1880-2004** *(Relative to 1961-90 average temperature)*

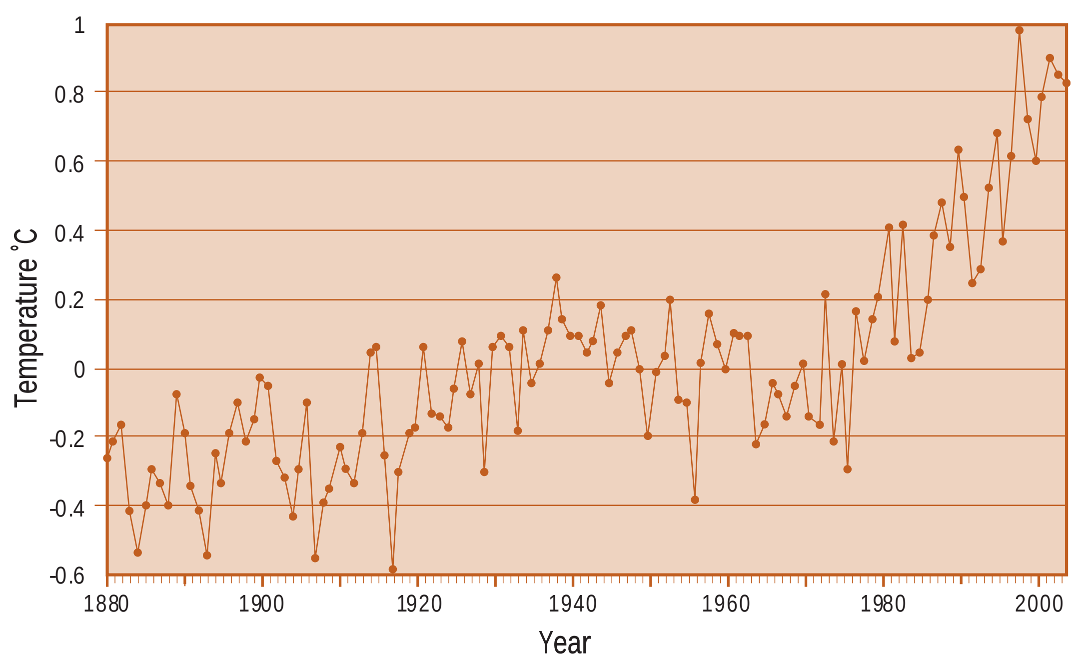



**Figure 18.14:** This graph of global temperature from 1880 to 2004 reveals that despite natural variations over the years, increasing temperature is the overall trend. *Courtesy of the U.S. National Oceanic and Atmospheric Administration*

### Recent Global Warming Attributed to Humans

In 1988, the World Meteorological Organization and the United Nations Environment Programme created the International Panel on Climate Change (IPCC). Its purpose was to assess available scientific information on climate change—and also the environmental, social, and economic impacts of climate change—and devise response strategies. By 1990, the IPCC included 2,500 climate change experts from more than seventy nations. This group's work has resulted in scientific consensus that humans have had a significant influence on climate. Canadian experts have played a key role in the IPCC's assessment process.

*"There is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities [and that] emissions of $CO_2$ due to fossil-fuel burning are virtually certain to be the dominant influence on atmospheric concentrations during the 21$^{st}$ century".*

The Intergovernmental Panel
on Climate Change (IPCC, 2007)

### Climate Models and Future Projections

Because climatologists cannot easily study global climate in a laboratory setting, they use sophisticated computer models of atmospheric and oceanographic processes to simulate the global climate of the future. Different climate models have been developed around the world. Each of these computer simulations provides a range of temperature projections to the year 2100, which vary according to differing assumptions about how successfully greenhouse gas emissions will be curbed over the next century.

The IPCC reviews the range of computer simulations to determine its own projections for temperature and sea-level rise. Its 2001 scientific report states that by the year 2100:

- Global mean temperature is expected to increase between 1.4°C and 5.8°C (relative to 1990 levels).

- The temperature increase will be uneven, varying in different areas around the world. It is expected that the air will warm more over land than over sea, and more warming will occur in the two Polar Regions than in the tropics.

- Thermal expansion of the oceans (water expands when heated) and the melting of polar ice caps and glaciers will increase the mean sea level by between 9 and 88 cm.

In most of the northern hemisphere, warming will increase the prevalence of extremely hot days and decrease the prevalence of extremely cold days. Warmer temperatures are predicted to lead to more intense precipitation (downpours) and longer periods between rainfalls. Even if precipitation increases moderately, warmer temperatures will cause a faster rate of evaporation, which will in turn lead to more frequent droughts.

**Figure 18.15:** As atmospheric carbon dioxide and temperature levels increase, it is predicted that ocean water temperatures will also increase. One exception to this is the ocean water temperatures off the east coast of Newfoundland and Labrador since large volumes of moving ice (i.e. icebergs and sea ice) from Canada's Arctic Region will melt. *Photo courtesy K. Bruce Lane Photography - lanephotography.com*

## Did You Know?

Temperature projections from a Canadian computer simulation show significant warming in central and northern areas of the country. Smaller temperature increases are predicted for coastal areas of Newfoundland and Labrador than the central and western areas of the province.

Greenhouse gases have a long lifetime in the atmosphere. This means that even if emissions were stopped today, global warming would continue for many years. Based on the amount of greenhouse gases in the atmosphere, and the amount we continue to add, it is highly likely that climate change over the coming century will exceed anything experienced since the end of the last ice age, 8,000 to 10,000 years ago.

Global warming is uncontrolled and historically unprecedented. Atmospheric carbon dioxide has already reached levels that have never been seen in human history (the last 200,000 years). Societies have not yet acted to adequately control the volume of human-caused greenhouse gases.

## CHECK your Understanding

1. What does the study of ancient pollen teach us about climate change?
2. Which areas of Canada are expected to have warmed the most by the year 2090? What is the expected temperature change for Newfoundland and Labrador? Is there variation within the province?
3. When a car is parked in the sun, the interior heats up more than the outside air—why? How is this similar to the greenhouse effect on Earth?

For Further Discussion and/or Research

4. If ice floating in the Arctic Ocean melts, will this affect global ocean levels? Explain.
5. What is "global warming potential"? If a kilogram of methane has twenty-one times the global warming potential of a kilogram of carbon dioxide, why is so much attention paid to the global warming effects of $CO_2$?
6. Sceptics are constantly trying to discredit the IPCC's wide-ranging scientific conclusions confirming climate change. What might be the basis for their scepticism? Is it factual or do other motivations drive their understanding of climate change?

### Potential Impacts of Climate Change

Climate affects everything on Earth—from society and economies to the planet's large and small ecosystems—and changes in climate can have complex and far-reaching effects. Initially, some local effects of climate change may seem beneficial (such as longer growing seasons in some locations), but on a global scale, it is thought that the negative impact will be far greater than the positive effects.

It is predicted that climate change is likely to cause forest productivity to decline and fish to migrate. Rising sea levels and storm surges will cause damage to coastline properties and ecosystems. Our health may be affected by heat stress, additional smog, and the northward migration of diseases. On the Canadian prairies, drought due to higher temperatures will probably be an ongoing concern. In Newfoundland and Labrador, changes may include wetter summers, more storm surges and coastal erosion, reductions in sea ice, and river flooding. Such changes in Newfoundland and Labrador's climate will in turn affect the province's ecosystems and natural resource industries.

*"Biological and economic systems tend to be optimized to the current climate . . . significant departures from that climate would be accompanied by some costs associated with readjustment to the new climate".*

Kevin Walsh
Principal Research Scientist,
Australian Commonwealth Scientific
and Research Organization

### 1. Wildlife and Natural Ecosystems

Climate is a key factor in plant and animal habitat. Climate change will therefore have an immediate and direct effect on each species in an ecosystem. Most changes in climate will affect each species' ability to successfully reproduce and compete. A few changes (such as severe weather events) may result immediately in plant and animal mortality.


**Figure 18.16:** Newfoundland is largely dominated by the Boreal climate zone **(a)**, but as atmospheric carbon dioxide and temperature levels increase, the Boreal climate zone (e.g., coniferous trees) is predicted to shift to the Temperate climate zone **(b)** (e.g., deciduous trees). Labrador is largely dominated by both the Boreal and the Arctic/Sub-arctic climate zones **(c)**. As carbon dioxide and temperature levels increase, the Arctic/Sub-arctic climate zone (e.g., shrubs, herbs, mosses, lichens) is predicted to shift to the Boreal climate zone.

Climate change will have dramatic affects on ecosystems in Canada. The predictions suggest that as climate warms, ecosystems will generally shift northward (or upwards on mountains). While individual plant species may do this, it is unlikely that entire ecosystems will simply move because:

1. Climate is much more than an average annual temperature. It is a complex pattern of temperature, rainfall, wind, sunshine or cloudiness, and storms or extreme events that occur throughout the year. It is unlikely that an entire climate pattern will simply shift northward.

2. Climate is not the only influence on where plant or animal species live. The soil type, day-length, and presence of water, prey, predators, and competing species also influence the ability of species to live and thrive in a particular location.

   For example, snow beds in the highlands of Gros Morne National Park usually last late into the summer, providing melt water for plant

Figure 18.17: Caribou on snow beds in Gros Morne National Park. *Photo courtesy Parks Canada/ Gros Morne National Park*

communities and a cool refuge for caribou seeking relief from flies. There is less winter snowfall now than forty years ago, however, and the snow beds are disappearing earlier in the year.

3. Species move (change their ranges) at different rates. Given the speed at which we expect climate to change over the next century—and the long life cycle of many species (such as trees)—not all species in an ecosystem will be able to move as quickly as the climate will change.

4. Changes in climate will not only directly affect individual species, but also their predators, prey, and competitors—and it will affect each species differently. For example, as the climate warms, a species with life events (such as breeding or migration) that respond to temperature may start to experience those events earlier in the year. Yet species whose life events are triggered by length of day (number of hours of light) will not be affected since climate change will not alter day length. The delicate relationship between events within an ecosystem (such as the presence of pollinating insects coinciding with the time plants are in flower) could be thrown off kilter by climate changes, especially if they prove to be permanent.

5. Increasing levels of carbon dioxide in the atmosphere will affect each species differently. During photosynthesis, all green plants take in $CO_2$. Higher atmospheric levels of the gas will benefit some plant species more than others, which will change the mix of plant species. This will affect animal species that use these plants for food or shelter.

6. Changes in climate will decrease biodiversity. The changes may make habitats for some specialized species less desirable. Specialized species are extremely well adapted to a very narrow range of habitat characteristics, but poorly adapted to other habitats. In the past, many species have become extinct even when habitat changes were slow. In the short time over which climates will change in the future, more species are likely to fail to adapt and so will disappear.

**Figure 18.18:** The Newfoundland marten is an example of a species with specific habitat needs. *Photo courtesy Parks Canada/John Gosse*

It is also possible that some habitats will disappear completely. The most severe impact may be the shrinking of the Arctic sea ice. This frozen platform is integral to the lives of a wide range of species, such as polar bears, ringed seals, and walruses, that feed, travel, and breed on its vast expanses. Algae living under the sea ice are the foundation of an ocean food chain that supports plankton, copepods, fish, sea birds, and mammals. The average thickness of the sea ice has shrunk by forty percent in the past three decades, jeopardizing the future of this web of life.

Consequently, it is highly unlikely that Newfoundland and Labrador will be experiencing the same vegetation types as today in the year 2070. Instead, the region will more likely be experiencing biodiversity loss and the scrambling of ecosystems—the mix of species found in an ecosystem today will be different from the mix found in the future. Climate change will add to the pressures on ecosystems, including those of air, water, and land-based pollution, loss of habitat due to agriculture, forestry, and urban sprawl, and hunting and fishing.

## Did You Know?

According to the Canadian Wildlife Service and Canadian Wildlife Federation, "The far-reaching impacts of climate change may be felt nowhere greater than in Canada's Arctic, one of the fastest-warming regions on Earth. With winter temperatures rising by 5 to 10°C in this century, northern habitats could experience the greatest climatic impacts of all: increasing snowfall, eroding shorelines, melting permafrost, and warmer oceans".

### 2. Natural Resource Industries

#### Forestry

At first glance, it might appear that global warming could increase forest productivity in Canada and maybe even in Newfoundland and Labrador. However, as outlined in the previous section, forest ecosystems will be subjected to changes in climate, range, and biodiversity.

**Figure 18.19:** Re-growth following a forest fire in Newfoundland and Labrador. Climate change may result in an increased frequency of forest fires in the province. *Photo courtesy Parks Canada/Janet Feltham*

Where forest management practices involve replanting large stands, knowing how the local climate is likely to evolve over the lifespan of the trees can help planters decide which species to plant. Forest managers can help forests adapt to climate change by choosing species that are likely to be more resistant to new pests, more frequent drought, warmer seasons, and stronger winds.

## Agriculture

Climate plays a key role in farming. Not only are average temperatures important, but so, too, are the length of the growing season (time between last and first frost), precipitation (too much or too little, not enough at the right time), frequency of extreme weather events, and the sensitivity of crop types to specific weather conditions.

Effects of projected greenhouse gas and sulphate aerosol increases

- Less precipitation in the Great Plains and Southeast U.S.
- More precipitation in the Arctic
- More extreme weather conditions

**Figure 18.20:** Climate change may lead to increased temperatures and decreased precipitation, thereby having a drastic effect on the most important agricultural areas in North America.

The projected climate for the period 2080 to 2100 suggests that significantly less precipitation may fall over parts of the Canadian prairies and the Great Plains in the United States. These areas are among the most important agriculture areas in North America. The projected precipitation is based on a climate model *scenario*—it is not a prediction per se. A combination of significantly warmer temperatures (which would cause faster evaporation) and significantly less precipitation would lead to drought. Drought would reduce the ability to maintain the current level of food production, with potentially disastrous consequences. On the other hand, if the amount of rainfall on the prairies and the Great Plains increases sharply, the ability to produce food in these key areas may rise.

In parts of Atlantic Canada, more precipitation may fall as heavy thunderstorms—over fewer days—which could result in flash flooding, more water run-off, and longer periods between rainfalls. If these conditions are combined with warmer temperatures, farmers in some areas of Atlantic Canada may have to consider installing high-cost irrigation systems. In addition to drought, crops are also sensitive to strong winds and hail, both of which are typically associated with severe thunderstorms.

Agriculture is a highly managed industry with a short turnover time (one or more crops per year). This means that farmers may be able to grow different crops as the climate changes. Some crops that need warmer summers and a longer growing season, which are not currently practical to grow in Atlantic Canada, may be grown here in the future. If summers become drier, farmers may find it easier and more economical to change to crops that require less water than to install irrigation systems.

#### Fishery

Predicting the possible effects of climate change on fish populations is difficult because of the many forces at play. Some of the main interconnecting factors include commercial fishing activities, the effects of pollutants, biological predation, competition for nutrients, availability of breeding grounds, water temperature, and availability of light. All things considered, however, the anticipated impact of climate change on marine resources is expected to be major.

Among the large-scale unknowns in the Atlantic region is how the possible warming of marine currents will affect inshore migratory fish populations. Atlantic cod, for example, will grow faster with an increase in water temperature. Capelin, however—which is a major food source for cod—prefer cooler water temperatures (2 to 4°C), so they might migrate if waters warm too much.

Like capelin, salmon and trout prefer cooler water, which is rich in oxygen. In the Atlantic region, young salmon (smolts) overwinter in the rivers of eastern Canada, but adults overwinter in the Labrador Sea. When and how many salmon return to the rivers to spawn is directly related to their success in the ocean environment, which is affected by water temperature. Studies have found that small changes in water temperature also affect the reproductive survivorship, long-term growth of juvenile salmon and distribution of the snow crab populations on the Eastern Scotia Shelf and the Grand Banks of Newfoundland.

Changes in commercial fish species may mean that fishers will have to change their practices. They might have to fish for different species, fish at different times of year, or go farther offshore. Making these adjustments might require investments in new equipment. The regulations about where and when fishing can occur, and which species can be caught, may also have to be adapted.

### 3. Coastal Zones

After examining a number of models, the Intergovernmental Panel on Climate Change estimated that global sea-level rise will be about half a metre by 2100. The range is from a low of 9 cm to a high of 88 cm—for planning purposes an average of 50 cm is commonly used.

Sea-level rise is a cause for concern because it increases coastal erosion and also the flood damage from storm surges that go along with it. As well, freshwater supplies located close to ocean coastlines may be infiltrated with salt water.

**Projected Global Sea Level Rise Year 1990 to 2100**

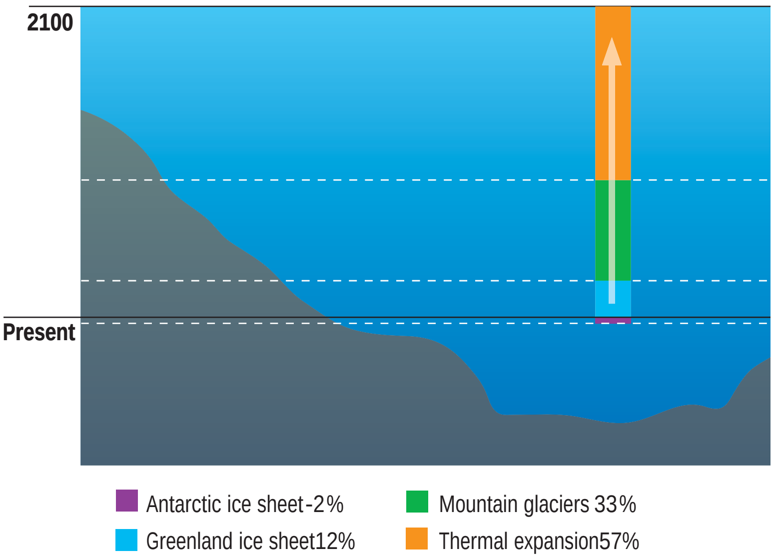



**Figure 18.21:** The projected global sea-level rise by 2100. *Courtesy of IPCC/Third Assessment Report, 2001*

### The Cause of Global Sea-level Rise

The two main causes of a projected *global* sea-level rise are the thermal expansion of ocean water (a fifty-seven percent contributor) and melting ice on land (forty-three percent). Most of the melt-water is predicted to come from receding glaciers and the Greenland ice sheet. Current climate predictions for the next century indicate that the Antarctic ice sheet will still be too cold to melt. In fact, it is predicted to grow slightly because of increased precipitation and the consequent accumulation of snow.

### Regional Sea Levels

Predicting sea-level rise for specific regions, including Atlantic Canada, is even more complex. Regional sea level can be affected by:

- global sea-level rise;
- changes in ocean currents; and
- the sinking or rising of land as a result of geological processes, such as when tectonic plates are pushed down or land rebounds from the weight of previous ice sheets.

In Canada, the impact of tectonic subsidence (or sinking land) on sea level over the past century has been most evident in the Maritimes, the south and southeast coasts of Newfoundland, and southern Labrador. Records across the Maritimes show a trend to rising sea levels, in the range of 19 to 21 centimetres per century depending on the location. The southern and southeastern coasts of Newfoundland have also experienced a relative rise in sea level (37 centimetres per century at Port aux Basques and 30 cm per century at St. John's).

Using an average for the southern half of the Atlantic region, the rise in sea level caused by sinking land is in the order of 10 to 30 centimetres per century. If this sinking trend continues and climate change causes the projected rise in global sea level (approximately 50 centimetres per century), the combined result could be a sea-level rise of 60 to 80 centimetres across much of southern Atlantic Canada by the year 2100.

## Main Effects of Climate-Attributed Sea-level Rise

**Figure 18.22:** Admiral's Beach on the Avalon Peninsula, Newfoundland and Labrador, showing evidence of coastal erosion. *Photo courtesy Department of Natural Resources.*

Higher sea levels mean that wave energy is directed higher on the shoreline, which increases the rate of coastal erosion. The predicted climate change-induced increase in storm intensity will further speed the erosion rate.

Newfoundland and Labrador's mainly rocky coastal geology may be more resistant to erosion than other areas in Atlantic Canada, but damage to harbour infrastructure could increase. Currently, on the Island, most of the coastline north of an imaginary line between Bay Roberts and Rocky Harbour is protected from the full force of winter storms by sea ice, which dampens the energy of incoming waves. If global warming causes the amount of winter sea ice to decrease, the northern shoreline will be exposed to more wave energy.

Sea-level rise is not expected to permanently flood large areas of Atlantic Canada. But even now, many coastal areas in the region are at significant risk of flooding during storms. A rise in average sea level would mean that storm surges could cause more frequent damage to coastal buildings, roads, bridges, ferry terminals, and other infrastructure, and could potentially contaminate coastal freshwater wells (which is called saltwater intrusion).

### High Water Extremes

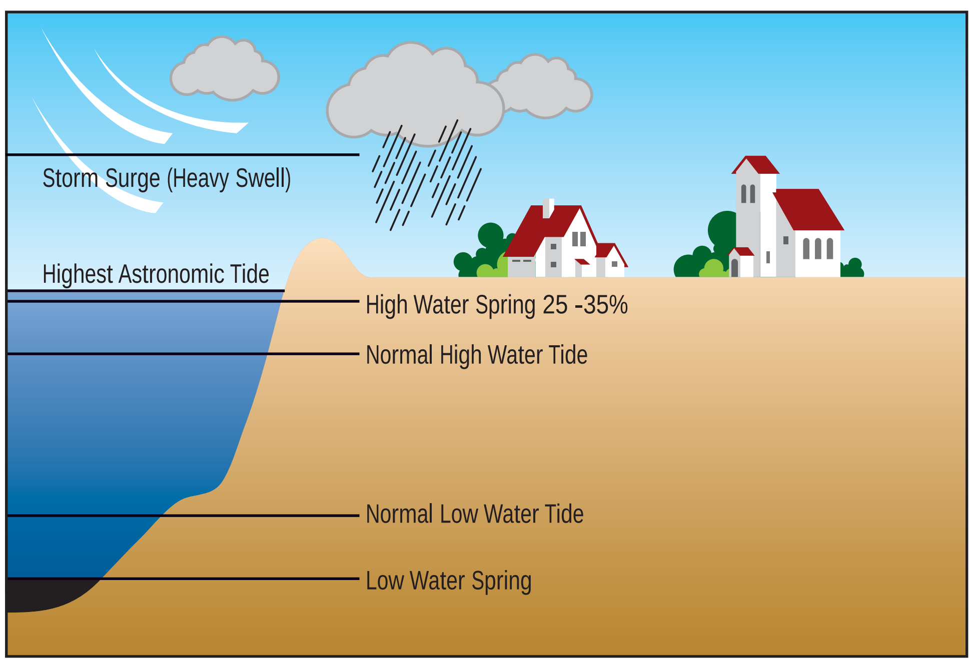



**Figure 18.23:** A rise in average sea level will increase the risk of flooding by storm surge. *Courtesy Environment Canada*

**Figure 18.24:** Frenchman's Cove on the Burin Peninsula is one community in the province that is particularly vulnerable to sea level rise. *Photo courtesy Elroy Grandy*

The Geological Survey of Canada (GSC) has assessed the sensitivity of Canada's coasts to sea-level rise based on the land elevations, landforms, rock types (vulnerability to erosion), past sea-level trends, tidal range, wave heights, and existing rate of shoreline movement. According to the GSC, three percent of the Canadian coastline is highly sensitive to rising sea levels, thirty percent is moderately sensitive, and sixty-seven percent has low sensitivity.

**Figure 18.25:** Because it lies near sea level Placentia is vulnerable to flooding caused by sea level rise.
*Photo courtesy Vicky Taylor-Hood*

In Canada, the Atlantic region has the greatest length of coastline susceptible to the impacts of sea-level rise (erosion and flooding). Areas of particular concern in the region are Prince Edward Island's north coast, the head of the Bay of Fundy, and Nova Scotia's Atlantic coast.

The areas most sensitive to sea-level rise in Newfoundland and Labrador are, from north to south:

- low-lying parts of coastal Labrador, south of Makkovik;
- the Strait Shore, from Cape Freels to Musgrave Harbour;
- the southern shore of Bay St. George; and
- the southern shore of Fortune Bay, including Grand Bank.

| Sea-level Rise: Additional Areas of Concern on the Island Portion of Newfoundland and Labrador | | |
|---|---|---|
| **Location** | **Context** | **Issue** |
| Conception Bay South | Coastline is receding at rates of 30–50 cm per year | Primarily erosion: incremental and storm-related |
| Middle Cove and Outer Cove | Rates of erosion similar to Conception Bay South | Incremental erosion |
| Placentia | Much of the town is near sea level | Flooding |
| Placentia Bay (Marystown–Burin–Lamaline) | Low-lying areas in landscape | Flooding |
| Eastport Peninsula | Coastline is receding | Primarily erosion: incremental and from north-easterly storms |
| Coom's Cove and Seal Cove (Coast of Bays) | Coastline is receding | Primarily erosion from southwesterly storms, with some flood risk |
| The Beaches (White Bay) | Low-lying areas, and coastline is receding | Flooding and storm surge, and erosion during storm surge |

**Figure 18.26:** *Courtesy of Norm Catto, Department of Geography, Memorial University*

**Figure 18.27:** The area adjacent to the lighthouse at Point Verde, Newfoundland and Labrador, continues to experience a receding coastline. *Photo courtesy Department of Natural Resources.*

4. Increased Number of Extreme Events

It is difficult to blame global climate change for any specific storm or weather event. As the table below shows, however, changing climate will likely cause several types of extreme weather to become more common or less common. The table's third column reflects the level of scientific confidence about the likelihood that the event will occur. "Very likely" indicates ninety percent or greater confidence of occurrence; "likely" means sixty to ninety percent confidence.

**Projected Frequency of Extreme Events Globally**

| Extreme Event | Trend with Climate Warming | Confidence |
|---|---|---|
| Thunderstorms | More frequent and severe | Very likely |
| Heat waves | More frequent | Very likely |
| Cold waves | Less frequent | Very likely |
| Floods | More frequent | Very likely |
| Drought | More frequent, possibly prolonged | Likely |

**Figure 18.28:** A Tropical Storm about to hit Newfoundland in July of 2006.

### Hurricanes

The track of an Atlantic Ocean tropical cyclone (hurricane) typically begins in the southeastern North Atlantic and progresses northwest toward the Caribbean Sea. Some hurricanes will curve northward and then north eastward toward Atlantic Canada. They feed off the warmer water of the tropical North Atlantic and typically diminish in strength as they move over the colder waters south of Atlantic Canada.

With global warming, southern sea-water temperature is expected to rise. This is projected to result in *more intense* hurricanes in the North Atlantic Basin. Atlantic Canada, already on the track of many systems, will be increasingly vulnerable to the impact of these storms.

### Vulnerability to Extreme Events

Not only is climate change playing a role in making weather more extreme, our vulnerability to extreme weather is related to human behaviour: people around the world are continuing to build in locations that will be at risk during severe weather. In some countries this may be because of population explosion and a lack of space or options to build in safer areas. In North America, however, continued expansion into vulnerable locations is due primarily to people's desire to live by the sea and their lack of understanding about how vulnerable particular landscapes are to weather-related hazards. Their risk is also increased by building designs that aren't site appropriate (such as including a finished basement in houses located in flood zones) and a lack

**Did You Know?**

Because of a major ice storm in Quebec in 1998, more than 2.6 million people (nineteen percent of Canada's labour force) had difficulty getting to work, or couldn't get to work at all. Close to 1.4 million Quebec electricity customers and more than 230,000 Ontario residents and businesses were without electricity for weeks. More than a thousand transmission towers and 30,000 wooden utility poles were downed. More than $1 billion in insurance claims were filed.

of land-use planning and/or environmental regulations that protect both vulnerable coasts from society, and society from severe weather along coasts.

Extreme weather can result in significant economic loss. Adaptation strategies that can lower our vulnerability to anticipated climate-change extremes that disrupt our electricity supply include strengthening or burying key electrical transmission lines and installing alternative heat sources (such as propane or woodstoves, or solar heating).

Closer to home, tropical storm Gabrielle (September 18 and 19, 2001) resulted in severe flooding in the northeast Avalon Peninsula—more than 120 millimetres of rain fell in some locations. The storm caused extensive damage and cost taxpayers $6.7 million for flood compensation. A year earlier, in January of 2000, Newfoundland experienced one of the most damaging weather events in recent history. Storm surge activity along the south coast of Newfoundland, from Channel-Port-aux-Basques east to the Burin Peninsula, caused damages that cost more than $3 million.

### 5. Human Health

All human health is ultimately dependent on the health of Earth's biosphere. Scientists believe that climate change will have major, irreversible effects on the environment and cause secondary consequences for human health and well-being that could occur within a matter of decades. These impacts could include increased mortality and illness caused by heat stress and increased air pollution, a higher incidence of insect-borne infectious diseases, and impaired food production.

*"As physicians, we fear that global climate change carries with it significant health, environmental, economic, and social risks and that preventive steps are justified".*

From the Physicians' Statement
on Climate Change, 2002
David Suzuki Foundation

#### Heat Stress

More frequent and severe heat waves may lead to an increase in illness and death, particularly among the young, the elderly, the frail, and the ill, especially in large urban areas. This is because heat waves amplify existing medical problems. In the summer of 2003, a heat wave caused about 14,800 heat-related deaths in France—it is an extreme example of the kind of event that could become more frequent with a rise in global temperature.

A research project undertaken jointly by the City of Toronto, Environment Canada, and Health Canada estimated that an average of seventy-nine people die of extreme-heat-related causes in Montreal and Toronto each year. Due to the increasing impacts of climate change, the study predicts that heat-related deaths in Canada will increase dramatically during the twenty-first century. It also projects that by the 2050s, heat-related deaths will more than double, and by the 2080s deaths in southern central Canada will triple.

*" [If we] treat the planet as if it was a business in liquidation, to convert our natural resources to cash as quickly as possible ... we can generate an instantaneous cash flow and the illusion of a prosperous economy".*

- Robert F. Kennedy Jr.

In anticipation of more intense and more frequent extreme heat events, the City of Toronto implemented a Heat-Health Alert system in 2001. The system uses computer models to determine when the probability of heat-related deaths could reach sixty-five percent, at which point the city issues a heat alert. When the probability percentage reaches ninety, an extreme heat alert is issued. During these alerts, cooling shelters open, vulnerable people are offered water, and an emergency vehicle with a specially trained paramedic goes into active service.

### Migration of Diseases

If the average global temperature increases, the range of diseases normally associated with warm climates may expand into regions that were formerly too cold. Some illnesses with the potential to expand northward include mosquito-borne diseases such as malaria, dengue fever, and yellow fever. Increased control measures, such as disease surveillance and prompt treatment, may help reduce the incidences of human illness.

### Adapting for Anticipated Climate

In all these areas of concern, taking steps now can help us prepare for predicted changes to the landscape. For example, we can reduce future financial losses and protect human life by establishing setbacks, which prescribe the distances that structures must be from a defined edge—in this case from areas where sea-level rise may cause erosion or flooding. Buildings, bridges, wharfs, and other structures should also be built to withstand the climate extremes that are expected during their lifetimes, not just the type of storms that we experience today.

**Rising Sea Level: Adaptation Responses**

| Approach | Action and Outcomes |
|---|---|
| Prevent the loss | Construct a sea wall |
| Tolerate the loss | Take no action, lose land |
| Spread/share the loss | Insurance, government assistance |
| Change usage or activity | Convert resort area to farmland |
| Relocate | Move cottage farther inland |
| Research and monitor | Measure erosion |
| Educate | Inform stakeholders |

**Figure 18.29:** *Courtesy of Environment Canada/ Steve Szabo, Atlantic Climate Change Section*

Many of the steps we can take to reduce our vulnerability to future climate change will also help us deal with existing climate extremes. For example, moving residential development back from coastal areas reduces our vulnerability not only to a future sea-level rise, but also to the existing threat of storm surges. Restricting building projects in flood plains reduces the risk of present and future flood damage. Installing larger storm-water pipes in new subdivisions to handle larger average storms in the future will reduce the risk of flooding during extreme storms today.

Adaptation is only a partial response to some of the challenges of course. Climate change may have many impacts for which there are no feasible or possible adaptation measures. For example, while the developed world may be able (at very high cost) to build sea walls to protect *some* existing communities, it is cost-prohibitive to protect most of the world's coastal areas with this approach.

## CHECK your Understanding

1. List the potential impacts of climate change on Newfoundland and Labrador, ranking them from what you consider to be the most important to the least important. What factors did you consider in prioritizing your list?
2. What is expected to be the largest contributor to global sea-level rise over the next hundred years?
3. Name two major threats that climate change poses to human health. Briefly explain why they are threats. Discuss possible adaptive measures that could reduce the impact of these two threats on human health.
4. Given that we expect most areas of the Earth to warm as a result of climate change, can ecosystems simply move toward the poles (or toward higher elevations) to stay within their preferred climate?
5. In general, what types of species are most at risk from climate change?
6. Are there feasible adaptation steps that we can take to fully protect ecosystems from the effects of climate change? Explain your answer.
7. Give examples of three possible measures that could be taken to adapt to sea-level rise.
8. Why might some areas of Newfoundland and Labrador be considered highly susceptible to sea-level rise? Use specific examples.

### For Further Discussion and/or Research

9. Humanity has experienced and survived climate change before (for example, during the last ice age). Should we be concerned about future climate change? Explain your reasoning.
10. List some island nations or delta areas outside Canada that are susceptible to sea-level rise. What steps could leaders take to protect people from coastal erosion and/or flooding?
11. Why does sea-level rise threaten their supply of fresh water?

# Chapter 19: Actions to Address Climate Change

**Figure 19.1:** Reducing greenhouse gases is going to take a commitment from all nations.

## INTERNATIONAL EFFORTS TO REDUCE GREENHOUSE GASES

Two of the most significant international agreements to reduce global greenhouse gas emissions are the *Rio Declaration* and the *Kyoto Protocol*.

### Rio Declaration

In June of 1992, in Rio de Janeiro, Brazil, the world's developed nations agreed under the United Nations Framework Convention on Climate Change "to consider what can be done to reduce global warming and to cope with whatever temperature increases are inevitable". Among its key contributions, the *Rio Declaration* introduced the "Precautionary Principle".

The Precautionary Principle states: "In order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation."

Source: UNEP

### Kyoto Protocol

The details of implementing the United Nations Framework Convention on Climate Change were negotiated in a series of meetings called Conference of the Parties. In 1997, after the third Conference of Parties in Kyoto, Japan, the *Kyoto Protocol* was adopted. This Kyoto Protocol laid out a basic framework for how nations would work together to reduce greenhouse gas emissions. For the Kyoto Protocol to come into effect, it had to be signed by fifty-five industrialized nations that accounted for at least fifty-five percent of the total global GHG emissions produced in 1990.

The *Kyoto Protocol* was ratified by 140 signatory countries. It officially came into effect on February 16, 2005. The *Kyoto Protocol* required that greenhouse gas emissions in the signatory countries, including Canada, be six percent less than their 1990 emissions, averaged over the period of 2008 - 2012. Negotiators for Canada agreed to the *Kyoto Protocol*, but successive Canadian governments have refused to pass the laws needed to require people to take action.

## Did You Know?

When measured on a per capita basis, Canada is among the world's top three emitters of greenhouse gases. Comparatively, many European nations that have climates and standards of living similar to Canada's emit less than half of the greenhouse gases per capita than we do!

Developing nations have very low emissions per capita and are not required to reduce their emissions under the Kyoto Protocol.

The *Kyoto Protocol* alone will only slightly reduce the impacts of climate change, but it is a necessary step. When it expires in 2012, other agreements must be in place to continue and strengthen efforts to reduce greenhouse gas emissions.

## ECONOMIC APPROACHES TO REDUCING GREENHOUSE GASES

Several different economic strategies can be used to help achieve emission reductions at domestic and international levels. These include:

Taxes: Taxes based on the production of greenhouse gases, which are called carbon taxes, can encourage businesses or people to produce less greenhouse gases. Many European countries, for example, have decreased income taxes and increased taxes on gasoline, oil, coal, and natural gas. As a result, fuel costs much more in Europe than in North America, which has encouraged people to reduce how much they use.

Subsidies: Subsidies can be paid to people or businesses to promote a desired behaviour. For example, a government can choose to remove taxes from hybrid vehicles, solar energy systems, or home energy-efficiency supplies such as weather stripping in order to encourage people to use them. Governments can—and do—subsidize public transit, which provides a greener alternative to travelling by car. In some cities, bus and ferry tickets would cost much more if government did not contribute to their operational costs. Government can also provide rebate cheques to people who have spent money improving the energy efficiency of their homes. Subsidies can also go to businesses to promote energy efficiency in their operations, or for generating or using renewable energy such as wind.

**Figure 19.2:** Public transit like the subway is a greener alternative to travelling by car.

Regulations: Regulations that are enforced by law may require that appliances, vehicles, and electronic equipment meet minimum standards of energy or fuel efficiency. These standards define the maximum amount of energy an item should consume when it is running or operating. For example, regulations state that in order to be ENERGY STAR®-qualified, a refrigerator must exceed minimum federal energy-efficiency standards for energy consumption by at least ten percent.

**Figure 19.3:** ENERGY STAR qualified appliances incorporate advanced technologies that use 10–50% less energy than standard models.

Cap and Trade: Also called "allowance trading", this approach limits (or caps) the amount of pollution that can be emitted from regulated sources (such as a power plant) in a specified time period. An allowance allows a company to emit a fixed amount of a pollutant. If it exceeds its cap, it can buy (trade for money) allowances from another source that has not used its total.
At the end of the period, the amount of allowances that a regulated source owns must be the same as the amount of emissions that it produced.

Clean Development Mechanism is a process in which developed nations can receive financial credit for building projects that reduce the amount of greenhouse gas emissions. This allows investment to flow to projects that achieve the greatest emissions reductions at the lowest cost (dollars per tonne), regardless of where they are in the world. This approach can be applied to projects such as renewable energy developments (wind farms, for example), and plants that produce electricity from coal—both of which are highly efficient and sequester carbon dioxide.

**Figure 19.4:** St. Lawrence Wind Turbine project. *Photo courtesy Greg Oliver, Penney Industrial Limited*

## Summary

As our scientific understanding of climate change has matured, governments have acted with efforts to reduce greenhouse gas emissions in order to reduce the severity of climate change impacts. Their most notable effort is the *Kyoto Protocol*. Canada's *Kyoto* commitment would require a six percent reduction in greenhouse gas emissions from our 1990 levels. As a means of achieving such targets, Canada and other countries around the world are devising strategies to reduce greenhouse gas emissions worldwide. Some of the strategies provide financial incentives to reduce emissions, some provide necessary education, and others use regulations.

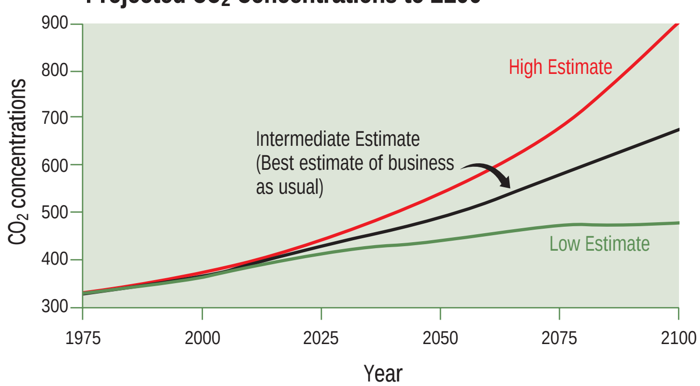
## CHECK your Understanding

1. While some subsidies can be used to reduce greenhouse gases, others are being used to assist industries that explore, extract, and process fossil fuels, which keeps market prices of fuel "artificially low".
   a) Why might governments subsidize the fossil fuel industry?
   b) How might the different levels of subsidies on fossil fuels and on renewable energy industries affect the growth of each?
   c) Should either the fossil fuel or renewable energy industries be subsidized? Give reasons for your answers.

### For Further Discussion and/or Research

2. Sweden's per capita emissions of greenhouse gases are one third of Canada's. What differences in how the Swedes design their cities, heat their buildings, and generate electricity makes this possible? Your answer should include the role of geography.
3. The *Kyoto Protocol* is an important first step in reducing risks associated with climate change. What other political steps might be taken?
4. Over the last twenty years, taxes on fossil fuels have been much higher in Europe than Canada. How does this relate to Europe emitting much lower amounts of greenhouse gases per unit of gross domestic product (GDP) than Canada?
5. What effect do you think the strategy of reducing taxes on income and increasing taxes on fossil fuels would have in Newfoundland and Labrador? Would this be a good idea?
6. In the graph below, the "high estimate" assumes economic growth and increased coal use worldwide, which will lead to concentrations of carbon dioxide of up to 950 parts per million volume by 2100 (more than three times pre-industrial levels). The intermediate estimate projects a concentration of about 770 ppmv by 2100. The lowest estimate would stabilize greenhouse gas emissions at 1990 levels (about seventy-five percent of pre-industrial levels).
   a) To achieve the lowest estimate, what role could changes in population size play?
   b) What is the role of renewable energy in achieving the "low estimate" target? What kinds of activities will prevent society from achieving the low estimate?
   c) The low estimate can only be achieved if there is no economic growth or if the population of humans on Earth drops drastically. Do you think either of these is realistic? Why or why not?

**Projected $CO_2$ Concentrations to 2100**



## INDIVIDUAL ACTIONS TO REDUCE GREENHOUSE GAS EMISSIONS

Our ability to reduce greenhouse gas emissions depends on the choices we make as individuals and as a society. We make personal choices about how we travel, how much electricity we use, how we heat our homes, and what we buy. As a society we make choices about how we generate electricity, design our cities, and price and regulate our energy. What we choose to do influences the rate and magnitude of human-induced climate change.

This section discusses three of Newfoundland and Labrador's major sources of greenhouse gases: transportation, electricity production, and space and water heating in buildings. It examines how we can reduce greenhouse gas emissions from these sources by reducing our demand for energy, using renewable energy sources and cleaner fuels, and using energy efficiently once it reaches homes and work spaces.

### 1. Transportation

#### Reducing the Need for Transportation

Reducing the need to drive or take fossil-fuel driven transportation is one of the most effective ways to reduce greenhouse gas emissions. An ideal vision for a community with low energy use is a neighbourhood where frequent destinations (work, school, daycare, food stores, and recreational and health centres) are all close to where we live.

Reducing our use of motorized transport is more likely to work in car-free, compact, "mixed-use" communities. A mixed-use community has a variety of detached houses, townhouses, apartments, localized commercial and office buildings, schools, recreational centres, and green spaces that are all connected by a network of streets and pedestrian and bicycle pathways. Today, in many suburban areas across North America, including a number of communities in Newfoundland and Labrador, very few destinations are within walking distance from people's homes, yet such conditions were common in small towns a generation ago. Re-designing suburban spaces to reflect small-town characteristics could decrease our dependence on cars, and thus reduce greenhouse gas emissions.

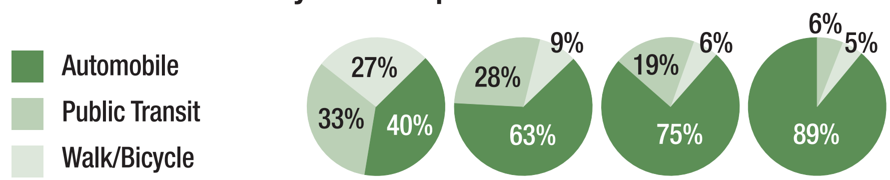
**Figure 19.5:** Reducing our use of motorized vehicles is a very effective way to reduce greenhouse gas emissions.

# CASE STUDY

## The Effects of Urban Density on Transportation

The figure below illustrates the impact of residential density on transportation choices in urban areas, using Toronto as an example. In that city's core, which has a density of 8,500 people per square kilometre, only forty percent of trips are made with an automobile.

### Effect of Urban Density on Transportation




| Toronto, Ontario | Core | Core Ring | Inner Suburbs | Outer Suburbs |
|---|---|---|---|---|
| Trips/day/capita | 2.06 | 2.23 | 2.26 | 2.51 |
| Motorized distance (km) | 12.5 | 15.0 | 17.3 | 25.7 |
| Households with no car | 52% | 31% | 17% | 6% |
| Residential density (p/km$^2$) | 8500 | 5900 | 2900 | 2000 |

Moving out from the core to lower-density suburbs, the proportions that biking, walking, and transit can claim have all decreased. By the outer suburbs, almost ninety percent of trips are made with an automobile.

Analysis

1. What is the trend in population density as one moves from the city core to the outer suburbs?
2. What could be put in place to reduce the increased dependence on the automobile for those living in the suburbs?
3. What changes in attitudes may have to be made to reduce the use of the automobile by people living in the suburbs?
4. Rates of obesity are much lower in urban areas. Account for this by referring to the data above.
5. Where do you think most public transportation is available, in the city core or in the suburbs? What might be the major barriers to increasing availability to public transportation to residents in the suburbs?
6. What factors contribute to the fact that 52% of the residents that live in the city core do not own cars?

In just over a century, Western society has become amazingly dependent on cars. To minimize driving a vehicle, we must devise creative strategies for rural and urban settings. A single person that chooses to car pool, walk, cycle, or use public transit will create significantly less greenhouse gases than if he or she drove alone in a car. In some workplaces, options that reduce the need for work-related driving include using conference calls or video conferencing, or working from home (telecommuting). Working slightly longer days in order to eliminate one day of work every second week can reduce travel emissions by ten percent. Another option is the "Walking School Bus": an arrangement whereby community volunteers walk with groups of elementary school children to school. This provides children with exercise and reduces the number of car-driven trips to school.

### Using Alternative Fuels

Most cars, trucks, ATVs and other vehicles today are powered by engines that burn fossil fuels, and there is no easy solution to immediately eliminate all the greenhouse gases that come from their tailpipes. Some alternatives are being used in limited numbers, however. The main options are discussed in this section.

#### Biofuels

Biofuels are produced from non-fossil organic material (biomass). Ethanol and biodiesel are two examples of biofuels.

**Figure 19.6:** Ethanol from the plant in Aylmer, Ontario will serve as an alternative fuel for powering engines (e.g., in vehicles) in the near future. *Photo courtesy Integrated Grain Processors Cooperated*

Ethanol, also known as ethyl alcohol, is a chemical compound made from fermenting and distilling crops such as corn, sugar cane, grains, or agricultural and forestry residue. Ethanol can be blended with gasoline to increase the gasoline's octane—which improves engine performance—and to reduce end-of-pipe emissions. Biodiesel is produced from vegetable oil (from soybeans and canola), animal fats, fish oils, or waste fats.

Although using biofuels can reduce greenhouse gases, using them is not without drawbacks. Growing crops, converting biomass to biofuel, and transporting the biofuel all use energy. The challenge to making biofuels a viable alternative is to use less energy to grow the crops and create the fuel than the amount of energy the fuel itself will eventually provide. As well, growing crops specifically for biofuels raises land-use concerns. Using valuable farmland exclusively for energy crops limits our ability to grow food, which will be a concern. As populations continue to grow and as the demand for the crops increase, food prices will increase.

Growing some crops for biofuels—such as sugarcane in Brazil—makes both economic and environmental sense. No North American crop for biofuel currently meets the requirement for either economic or environmental gain. However, the United States has made a major effort to turn corn into ethanol, which has driven up the cost of corn, but the energy returned and energy used from this source are about the same. The project is continuing only because of government subsidies. Low-grade recycled cooking oils, fats, and greases, such as the waste produced in restaurants or slaughterhouses, can be processed economically into environmentally friendly biodiesel for a standard diesel engine.

### Electric Vehicles

Despite what many people think, electrically powered vehicles are not completely climate friendly and clean. They have no direct tailpipe emissions, but they do require electricity to recharge their batteries. Because any large additional demand for electricity on the North American electricity grid (the web of power lines woven across the continent) is usually met by fossil fuel-driven generators, plugging in the car can cause greenhouse gas emission. The introduction of electric cars across North America would almost certainly increase fossil-fuel combustion for electricity production, and add additional GHG output.

Reducing Fossil Fuel Use: Driving Checklist

- Buy the most energy-efficient car that will meet your needs.
- Avoid aggressive driving.
- Drive at the posted speed limit.
- Keep idling to a minimum.
- Warm up your vehicle by driving it, not idling.
- Keep your tires properly inflated.
- Minimize your use of air conditioning.
- Plan your trips to avoid unnecessary driving.

### Fuel Cells

Like electric vehicles, cars powered by fuel cells have environmental limitations. Fuel cells need a source of hydrogen, which is often produced through the electricity-demanding process of water electrolysis. If the use of fuel cells were to become common, the additional demand for electricity (required for electrolysis) would likely have to be met by fossil fuel-driven generators. Similarly, if the hydrogen is created using a fossil fuel, then this approach cannot be considered a renewable energy solution.

### Diesel-fuelled Vehicles

Diesel-fuelled engines are twenty to thirty-five percent more fuel efficient and durable than gas-fuelled engines. "Better fuel efficiency", however, does not necessarily equate with "better for the environment" or "better for human health".

Diesel vehicles emit less carbon dioxide than comparable gasoline-fuelled vehicles, but they often emit higher levels of nitrogen oxides and particulate matter, which are key ingredients of smog. Overall, even though diesel engines emit fewer greenhouse gases, the serious degradation of air quality they do cause makes them a questionable substitute. As diesel technology continues to advance, the air-quality impact of this fuel may be reduced.

### Gas-electric Hybrids


**Figure 19.7:** A gas-electric hybrid car on the showroom floor at Toyota Plaza, St. John's, Newfoundland and Labrador. *Photo courtesy Sheldon Marsh*

A gas-electric hybrid car uses two sources of power: a small gasoline engine and an electric battery. At times the gasoline engine can even be off while the car is running. In these cars, the battery is not charged by plugging it into the electricity grid, but by energy that is otherwise lost during coasting and braking (it can also be charged by the gas engine). The hybrid also uses its electric motor in tandem with the car's small gasoline engine to access extra power when climbing a hill or accelerating quickly. These characteristics reduce the car's overall fuel consumption, which significantly decreases greenhouse gas emissions and protects air quality—a win-win situation.

CORE LABORATORY ACTIVITY

## Home Energy Audit

### Introduction

Canadians have been challenged to reduce their greenhouse gas emissions by one tonne per year. This would reduce overall emissions by about twenty percent of current levels (about five tonnes per person). This Core Laboratory challenges you to see how you could reduce wasteful energy use at home to help meet the "One-tonne Challenge".

The main focus of this activity is household appliances and other devices, whose energy use is easy to measure and calculate. It is more difficult to measure hot water and heating energy use, two of the major greenhouse gas culprits; you will use a modified way to calculate those heating costs and the GHGs produced.

## Part A: Understanding Home Electricity and the GHG Link

### Home Research

1. Make a list of everything in your home that uses electricity. Include appliances, computers, music players, and the hot water heater. Also, list all the ways your house is heated—oil, wood, propane, electricity, heat pumps, and/or other sources.

2. With your teacher, assemble one complete list of appliances and devices, using each student's contributions. Discuss which of the items on it (if any) could be powered by renewable energy sources. Also, create a list of the types of energy used to heat the homes of everyone in the class.

   While some non-renewable sources of heat, such as oil or coal, add substantially to greenhouse gas emissions, wood heating is not considered a GHG source. This is because the trees that were burned as firewood are replaced by growing trees that take carbon dioxide back out of the atmosphere. Wood is thus a renewable energy source and considered GHG neutral.

3. Select ten appliances/devices from the class list and, working in pairs or groups, rank the energy-use per hour of each one from highest to lowest. Compare the information in your rankings to what you find in the table, **Energy Use at Your House** (available from the teacher). Are your top energy uses the same as those in the table?

### Part B: Home Energy Audit

1. Review each student's chart, either as a class or in small groups as directed by your teacher. Discuss the "One Tonne Challenge", which asks Canadians to reduce their greenhouse gas emissions by one tonne (twenty percent). Brainstorm ways that you and your family could reduce energy use in your home.

2. Write an energy audit report and action plan for reducing energy use and greenhouse gas emissions in your home (400 to 800 words). The report could answer these questions:
   - What did you learn about GHG-emitters in your home? Did you learn something you didn't already know? Did you learn anything surprising?
   - How could your family reduce its greenhouse gas emissions? How could you help them make changes?
   - What changes do you plan to make? Try to be as specific as possible and work with your family to create an energy-reduction action plan.

3. Visit *www.onelesstonne.ca/home.cfm* and use the "One Less Tonne" challenge, or visit *www.seedsfoundation.ca/otc/* and take their "One Tonne Challenge".

### Part C: How Many Watts? How Many Greenhouse Gases (GHGs) per Kilowatt-hour (kWh)?

Assigned values:

- If your electricity comes exclusively from a hydro-generated power source, 1 kWh of use results in 0 grams of GHG emissions.
- If your electricity comes from wind- or solar-generated sources, 1 kWh of use results in 0 grams of GHG emissions.
- If you live on the island of Newfoundland and your source provider is Newfoundland Power, it generates electricity by burning diesel fuel about thirty-three percent of the time. Electricity supplied entirely by fossil-fuel burning produces

  795 grams of greenhouse gas emissions for every kilowatt-hour of energy use. In Newfoundland, 1 kWh results in 262 grams of GHG emissions.

1. Review your family's electricity bill and note how many kilowatt-hours were used during the billing period. Copy the table below into your notebook and then follow these steps to complete it and determine how your family consumes electricity:
   a) Record your major appliances and energy-using devices (omit your hot water heater and furnace).
   b) With your family, estimate how many hours per week (on average) the appliance is used.
   c) Using the "Energy Use at Your House" table, provided by your teacher, determine the number of watts used per hour of operation for each appliance.
   d) Multiply (b) by (c) to calculate the total watts per week.
   e) Divide by 1,000 to determine the kilowatt-hours per week.
   f) Check your electricity bill and record the cost for each kWh.
   g) Multiply (e) by (f) to determine the cost per week to operate each appliance.
   h) Using the assigned values listed above; record the number of grams of greenhouse gas per kWh that applies in your home.
   i) Multiply (e) by (h) to determine the total greenhouse gas emissions created by each appliance/device in a week.
   j) Total all the columns.

One more set of factors must still be examined. Reserve this table, and go on to the next section, which explains how to determine how many kilowatt-hours your family uses to heat your home and its hot water.

**Household Appliances and Weekly Greenhouse Gases per kWh**

| (a) Appliance or Device | Oven | | | | | (j) Totals |
|---|---|---|---|---|---|---|
| (b) Hours Operated Weekly | 4 | | | | | |
| (c) Watts Used | 3,060 | | | | | |
| (d) Total Weekly Watts | 12,240 | | | | | |
| (e) Kilowatt-hours per Week | 12.2 | | | | | |
| (f) Cost per kWh | $0.0892 | | | | | |
| (g) Cost per Week | $1.09 | | | | | |
| (h) GHG Emissions per kWh | 262 | | | | | |
| (i) Grams of GHGs/week | 3196 | | | | | |

## Part D: More Pieces of the Energy Puzzle: Heating Homes and Hot Water

Two major home-based greenhouse gas-emitters missing from the chart you filled out in Part C are home heating and hot-water heating. Use the following information to calculate the green house gases emitted from heating your home and water. Add this to the total from appliances in table for Part C to complete your audit.

**Household Heating –** How do you heat your home? Home heating, especially fossil-fuel-burning furnaces or electricity that relies on fossil-fuel-burning generating plants, is a big emitter of greenhouse gas emissions. Determine your household's greenhouse gas contributions from this source by using the method that applies to your situation:

- **Oil Heat**: If your house is heated by an oil furnace, review your family's heating-fuel bill and note how many litres of oil have been used during the billing period. Burning a litre of furnace oil creates 2,830 grams of greenhouse gases. Multiply the number of litres on your bill by 2,830 grams to determine how many grams of GHGs your household emitted.

- **Wood Heat**: Burning wood produces relatively few greenhouse gases. Record a zero for greenhouse gas emissions if your home is heated this way.

- **Electrical Heat – Home and Hot Water**: If your family home is heated by electricity, you can roughly determine the kilowatt-hours it uses. Subtract the total kilowatt-hours used by your appliances for the total billing period (which will be longer than a week) from the total kilowatt-hours on your bill. The remaining kilowatt hours were probably used to heat your home and water. Calculate your greenhouse gas emissions by multiplying this amount by the GHG rate for your energy-source.

- **Electrical Heat – The Meter-reading Method**: If you heat by electricity, you can estimate how much energy is required to heat your house for an hour (on an average cold day) by asking your family if they will turn off all electrical appliances for an hour.
  If they agree, read the meter at the beginning and end of the sixty minutes, and calculate the difference between the two readings. Multiply that amount by 168 (the number of hours in a week) to

see how many kWh you use in a week. (Note: Different types of meters can make this approach challenging. Meter-reading tips are available online.

- Hot-water Heating: Heating hot water is a huge energy-guzzler. How do you determine exactly how much energy the hot-water tank in your home uses? If it's an electric heater but your home is not heated by electricity, you can still use the method described under "Electrical Heat – Home and Hot Water" to determine the kilowatt-hours it requires. Simply subtract the total kilowatt-hours used by appliances from the kilowatt-hours on your electricity bill. (It should be about ten percent of the amount of energy used to heat your house. Remember that a litre of heating oil contains about 8 kWh of heat, if the furnace is about seventy-five percent efficient.)

## 2. Electricity Production and Heating

### Alternate Energy Sources

As you saw in the home audit activity, the energy we use to heat our homes and water, and to run our appliances, produce large amounts of greenhouse gases.

Sources of electricity vary depending on where people live. If the electricity in your home comes from a provider that burns diesel or oil, then your greenhouse gas (GHG) emissions per kilowatt-hour (kWh) will be much higher than if your electrical provider uses a renewable resource such as wind or hydro-electricity.

Our cold climate and dependence on fossil fuels for electricity makes Newfoundlanders and Labradorians relatively high greenhouse gas emitters. Newfoundland Hydro generates between thirty and forty percent of its annual energy output at its large oil-fired generating facility at Holyrood. Overall, thermal electrical production (which burns fossil fuels), accounts for about thirty-three percent of the total electrical production in the province. Communities here need to develop energy alternatives to diesel, and residents need to become more aware of energy-use patterns and how to reduce energy demands.

#### Wind Generated Energy

To date, the amount of wind energy operating globally is relatively small compared to hydro-electric power. But the wind industry is growing quickly. There are two major applications of wind power: large utility-scale turbines that are connected to the power grid and smaller turbines for remote communities.

Large-scale turbines are responsible for most of the electricity generated from wind power. As the technology of making large wind turbines improves and the cost of fossil fuels increases, wind power is becoming more competitive economically with power created at nuclear, natural gas, and oil-fired generating stations. Given its huge environmental benefits, many countries have been encouraging wind power through tax incentives and subsidies, or by requiring utilities to generate a minimum percentage of their electricity using renewable energy sources.

**Fuel Efficiency**

Fuel efficiency refers to the amount of fuel consumed to travel a given distance-it's often expressed as litres per hundred kilometres (L/100 km), or as miles per gallon (mpg). Fuel consumption varies widely from one vehicle to the next. The lower the fuel efficiency of a vehicle, the more greenhouse gases it emits per kilometre driven.

Consumer choice governs which cars we drive, but governments can influence these choices by offering taxes and subsidies. The federal government publishes the fuel efficiency of all vehicles sold in Canada (call 1-800 O-Canada). As well, an EnerGuide Label in the window of new cars displays its average fuel efficiency for both city and highway driving.

**Figure 19.8:** St. Lawrence Wind Turbine project. *Photo courtesy Greg Oliver, Penney Industrial Limited*

On the island of Newfoundland, turbines could be effectively worked into the power grid. They can also support hydro-electric sources: when the wind is strong, these plants could reserve more water behind their dams, and when conditions are calm, the water would be released to generate power.

Remote communities, which are not connected to a major electrical grid, often rely on diesel generators to supply their electricity. Diesel generation is both expensive and contributes to greenhouse gases, however. Using wind energy to supplement diesel generation in a wind-diesel hybrid system is now economically attractive in many remote communities in Canada and around the world. As of 2008, sixteen communities in Labrador and eleven in Newfoundland were not connected to a major electrical grid. These communities emit a large carbon footprint and can be considered for wind power.

### Generating Electricity using Tidal Energy

**Figure 19.9:** The tidal power generating plant at Annapolis Royal, Nova Scotia. *Photo courtesy Nova Scotia Power*

Tidal energy is a rapidly emerging turbine technology that is emissions-free. Generating electricity by using the energy in tides (or in continuous ocean currents) is similar to how power is generated by wind: the movement of the water turns rotor blades, like aircraft propeller blades, that spin a shaft connected to the generator that creates the electric current. The energy in moving water provides the power needed to create electricity.

One advantage of tidal energy over wind energy is that water is a thousand times denser than air, so the blades can be much smaller than in a wind turbine and still generate a significant amount of electricity. In addition, because the movement of tides (and of continuous ocean currents) is more predictable in a specific location than the presence and strength of the wind, this energy source is more predictable. This is an important factor for power companies, which need to count on power sources so they can match supply with consumer demand.

## Did You Know?

The need to warm the engine for several minutes in winter is a myth. With computer controlled, fuel-injected engines, you need no more than thirty seconds of idling on winter days before driving away. Anything more simply wastes fuel and increases emissions.

In Annapolis, Nova Scotia, the tidal action of the Bay of Fundy (which has the world's highest tides) is now being harvested by a power plant. It captures the flow of water in a head pond and can produce up to 20 megawatts daily. In 2008, it was one of only three tidal plants in the world.

Environmental concerns attached to tidal energy include potential damage to fish and marine mammals, and degradation of their habitat. Consequently, tidal energy technologies must be thoughtfully designed and located to minimize their impact. The blades in the turbines turn quite slowly, which also reduces the risks (some turbine designs don't have blades).

Operational concerns about tidal energy turbines include possible interference with ocean-going vessels and fishing gear. As well, the saltiness of the ocean can potentially cause corrosion if equipment is not designed to withstand the marine environment. Accessing equipment for maintenance and repair can also pose some challenges.

### Biomass-generated Electricity

Biomass is simply biological material that is used as—or converted to—a fuel for generating heat or electricity. One example is wood waste: sawdust, wood chips, and residue (such as slash or unusable wood) from lumbering or forestry processes.

Wood waste is also created by the paper-making process (this waste is termed "sludge"). Mills such as Corner Brook Pulp and Paper Limited use sludge to help generate electricity (co-generation). The sludge is burned in a special boiler that produces steam. A steam turbine then generates electricity that is either used in mill operations or sold into the Island's electricity grid. Using sludge in this way is a carbon neutral process.

## Nuclear Energy

**Figure 19.10:** A uranium nuclear fuel pellet. *Photo courtesy Canadian Nuclear Association*

To create energy, nuclear power plants use nuclear fission. Nuclear fission splits an atom's nucleus and creates two new nuclei. The mass of the two new nuclei is less than that of the original nucleus— during the split the missing matter was converted into energy in the form of heat. In a nuclear power plant, this heat is used to produce steam, which runs an electricity-producing generator.

The fuel for most nuclear reactors is concentrated from uranium ore. The energy in one uranium nuclear fuel pellet as shown in figure 19.10 is equivalent to the energy provided by 807 kilograms of coal or 564 litres of oil. Canada is the world's leading uranium producer, accounting for a third of global production and fifteen percent of global reserves.

For several key interrelated reasons, nuclear energy is now receiving renewed attention following a period of declining interest in the 1980s. First, global demand for electricity continues to rise and sources must be found to meet it. Second, there is heightened awareness that fossil fuels alone cannot be used to respond to the

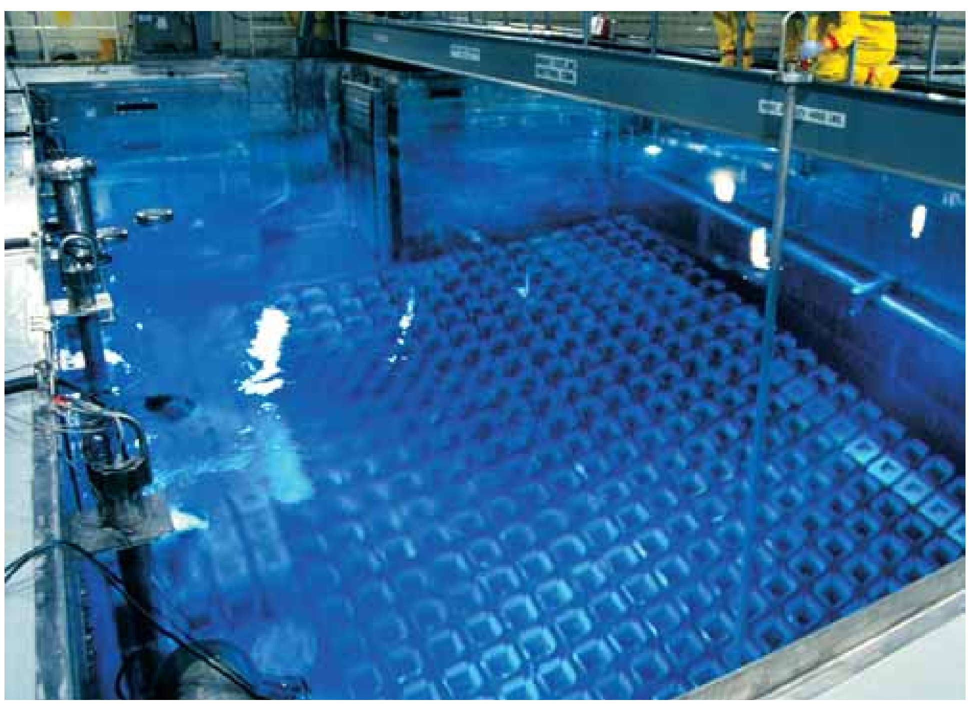


**Figure 19.11:** A containment pool at a nuclear power plant. *Photo courtesy Nuclear Energy Institute*

challenge. Third, compared to fossil fuels, primary greenhouse gas emissions and air contaminants from nuclear electricity production are negligible.

## Did You Know?

"Heavy water is the common name for deuterium oxide ($D_2O$). It is similar to light water ($H_2O$) in many ways, except that the hydrogen atom in each water molecule is replaced by heavy hydrogen, or deuterium. The deuterium makes $D_2O$ about ten percent heavier than ordinary water."

*www.nuclearfaq.ca*
by Dr. Jeremy Whitlock

Nuclear energy remains a contentious issue in Canada, however. For every person touting its benefits, there is another who warns of its risks. The reasons people oppose the use of nuclear energy include:

- the process creates radioactive waste that needs to be stored very carefully for an indefinite period (at a cost);
- there is potential for radioactive contamination (either through accidents or sabotage); and
- continuing to pursue nuclear energy could facilitate the creation of nuclear weapons.

Nuclear waste (which includes used nuclear fuel) can be radioactive for tens of thousands of years. It must be managed wisely to minimize risk to the environment and human health—not only by us, but by the generations who come after us. The storage method is determined by the radioactive level of the waste. Typically, waste is cooled in specially built pools of heavy water until it can be stored on-site, or transported to and stored in a dry, underground long-term containment facility (this method is called "geological disposal"). According to a 1990 National Research Council statement, geological disposal, although costly, is "the best option currently available to us for disposing of highly radioactive waste".

In 2008, there were twenty-two nuclear power plants in Canada. They supplied fifteen percent of the country's electricity. As is the case in most countries, Canadian nuclear power plants have multiple safety systems designed to protect human health and the environment from human operational errors. Nevertheless, the safety of nuclear power plants remains a key concern for the general public. This is due, in part, to two major accidents in the history of civil nuclear power generation (which includes more than 12,000 cumulative years of operation in thirty-two countries);

- Three Mile Island (U.S.A., 1979): Equipment failure, inadequately designed instrumentation, and confusion on the part of the plant operators caused an accident in which the reactor at this plant was severely damaged. The radiation was contained.
- Chernobyl (Ukraine, 1986): The reactor was destroyed by an explosion and fire that caused loss of life and created serious health and environmental consequences. The accident was due to design deficiencies in the reactor, violation of operating procedures, and the absence of an adequate safety system.

When fission of a uranium (or plutonium or thorium) nucleus occurs in the controlled setting of a nuclear reactor, the slow release of energy can be used to generate electricity. Comparatively, the release of energy in an atomic bomb is explosively rapid and extremely destructive. Unfortunately, the technology and materials of nuclear energy can be manipulated for weaponry. As nuclear power reactors, research reactors, and their fuel components become more widespread, the world faces the challenge of safeguarding their use. An international treaty (the Non-Proliferation Treaty) and a watchdog agency (the International Atomic Energy Agency) are in place, but not all countries have signed the treaty or abide by its principles. A concern remains, that nuclear materials could end up being used to cause harm.

## Summary

Climate change will have major consequences around the world. The widespread impacts will affect economies, ecosystems, and people. Some positive effects may result from climate change, but on a global basis most impacts are expected to be negative.

Not only are the risks of climate change real, they are potentially disastrous. In addition to the changes in ecosystems and the loss of biodiversity, the other risks include changes in the frequency and intensity of extreme weather events and in our ability to grow food. Continuing to identify locations that are vulnerable to the impacts of climate change and planning our communities wisely are steps we can take to reduce our vulnerability to some climate-change effects.

Western culture is heavily dependent on energy. As individuals, we can make choices about our energy consumption: how much we use, how efficiently we use it, and where it comes from. We can reduce our greenhouse gas emissions by making wise choices about transportation, electricity, home and water heating, and what we buy.

Unfortunately, there are no instant or easy cures to the complex and challenging issues related to climate change. We must balance the trade-offs offered by fuels and technologies now available to power our automobiles and create our electricity, and use the mix of fuels and technologies that make the most sense for our environment—and thus are best for the well-being of life on Earth.

## CHECK your Understanding

1. List the potential advantages and disadvantages of using diesel fuel instead of gasoline in hybrid vehicles.
2. What are some of the advantages of driving less or using cars that produce fewer emissions? What steps can we take, as individuals and as a society, to reduce transportation-related greenhouse gas emissions?

For Further Discussion and/or Research

3. What is the difference between an EnerGuide label and an ENERGY STAR symbol? Which provides the most useful information to consumers? Explain your choice.
4. Compare the accident statistics of energy production using coal with energy production using nuclear energy. Outside of the process of mining the fuel (coal or uranium) and generating electricity, what are the dangers associated with each method of energy production?
5. Is burning wood the best way to prevent adding greenhouse gases to the atmosphere? Explain your reasoning.
6. Wind energy has supporters and opponents. What is your view? Support your opinion with an explanation of what you see as the key environmental and economic benefits and disadvantages of constructing wind farms.
7. What are the reasons to support or oppose investments in clean coal technology?
8. Conduct research into the pros and cons of using nuclear energy to supply our energy needs. Would you support constructing a nuclear power plant in your community? Why or why not?
9. In your opinion, should governments require all new homes built in Newfoundland and Labrador to meet R-2000 standards? Why or why not?
10. Small homes consume less energy than large ones that are just as well insulated. Should governments set limits on potential energy use for heating so that larger homes would have much higher standards for insulation?
11. In your opinion, should additional hydroelectric dams be built on the island of Newfoundland to replace the oil-fired generating plant at Holyrood? Support your opinion with an explanation of what you see as the key environmental and economic benefits and disadvantages of constructing additional hydroelectric dams versus maintaining the Holyrood station.

# Unit 5: For Further Reading


Nellemann, C., Hain, S., and Alder, J. (Eds). February 2008. In Dead Water - Merging of climate change with pollution, over-harvest, and infestations in the world's fishing grounds. United Nations Environment Programme, GRID-Arendal, Norway, *www.grida.no* ISBN: 978-82-7701-048-9.

State of Polar Research
The report reviews the multidisciplinary research from IPY 2007-2008 on the effects of global warming in the polar regions and recommends priorities for future action. *http://www.ipy.org/index.php?/ipy/detail/state_of_polar_research/*.

Climate Change and Invasive Species
The report examines how climate change considerations factor into work on invasive species, particularly in terms of risk assessment and risk management. The report entitled "Integrating Climate Change into Invasive Species Risk Assessment/Risk Management" is available at *http://www.policyresearch.gc.ca/doclib/WR_SD_InvasiveSpecies_200811_e.pdf*.

Greene, C. H., Pershing, A. J., Cronin, T. M., & Ceci, N. (2008). Arctic climate change and its impacts on the ecology of the north Atlantic. *Ecology*, 89 (11), 24-38.

Environment Canada (2003). Various publications are available at *http://www.msc.ec.gc.ca/education/scienceofclimatechange/index_e.html* that relate to understanding climate change science and responding to climate change science.

Natural Resources Canada. *Climate change impacts and adaptation: a Canadian perspective.* Retrieved April 3, 2009, from *http://adaptation.nrcan.gc.ca/perspective/index_e.php*

Natural Resources Canada. *From impacts to adaptation: Canada in a changing climate 2007.* Retrieved April 3, 2009, from *http://adaptation.nrcan.gc.ca/assess/2007/index_e.php*

Intergovernmental Panel on Climate Change (n.d.). Various presentation materials relating to climate change are available at *http://www.ipcc.ch/*.

Department of Environment and Conservation (2008). *Strategic plan 2008-2011*. Retrieved April 9, 2009, from *www.assembly.nl.ca/business/tabled/envirocon_strategic08-11.pdf*.

# Glossary of Terms

A

Abiotic Factors: parts of the biosphere that are nonliving; e.g. sunlight, temperature, minerals, air, water.

Access Road: a road that provide access to wilderness areas for economic, recreational, and domestic activities.

Acid Mine Waste: unwanted waste that is produced from the refining or smelting stage of mining; can have devastating effects on the environment if not properly treated or contained.

Acid Precipitation: precipitation that is abnormally high in sulphuric acid and nitric acid and that is caused by atmospheric pollutants; has a pH below 5.6.

Acidification: the process of becoming an acid; acid precipitation changes the chemistry of terrestrial soils and aquatic ecosystems having a negative impact on the organisms in those ecosystems.

Acidophiles: organisms that live in acidic environments.

Aerial Logging: an expensive logging practice where helicopters are used to airlift logs to more accessible sites.

Aerobic Bacteria: bacteria that require the presence of oxygen to live and grow.

Aerosol: a gaseous suspension of fine solid or liquid particles.

Age Class: a range of ages of trees into which forest stands are divided; common age classes include 0-20 years (regeneration), 21-40 years (immature), 41-60 years (immature), 61-80 years (mature), and 81 + (over-mature).

Agriculture: the land-based cultivation of living organisms for the benefit of humans, such as the production of crops and the management of livestock.

Agrifoods: foods produced through an agricultural process including the industries that are involved in the production, processing, and inspection of food products made from agricultural materials.

Agrometeorology: the study of the interaction between meteorology and agriculture.

Air Quality: a measurement of the pollutants in the air; describes the health and safety of the atmosphere.

Alien Species: a species that has been either intentionally or inadvertently introduced into a location outside its natural distribution.

Alternate Fuels: other fuels, such as biodiesel and ethanol, which can be substituted for conventional fuels.

Ambient Water: water that exists all around us; surface water and ground water.

Anaerobic Digestion: a biological process where bacteria breaks down organic material in a low oxygen environment; necessary process for composting; methane, carbon dioxide, and heat are given off.

Annual Allowable Cut: The amount of wood that may be harvested each year.

Anthropogenic Extinction: extinction of a species due to the actions of humans.

Aquaculture: the breeding and raising of fish or shellfish in a controlled environment.

Aqueous Mud: a water-based drilling mud; suitable for drilling through stable formations, vertical wells, and drilling at moderate temperatures.

Aquifer: any geological formation containing or conducting ground water, especially one that supplies the water for wells, springs, etc.

Autotroph: an organism that makes its own food; e.g. plants through the process of photosynthesis.

B

Ballast Water: water that is pumped in and out of ocean-going vessels to improve stability in open water.

Barren: an open area of land composed mostly of shrubs and low-growing plants such as lichen and mosses.

Benthic Invertebrate: organisms that inhabit the bottom of the ocean for at least part of their life cycle.

Big Game Species: large, animal species that have small populations, low mortality rates, and low reproductive rates; e.g. moose, bear.

Bilge Dumping: the dumping of bilge water (water that accumulates in the hull from the workings of ship machinery); a source of pollution when the oil is not separated from the water before dumping; a major concern for marine species.

Bioaccumulation: the process where substances from the environment build up in the tissues of a living organism at a specific tropic level.

Biochemical Oxygen Demand: see biological oxygen demand.

**Biochemical Process**: process by which water is purified mainly by the actions of living organisms.

**Biodegradable**: capable of being decomposed by organisms, such as bacteria, fungi, and earthworms.

**Biodiesel**: a fuel made primarily from oily plants (such as the soybean or palm oil) and to a lesser extent from other oily sources (such as waste cooking fat from restaurant deep-frying).

**Biodiversity Index**: a formula that describes the amount of species diversity in a given area, calculated as follows: the number of species in the area (numerator) divided by the total number of individuals in the area (denominator).

**Biodiversity**: the variety of different species in a particular habitat.

**Bioenergetics Model**: a model used to predict the food consumption of animals; used to assess the impact of animals on their prey.

**Biofuel**: fuel produced from renewable resources, especially plant biomass, vegetable oils, and treated municipal and industrial wastes; considered carbon neutral.

**Biogeography**: the study of the distribution of biodiversity over space and time which reveals where organisms live and at what abundance.

**Bioleaching**: a process that uses bacteria to break down ore and release the valuable metal (e.g. copper, zinc) in the form of ions which are then collected and converted back to metal using electrolysis.

**Biological Control Agents**: naturally occurring agents that target specific forest pests; includes viruses, bacteria, and pheromones.

**Biological Oxygen Demand**: the amount of oxygen required by aerobic micro-organisms to decompose the organic matter in a sample of water, such as that polluted by sewage. It is used as a measure of the degree of water pollution; also called biochemical oxygen demand.

**Biological Remediation**: processes that use micro-organisms, fungi, green plants or their enzymes to remove contaminants from the environment.

**Biomagnification**: the increasing concentration of a substance, such as a toxic chemical, in the tissues of organisms at successively higher levels in a food chain.

**Biomass**: the mass of a group of organisms, not including water content; usually measured by mass.

**Biome**: a large geographical area characterized by distinct plants and animals.

**Biosphere**: wherever living organisms are found on or in the air, land, and water.

**Biotic Factors**: parts of the biosphere that are living; e.g. plants, animals, bacteria.

**Bird Guild**: a group of bird species that take advantage of a given variety of habitat types.

**Black Smoker**: a vent on the ocean floor through which superheated water containing dissolved minerals from Earth's crust is released; when the superheated water strikes the cold ocean water, minerals (mostly sulphide minerals) precipitate out of solution forming a black chimney-like structure around the vent.

**Black Water**: the water and its contents flushed away in toilets.

**Bloom**: rapid growth, particularly with respect to the growth of plankton.

**Blowdown**: an area of trees that are highly affected by wind after many of the surrounding trees, that have previously provided protection, have been cut down.

**Bog**: a characteristically nutrient poor, acidic wetl and that is dominated by a waterlogged, spongy mat of sphagnum moss, ultimately forming a thick layer of acidic peat; an extremely sensitive habitat of high importance to biodiversity.

**Boom**: a floating barrier which functions to contain an oil spill.

**Boreal Forest**: a forest biome where coniferous trees are dominant, also known as the taiga and northern coniferous forest; largest biome in Canada; one-third of all Earth's forests.

**BTK**: a naturally occurring bacterium, Bacillus thuringiensis, that is sprayed to kill the larvae of selected butterflies and moths, including the gypsy moth, spruce budworm, and hemlock looper.

**By-catch**: non-targeted fish species and other marine life caught unintentionally by fishing gear.

## C

**Cable Yarding**: the system for the removal of timber from very steep slopes when other methods of removal are inaccessible; requires high volumes to be cost-effective.

**Camouflage**: markings or colorations that help disguise an animal so it blends with the environment and is less visible to predators.

**Canadian Model Forest Network**: partnership of fourteen working-scale forest-based landscapes across Canada sharing the goal of sustainable forest management; the Western Newfoundland Model forest covers 700,000 hectares.

**Canadian Standards Association**: a not-for-profit membership-based association serving business, industry, government and consumers in Canada and the global marketplace; purpose is to develop standards that address real needs, such as enhancing public safety and health, advancing the quality of life, helping to preserve the environment, facilitating trade.

**Canopy Cover**: proportion of ground surface covered by the canopy layer(s) of trees.

**Cap and Trade**: an approach that limits (caps) the amount of pollution that can be emitted from a regulated source in a specified time period. If a company exceeds its cap, it can buy allowances from another company that has not used its total.

**Carrying Capacity**: the maximum number of organisms of a particular species that can be supported indefinitely in a given environment.

**Catalyst**: a substance that enables a chemical reaction to proceed at a faster rate.

**Catch Per Unit Effort**: the weight of fish landed given a specific amount of effort.

**Chlorination**: disinfection of water by the addition of small amounts of chlorine or a chlorine compound.

**Chlorofluorocarbons**: chemical substances used in refrigerators, air conditioners, and solvents that drift to the upper stratosphere; chlorine released by CFCs reacts with ozone, eroding the ozone layer.

**Clean Development Mechanism**: a process in which developed nations can receive financial credit for building projects that reduce the amount of greenhouse gas emissions.

**Clear Cutting**: a section of forest where all commercially harvestable timber has been removed.

**Climate Change**: a long-term significant change in the "average weather" that a geographical region experiences over time.

**Closed System**: a system in which little or no materials may enter or leave.

**Co-generation**: the production of heat and/or power from the waste energy of an industrial process.

**Cole Crop**: a term used to describe several crops of the mustard family including broccoli, brussel sprouts, cabbage, and cauliflower; can withstand light frosts without injury.

**Combustion**: the act or process of burning; rapid oxidation accompanied by heat and usually light.

**Commercial Fishery**: any fishery conducted for profit either by an individual or a company.

**Community**: a group of plants and animals living and interacting with one another in a specific region under relatively similar environmental conditions.

**Composting**: the act of composting; a mixture of organic matter, often using leaves and kitchen scraps; this may be used to improve soil structure and provide nutrients.

**Concentration**: a measure of the amount of substance per unit of volume.

**Conifer**: a cone-bearing tree with needle-like leaves; dominant in the boreal forest.

**Conservancy**: a nongovernmental organization that acquires resources for the purpose of protecting biodiversity; e.g. Ducks Unlimited, Nature Conservancy, World Wildlife Federation.

**Conservation Ethic**: an ethic of resource use, allocation, and protection. Its primary focus is upon maintaining the health of the natural world: its forests, fisheries, habitats, and biological diversity.

**Conservationist**: a person who promotes conservation; especially keeping a resource in existence.

**Consumptive Outdoor Activity**: outdoor activities that extract resources from the environment; e.g. hunting, fishing.

**Contact Pesticide**: a pesticide that must directly touch a pest in order to have an effect.

**Contamination**: the addition of one or more chemical substances to an ecosystem causing harm; e.g. toxins.

**COSEWIC**: an independent advisory organization, known as the Committee on the Status of Endangered Wildlife in Canada, which evaluates the country's wild species risk status.

**Crippling Loss**: the percentage of organisms of a certain species that are hurt during a hunt, later die, and that are never retrieved.

**Criteria Air Contaminants**: a group of pollutants interacting in the air; main cause of smog and acid rain; produced from a number of sources, including the burning of fossil fuels.

**Crop Rotation**: alternating the annual crops grown on a specific field in a planned pattern or sequence in successive crop years to avoid excessive depletion of soil nutrients.

**Crustacean**: an aquatic invertebrate of the class Crustacea, including lobsters, crabs, shrimps, and barnacles; having a segmented body, a protective exoskeleton, and paired jointed limbs.

**Cut-over**: a forest area from which the trees have been harvested.

D

DDT: dichlorodiphenyltrichloroethane; a colorless contact insecticide that is toxic to humans and animals when swallowed or absorbed through the skin.

Degradable Waste: waste material that breaks down into simpler compounds by stages. Also, see biodegradable waste.

Denitrification: a biological process in which bacteria convert nitrates in the forest floor to nitrogen gas that is harmlessly released into the air.

Detritus: dead and decomposing organic material on a forest floor.

Development Ethic: an assumption that humans should be the master of nature and that Earth and its resources exist for our benefit.

Dioxin: typically used to refer to one isomer, TCDD, a by-product of pesticide manufacture: a toxic compound that causes cancer and birth defects in certain animals.

Discharge: the volume of water that passes a given point within a given amount of time.

Dispersant: chemicals designed to cause oil to break down into smaller droplets that disperse throughout the water column.

Disposal Field: an underground area comprising of trenches containing coarse aggregate (stone) around distribution pipes permitting septic-tank effluent to seep into surrounding soil.

Dissolved Oxygen: the amount of oxygen dissolved in a body of water; measured in milligrams per litre. Also, refer to biological oxygen demand.

Distribution Box: in sanitary engineering, a box in which the flow of effluent from a septic tank is distributed equally into the lines that lead to the absorption field.

Domestic Harvest: the harvest of wood for personal use.

Domestic Stock: the fish stock that exists totally within Canada's Exclusive Economic Zone, such as northern Gulf cod.

Drainage Basin: an area of land in which the surface water and ground water all drain to a common waterway such as a stream, wetland, lake, or even the ocean. Also, it is referred to as watershed.

Drainage Divide: the raised land that separates two watersheds.

Drilling Mud: a mixture of chemicals and minerals in a water or oil solution that is pumped down a drill string to cool the rotating drill bit and is then pumped back to the surface bringing the rock cuttings.

Dug Well: a hole in the ground, which is dug by a shovel or a backhoe. Historically, a dug well was excavated below the groundwater table, then lined (cased) with stones, brick, tile, or other material to prevent collapse. It was covered with a cap of wood, stone, or concrete.

E

Eco-citizenship: taking an active role in bettering the environment.

Ecological Capacity: the overall ability of an ecosystem to maintain its natural, original, or current condition and to produce goods and services.

Ecological Footprint: something which has permanently damaged the environment or has had a negative impression on the environment; the impact of humans on ecosystems created by their overuse of land, water, and other natural resources.

Ecological Integrity: the long term ability of an ecosystem to self-support and maintain an adaptive community of organisms having a species composition.

Ecological Niche: the role that members of a population play in a community, including the feeding relationships.

Ecological Reserve: a provincially protected area of less than 1,000 $km^2$ - smaller than a wilderness reserve.

Ecology: the study of the interrelationships among living things and their nonliving environment.

Ecoregion: a large geographical area dominated by distinctive plant and animal communities that are adapted to the same environment.

Ecosystem: a collection of living things as well as the environment in which they live; e.g. a prairie ecosystem including coyotes, the rabbits on which the coyotes feed on, and the grasses on which the rabbits feed on.

Ecotourism: a form of sustainable tourism; involves responsible travel to natural areas that conserves the environment and improves the welfare of local people.

Effluent: an outflow from a sewage system; a discharge of liquid waste, as from a factory or nuclear plant.

Electrostatic Precipitators: highly efficient filtration devices that remove particles, such as dust and smoke, from air using the force of an induced electrostatic charge.

Emergent Plant: a plant that can tolerate flooded soil conditions, but cannot tolerate being completely submerged in water; e.g. cattails.

Emissions: substances discharged into the air, especially by internal combustion engines.

Emulsification: a mixture of two unblendable liquids; one liquid is dispersed in the other; e.g. water and oil, butter and margarine, milk and cream, vinaigrettes.

Endangered Species: a species endangered of becoming extinct.

Environmental Assessment: The process of collecting and/or gathering information on the environment with a special focus on how it will be impacted by human action.

Environmental Conservation: the movement to protect the quality and continuity of life through conservation of natural resources, prevention of pollution, and control of land use.

Environmental Farm Plan: a plan that helps farmers apply a sustainable environmental management perspective to their land, buildings, and work materials.

Environmental Impact: a change in the make-up, working, or appearance of the environment. Such a change can be planned or accidental and lead to unexpected or undesirable effects that may be irreversible.

Environmental Protection Agency: an independent United States federal agency established to coordinate programs aimed at reducing pollution and protecting the environment.

Environmental Science: the study of ecological principles - the natural workings of the planet - and how they relate to human use of the environment.

Estuary: a semi-enclosed nutrient-rich body of water in which fresh water from a river mixes with saltwater from an ocean; important and rich; also known as a barachois.

Eutrophication: the addition of nutrients to a body of water through the use of fertilizers or the discharge of untreated sewage.

Exclusive Economic Zone (EEZ): that portion of the sea extending to 200 miles off the coast of a state where the state has the right to control living and nonliving resources of the sea while allowing freedom of navigation to other states beyond twelve miles; as agreed upon by the Third United Nations conference on the Law of the Sea (UNCLOS).

Exotic Species: an organism that is not native to a particular environment, but has been introduced (planned or accident) from another location.

Exponential Growth: a population that rapidly increases in number by a factor of ten; occurs in an environment with unlimited resources.

Extirpated: a species no longer existing in the wild in a particular area, but occurring elsewhere in the world; e.g. Newfoundland wolf.

## F

Fauna: animal life occurring in an area.

Feller Buncher: a harvesting machine with arms that grab a tree, saw through the base, and cut off the branches; computerized.

Fen: peat-forming wetlands that are less acidic and have higher nutrient levels than bogs.

Filtration: the mechanical separation of a liquid from the undissolved particles suspended or floating in it.

Fish Stock: a group of fish having a common genetic make-up, inhabiting a particular region, and maintaining a similar migration pattern.

Flame Retardant: a material that inhibits or resists the spread of fire.

Flocculation: having formed lumpy or fluffy masses.

Flora: plant life occurring in an area.

Focal Species: grouping priority species according to potential limiting factors or threats (e.g. habitat loss, changes in fire regime, etc.) within a habitat category; the species thought to be most sensitive to, or have the most stringent ecological requirements for, the particular factor is usually identified as the focal species.

Foliage: leaves on plants.

Food Chain: a simple step-by-step sequence of who eats whom in an ecosystem.

Food Web: a network of food chains that are interdependent; each organism may have several food sources.

Forage: animal food such as clover, timothy, alfalfa, and silage corn.

Forest Regeneration: the regrowth of trees to maintain a stable forest ecosystem.

Fossil Air: samples of atmosphere trapped in rocks and ice for millions of years; used to provide clues about climates long ago.

Fossil Fuel: any combustible organic material, such as oil, coal, or natural gas, derived from the remains of former life.

Free-floating Plant: a plant that is not rooted and therefore, floats to the surface of a water body; e.g. algae.

Frontier Forest: a large intact natural forest ecosystem that experiences natural disturbances, but has been relatively undisturbed by human developments; also it is known as an intact forest.

Frost Free Day: a day when the temperature does not fall below 0°C.

Fry: young, recently hatched fish.

Fuel Cell: an electrochemical device where a chemical reaction produces energy that is converted directly into electricity; do not pollute the environment.

Full-tree Harvesting: a cost-saving harvesting method in which whole trees are cut down and removed from the site.

Furan: a colorless, toxic, and flammable liquid that is used in the synthesis of nylon.

G

Gap Replacement: occurs when the death of an individual tree, or a small group of trees, allows more light to reach the forest floor so that younger trees can grow.

Genetic Diversity: a level of biodiversity that refers to the total number of genetic characteristics in the genetic makeup of a species.

Genetically Modified: pertaining to a living organism whose genetic material has been altered, changing one or more of its characteristics; bioengineered.

Geographic Information Systems (GIS): systems for the analysis, management, and display of geographic knowledge; digital maps can be produced from the data and are important tools in practices such as forest management.

Greenhouse Gas (GHG) Emitter: a device, business, country, etc, that produces greenhouse gases.

Gigajoule: a measure of energy; one gigajoule is equivalent to about 30 litres of gasoline.

Global Governing Period: cooperative problem solving arrangements; can involve making laws or creating institutions.

Global Positioning System: a technology that utilizes a network of satellites to locate precise coordinates on Earth's surface.

Global Warming: the increase in the average temperature of Earth's near-surface air and oceans since the mid-20th century; primary cause is believed to be human activity, most significantly the burning of fossil fuels to drive cars, generate electricity, and the operation of homes and businesses.

Grasshopper Effect: persistent and volatile pollutants - including certain pesticides, industrial chemicals, and heavy metals - evaporate out of the soil in warmer countries where they are still used and travel in the atmosphere toward cooler areas, condensing out again when the temperature drops. The process, repeated in "hops", can carry them thousands of kilometres in a matter of days.

Green Certification: standards used to indicate whether a facility impacts negatively or positively on ecosystems.

Greenhouse Effect: warming that results when solar radiation is trapped by the atmosphere; caused by atmospheric gases that allow sunshine to pass through but absorb heat that is radiated back from the warmed surface of Earth.

Greenhouse Gas: a gas that absorbs solar radiation and is responsible for the greenhouse effect; includes carbon dioxide, methane, ozone, and the fluorocarbons.

Grey Water: the water that drains from sinks, dishwashers, laundry tubs, clothes washing machines, bathtubs, and showers. It contains particles of soap, fat, food, cleaning solvents, and other materials.

Gross Domestic Product (GDP): a measure of the national income and output for a given country's economy.

Ground Pressure: the pressure exerted on the ground by the tires or tracks of a motorized vehicle, and is one measure of its potential mobility.

Ground Truthing Plots: plots of trees visited to confirm the accuracy of interpreters' estimations in specific locations.

Ground-level Ozone: formed by gases, oxides of nitrogen and organic compounds, which in the presence of heat and sunlight, react to form ozone. Ground-level ozone forms readily in the atmosphere, usually during hot weather; known as a "summer-time" air pollutant; produced primarily when fossil fuels are burned in motor vehicle engines, power plants, and industrial boilers.

Groundwater: water found under Earth's surface.

Growing Degree Day: the date that a flower will bloom or a crop will reach maturity; as predicted by horticulturists and gardeners.

H

Hard Rock Mining: hard rock mining is very common and involves the extraction of minerals that are embedded in rock.

**Heap Leaching:** a technique for extracting valuable materials out of an ore. The ore is put into a heap and then irrigated with a liquid that serves to percolate down through it dissolving out the valuable materials.

**Heavy Metals:** any metallic chemical element that has a relatively high density and is toxic or poisonous at low concentrations; e.g. mercury (Hg), cadmium (Cd), arsenic (As), chromium (Cr), thallium (Tl), and lead (Pb).

**Hectare:** a metric unit of surface or land measurement equal to 2.471 acres or 10,000 square metres; symbol for hectare is ha.

**Herbicide:** a substance used to kill unwanted plants.

**High Grading:** a type of selection cutting where the largest and best trees are harvested; over time, this form of harvesting greatly weakens the forest.

**Host Rock:** also called country rock; it surrounds and includes the minerals of interest.

**Household Hazardous Waste:** leftover household products that contain corrosive, toxic, ignitable, or reactive ingredients; products, such as paints, cleaners, oils, batteries, and pesticides, require special disposal care.

**Hunter Success:** the percentage of a population that is successfully hunted and accounted for.

**Hybrid:** a car that uses two sources of power: a small gasoline engine and an electric battery.

**Hydroacoustics:** the study and application of the transmission of sound waves through water; as in fish finders or sounders used to locate fish.

**Hydrocarbon:** a chemical compound containing both hydrogen and carbon; serves as fuel, lubricant, and raw material for the production of plastics, fibres, rubbers, solvents, explosives, and industrial chemicals.

**Hydrogen-chlorofluorocarbons:** chemical substances considered to be a contributor to the destruction of the ozone layer; 1/20th as potent as CFCs.

**Hydrologic Cycle:** the water cycle.

**Hydroponics:** the cultivation of plants by placing the roots in liquid nutrient solutions rather than in soils.

## I

**Indicator Species:** a plant species that can be used reliably to indicate certain soil or site conditions; a species that is used to indicate the overall health of a particular ecosystem.

**Industrial Mineral:** a product of mining that does not include coal, oil, gas, metals, and gemstones. For example, roads are constructed using sand and gravel, both of which are products of mining.

**Industrialization:** the development of industry on an extensive scale; to organize the production of something as an industry.

**Infiltration:** the seepage of water (fresh or salt) into soil or rock.

**Insecticide:** a substance that kills insects; a specific category of pesticides.

**Integrated Pest Management:** a method of controlling or managing pests that uses a variety of strategies.

**International Stock:** fish stock that exists totally outside of Canada's Exclusive Economic Zone, such as a fish stock found on the Flemish Cap.

**Interspecific Competition:** when individuals of different species compete for the same resources in an ecosystem; e.g. foxes and coyotes competing for food and living space.

**Intertidal Zone:** the area between land and sea; the shoreline, a highly productive and demanding habitat where organisms are exposed to the extremes of flooding and drying out.

**Introduced Species:** a species that has been accidentally or intentionally introduced to an ecosystem by human activity.

**Invasive Species:** non-native species of plants and animals that out-compete native species of plants and animals in a specific habitat.

## K

**Juvenile:** a young individual resembling an adult of its kind, except in size and reproductive activity.

**Keystone Species:** a species that has an important stabilizing role on ecosystems; its large influence is out of proportion to its population size; e.g. capelin.

## L

**Lagoon:** a shallow body of water, especially one separated from a sea by sandbars or coral reefs; a shallow body of liquid waste material, which could be referred to as a dump.

**Landscape Diversity:** diversity within and between different ecosystems, which depends upon local and regional variations in environmental conditions as well as the species supported by those environments.

**Limiting Factor:** an environmental variable that limits or slows the growth of an organism or population.

**Littoral Zone**: a region of shallow coastal water where light can penetrate, enabling a variety of plants to grow on the ocean floor; rich in nutrients.

## M

**Macronutrients**: nutrients required in large amounts by plants; e.g. nitrogen, potassium, phosphorous, calcium, magnesium, sulphur.

**Macro-porosity**: large spaces between soil and rock particles, which allow air and water to move readily.

**Manure**: the organic waste produced by animals; not composted; when mature, it adds nutrients to the soil.

**Marsh**: a tract of low, wet land that is often treeless and either always submerged or periodically submerged; generally characterized by a growth of grasses, sedges, cattails, and rushes.

**Mature Forest**: forest dominated by trees that are old enough to be harvested.

**Mesotrophic**: a body of water with moderately enriched nutrient levels.

**Meteorology**: the study of weather and atmospheric conditions.

**Methyl Mercury**: any of several extremely toxic organometallic compounds, $Hg(CH_3)_2$, that is formed from metallic mercury by the action of microorganisms and that is capable of entering the food chain; used as seed disinfectants.

**Migration**: the movement of organisms, either permanently or temporarily, from one area to another.

**Migratory Corridor**: allows fish or other wildlife species to move from one location to another for reproduction, feeding, or protection.

**Mineral**: a solid, naturally occurring, and inorganic substance that has a definite chemical composition and structure. A mineral can be composed of a single atomic element such as gold or, as is more often the case, composed of two or more elements such as pyrite (FeS).

**Mining**: the systematic extraction of valuable minerals or other geological materials from Earth, usually (but not always) from an orebody, vein, or seam.

**Mitigating Measure**: an action that minimizes the impact of human activities on ecosystems.

**Modified Snare**: a snare consisting of a wire loop attached to a tree by a coil; prevents pine martens from being snared unintentionally.

**Monoculture**: the agricultural practice of producing or growing one single crop over a wide area.

**Moose Exclosure**: several fences constructed and joined to keep moose out of a certain area in order to reduce the effects that they can have on forest vegetation.

**Moose Management Area**: an area surveyed to estimate the population density of moose.

**Moratorium**: a suspension of an ongoing activity; e.g. cod fishery.

**Mortality Rate**: the number of individuals in a population that die during a specified period of time.

**Mulch**: a covering, such as straw, compost, or plastic sheeting, which is spread out on the ground to prevent excessive evaporation, temperature fluctuations, or erosion, as well as to enrich the soil, inhibit weed growth, etc.

**Multi-layered Forest**: forest characterized by trees of different ages; canopies of trees are at different levels.

## N

**Native Species**: plants, animals, fungi, and micro-organisms that occur naturally in a given area or region.

**Natural Biodiversity**: a variety of native species in a natural ecosystem; an increase in natural biodiversity results in increased stability in an ecosystem.

**Natural Mortality**: the percentage of individuals in a population that die through natural means such as predation, disease, old age, etc.

**Natural Resource**: a useful commodity found in the natural environment; e.g. fish, water.

**Naturalized Species**: a non-native organism not considered harmful to a native species.

**Niche**: the position or function (role) of an organism within its environment and community.

**Nitrogen Oxides**: any binary compound of oxygen and nitrogen; e.g. nitrogen monoxide (NO), nitrogen dioxide ($NO_2$).

**Non-aqueous Mud**: an oil-based drilling mud; suitable for drilling through water-sensitive formations, slanted and horizontal wells, and drilling at high temperatures.

**Non-consumptive Outdoor Activity**: an outdoor activity that does not take (or consume) anything from the environment; e.g. hiking, photography.

**Non-renewable Resource**: a nonliving resource that cannot be renewed; e.g. minerals, oil.

**Non-target Species**: a species that might be unintentionally caught or taken.

North Atlantic Fisheries Organization (NAFO): an intergovernmental fisheries science and management body whose overall objective is to contribute through consultation to the utilization, management, and conservation of the fishery resources.

Nuclear Energy: energy that is released either by splitting atomic nuclei or by forcing the nuclei of atoms together.

Nutrient Cycling: the uptake, use, release, and storage of nutrients by plants and their environments.

Nutrient Leaching: the removal of soluble nutrients from soil by the action of a percolating liquid.

## O

Old-growth Forest: a forest that has avoided naturally occurring disturbances to become dominated by over-mature trees.

Oligotrophic: a body of water that is lacking in nutrients.

Open Pit Mining: a method of extracting rocks or minerals from Earth, typically from open pits, borrows, or quarries. It is used when underground mining is either impractical or too expensive.

Optimum Range: the best range of abiotic factors in which a population thrives; beyond this range, one finds less and less numbers of these organisms.

Ore: rock that contains minerals that can be extracted through mining and refined for use.

Organic Fertilizer: organic materials such as manure, compost, ground bones, and seaweed that are more environmentally friendly fertilizers.

Organic Matter: something that is part of a living organism, was produced by a living organism, or once lived.

Otolith: a bone-like structure found in the ear of a fish from which the mineral bands can be counted to determine age.

Overexploitation: the taking of too many plants and animals which can lead to species becoming at risk or even extinct; causes can include over-harvesting and excessive hunting.

Overstory Vegetation: trees that cover the forest floor, thereby blocking out much sunlight.

Ozonation: the act of bubbling ozone, ($O_3$ - a toxic form of oxygen), through water to kill harmful micro-organisms; used as an alternative to chlorination in water treatment.

Ozone-depleting Substances: substances that chemically break down ozone into a different substance; main sources include chlorofluorocarbon (CFC) compounds, freons, and halons.

## P

Paradigm Shift: a radical change in a view previously held by a great number of people.

Parr: young salmon during its first two years of life when it lives in fresh water; has dark crossbars on its sides.

Particulate Matter: material suspended in the air in the form of minute solid particles or liquid droplets, especially when considered as an atmospheric pollutant.

Parts Per Million (ppm): a unit of concentration often used when measuring levels of pollutants in air, water, body fluids, etc; one ppm equals 1 part in 1,000,000.

Pathogens: disease-causing organisms; includes viruses, bacteria, protozoa, and parasitic worms.

Peat: a type of soil with a high proportion of dead organic matter (mainly plants); often found in peatlands, which are wetlands.

Pelagic: relating to the area of open water.

Percolation Rate: the rate at which water moves through the pores in soil or permeable rock.

Perfluorocarbons: a powerful greenhouse gas emitted during the production of aluminium.

Permanent Sample Plot: a plot of trees varying in size, including a sample of at least seventy-five years old; data is collected every four or five years.

Persistent Organic Pollutants: chemical substances that persist in the environment, bioaccumulate through the food web, and pose a risk of causing adverse effects to human health and the environment.

Pesticide: a substance or mixture of substances used to kill a pest.

Pheromone: a chemical compound secreted by animals to influence the behaviour of others of the space species or to communicate with others of the same species; synthetic versions of these pheromones, usually sex pheromones, are used to lure insects inside traps.

Photosynthesis: the process by which carbon dioxide is combined with water to produce oxygen and a carbohydrate (e.g. glucose). Note that sunlight is the driving force for photosynthesis and photosynthetic organisms include plants, blue-green algae or blue-green bacteria.

**Phytoplankton**: the microscopic plant or plant-like component of plankton which includes free-floating algae; the main producers in the aquatic food chain.

**Placer Mining**: mining for materials such as gold, platinum, chromium, tin, titanium, and diamonds, which accumulated among river and beach gravels because of density.

**Point Source Discharge**: a pipe, ditch, channel, or some other natural or unnatural container, from which pollutants may be discharged.

**Pollutant**: any substance that, when introduced to the environment, adversely affects a resource or the health of humans, wildlife, or ecosystems; e.g. sewage, chemicals.

**Population Estimate**: an estimate of the size of a population of a particular species.

**Population**: a collection of inter-breeding organisms of a particular species.

**Porosity**: the spaces between particles or grains in soil or rock which could store liquids or gases.

**Potable Water**: water that is suitable for drinking.

**Poultry**: domestic fowls such as chickens, turkeys, ducks, or geese that are raised for either meat or eggs.

**Power Grid**: a system of high tension cables by which electrical power is distributed throughout a region.

**Precautionary Principle**: the theory that an action should be taken when a problem or threat occurs in contrast to taking an action after harm has already been inflicted; an approach to decision-making in risk management which justifies preventative measures.

**Precipitation**: any form of water such as rain, mist, snow, sleet, or hail that falls to Earth's surface.

**Pre-commercial Thinning**: removal of nonmarketable trees from forests to reduce the competition for light, nutrients, and water, thereby allowing for improved conditions for growth of the remaining trees.

**Preservation Ethic**: a way of thinking that considers nature special in itself; nature having intrinsic value or worth apart from human reliance on it.

**Preservation**: the act of protecting a natural resource against damage.

**Pre-treatment**: a method of waste treatment that includes screening to remove debris and pre-sedimentation that removes silt and other similar materials.

**Prevailing Winds**: the trends in speed and direction of wind over a particular point on Earth's surface. A region's prevailing winds often show global patterns of movement in Earth's atmosphere. Prevailing winds are the causes of waves as they push ocean water.

**Primary Succession**: succession that begins in an area that lacks soil such as bare rock; pioneering organisms, such as lichen, slowly break down rock to build up soil in order to eventually sustain the growth of plants.

**Prion**: an infectious protein molecule similar to a virus, but lacking genetic material. Prion-caused diseases are usually rapidly progressive and always fatal.

**Productivity**: the percentage of individuals born in a population of a particular species in a given year.

**Protected Area**: a location which receives protection because of its environmental and/or cultural value; e.g. parks, reserves, wildlife sanctuaries.

## Q

**Quarry**: a type of open pit mine from which rock or minerals are extracted. A quarry is generally used for extracting building materials such as dimension stone.

**Quota**: a limit on the maximum number of organisms that can be hunted or fished.

## R

**Radioactive Material**: material made up of atoms in which radioactivity occurs; the process in which an unstable atomic nucleus loses energy by emitting ionizing particles and radiation.

**Range of Tolerance**: the upper and lower limits of a limiting factor in which organisms can survive.

**Reclamation**: the process by which lands that were disturbed as a result of human activities (e.g. mining) are reclaimed back to a beneficial land use.

**Recovery Plan**: a plan that details how a species is to be recovered, identifies habitat needed for its survival, and timelines as to when the plan is to be carried out.

**Recovery Team**: a group of people responsible for directing a recovery process for listed species at risk; the team is composed of government representatives, interested persons, and species experts.

**Recovery**: an increase in population size occurring after habitat regeneration; the reclaiming of something that was once lost, missing, or absent.

**Recruitment Rate**: the number of young that survive to adulthood.

**Refining Process**: to separate things into various components; e.g. petroleum, air.

**Rehabilitation**: restoring the condition of an ecosystem, population, etc.

Remote Sensing: the science of acquiring information about Earth's surface without actually being on location; includes the use of ground-based sensors, aircrafts, satellites, and space stations.

Renewable Resource: a living resource that can renew itself given the proper conditions; e.g. trees, wildlife.

Reproductive Potential: the number of offspring a female of a given age can be expected to produce.

Residual Concentration: the amount of chlorine that remains in the water after the disinfection process.

Resource Extraction: the removal of a resource, usually natural, from the environment.

Runoff: the process of water (often containing dissolved soil particles and fertilizers) flowing from wherever it falls on the land (following the process of precipitation) to streams, rivers, oceans, or other bodies of water.

## S

Salinity: the salt content of water.

Salmonid Species: a family of fish (salmonidae) that includes many commercially farmed species such as salmon, trout, and char.

Salt Marsh: a type of marsh that is located between the ocean and land; dominated by salt-tolerant vegetation.

Salvage Cut: the harvest of sellable timber from an area that is heavily damaged by insect infestations.

Scarification: the mechanical disturbance of the top layers of soil to allow seedlings to take root.

Scavenger: an organism that feeds on dead organic matter; e.g. seagull, crab, lobster.

Scrubber: a modern technology that is placed on an industry stack for the purpose of reducing sulphur emissions. A scrubber contains chemicals that react with the sulphurous gases.

Secondary succession: succession that begins in an area where the vegetation was destroyed by a disturbance such as fire or forest harvesting.

Sedimentation: the settling out of soil and rock particles from a medium (air or water); also known as deposition.

Selective Cutting: harvesting only trees of a particular age, size, species, or quality.

Sentinel Fishery Program: a survey program in which professional inshore fisherpersons work with the Department of Fisheries and Oceans to determine the relative abundance of inshore cod populations.

Septic Tank: a sewage-disposal tank in which a continuous flow of waste material is decomposed by anaerobic bacteria; tanks do not treat sewage; they merely remove some solids and condition the sanitary flow so that it can be safely transferred to a subsurface facility such as a tile field, leaching pool, or buried sand filter.

Sheet Erosion: occurs when water flows in a sheet across the surface of the ground, picking up material as it moves along; occurs in campsites, picnic areas, and on level ground.

Short Wood Harvesting: the preferred method of harvesting where the branches and tops of trees are left on the site to protect the forest floor and to add nutrients to the soil; also known as cut to length.

Silage: food prepared by storing and fermenting green forage plants in a silo.

Silt Fence: a temporary sediment barrier made of woven, synthetic filtration fabric that is supported by steel or wood posts; used on developments where the life of the project is six months or greater.

Silting: the coming to rest or deposition of silt, most often in water, that has been created by the process of weathering and moved by the process of erosion.

Silviculture: the science of the cultivation and care of forest trees.

Sinkhole: a hole formed in porous and permeable rock by the action of water, which serves to conduct surface water to an underground passage; also called a sink (or a depressed area) in which waste or drainage collects.

Skimmer: equipment used to recover oil from a water surface.

Sludge: semisolid material such as the type precipitated by sewage treatment.

Small Game Species: small, animal species that have high mortality rates and therefore, high reproductive rates. High reproductive rates are meant to increase the chances of offspring survival; e.g. rabbit, mink, fox, coyote.

Smelting: also known as refining or processing; the final stage of mineral refining or processing in the mining industry.

Smog: a form of air pollution that is produced by the reaction of sunlight with hydrocarbons and nitrogen oxides, which have been released into the atmosphere, particularly by automotive emissions.

Smolt: a juvenile salmonid that is undergoing the physiological change that is required to be able to migrate from fresh to salt water.

Soil Compaction: occurs when soil particles are pressed together, thereby reducing the pore space between them; compacted soils contain few large pores and have a reduced rate of both water infiltration and drainage from the compacted layer.

Soil Erosion: the loss of soil due to the actions of erosion agents such as wind and water.

Soil Horizons: layers of soil that can be distinguished from each other by such features as chemical composition, color, and texture.

Soil Litter: dead plant and animal material on the surface of the ground, above the humus layer.

Soil Profile: the description of the various layers, known as soil horizons, present in soil at a particular geographic location.

Solar Radiation: electromagnetic radiation that emanates from the sun; e.g. x-rays, ultraviolet radiation, infrared radiation, radio emissions, visible light.

Spawning: the production or deposition of large quantities of eggs by aquatic organisms.

Special Concern: any species or subspecies of wildlife that has entered a long-term decline in abundance and could be facing extinction.

Species Diversity: the variety of species within a particular habitat or region.

Sphagnum Moss: a type of moss that is native to damp locations such as bogs and marshes. It is highly water absorbent.

Stewardship: being a steward involves caring for the environment as you would your home.

Stock Assessment: a determination of the production of a fish stock by calculating the sum of the recruitment of young fish, plus the growth of larger fish, minus the natural mortality or numbers that are dying; if positive, the stock will grow; if negative, the stock will decline.

Stream: a flow of water in a channel or bed such as a brook, rivulet, or small river.

Submerged Plants: plants that grow and reproduce while completely submerged in water; e.g. water lilies.

Subtidal: the region of a shallow coastal area that is submerged by water, even at low tide.

Succession: the gradual change from one dominant plant community to another.

Sulphur Oxide: any binary compound of oxygen and sulphur or a mixture of such compounds; e.g. sulphur monoxide (SO), sulphur dioxide ($SO_2$).

Surface Water: water found on Earth's surface; e.g. streams, lakes, rivers, oceans.

Suspended Particulates: tiny airborne particles that are less than 100 micrometers are collectively referred to as total suspended particulate matter (TSP). These particles constantly enter the atmosphere from many sources.

Sustainability: living within the resources of the planet without damaging the environment now or in the future.

Sustainable Development: the development of our resources to meet our present needs without reducing the ability of future generations to meet their needs.

Sustainable Tourism: an industry that aims to have a low impact on the natural environment and local culture while helping to generate income and employment for locals.

Swamp: a tract of wet, spongy land, often having a growth of certain types of trees and other vegetation.

## T

Tailings: the materials that are left behind after the valuable component of an ore have been extracted.

Temporary Sample Plot: a plot of trees that are randomly selected to sample various forest data including the volume of timber within a stand.

Terrestrialization: the formation of a bog that results when sphagnum moss grows over a lake or pond and slowly fills it in.

Thermal Power: water is heated, turns into steam, and spins a steam turbine that drives an electrical generator.

Thermocline: a layer in a large body of water, such as a lake, that sharply separates regions differing in temperature; the layer between the mixed layer and the deep layer. This zone can extend to a depth of 1000 meters.

Thermoenergy: also known as thermal energy; heat energy.

Tillage: cultivation of soil to prepare it for seeding.

Topographic Map: a map that shows elevation above sea-level using contour lines. It also shows man-made (or cultural) and natural geographic features.

Topsoil: the fertile, uppermost layer of soil.

Total Allowable Catch: the total catch, measured in tones, allowed from a stock during a specified period of time.

Total Dissolved Solids: all inorganic and organic substances that are dissolved in a liquid; cannot be filtered.

Total Suspended Solids: a measurement of the particulates that are suspended in water; can be removed by filtration.

Toxic Substance: a chemical or mixture that may present an unreasonable risk of injury to health or the environment.

Tributary: a stream that flows to a larger stream or another body of water.

Trihalomethanes: chemical compounds containing three halogen atoms substituted for the three hydrogen atoms normally present in a methane molecule. It can occur in chlorinated water as a result of the reaction between organic materials in the water and chlorine added as a disinfectant.

Trophic Level: any of the sequential stages, or position, in a food chain, occupied by producers at the bottom and in turn by primary, secondary, and tertiary consumers.

Tuckamore: a stunted form of forest growth caused by climatic or nutritional extremes; also known as tuck.

Turbidity: the measure of solid particles suspended in water; also known as cloudiness.

Turbine: a device used in the generation of electricity; water, steam or some other energy source pushes a shaft with blades on one end and electromagnets at the other. As the electromagnets spin, electricity is produced in a coil of wire surrounding the magnets.

## U

Underseed: to plant a crop that grows low to the ground and between the primary crop; eliminate bare ground and tillage operations between crops.

Understory: the shrubs and plants growing beneath the main canopy of a forest.

United Nations: an international organization, with headquarters in New York City, formed to promote international peace, security, and cooperation under the terms of the charter signed by 51 founding countries in San Francisco in 1945.

Unsustainable: not able to be maintained or supported in the future, especially without causing damage or depletion of a resource.

Urbanization: the process by which cities grow.

## V

Volatile Organic Compounds: emitted as gases from certain solids or liquids; includes a variety of chemicals, some of which may have short- and long-term adverse health effects. Concentrations of many VOCs are up to ten times higher indoors than outdoors. Examples include: paints and lacquers, paint strippers, cleaning supplies, pesticides, building materials and furnishings, office equipment.

## W

Waste Management Strategy: an approach to dealing with waste that gives priority to pollution prevention, waste minimization, and recycling before resorting to treatment and disposal of waste.

Wastewater: water that has been used, as for washing, flushing, or in a manufacturing process, and so contains waste products; sewage.

Water Quality: the characteristics of water in relation to what is suitable for human consumption and for all usual domestic purposes including personal hygiene. Components of water quality include microbial, biological, chemical, and physical aspects.

Water Table: the level below which the ground is completely saturated with water.

Watershed: an area of land in which the surface water and ground water all drain to a common waterway such as a stream, wetland, lake, or even the ocean; also known as a drainage basin.

Waterway: a navigable body of water such as a river, channel, or canal.

Wet Boreal Forest: old-growth forest that is dominated by conifer species that have high moisture levels.

Wetland: the most biologically diverse ecosystem where soil is saturated with water, either permanently or seasonally; e.g. marsh, bog.

Wilderness: a wild and uninhabited area left in its natural condition.

Wildlife Park: a park that serves to protect plants and animals within its boundaries and provide educational opportunities to the public.

## Y

Year-class: fish of the same age that are hatched in the same year.

## Z

Zooplankton: the animal or animal-like component of plankton that includes small protozoa, crustaceans (such as krill), and the eggs and larvae from larger marine animals that are suspended, swimming, or drifting in the ocean; source of food.

# Index

# TOWARD A SUSTAINABLE FUTURE

Challenges
Changes
Choices

Everyday, in every country, people are talking about the environment - our environment - and how we need to ensure that our use of natural resources is sustainable. We hear and read about environmental issues and sustainable development in all the media. Why are so many people discussing this topic? Maybe people are realizing that our generation is the first generation that has the ability to determine the future habitability of the planet for humans and other species.

While there is much negativity in what is being said about the environment, we are fortunate to live in a time when many people of different ages, beliefs and backgrounds are trying to find answers or are taking actions to address the environmental issues affecting our future. While some of these answers will be technological (e.g., more fuel-efficient vehicles, alternative energy sources), much of the solution lies with the individual - with you. We cannot underestimate the power of each individual when it comes to making positive, long-term environmental impacts.

As the title suggests, there are many *Challenges* ahead that will require us to make appropriate *Choices* to secure the necessary *Changes* to create a sustainable future for ourselves and all other species on this planet.

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