The Greenhouse Effect

We know that climate change is being caused by the warming of our planet. But what causes this warming? Who – or what – is in control of the thermostat?

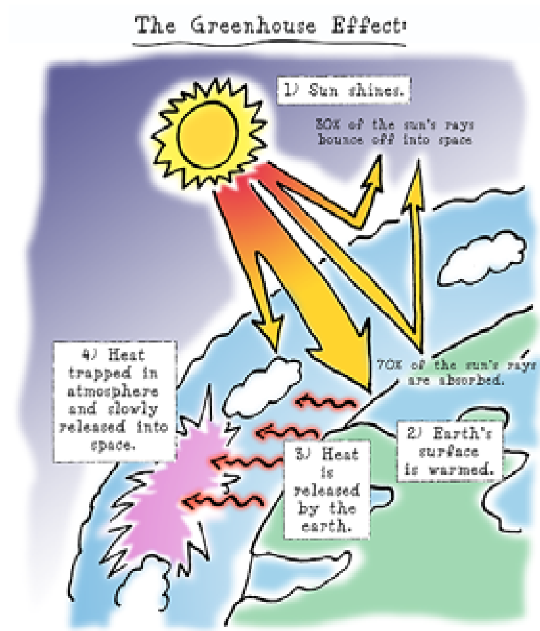
This backgrounder provides the answers to these questions.

You Think the North is Cold!

If you went for a walk on Mars during the day, you'd probably want to wear a bathing suit and a lot of sunscreen, as it would be about 37°C. But at night, the warmest parka wouldn't do you much good as temperatures would plummet down to a nippy –123°C or so!

Why does Mars cool off so much at night? It's because the sun's heat scoots right back out into space when the sun goes down. Mars doesn't have much of a blanket to keep the warmth of the day in.

A Blanket Around Our World



Down here on Planet Earth, about half of the sun's heat that reaches us is absorbed by the land and water. When the sun goes down, the absorbed heat is slowly released into the air. We also have an atmosphere – a layer of gases surrounding the earth – that absorbs some of the sun's heat and also helps keep the released surface heat from floating quickly off into space. The atmosphere is like a blanket that surrounds the world.

This atmosphere also lets in just the right amount of the sun's heat (about 70%) and reflects the rest – sending it packing back out into space.

Most of the atmosphere is made up of nitrogen and oxygen. As you know, oxygen is pretty important as it allows us to breathe! However, it is the water vapour in the atmosphere and a tiny amount of trace gases that keep us from frying and freezing on Planet Earth.

The trace gases make up less than 0.1% of the atmosphere. These gases include carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). Although the trace gases make up just a tiny part of our atmosphere, they are big-time players when it comes to keeping the world at temperatures we can survive. *(For more details on these trace gases, check out Backgrounder 3)*.

Riding the waves: Solar travel to Earth

Details on the Natural Greenhouse Effect

Incoming!

The sun's energy comes to earth as solar radiation in short and medium wavelengths.

- Most of the short wave radiation (called gamma rays, x-rays, and Ultraviolet (UV) light) is absorbed by the mid to high regions of the atmosphere.
- The medium waves are visible light and travel pretty much uninterrupted through the atmosphere to earth.
- These waves are absorbed by the Earth's surface and by the carbon dioxide and water vapour in the lower atmosphere.

Some gets reflected
When the sun shines on Earth, about 31% of the incoming visible light is reflected back into space. Clouds and suspended solid materials reflect about 22%, while land and ocean surfaces, particularly snow and ice, reflect about 9% of visible light upwards.

And some gets absorbed
The 69% of the sun's visible light that gets through is absorbed mostly by land and water on the earth's surface (49%) and by the clouds and atmosphere (20%).

And released later
Heat absorbed by the surface is radiated back as long-wave infrared (IR) radiation. This warms the air immediately above the earth's surface.

To be trapped again – for a while
Water vapour and other greenhouse gases in the atmosphere absorb this IR radiation, holding it in. The trapped heat is also radiated up, down and all around. Eventually it disperses to outer space.

This is called the Greenhouse Effect because the atmosphere acts like the glass in a greenhouse. It helps to trap in the sun's heat, slowing its release into the colder space.

Hanging Out in the Greenhouse

Like the plastic or glass covering a greenhouse, water vapour and trace gases trap the heat radiated from the sun. If we didn't have these Greenhouse Gases (GHGs for short), the earth would be an icebox. Our average temperature would be about -18°C. This is the average temperature of Antarctica. If this were the earth's temperature, there would be very little (if any) liquid water anywhere on the planet. It's likely there wouldn't be any living organisms either!

People refer to this heat-trapping role of the atmosphere as the "greenhouse effect". It's a natural process that allows us to live on earth.

However, too much – or too little – of a good thing can be bad for you. We need just the right balance of GHGs in the atmosphere. Unfortunately, there are starting to be too many GHGs in the atmosphere. This means that more heat is being trapped by the atmosphere. And our greenhouse is starting to get a little too warm for comfort.

Balancing the Carbon Teeter-Totter

To understand why we are getting too warm in our greenhouse, let's look at carbon dioxide (CO_2), one of the most important GHGs. Carbon dioxide makes up about 25% of the natural greenhouse effect and is therefore a key player.

A number of things put carbon dioxide in the atmosphere:

- Forest fires or erupting volcanoes are natural sources of carbon dioxide.
- Trees and plants also contain a lot of carbon. When they die and decompose (rot) half of the carbon contained in the trees and plants is released into the atmosphere as carbon dioxide. The other half is absorbed by the soil. However, soils also slowly decay, especially if they are disturbed by fire and other processes. This releases more carbon dioxide into the atmosphere.
- Humans, animals and insects consume plant materials that contain carbon. Much of the carbon in the plants is eventually released into the atmosphere when humans, animals and insects breath-out carbon dioxide.

- Oceans contain and release huge amounts of carbon dioxide that bubble into the air from their surfaces.

Some things also *remove* carbon dioxide from the atmosphere.

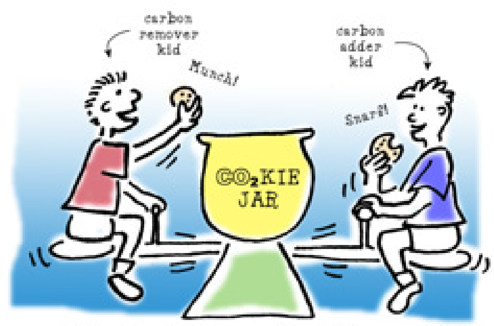
- Plants and trees take in carbon dioxide when they turn the sun's energy into food (through photosynthesis).
- Oceans also absorb large amounts of carbon dioxide into their surface waters. The carbon dioxide dissolves in the ocean like the fizz in a soft drink.
- Phytoplankton – a big name for little organisms that float around in the ocean – take up a large portion of the ocean's carbon dioxide through photosynthesis (though much of this is later released).

This removal of carbon dioxide from the atmosphere helps keep things in balance.

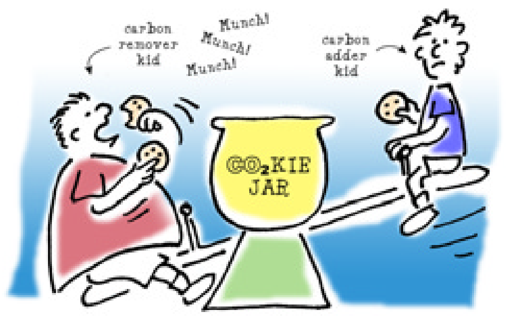
Over the past 10,000 years, the balance between the annual atmospheric release and removal of large amounts carbon dioxide has been remarkably stable on average.

Imagine two kids playing on a teeter-totter. At one end, the child weighs the same as the amount of carbon dioxide *removed* from the atmosphere. The child on the other end weighs the same as the amount of carbon dioxide *put into* the atmosphere. The teeter-totter was essentially in balance for about 10,000 years

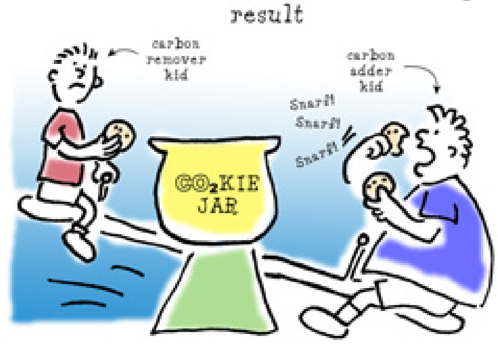
The Carbon Teeter-Totter



The Basic Scenerio: Balanced for the past 10,000 years.



Out of balance:
Too much carbon removed: Ice ages result



Tipping the other way:
Too much carbon added: global warming results

Out of Balance

However, things have not always been in perfect balance. If you had been hanging around for the last 400,000 years, you would have seen four major periods of time where very warm clothes would have been in high demand as the teeter totter dropped to one side!

Each of those times, the amount of carbon dioxide in the atmosphere decreased naturally (from about 275 parts per million down to about 220 parts per million). In other words, the kids on the teeter-totter changed their diets. The kid that removed carbon dioxide took some of the other kid's carbon dioxide away and the balance tipped. The one putting carbon dioxide into the atmosphere got thinner.

Less carbon dioxide in the atmosphere meant that less of the sun's heat was trapped by the atmosphere. This caused the average temperature of the world to cool by about 5°C. Each time, this temperature drop was enough to start an ice age!

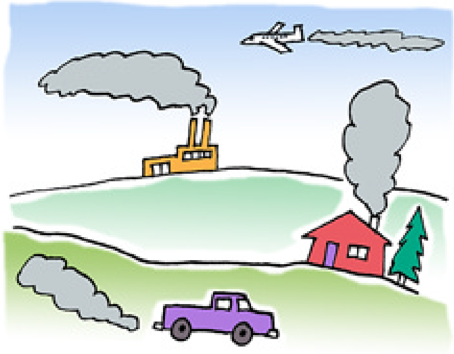
You might want to keep in mind that during the last ice age – just over 10,000 years ago – most of North America and Europe were covered by ice. So a few degrees can make a big difference!

Tipping the Other Way

Since the end of the last ice age, the amount of carbon in our atmospheric blanket has been pretty stable and temperatures on earth have been pretty comfortable. That is, until the last 200 years or so.

Unfortunately, when the industrial revolution began in the late 1700s, people started to add billions of tonnes of extra carbon dioxide to the atmosphere.

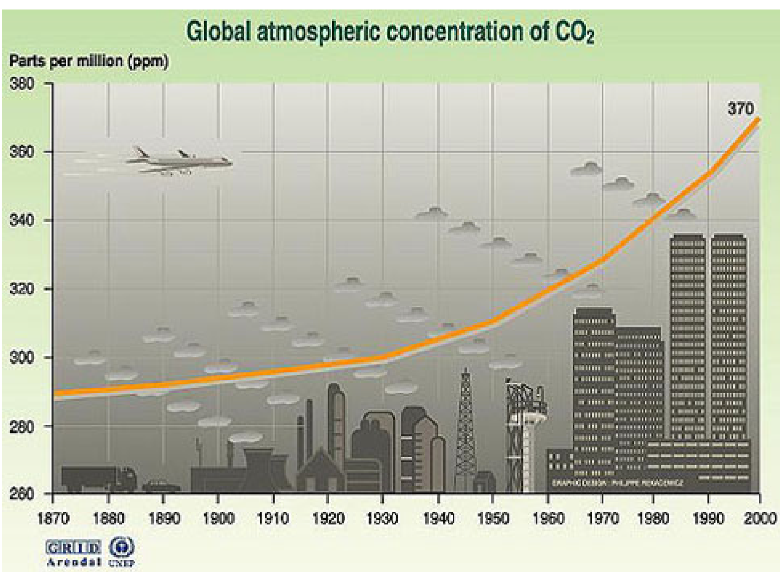
People put carbon dioxide into the atmosphere when we run our industries, heat our homes and drive our cars. This is because when we do these things, we usually burn fossil fuels – oil, gas and coal. These fossil fuels are made from the carbon of plants and animals that decomposed millions of years ago. Over time, these decomposed materials were buried by layers of soil and other decomposed material. Heat and pressure helped to turn decomposed plants and animals into what we now call oil, gas and coal.



So these fossil fuels are made up of a lot carbon – carbon that was trapped below the surface of the earth for millions of years. When we bring carbon – in the form of oil, gas and coal – back to the surface and burn it as fuel, it combines with oxygen to release a lot of carbon dioxide into the atmosphere.

Based on studies of ice cores from glaciers, scientists believe that there is much more carbon dioxide in the atmosphere now than there has been for a very, very, very long time. We have now reached about 370 parts per million (ppm) of carbon dioxide in the atmosphere and its still increasing. Scientists believe that in the last 400,000 years, carbon dioxide has never been much above 300 ppm. So this is a big jump in the amount of carbon dioxide in the atmosphere. The teeter-totter has now tipped the other way. The kid who puts carbon dioxide into the atmosphere is now much heavier than the kid that takes carbon dioxide out of the atmosphere. And the one putting it in keeps getting heavier and heavier.

Having this much carbon dioxide in the atmosphere is kind of like throwing a much thicker blanket on your bed – things can get a little too toasty for comfort. It is time for the kid putting carbon dioxide into the atmosphere to go on a diet!



Graph showing changes in CO_2 since industrial revolution.

It's not like we learned this yesterday!

In 1824, French physicist Jean Fourier first described how the atmosphere acted like a greenhouse and trapped the sun's heat in.

In 1896, Swedish physicist Svante Arrhenius argued that increases in carbon dioxide in the atmosphere enhanced the Earth's greenhouse effect and led to global warming. He calculated that historical volcanic eruptions could have caused carbon dioxide concentrations in the atmosphere to double over time. He believed that this increase in carbon dioxide could cause an average temperature increase of 5° to 6°C.

The first real warning that humans were putting too much carbon dioxide into the atmosphere came in 1957. Two scientists, Roger Revelle and Hans Seuss, wrote a scientific paper. It described the build-up of carbon dioxide in the atmosphere as "a large-scale geophysical experiment" with the earth's climate.

Little was done about the increasing carbon dioxide in the atmosphere for many years. But in 1992, many countries signed the first international agreement that dealt with GHGs in the atmosphere. It was called the United Nations Framework Convention on Climate Change (UNFCCC)
(see Backgrounder 16)

Why would the Northern part of the greenhouse get hotter?

The increase of GHGs in the atmosphere is expected to cause global temperatures to go up an average of 1.4° to 5.8°C in the next 100 years. However, temperatures in the Arctic are expected to rise more than the average. For example, winter temperatures over the land areas in the Arctic could rise 2.5° to 14°C above current normal temperatures. What's up with that?

Less reflection, more absorption: The snow and ice in the North normally reflect back a lot of the solar heat that gets to the earth surface. This is one reason why the north stays cooler than the rest of the world. Unfortunately, a lot of snow and ice will melt, as the world gets warmer. This means there will be less reflection – and more absorption – of the sun's heat by the land and open water. As more heat is absorbed in the North, even more of the North's snow and ice will melt... which means even more of the sun's energy will be absorbed (this is called a positive feedback effect).

The loss of snow and ice to reflect away the sun's heat is one of the main reasons the north will see dramatic increases in temperature. We will likely always have some snow and ice and so we will stay cooler than many other parts of the world. However, our temperatures will change more than the places in the world that don't have any snow and ice to lose in the first place.

Warmth from the polar oceans: In winter, the polar oceans are much warmer than the very cold air above them. As warmer climates cause the ice on the oceans to form later in the fall, break up earlier in the spring, and become thinner during the winter, much more heat escapes to warm the air above. That is why winters are expected to warm so much more over polar regions, particularly over the Arctic Ocean, than in regions closer to the equator.

Moisture carries warmth: As climate change happens, warm air from the tropics – that moves northward – will likely carry more moisture with it. The moisture in the air is actually water that has been warmed and turned into vapour. When the moist vapour eventually cools over the arctic, it will fall to earth. When it does this, it will transfer the heat it carries into northern regions.

Greenhouse on Steroids?

When we add more GHGs to the atmosphere we get what is called the "enhanced greenhouse effect". We are changing the natural processes of the world and making it difficult for the atmosphere to keep a balance.

This enhanced greenhouse effect isn't making us sweat buckets yet, but it is starting to change the climate and the world we are used to. To get a sense of these changes, check out the other backgrounders to learn more about the role of GHGs and the impacts of climate change.

Key Points

- The atmosphere helps trap the heat of the sun close to earth. The atmosphere, together with the Earth's surface also reflects 31% of the sun's heat back into space.
- It is the greenhouse gases (GHGs) in the atmosphere that absorb and trap the heat. Water vapour is the main GHG. Carbon Dioxide (CO_2) is the next largest GHG.
- Trees and plants, as well as oceans, help remove carbon dioxide from the atmosphere.
- Many natural things put carbon dioxide into the atmosphere: forest fires, volcanoes, decomposing trees and plants, and gas bubbles from ocean surfaces.
- Humans are now also releasing carbon dioxide by burning fossil fuels. Carbon dioxide concentrations in the atmosphere have been going up steadily since we started burning fossil fuels over 200 years ago.
- More carbon dioxide and other GHGs in the atmosphere, means more heat is trapped and absorbed. This causes global temperatures to increase.

Want to Know More?

Here are some websites to help you find out more about the Greenhouse Effect:

- **The Australian Greenhouse Office:** http://www.greenhouse.gov.au/education/factsheets/what.html – Contains a wealth of information about different aspects of climate change
- **BBC World Service:** http://news.bbc.co.uk/hi/english/static/in_depth/sci_tech/2000/climate_change/default.stm – Click on 'Greenhouse Effect' for an animated explanation
- **Encyclopaedia of the Atmospheric Environment:** www.doc.mmu.ac.uk/aric/eae/english.html – Find write-ups on all aspects of climate change by clicking on 'Climate Change' or 'Global Warming.'
- **EPA Kids' Site (Greenhouse Effect):** http://www.epa.gov/globalwarming/kids/greenhouse.html – Has a great animation that takes you through the whole process
- **Living Landscapes:** http://royal.okanagan.bc.ca/mpidwirn/atmosphereandclimate/greenhouse.html#a – Gives a good overview, complete with pictures and graphs.
- **A Climate Change Timeline:** www.ec.gc.ca/climate/timeline-e.html