The Carbon Cycle and Climate Change

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What is Climate Change?

Climate change is the increase in the average temperature of the planet.

Climate change affects the planet in many ways: for example, there will be more heatwaves, wildfires, floods, droughts, and landslides.

The Atmosphere

The atmosphere is a jacket of gases that surround our planet. It is made of:

Nitrogen (N_2) - 78.1 %

Oxygen (O_2) - 20.9 %

Argon (Ar) - 0.9 %

Carbon dioxide (CO_2) - 0.04 %

And very small amounts of other gases

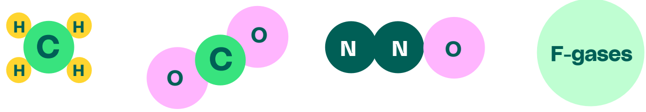
Why is the earth warming?

Greenhouse gases

Climate change is caused by the increase in the atmospheric concentration of greenhouse gases. Greenhouse gases are gases in the Earth's atmosphere that trap heat reflected from the earth's surface (like how heat is trapped in a greenhouse). We need some greenhouse gases to survive, without them the earth would be -19°C, which is about the same temperature as your freezer!

However, in recent years, the amount of greenhouse gases in the atmosphere has increased so much that more heat is being trapped, causing the increase in the average temperature of the Earth (the planet is becoming warmer), and the global climate to change. The increase in the amount of greenhouse gases is caused by people and their actions.

There are a number of gases that contribute to global warming – some of these are:



Methane

Carbon Dioxide

Nitrous Oxide

Fluorinated Gases

The Global Carbon Cycle

Carbon

Carbon is a chemical element and is found in many forms, as an energy source for building things:

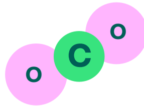
- Our bodies (18% of a person) – in our DNA, muscles, bones and more
- The atmosphere, as CO_2
- Rocks, soils and the earth's crust
- Fuel (e.g. petrol and diesel)
- Oceans
- Animals
- Plants
- Buildings

Carbon moves around the earth between these different forms through the 'carbon cycle'. The carbon cycle is the movement of carbon, in the form of CO_2, into and out of the atmosphere.

Carbon Dioxide

Carbon dioxide, also called CO_2 (pronounced see-oh-two), is the most important of the greenhouse gases as it is emitted in large quantities and has a long-lasting influence. CO_2 stays in the atmosphere for thousands of years (also known as 'atmospheric lifetime'), this is one of the reasons why it builds up in the atmosphere and why we need to reduce emissions.

Other greenhouse gases have shorter lifetimes or much smaller concentrations in the atmosphere. For example, 0.04% of the atmosphere is CO_2, while methane accounts for 0.00018%, and nitrous oxide 0.00003%. Even such small quantities are enough to trap lots of heat. Carbon dioxide in the atmosphere is part of the 'carbon cycle'.



The Global Carbon Cycle

Key

- CO_2 emissions
- CO_2 uptake
- Net uptake

The carbon cycle contains sources and sinks of carbon dioxide from the atmosphere.

A **carbon sink** is a system that takes in more carbon from the atmosphere than it releases.

A **carbon source** is a system that releases more carbon than it takes in.

These sources and sinks control the amount of carbon – in the form of CO_2 – that is in the atmosphere.

Carbon Sinks and Sources

Forests

Forests and soils have a role in the amount of CO_2 in the atmosphere. CO_2 is removed from the atmosphere by plants during photosynthesis, and returned to the atmosphere by respiration of plants, animals and soil microbes, and fires. As climate change makes the earth warmer there are more forest fires, which releases carbon back into the atmosphere as CO_2.

Oceans

Oceans also exchange carbon with the atmosphere. CO_2 from the air dissolves into the ocean's surface, where it is used by plants and animals. CO_2 is also released from the ocean's surface. However, too much carbon in the ocean can damage plants and animals as it makes the water more acidic. Climate change is also causing the ocean to get warmer, meaning it can store less CO_2.

Fossil Fuels

Fossil fuels are a large source of the CO_2 in our atmosphere. They are burnt by humans, and unlike the ocean and forest sources, fossil fuels do not have a compensating sink.

Fossil fuels, such as coal, gas and petrol, are mostly made of carbon and formed from the buried remains of ancient organisms (hence the name 'fossil' fuels!). These fossil fuels are burnt to produce electricity, power and heat. As humans have burnt fossil fuels, more and more carbon has been added to the atmosphere and oceans, instead of being stored deep underground. People are adding carbon into the atmosphere faster than it can removed.

The Carbon Cycle in Cities

Key

Fossil fuel CO_2

Bio-CO_2

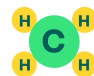
Residences and industries also emit CO_2 from biogenic sources, such as from wood burning.

Emissions and uptake amounts based on Auckland estimates

The urban carbon cycle
CO_2 in cities

Most of the world's population lives in cities, and cities create a lot of CO_2 fossil fuel emissions through transport, domestic activities, electricity use and more. Cities are responsible for 70% of CO_2 fossil fuel emissions globally.

Auckland is the largest city in Aotearoa New Zealand. In Auckland it is estimated that 44% of the total greenhouse gas emissions come from transport! Typically, the concentrations of greenhouse gases are higher in cities than in rural areas, because there are significantly higher emissions in highly urbanised areas. Although, in rural areas where there is pasture, lots of methane is also emitted!



Methane

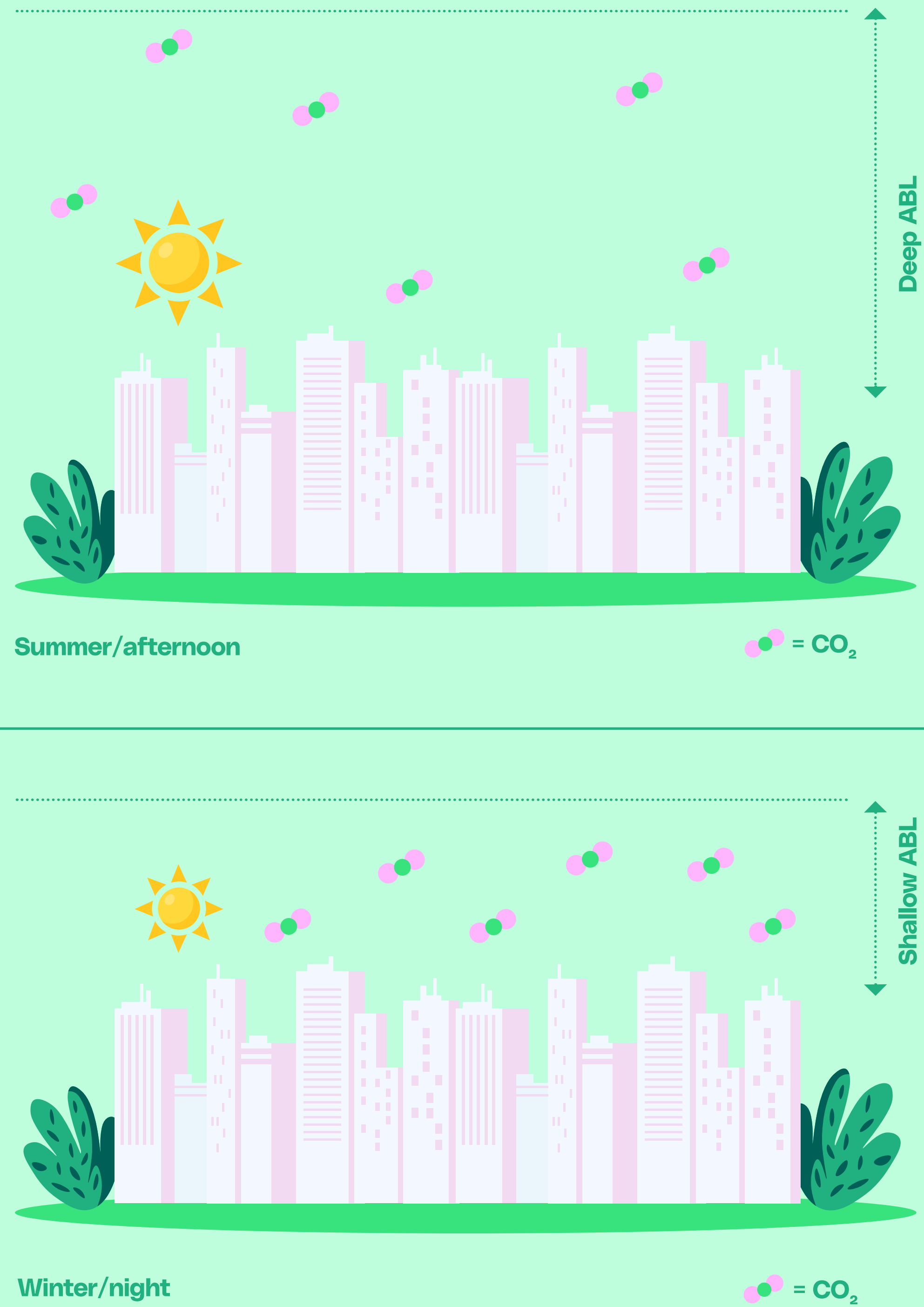
Methane (CH_4) is another very important greenhouse gas. It only makes up 0.00018% of the atmosphere but it is a very strong greenhouse gas. Methane is produced naturally by wetlands, and by humans from landfills, agriculture, and fossil fuels. The largest sink for methane is reaction with other gases in the atmosphere.

Atmospheric mixing

The wind plays a part in atmospheric mixing. When it isn't very windy, emissions will stay around the area where they were emitted, however strong winds will blow away emissions from the source.

The atmospheric boundary layer (ABL) is a thin layer of air (which can range from 100 to 3000 metres) closest to the ground. Greenhouse gases are mostly emitted close to the Earth's surface, within the 'atmospheric boundary layer'. The atmospheric boundary layer changes height throughout the day and year depending on temperature.

When the Earth is warm the boundary layer is at its deepest (e.g. summer/afternoons), meaning that the emissions are going into a larger volume and are becoming more spread out. This makes the concentration of gases look smaller than during the days and hours of colder temperatures, when the ABL is shallow. If we release the same amounts of gases within a shallow ABL (e.g. 200 metres), they will be very dense in that air volume (very close to each other), so will have a higher concentration!



Measuring CO_2

CO_2 is measured all around the world for climate change research. When we measure CO_2 we are measuring the concentration, not the emissions. The concentration is the amount of CO_2 in proportion of the total volume of the air. The emissions are how much CO_2 is being put into the atmosphere.

CO_2 is measured in the unit 'parts per million' (ppm). So, if the concentration is 415 ppm, this means that for every million molecules of air, 415 of them are CO_2 (415 / 1,000,000).

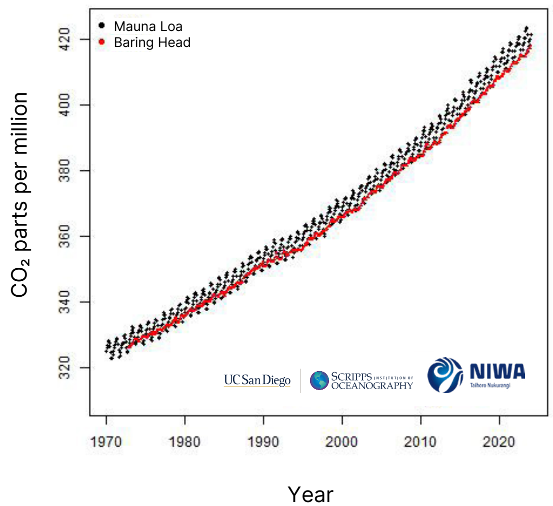
Because of the changing atmospheric mixing, figuring out emissions from measurements of CO_2 concentration can be complicated. For example, emissions in the morning are into a smaller volume of air than emissions in the afternoon, as the atmospheric boundary layer is lower in the sky, so the concentration of CO_2 measured by the analyser will be larger.

In Auckland, scientists from GNS Science and NIWA are measuring CO_2 concentrations around the city as part of the CarbonWatch-NZ and CarbonWatch-Urban research projects.

> The longest running CO_2 record in the world began in 1958. It was started by Charles Keeling of the Scripps Institution of Oceanography.

At Baring Head, near Wellington, NIWA has been measuring CO_2 since 1972 – this is the longest-running continuous CO_2 record in the Southern Hemisphere! In the Northern Hemisphere there is Mauna Loa (Hawaii), since 1958. At both of these measurement sites we can see an increase in the concentration of CO_2 in the atmosphere over time.

Mauna Loa and Baring Head CO_2



What can we do?
Climate action

Everyone can have an impact in reducing CO_2 emissions! For example, instead of driving to school you could walk or scooter.

Some other ways to reduce emissions are:

- Buy less new things! Making things requires energy which can come from fossil fuels, so to reduce emissions we can buy second hand things and only things we need.
- Unplug electronics and turn off lights.
- Write to your local politician asking for better low carbon transport around your city.

Reducing your impact begins with understanding it. Once you know where your emissions are coming from, you can find opportunities to cut down. You can calculate your carbon footprint online to see where most of your own emissions are coming from!

Authors

Written by Leigh Fleming, edited by Jocelyn Turnbull, Vanessa Monteiro and Erin Edmonds
Illustrations by Michelle Cosnett (Buravleva Stock, Envato)
Booklet designed by Michelle Cosnett

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Contact

driveitdown@gns.cri.nz
www.gns.cri.nz/driveitdown

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