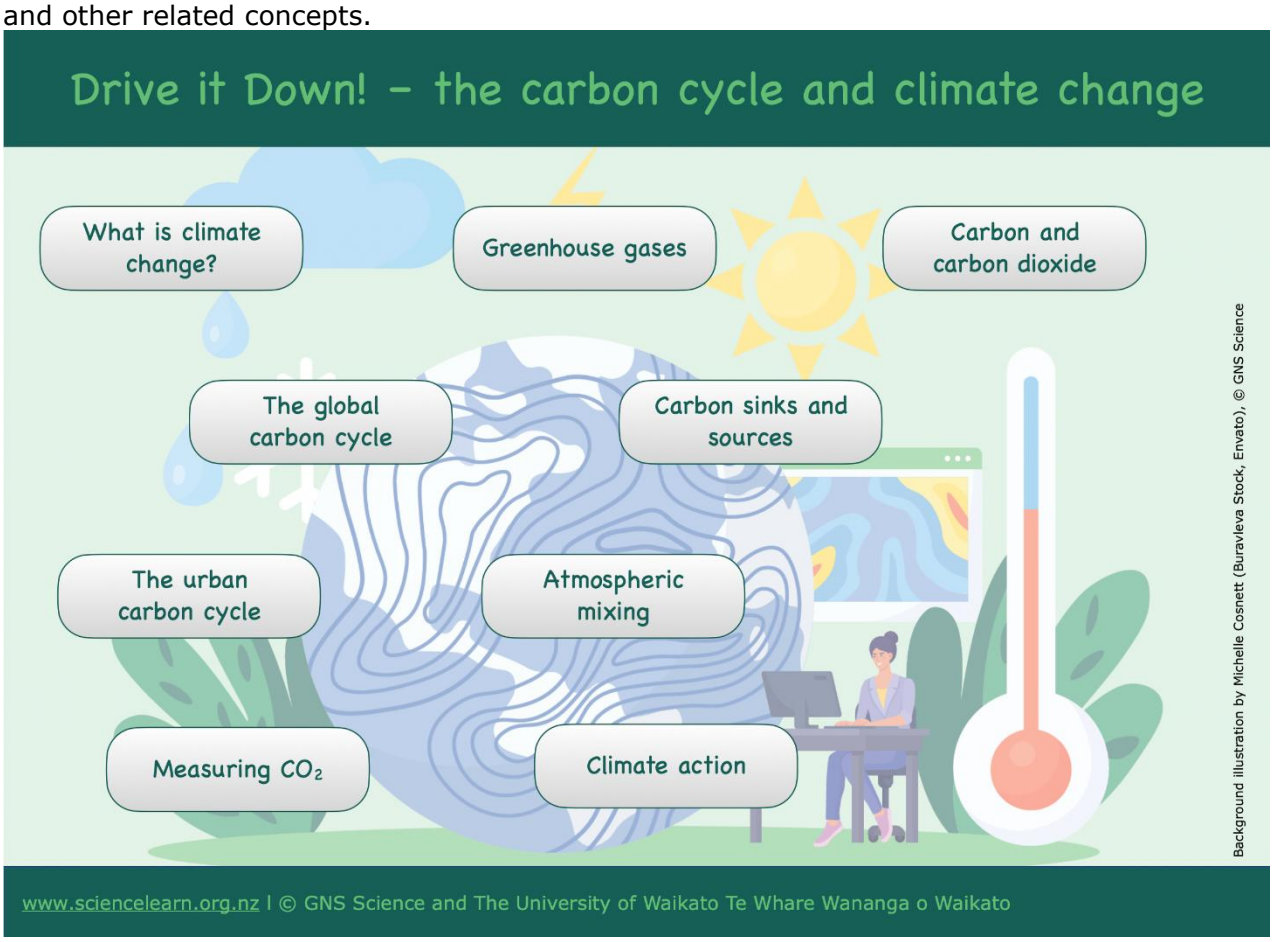
Drive it Down! – the carbon cycle and climate change

This interactive provides an overview of climate change, greenhouse gases, the carbon cycle and other related concepts.



The interactive uses text from the GNS Drive it Down! carbon cycle teaching resources to briefly explain some of the key science concepts that underpin understanding about the carbon cycle, carbon dioxide and its role in climate change. It also includes links to supporting articles, media and student activities from the Science Learning Hub and other websites.

The article Drive it Down! – a context for learning provides pedagogical suggestions and links to the New Zealand Curriculum.

Acknowledgement
This resource has been adapted from resources by GNS Science for the Drive it Down! Measuring and mitigating school-gate emissions project.

Index

What is climate change?	2
Greenhouse gases	4
Carbon and carbon dioxide	7
The global carbon cycle	9
Carbon sinks and sources	11
The urban carbon cycle	13
Atmospheric mixing	15
Measuring CO_2	16
Climate action	18

What is climate change?

© Derek Quinn, 111Emergency. CC BY 2.0

Climate change refers to the long-term changes in the Earth's climate, especially the increase in the average temperature of the planet.

Climate change affects the planet in many ways. With the changes in global temperature, extreme events are more likely to happen – for example, there will be more heatwaves, wildfires, floods, droughts and landslides due to heavy rain.

These events can also affect food and water supplies. People can get sick with more disease and have heat-related illnesses.

Animals and plants are also threatened by climate change. Threats include loss of food sources and water, habitat loss and the collapse of fragile ecosystems, which can result in species extinctions.

Why is the Earth warming?

Climate change is caused by the increase in the atmospheric concentration of greenhouse gases. These are gases from the Earth's atmosphere that trap heat reflected from the Earth's surface (like how heat is trapped in a greenhouse).

Related articles

- What is climate change?
- Climate connections – why climate change matters
- Aotearoa's contributions to climate emissions

- Climate change literacy learning links
- Planning pathways using climate change resources
- Agency in the Anthropocene
- Understanding the basics of climate change
- Exploring climate change education in primary schools

Related activities

- Climate change – challenging conversations
- Drive it Down! – climate change discussions
- Interpreting representations using climate data

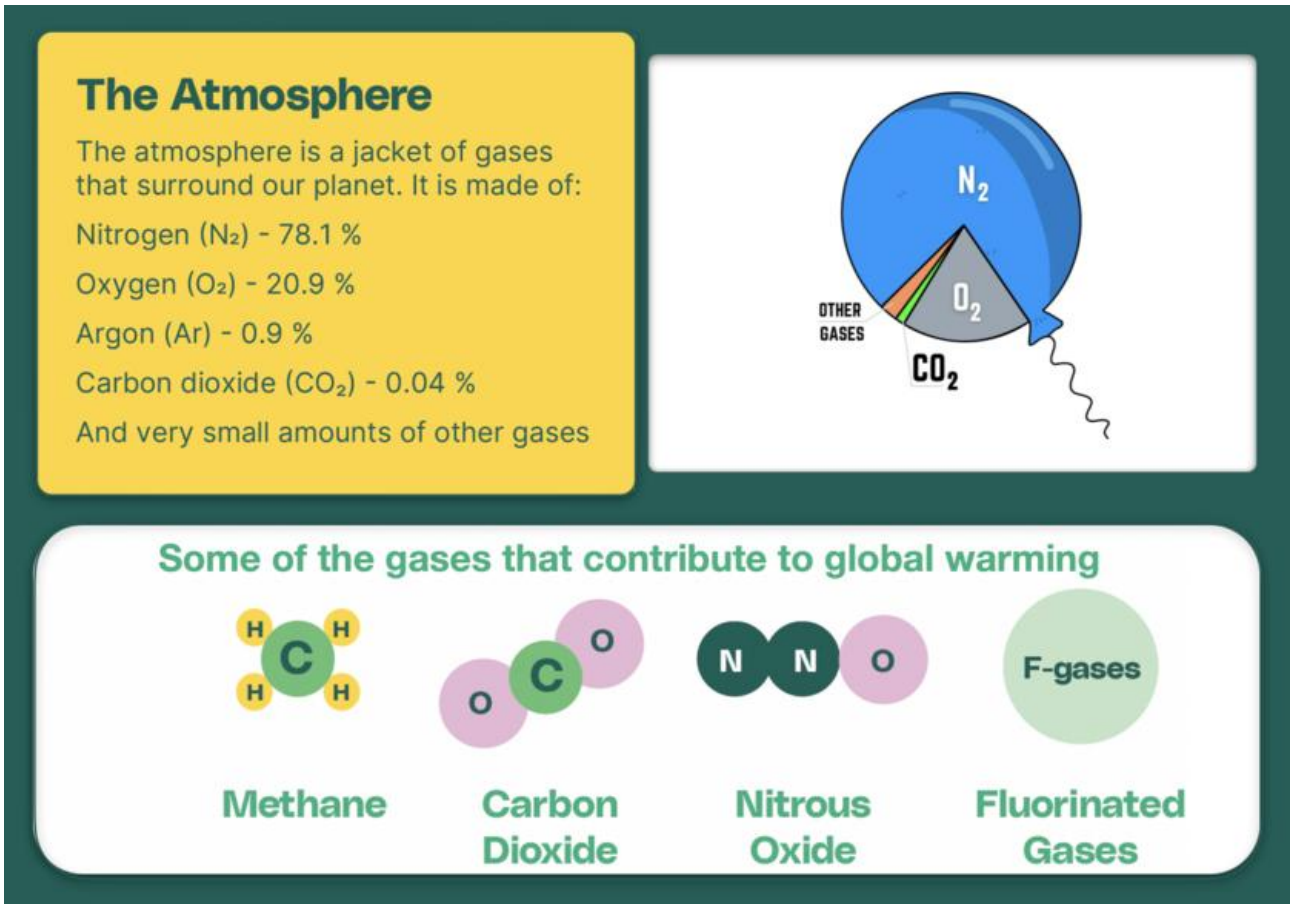
Related media

- Human contributions to climate change – video
- Understanding the basics of climate change – webinar

Useful links

- How carbon affects nearly everything on Earth – including our future – video by Smithsonian's National Museum of Natural History
- Climate change: Our biggest challenge – *School Journal* Level 4 June 2018
- House of Science Climate Change Kit – these are available throughout the North Island. You will need an account and subscription to order the kit.

Greenhouse gases



The atmosphere

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

- nitrogen (N) – 78.1%
- oxygen (O) – 20.9%
- argon (Ar) – 0.9%
- carbon dioxide (CO_2) – 0.04%.

The rest is made of very small amounts of other gases, including water vapour.

Greenhouse gases and climate change

Greenhouse gases are gases from 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!

In recent years, the amount of greenhouse gases in the atmosphere has increased so much that more heat is being trapped, causing an 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. Human activities like burning fossil fuels (coal, oil and gas), deforestation and industrial processes release greenhouse gases into the atmosphere.

Several gases contribute to global warming:

- Methane (CH_4) makes up 0.00018% of the atmosphere but is a very strong greenhouse gas. Methane is produced naturally by wetlands and by humans from landfills, agriculture and fossil fuels. In New Zealand, most methane is emitted from the digestive systems of ruminant livestock such as cattle and sheep.
- Carbon dioxide from urban fossil fuel burning is responsible for 40% of Aotearoa's gross carbon emissions.
- Nitrous oxide (N_2O) is a potent and long-lived greenhouse gas. In New Zealand, most nitrous oxide is produced by micro-organisms acting on nitrogen introduced to the soil via livestock urine or synthetic fertilisers.
- Fluorinated gases (F-gases) are manmade gases often used in coolants, foaming agents, fire extinguishers, solvents, pesticides and aerosol propellants. They are powerful greenhouse gases.

What is the difference between air pollutants and greenhouse gases?

We look at air pollutants and greenhouse gases differently because they affect the Earth in different ways.

Air pollutants can harm our health and environment. We measure air pollutants based on how much of these harmful substances are in the air and how they affect us in the short term, like causing breathing problems or making the air look dirty.

Greenhouse gases trap heat in the atmosphere, which causes the planet to warm up over time. We measure greenhouse gases by counting how much of these gases are in the air and assess how much heat they can hold and their long-term effect on the climate.

Related articles

- Aotearoa's contributions to climate emissions
- Greenhouse gases and the atmosphere
- Methane – a greenhouse gas
- Measuring methane from space
- Plantain research
- Ruminant digestion
- Breeding low-methane sheep
- Structure of landfills

Related activities

- Greenhouse simulation
- Label the landfill
- Looking at modern landfill systems

Related media

- Human contributions to climate change – video
- Fuels and greenhouse gases – video
- Greenhouse gases and the atmosphere – video
- Greenhouse gases – video
- Sources of atmospheric methane – video
- Methane emissions – cow burps, not farts – video

Useful links

- How carbon affects nearly everything on Earth – including our future – video by Smithsonian's National Museum of Natural History
- Overview of greenhouse gases – resource, US Environmental Protection Agency
- The greenhouse effect – video, US Environmental Protection Agency

Carbon and carbon dioxide

© GNS Science

Carbon

Carbon (C) is a chemical element that is found in many forms as an energy source for building things such as:

- 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
- fossil fuels – for example, petrol and diesel
- oceans
- animals
- plants
- buildings
- the atmosphere.

In the atmosphere, carbon can be found as carbon dioxide (CO_2), carbon monoxide (CO) and methane (CH_4).

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 the atmospheric lifetime). This is one of the reasons why it builds up in the atmosphere and why we must 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 0.00003%. Even such small quantities are enough to trap lots of heat.

Carbon dioxide in the atmosphere is part of the carbon cycle. 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.

Global warming potential

Global warming potential (GWP) is a way to compare how much heat a greenhouse gas can trap in the atmosphere over a period of time. It helps us compare the different greenhouse gases.

Related articles

- Carbon cycle
- The ocean and the carbon cycle
- Carbon dioxide in the atmosphere
- Carbon – life's framework element
- The carbon cycle and climate change – key terms
- Climate change and the carbon cycle – kuputaka
- Trees, seas and soil

Related activities

- Drive it Down! – climate change and carbon cycle quiz
- Carbon cycle quiz
- Carbon cycle – three-level reading guide

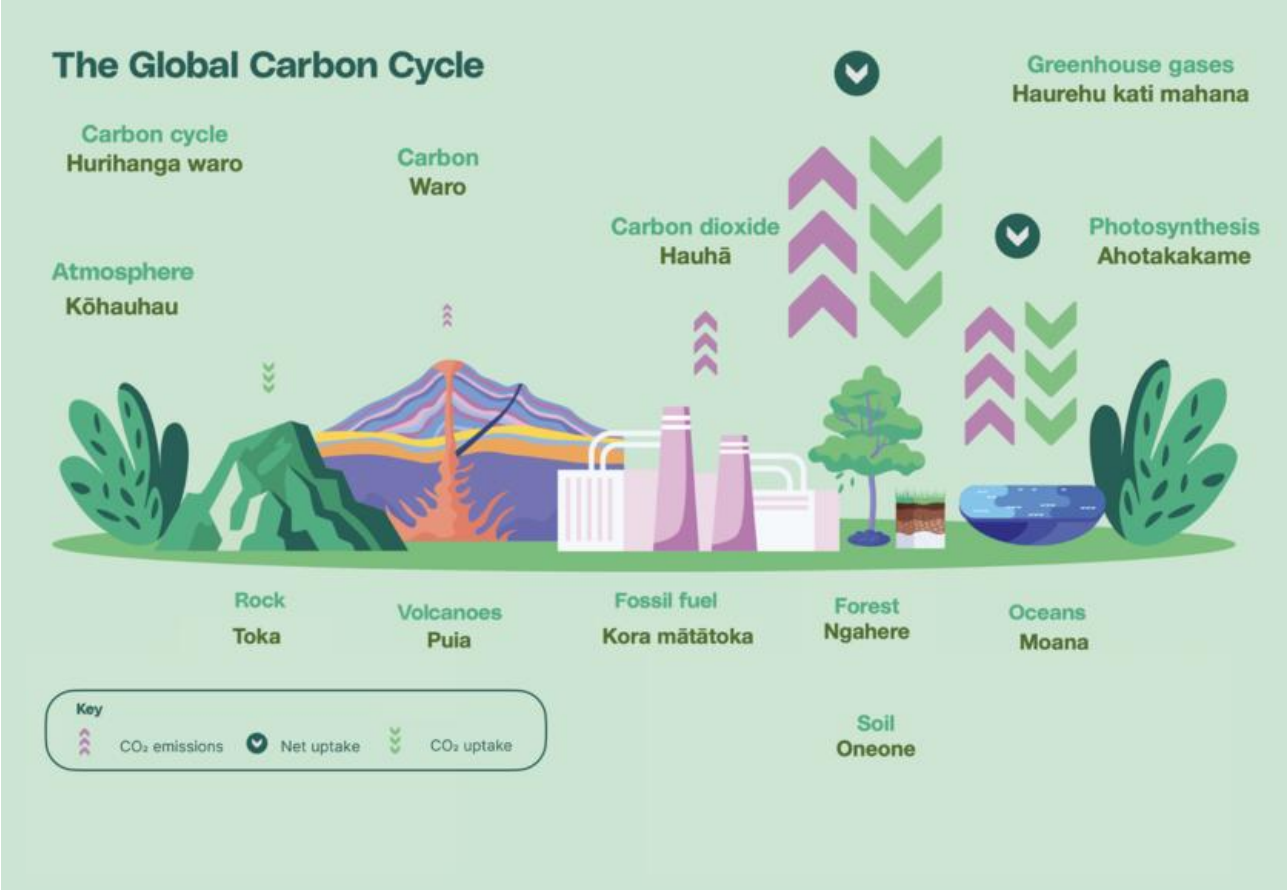
Related media

- Carbon cycle – interactive
- SLH and the carbon cycle – webinar

Useful links

- How carbon affects nearly everything on Earth – including our future – video by Smithsonian's National Museum of Natural History
- The carbon cycle is key to understanding climate change – video, The Economist
- Overview of greenhouse gases – resource, US Environmental Protection Agency
- The greenhouse effect – video, US Environmental Protection Agency

The global carbon cycle



© GNS Science

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 carbon dioxide (CO_2) that is in the atmosphere.

Did you know volcanoes are also part of the carbon cycle?! When the magma rises to the surface and erupts, the carbon dioxide escapes into the air, which is a natural geological process, but this contribution is still much smaller compared to human activities like burning fossil fuels.

What is a carbon footprint?

A carbon footprint is the total amount of CO_2 and other greenhouse gases that are released into the atmosphere because of human activities.

It includes things like the energy we use, the food we eat, the products we buy and the travel we do. The bigger the carbon footprint, the more it contributes to climate change. Reducing our carbon footprint means making choices that are less harmful for the planet.

Related articles

- Carbon cycle
- The carbon cycle and climate change – key terms
- Climate change and the carbon cycle – kuputaka
- The ocean and the carbon cycle
- Carbon dioxide in the ocean
- Carbon dioxide in the atmosphere
- The Southern Ocean's ecological richness and significance for global climate

Related activities

- Drive it Down! – climate change and carbon cycle quiz
- Carbon cycle quiz
- Carbon cycle – three-level reading guide
- Fossil Atmospheres – Zooniverse – citizen science project

Related media

- Increasing atmospheric carbon dioxide – video
- Southern Ocean carbon sink – video
- Carbon dioxide exchange – video
- SLH and the carbon cycle – webinar

Useful link

- Feedback – *School Journal* Level 4 2020

Carbon sinks and sources

© University of Waikato Te Whare Wānanga o Waikato

Forests

Forests and soils have a role in the amount of carbon dioxide (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. 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 CO_2 in our atmosphere. They are burnt by humans, and unlike the forest and ocean 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 be removed.

Some other natural sources of CO_2 in the atmosphere are the weathering of rocks and volcanoes erupting. When the magma rises to the surface of a volcano and erupts, the carbon dioxide escapes into the air, which is a natural geological process, but this contribution is still

much smaller compared to human activities like burning fossil fuels.

Related articles

- COVID-19 and greenhouse gas emissions
- The Southern Ocean's ecological richness and significance for global climate
- The rock cycle
- Non-renewable energy sources
- The ocean and the carbon cycle
- Carbon cycle
- Carbon dioxide in the ocean
- Carbon dioxide in the atmosphere
- Alternative conceptions about fossil fuels

Related activities

- Ocean acidification and eggshells
- Carbon cycle quiz

Related media

- Increasing atmospheric carbon dioxide – video
- Southern Ocean carbon sink – video
- Carbon dioxide exchange – video
- Oil formation – animation
- Carbon cycle – interactive

Useful link

- Feedback – *School Journal* Level 4 2020

The urban carbon cycle

© GNS Science

Most of the world's population live in cities, and cities create a lot of carbon dioxide (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. In rural areas where there is pasture, lots of methane is emitted!

Related articles

- Aotearoa's contributions to climate emissions
- Climate connections – why climate change matters
- COVID-19 and greenhouse gas emissions
- Climate change implications for dairy farming
- Dairy farming and climate change – a context for learning

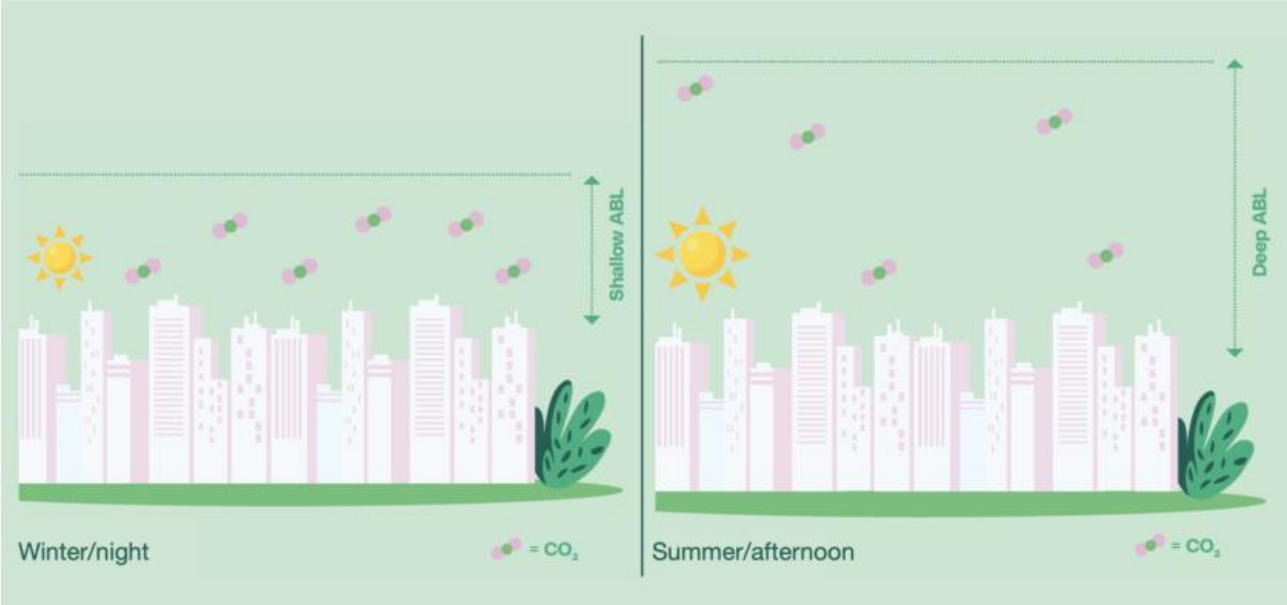
Related activities

- Drive it Down! – climate change and carbon cycle quiz
- Climate data analysis
- Interpreting representations using climate data

Useful link

- House of Science Fossil Fuels Kit and Clear the Air Kit – these are available throughout the North Island. You will need an account and subscription to order the kit. This collection supports the Clear the Air kit.

Atmospheric mixing



Before you can measure greenhouse gases, you need to understand atmospheric mixing – the way air and gases in the atmosphere are stirred and mixed. The wind plays a part in atmospheric mixing. When it isn't very windy, emissions will stay around the area where they were emitted. Strong winds will blow the emissions away from the source.

The atmospheric boundary layer (ABL) is the thin layer of air closest to the ground. It can range from 100 to 3,000 metres. Greenhouse gases are mostly emitted close to the Earth's surface within the ABL. The ABL changes height throughout the day and year depending on the temperature.

When the Earth is warm, the ABL is at its deepest – for example, during summer and afternoons. This means the emissions are going into a larger volume and become more spread out. This makes the concentration of gases look smaller than during the days and hours when temperatures are colder and the ABL is shallow. If we release the same amount of gases within a shallow ABL – for example, 200 m – they will be very dense in that air volume.

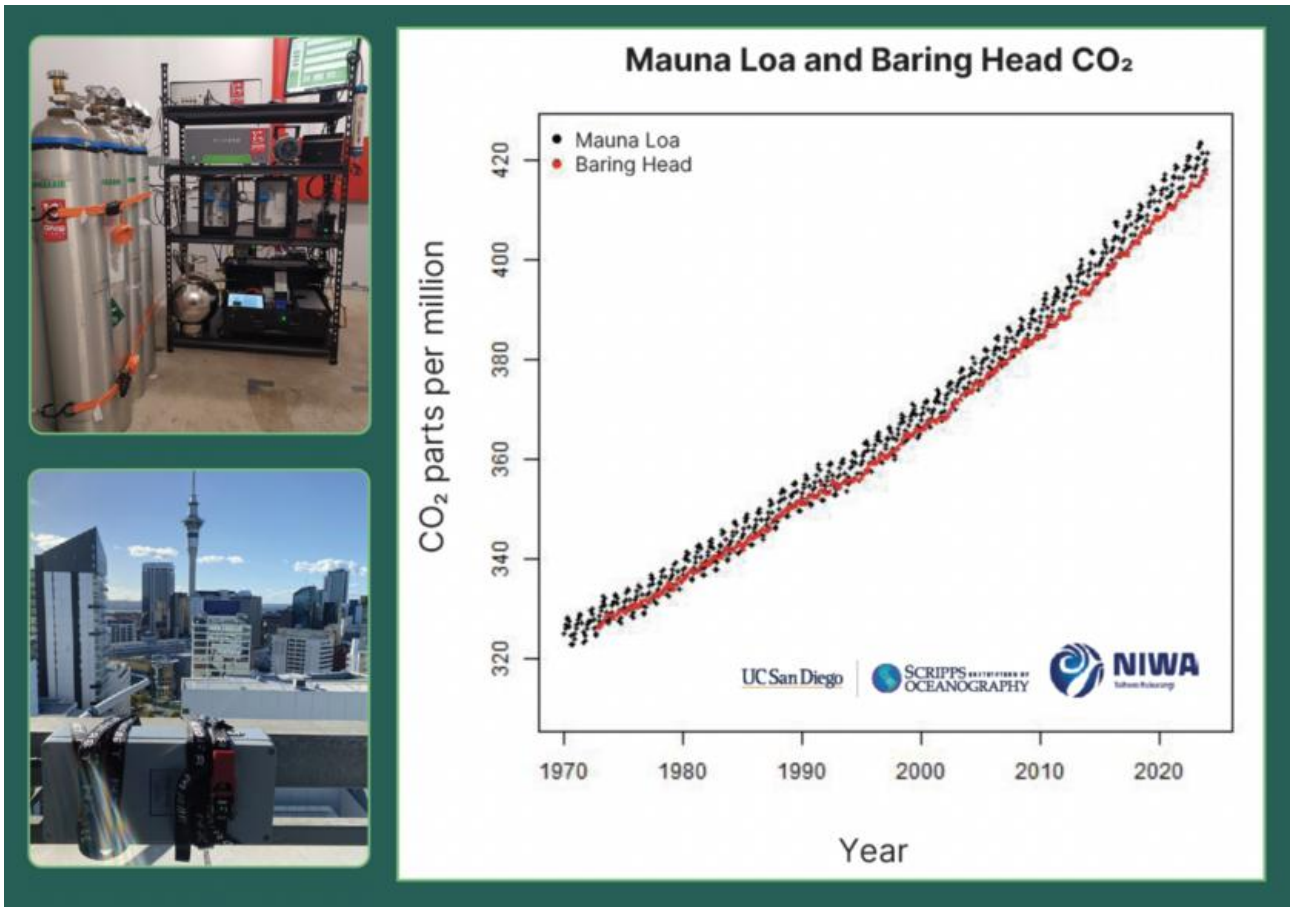
Related articles

- Gaseous atmosphere
- Greenhouse gases and the atmosphere
- Our atmosphere and climate – introduction

Related media

- MethaneSat – building accurate models – video
- Fuels and greenhouse gases – video
- Greenhouse gases and the atmosphere – video
- Greenhouse gases – video

Measuring CO_2



© GNS Science

Carbon emissions versus carbon concentrations

Carbon dioxide (CO_2) is measured all around the world for climate change research. When we measure CO_2 we are measuring the concentrations, not the emissions. Carbon emissions and carbon concentration are both about quantifying carbon but they mean different things. Carbon emissions is the amount of carbon (usually as CO_2) that is being released into the air. This happens when we burn things like coal, oil and gas or through activities like cutting down trees. The concentration is the amount of CO_2 in proportion to the total volume of the air.

Measuring CO_2

CO_2 concentration is measured in the parts per million (ppm). 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 when the atmospheric boundary layer is lower in the sky and the concentration of CO_2 measured will be larger.

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

How do you measure CO_2?

Scientists use several methods and tools to help determine the concentration of different

gases. Here are some ways scientists can measure atmospheric concentration of CO_2:

- Remote sensing – for example, the use of drones or satellites to measure gases from the sky.
- Gas collection flasks – samples of the air are collected in flasks for analysis. (This is one of a number of methods used at the NIWA Baring Head facility in New Zealand. You can see the flasks in the video Journey of the greenhouse gas data.)
- Gas analysers – these measure gases directly using light such as infrared sensors and spectroscopy techniques.

Each method has its own advantages and is chosen based on where it's being measured and how accurate the results need to be.

Related articles

- Measuring greenhouse gas emissions
- Carbon dioxide in the atmosphere
- Carbon dioxide and climate

Related activities

- Climate data analysis
- Carbon dioxide emissions calculator
- Some properties of carbon dioxide

Related media

- Journey of the greenhouse gas data – video

Climate action

© GNS Science

Why take action?

Reducing carbon emissions is essential for protecting the environment, improving health, supporting a sustainable economy and securing a better future for everyone.

What can we do?

Everyone can have an impact in reducing carbon dioxide (CO_2) emissions! Instead of driving to school, you could walk or take a scooter. Other ways to reduce emissions can involve communicating about the need for action on climate change. You can reach out to politicians, governing bodies and businesses. You could write to your local politician asking for better low-carbon transport around your city.

Reducing your own 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 emissions are coming from.

How to reduce your carbon footprint

A carbon footprint is the total amount of CO_2 and other greenhouse gases that are released into the air because of our activities. These gases come from things like driving cars, using electricity, buying goods and even eating certain foods. The more we do things that release these gases, the bigger our carbon footprint.

Even though we can't control everything that affects the carbon footprint, there are many ways to help reduce it and make the world a cleaner place. Here are some ideas:

- Walk or bike instead of driving. If it's safe, walk or ride your bike instead of getting a ride in a car. This helps reduce the carbon emissions from cars.
- Turn off lights and electronics. When you're not using a light, TV or computer, turn it off to save electricity. This reduces the amount of energy needed, which helps lower emissions.
- Plant trees. They help absorb CO_2 from the air, so planting trees is a great way to fight climate change.
- Save water. Taking shorter showers or turning off the tap while brushing your teeth saves water and energy. Heating water uses energy, and saving it reduces emissions.
- Eat more plant-based foods. Eating more fruits, vegetables and grains can lower your carbon footprint because farming animals releases a lot of greenhouse gases.
- Recycle and reuse. Try to reuse things like water bottles or clothes, and recycle paper, plastic and cans. This helps reduce waste and the energy used to make new things.
- Don't buy so many new things! Making things requires energy that can come from fossil fuels, so to reduce emissions, we can buy second-hand things and only things we need.
- Talk about it. You can share ideas with your friends and family. The more people who understand it, the bigger the impact we can have together!

To reduce carbon emissions, we need to make changes in many areas. This includes using clean energy, saving energy, practising sustainable farming, supporting cleaner industries and encouraging low-carbon transportation. Every action, big or small, helps lower our carbon footprint and fight climate change, leading to a healthier and more sustainable future.

Related articles

- Climate action
- Mitigation, innovation and action
- Agency in the Anthropocene
- The environmental footprint of electric versus fossil cars
- Renewable energy sources
- Biodegradability, compostability and bioplastics
- Plastics and recycling
- Global action

Related activities

- Drive it Down! – reducing emissions at your school
- Drive it Down! – climate change discussions
- Utilising Our climate, our biodiversity, our future
- Climate change – challenging conversations
- Ko e feliuliuaki ʻa e ʻea – ko e talanoa fakakoloa
- Carbon dioxide emissions calculator

Related media

- Can we stop climate change? – video
- What can I do to stop climate change? – video
- Don't give up hope – video
- Exploring climate change education in primary schools – webinar
- Exploring climate change education in secondary schools – webinar

Useful links

- School Strike 4 Climate – website set up by high school students to rally support for government action on climate change
- Generation Zero – youth-led climate justice organisation
- Force of habits – video to get young people thinking about what they could do in their everyday life to make a difference around climate change, Mātai Media