

# Climate science: background briefing for teachers

## What's the issue?

Earth's climate is changing. Its average temperature is projected to rise several degrees Celsius by 2100, causing a rise in sea levels and most likely more extreme weather, massive crop failures and threats to biodiversity and our way of life.

## Key terms

- **Weather** describes conditions such as temperature, rainfall and cloud cover at a particular moment or over a few days in a particular place. Climate describes the averages and ranges of these conditions over many years.
- **Global warming** describes Earth's increasing temperature. Over the past 100 years, the global average temperature (just above the land and sea) has risen by 0.74 °C. If our greenhouse gas emissions continue to rise at their current rate, then scientists estimate the global average temperature could rise between 2 and 6 °C by the end of the century.
- The total amount of carbon on Earth remains the same, but carbon moves from one system to another, through various chemical and physical processes – such as photosynthesis, combustion and decomposition. The **carbon cycle** is the collection of all these processes.

- The **greenhouse effect** is what makes our planet warmer than it would otherwise be. Greenhouse gases such as carbon dioxide absorb low-frequency radiation that would otherwise leave our planet's atmosphere. This adds to Earth's energy budget and raises its average temperature.

## What's all the fuss about?

Climate change has become a major concern, in the media as well as in the scientific community, because it threatens our way of life and could have severe consequences for the entire human race.

Most scientists conclude that climate change is caused by an enhanced greenhouse effect, owing to a build-up of greenhouse gases, in particular carbon dioxide released by burning fossil fuels. However there is more debate on the best ways to combat it.

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## Statistics

- Atmospheric carbon dioxide concentration was 280 parts per million (0.028%) before the Industrial Revolution; in 1958 it was 320 ppm. In late 2010 it was around 390 ppm,<sup>1</sup> and still rising.
- Burning fossil fuels releases about 26 billion tonnes of carbon dioxide – about 6 billion tonnes of fossil carbon – into Earth's atmosphere each year.<sup>2</sup>
- Every year, the fossil fuels we burn are the equivalent of 400 years worth of global plant growth. Fossil fuels burned in the last 200 years are the equivalent of 13,000 years of plant growth.<sup>3</sup>

1. 'Trends in atmospheric carbon dioxide', National Oceanic and Atmospheric Administration

2. Intergovernmental Panel on Climate Change, 2007

3. J Dukes, *Human Consumption of Ancient Solar Energy* (Stanford University, 2003)

## Science Q&A

### What are carbon sources and carbon sinks?

Carbon sources are those parts of the carbon cycle that release more carbon than they take in. Examples are the burning of fossil fuels and the decomposition of dead organisms. Carbon sinks are those parts of the carbon cycle that take in more carbon than they release. A carbon sink stores carbon for a period of time – in other words, it acts as a 'reservoir'. Examples are forests, oceans and ocean sediments.

### What is anthropogenic global warming?

'Anthropogenic' means 'produced by humans'. Anthropogenic influences on the carbon cycle include burning fossil fuels, deforestation, cement production, carbon capture and planting forests. Anthropogenic global warming is that part of the global temperature increase attributable to increased carbon dioxide and other greenhouse gases in the atmosphere caused by human activity.

### What was the Industrial Revolution?

In the 18th century, several countries began using coal – to smelt iron and to power engines – bringing about a revolution in industry and transport. Some historians prefer the term 'age of industrialisation'. The use of oil and natural gas grew later.

### Why is carbon important?

Carbon atoms form the molecules that are the basis of all living things because of their ability to form rings, long chains and branched molecules.

## How does carbon enter living things?

Carbon enters the biosphere as part of carbon dioxide molecules, diffusing through tiny holes (stomata) on the underside of leaves, or passing into other photosynthetic organisms, such as phytoplankton in the oceans.

When animals eat plants – and other animals eat those animals – the carbon remains within the biosphere, in a huge number of different molecules, such as proteins, carbohydrates, fats and DNA. As much as 18% of your body mass is carbon – one in every ten atoms in your body is a carbon atom.

## How do living things release carbon?

Living things respire – that is, they use some of their carbon compounds as fuel. Aerobic respiration, combustion taking place in living cells, results in the release of carbon dioxide gas into the atmosphere.

When an organism dies, some of its carbon content may be consumed by 'decomposer' organisms, which then release it to the atmosphere as they respire. But some of its carbon may remain in the soil, locked away for long periods. If the decomposition happens away from oxygen – say, at the bottom of a lake – the carbon may end up as oil or coal.

## Why does burning fossil fuels release carbon?

When we burn fossil fuels, we are releasing carbon into the atmosphere that was trapped anywhere between 100 million and 500 million years ago. Fossil fuels are mostly made of hydrocarbons – molecules that contain almost exclusively hydrogen (H) and carbon (C). When this burns (combines with oxygen, O<sub>2</sub>), the two products are water (H<sub>2</sub>O) and carbon dioxide (CO<sub>2</sub>).

## Is there carbon in the oceans?

There is a huge amount of carbon present in the oceans – about 45 times as much as there is in the atmosphere. One source of carbon in the oceans is the weathering of carbon-containing rocks.

There is a constant exchange of carbon dioxide between the oceans and the atmosphere: the gas diffuses into and out of the surface layer. Most of it becomes dissolved as bicarbonate ions.

As the concentration of carbon dioxide in the atmosphere increases, there is a net absorption of the gas into the oceans. As a result, the oceans have so far absorbed between 30 and 50% of the carbon dioxide released by burning fossil fuels. But the solubility of carbon dioxide will decrease as the global temperature rises – and the oceans will eventually become saturated.

### Does the carbon cycle only concern living things, oceans and atmosphere?

No – there is plenty of carbon in rocks, too, and that carbon is involved in the carbon cycle, though on a much longer timescale. In fact, rocks represent the world's biggest accumulation of carbon. Most of the carbon is in carbonate minerals, such as limestone.

Carbonate minerals do take part in the carbon cycle, through weathering of carbonate rocks, the sedimentation of marine animals to form new rocks, and the release of carbon dioxide by volcanoes as one seabed is pushed underneath another by tectonic action. But this takes place over very long periods of time – **so it is not normally included in a simplified view of the carbon cycle.**

### Have carbon dioxide levels ever been much different?

The amount of carbon in the atmosphere has varied hugely during the history of our planet. For example, before plants became established on land around 400 million years ago, atmospheric carbon dioxide levels were about 15 times what they are today. Carbon dioxide became depleted when plants became established, as the new forests drew down huge amounts of carbon dioxide during photosynthesis. Much of the coal comes from this time, the Carboniferous period.

But for long periods of time, the carbon cycle has remained in balance, and the concentration of carbon dioxide in the atmosphere has remained more or less constant. In particular, in the 11 million years leading up to the Industrial Revolution, it remained below 300 parts per million (0.03%).

### What is the greenhouse effect?

Carbon dioxide and methane are important 'greenhouse gases': they absorb some of the radiation that would otherwise leave our planet. When they re-radiate the energy of that radiation, some of the energy ends up back on the surface, some remains in the atmosphere and radiates into space. As a result, the temperature is higher than it would otherwise be. If there were no greenhouse effect, our planet's average temperature would be about  $-15^{\circ}\text{C}$ . Methane is about 25 times more potent as a greenhouse gas than carbon dioxide, but there is much less of it, which is why carbon dioxide is the more important consideration.

### How can switching to biofuels help?

Biofuels do release carbon dioxide into the atmosphere when they burn, but only as much as they took in during their lifetime. However, biofuel production uses land that could be used to grow food, and processing and transport may involve fossil fuels.

### Why is deforestation a problem?

Forests represent an important carbon sink. Cutting them down removes that sink, putting the carbon cycle out of balance. This makes deforestation effectively a carbon source. Also, whether through burning or decomposition, the huge amounts of carbon stored in the forest end up back in the atmosphere, as carbon dioxide or methane.

### What if we stopped using fossil fuels today?

If we stopped burning fossil fuels, and used forests sustainably, the whole world would be 'carbon neutral': there would be no net emissions of carbon into the atmosphere. The level of carbon dioxide in the atmosphere would slowly reduce, as carbon dioxide dissolves in the oceans and is taken up by plants. But it would take hundreds of years for the concentration of the gas to return to the levels before the Industrial Revolution. Meanwhile, the temperature would continue to rise. Another gas released when we burn fossil fuels – sulphur dioxide – has a cooling effect, but only a short lifetime in the atmosphere. According to one recent climate model, sulphur dioxide would quickly disappear from the atmosphere, removing the cooling effect – so the average global temperature would actually rise by as much as  $2^{\circ}\text{C}$  over the next 20 years or so, before levelling off and beginning to fall slowly.



### You could discuss ...

- What things can we do to slow the increase in carbon dioxide?
- What is wrong with a warmer climate?
- Was the Industrial Revolution a good thing?
- What sources of energy are there as alternatives to fossil fuels?
- Why is deforestation part of the problem?
- What would happen if everyone became vegetarian?

## Where can I go for more information?

### Teachers TV

*Teaching Climate Change*

[www.teachers.tv/videos/ks3-ks4-geography-teaching-climate-change](http://www.teachers.tv/videos/ks3-ks4-geography-teaching-climate-change)

*Climate Change – The Causes*

[www.teachers.tv/videos/climate-change-the-causes](http://www.teachers.tv/videos/climate-change-the-causes)

### Global Carbon Project

This project aims to build up a complete picture of the global carbon cycle.

[www.globalcarbonproject.org/carbonbudget/08/hl-brief.htm](http://www.globalcarbonproject.org/carbonbudget/08/hl-brief.htm)

### Greenhouse gases videos

Professor Scott Denning of the Atmospheric Science Department at Colorado State University explains how greenhouse gases in Earth's atmosphere warm our planet.

<http://bit.ly/apWREM>

In this short extract from the BBC series *Earth: The Climate Wars*, Iain Stewart demonstrates carbon dioxide absorbing heat radiation.

<http://bit.ly/9DSvpr>

### NASA Earth Observatory: Global Warming

Authoritative and accessible background information on climate change and its causes.

<http://earthobservatory.nasa.gov/Features/GlobalWarming>

### *Eyewitness: Climate Change*

Published by Dorling Kindersley, 2008.

### *The Rough Guide to Climate Change*

Published by Rough Guides, 2008.

### Impacts of Climate Change, Science Museum *atmosphere* gallery

Climate change: a summary of the science, The Royal Society, September 2010

<http://royalsociety.org/climate-change-summary-of-science>

### Climate change to continue to the year 3000 in best case scenarios

[www.ucalgary.ca/news/utoday/january10-2011/climatechange](http://www.ucalgary.ca/news/utoday/january10-2011/climatechange)

## Curriculum links

KS3 Science QCA (2007):

1.2 b; 2.2 a; 3.4 a, c; 4a, c, g; How Science Works Attainment targets 2, 3

KS4 Science QCA (2007):

2.4 a

KS3 Geography QCA (2008):

1.6 a, b; 1.7 b; 2.1 a; 2.4 a, b; 3 g; 4 a, b, g, i

KS3 Citizenship QCA (2007):

1.2 b, c; 2.1 a; 2.2 b; 3 e; 4 a, g

KS4

Supports work in the AQA, OCR and Edexcel areas of climate change, sustainability and the environment.

## Science Museum links

For more information about climate science go to the Climate Science Info Zone.

[www.sciencemuseum.org.uk/ClimateChanging/ClimateScienceInfoZone](http://www.sciencemuseum.org.uk/ClimateChanging/ClimateScienceInfoZone)

The following animations are particularly useful to help prepare for or follow up the Climate Report activity:

- Climate or weather? A simple explanation about the difference between climate and weather.  
[www.sciencemuseum.org.uk/ClimateChanging/ClimateScienceInfoZone/ExploringEarthsclimate/1point2.aspx](http://www.sciencemuseum.org.uk/ClimateChanging/ClimateScienceInfoZone/ExploringEarthsclimate/1point2.aspx)
- Climate or weather quiz. A fun quick quiz to check students understand the difference between climate and weather.  
[www.sciencemuseum.org.uk/ClimateChanging/ClimateScienceInfoZone/ExploringEarthsclimate/1point2/1point2point3.aspx](http://www.sciencemuseum.org.uk/ClimateChanging/ClimateScienceInfoZone/ExploringEarthsclimate/1point2/1point2point3.aspx)
- How do we know the world is warming? This animation explains how scientists know the world is warming, by collecting evidence of the impact of the human-caused greenhouse effect in action.  
[www.sciencemuseum.org.uk/ClimateChanging/ClimateScienceInfoZone/Exploringwhatmighthappen/2point1.aspx](http://www.sciencemuseum.org.uk/ClimateChanging/ClimateScienceInfoZone/Exploringwhatmighthappen/2point1.aspx)

- How does climate change affect people? A look at the various ways climate change can affect people around the world, focusing on food, water, health and homes.  
[www.sciencemuseum.org.uk/ClimateChanging/ClimateScienceInfoZone/Exploringwhatmighthappen/2point5.aspx](http://www.sciencemuseum.org.uk/ClimateChanging/ClimateScienceInfoZone/Exploringwhatmighthappen/2point5.aspx)
- Climate change and food production. A closer look at how rising temperatures could affect our ability to grow food.  
[www.sciencemuseum.org.uk/ClimateChanging/ClimateScienceInfoZone/Exploringwhatmighthappen/2point5/2point5point1.aspx](http://www.sciencemuseum.org.uk/ClimateChanging/ClimateScienceInfoZone/Exploringwhatmighthappen/2point5/2point5point1.aspx)
- Impacts on the UK. Find out about the impacts on the UK in a warmer world.  
[www.sciencemuseum.org.uk/ClimateChanging/ClimateScienceInfoZone/Exploringwhatmighthappen/2point6.aspx](http://www.sciencemuseum.org.uk/ClimateChanging/ClimateScienceInfoZone/Exploringwhatmighthappen/2point6.aspx)
- UK climate preparations. Real-life examples of what the UK is doing to prepare for climate change.  
[www.sciencemuseum.org.uk/ClimateChanging/ClimateScienceInfoZone/Exploringourfuturechoices/3point6.aspx](http://www.sciencemuseum.org.uk/ClimateChanging/ClimateScienceInfoZone/Exploringourfuturechoices/3point6.aspx)
- Predictability of climate. More detailed information about the predictability of climate.  
[www.sciencemuseum.org.uk/ClimateChanging/ClimateScienceInfoZone/ExploringEarthsclimate/1point2/1point2point2.aspx](http://www.sciencemuseum.org.uk/ClimateChanging/ClimateScienceInfoZone/ExploringEarthsclimate/1point2/1point2point2.aspx)

**For this activity and many more, visit [sciencemuseum.org.uk/climatescienceresources](http://www.sciencemuseum.org.uk/climatescienceresources)**

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