Education Scotland
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Exploring Climate Change

The basics

Transforming lives through learning

The basics

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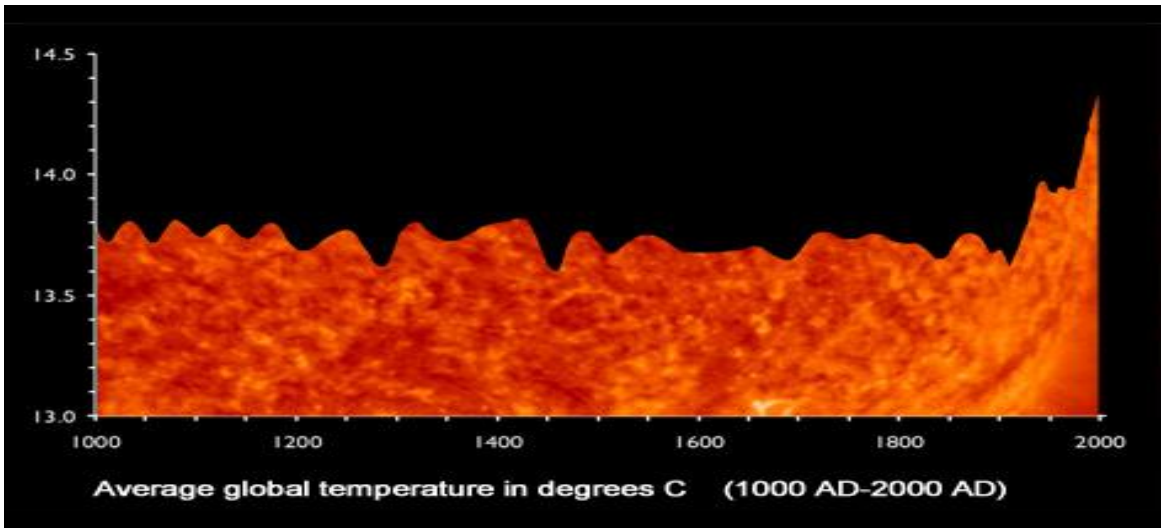
The Earth's climate is changing. The world is growing hotter. The average global temperature has increased more rapidly in the last 50 years than at any time in the whole of recorded history. The biosphere, where all life on Earth exists, is under threat.

Every day millions of tons of the greenhouse gases such as carbon dioxide are emitted into the atmosphere as we burn fossil fuels for energy, heat and transport. Climate scientists warn that global warming is accelerating and that our reliance on fossil fuels is at least partly to blame.

Scotland is already feeling the effects of a changing climate. Winters are becoming wetter as rainfall increases dramatically, while there is less snow and frost. As spring and summers grow warmer the growing season has lengthened. Across the UK widespread flooding has claimed lives and caused more than £1 billion worth of damage.



'Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level.'

Intergovernmental Panel on Climate Change (IPCC)

We cannot predict how individuals, businesses and governments will respond to the need to reduce their greenhouse gas emissions and what the effect will be, but we all have a responsibility to tackle climate change. We can all make a difference.

The biosphere

All life on Earth exists in the small space on the surface of our planet known as the biosphere. Planet Earth is the only place in our solar system that can sustain life - as we know it.

Image courtesy NASA Johnson Space Center Gateway to Astronaut Photography of Earth. Available for use under Creative Commons Attribution-NonCommercial 2.0 conditions.

The biosphere extends from the deepest ocean trenches, about 8 km below the Earth's surface, to approximately 12 km above. Life on Earth is not evenly distributed: the poles have limited life, whilst the tropical rainforests are incredibly diverse.

Scientists estimate that there are between 2 and 100 million species in the biosphere; the best estimate is approximately 10 million. So far science has recorded 1.4 million. More than half of recorded species are classified as insects, 30% are classified as micro-organisms, while the remaining 20% include all other vertebrates (including human beings), invertebrates, flowering and non-flowering plants, fungi, algae, etc.

Only a fraction of the total species which currently live on this planet have been found, identified and described, but all species form part of a complex interacting and interdependent system. Even a minor disruption to any part of that system can produce dramatic consequences for the maintenance of the biosphere on which all life on Earth depends.

'The absolutely best case scenario - which in my opinion is unrealistic - with the minimum expected climate change... we end up with an estimate of nine percent [of all species] facing extinction… The midrange estimate is that 24 percent of plants and animals will be committed to extinction by 2050… We're not talking about the occasional extinction – we're talking about 1.25 million species. It's a massive number.'

Professor Chris D Thomas, ecologist

A recent assessment report by the Intergovernmental Panel on Climate Change concluded that approximately 20-30% of plant and animal species assessed are likely to be at increased risk of extinction if increases in global average temperature exceed 1.5 to 2.5ºC.

There are about 6 billion people on Planet Earth. It is estimated that the population of the planet will probably reach 9 billion by 2050. By 2020 more than 80% of the Earth's population will live in developing countries and they will all need food, energy and work, all of which have implications for the future of climate change.

If everyone in the world used the same number of resources as people in Scotland we would need three Planet Earths to provide these resources and manage all our waste. It's up to us to work towards a fairer, more sustainable future.

The consumption of scarce resources is in itself contributing to global warming. Oil, gas, coal and even uranium will eventually run out. The first two may already have reached their maximum production levels with no new large fields to be found. We need to reduce our consumption of the Earth's resources to a sustainable level, end our reliance on fossil fuels,

and cut emissions of associated greenhouse gases.

The atmosphere

'We are upsetting the atmosphere upon which all life depends. In the late 80s when I began to take climate change seriously, we referred to global warming as a 'slow-motion catastrophe', one we expected to kick in perhaps generations later. Instead, the signs of change have accelerated alarmingly.'

David Takayoshi Suzuki, scientist and broadcaster

Planet Earth's atmosphere is much thinner than most people imagine. The densest, innermost part of the atmosphere, the troposphere, is just 17 km thick at the equator and 7 km thick at the poles. Seventy-five per cent of atmospheric gases are found in the troposphere. The Kármán line, 100 km up in the stratosphere, is usually used as the point where the atmosphere ends. The cosmologist Carl Sagan noted that the atmosphere would be equivalent to a single layer of varnish on an ordinary classroom globe.

The atmosphere protects the Earth from ultraviolet radiation from the sun and regulates global temperature. Without the protection of the atmosphere, life on Planet Earth would cease to exist. Understanding the atmosphere, its chemistry and physics, is central to understanding climate change.

The Earth is 12,700 km in diameter - comparatively the atmosphere is a very thin layer.

'…we face an enormous problem, which is global warming… because the atmosphere is so small and we're putting so much crap into it… Burn a ton of coal you get 3.7 tons of carbon dioxide… How many people are there in the planet? 6.6 billion… Our planet is lit up like a bloody Christmas tree at night now with so many cities around the world, most of them dependent on fossil fuels, putting all of that pollution up into the atmosphere.'

Tim Flannery, author of 'We Are the Weathermakers', talking to secondary school students in Melbourne, Australia

The concentrations of greenhouse gases in the Earth's atmosphere have changed since the industrial revolution, around 1750, increasing as a result of human activity.

The global mean concentration of carbon dioxide (CO_2) in parts per million (ppm)

	Pre-1750	2009
Carbon dioxide	280	387

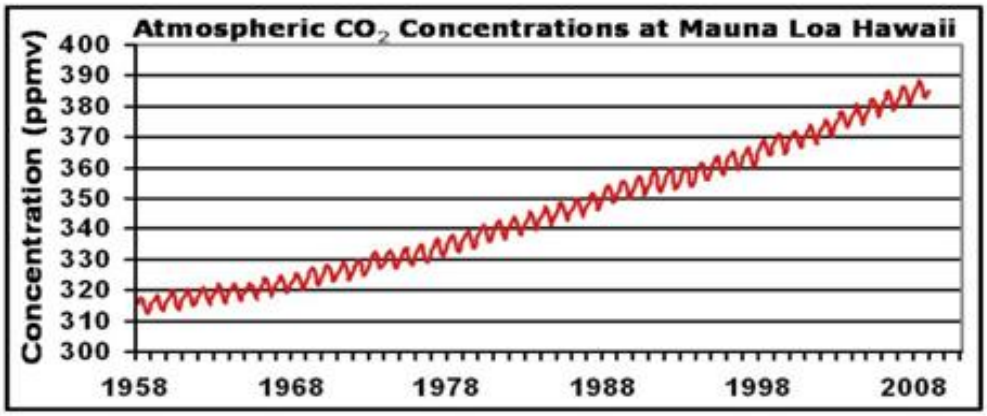
The global mean concentration of Nitrous oxide (N_2O) and Methane (CH_4) in parts per billion (ppb)

	Pre-1750	2009
Nitrous oxide	275-280	323
Methane	750	1790

[Source: IPCC WG1 AR4 Report with 2009 from NOAA]

Since 1957 Mauna Loa Observatory, an atmospheric research facility on Mauna Loa volcano, Hawaii, has continuously monitored levels of carbon dioxide in the atmosphere. Mauna Loa is special as it is high and well away from any nearby sources of CO_2. The air it samples effectively represents the average CO_2 concentration for the entire northern hemisphere. Over the decades the observatory has measured rising carbon dioxide concentrations in the atmosphere.

The data is presented in a graph that is sometimes known as the 'Mauna Loa Curve' or the 'Keeling Curve'.



Dr Charles David Keeling of the Scripps Institution of Oceanography was the first person to regularly take readings of atmospheric carbon dioxide concentrations at Mauna Loa, alerting the world to the role of human activity in global warming. When Dr Keeling died in 2005 it was said that:

'His pioneering work on atmospheric carbon dioxide fundamentally changed the way we view the planet and our role on it'.

'[Levels of] greenhouse gases in the Earth's atmosphere are currently higher than has been seen in over 150,000 years.'

Greenpeace International

Global warming

The composition of gases in the Earth's atmosphere has been changed by human activity. Billions of tonnes of greenhouse gases are emitted into the Earth's atmosphere every year by the burning of fossil fuels, such as coal, oil and gas.

Greenhouse gases are the elements of the atmosphere, both natural and human-made, that absorb and emit radiation. The natural role of these gases is to trap the sun's heat in the Earth's atmosphere (after this heat has been reflected off the Earth's surface), warming the Earth's surface by over 30˚C to a level at which humans and other living things can survive. This is known as the 'natural greenhouse effect'. Natural global warming by the greenhouse effect means that the planet is on average 15˚C, rather than the -18˚C that it would be without the Earth's atmosphere.
Human activity, such as the burning of fossil fuels, is increasing the concentrations of greenhouse gases in the atmosphere above natural levels. These additional greenhouse gases act like a blanket around the planet; they allow the sun's energy to reach the Earth's surface but trap more of the heat that is reflected back. This is called the 'enhanced greenhouse effect'.

'There is broad agreement within the scientific community that amplification of the Earth's natural greenhouse effect by the build-up of various gases introduced by human activity has the potential to produce dramatic changes in climate. Only by taking action now can we ensure that future generations will not be put at risk.'

Statement by 49 Nobel Prize winners and 700 members of the National Academy of Sciences, 1990

There is a wide consensus among climate scientists that the enhanced greenhouse effect is increasing the world's average temperature, changing our climate. Since 1961 the average temperature in Scotland has increased in all seasons. It is thought that annual temperatures averaged across Scotland will rise by up to 3.5˚C in the summer and 2.5˚C in the winter in the 21st century.

Around the world the average global temperature has increased by about 0.2 to 0.3°C over the last 40 years and by about 0.7°C since 1860. Levels of the greenhouse gas carbon dioxide (CO_2) remained around 280 parts per million (ppm) until the industrial revolution. This level has now risen to over 380 ppm, and continues to rise every year.

Greenhouse gases

Governments around the world are seeking ways to reduce emissions of greenhouse gases. The Kyoto Protocol makes reference to a basket of six greenhouse gases: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and the F-gases: HFC, PFC and SF_6.

Carbon Dioxide (CO_2) is a natural part of the atmosphere and also the principal gas emitted by human activity. It is produced when fossil fuels are burned and during respiration and decomposition. Forests, plants and the oceans absorb huge amounts of CO_2, reducing the levels of CO_2, but the exchange is small compared to the total amount of CO_2 in the atmosphere. A molecule of CO_2 can stay in the atmosphere for as long as 100 years.

Methane (CH_4) can come from cows and sheep and paddy fields as well as from landfills or the breakdown of organic materials. Although methane stays in the air for about 10 years, in that time it absorbs about 20 times more heat energy than a CO_2 molecule does in 100 years. 1 kg of methane has the equivalent global warming potential of 25 kg of CO_2. There are huge amounts of CH_4 trapped in frozen tundra which may be released if the tundra thaws.

Nitrous oxide (N_2O) is only found in small amounts in the atmosphere but has a powerful effect because of its ability to absorb infrared energy. The global warming effect of 1kg of N_2O is the equivalent of 298 kg of CO_2.

F-gases (HFC, PFC and SF_6) are man-made gases which have only been widely used since the 1990s. They can last for thousands of years in the atmosphere so have very high global warming potentials.