BRIEFING

Energy&Climate INTELLIGENCE UNIT

# What's causing Climate Change?

Last modified: 21 Oct 2014

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The main cause of modern-day climate change is the rising level of greenhouse gases in the atmosphere – carbon dioxide, methane, nitrous oxide and others – produced largely by the burning of fossil fuels. These gases have a warming effect at the Earth's surface.

On the other hand, man-made emissions of tiny dust particles ('aerosols') generally have a cooling effect. And changes in land use, including loss of forest, also have an impact both globally and regionally.

*Drax power station in Yorkshire is the UK's biggest single greenhouse gas emitter. Image: Gareth Davies - Creative Commons licence*

## What do greenhouse gases do?

About half of the solar energy reaching the top of the Earth's atmosphere travels down to the surface, which heats up as a result. The warm surface gives off heat (infrared radiation), which travels up through the air. Here, molecules of various greenhouse gases absorb it. The warmed gases give off heat again, some of which travels downwards to the surface again. This trapping of heat is called the 'greenhouse effect'. The more greenhouse gas molecules there are, the more heat is trapped.

*Since the beginning of the Industrial Revolution… the concentration of CO2 has gone up by 40%*

The Earth possesses a natural greenhouse effect, which is essential to life. Without it, the average surface temperature would be about minus 15-18°C. The most important gas in the natural greenhouse effect is water vapour, with carbon dioxide playing a secondary role.

Since the beginning of the Industrial Revolution, human activities have been increasing the concentrations of greenhouse gases in the atmosphere.

The concentration of carbon dioxide has gone up by 40%, methane by 160%, and nitrous oxide by 20%. This increases the amount of energy being trapped near the Earth's surface – the 'man-made greenhouse effect', which has added an estimated 0.8°C to the global average temperature.

## Where do greenhouse gases come from?

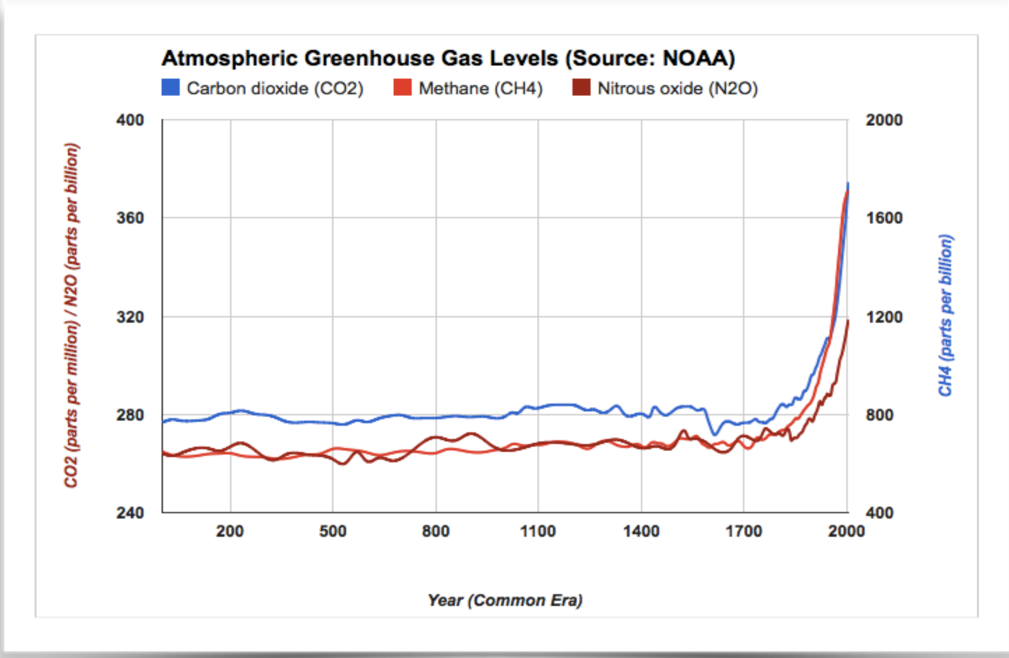
Carbon dioxide (CO 2) is the most important gas in the man-made greenhouse effect, contributing almost two-thirds of the total warming. The next most important are methane, nitrous oxide and hydrofluorocarbons (HFCs).

*CO2 has contributed almost two-thirds of the total warming*

The main source of greenhouse gases (GHGs) is the burning of fossil fuels for energy, industry, heating and transport. Just over one-third of emissions globally come from the energy sector, and one-quarter from agriculture, forestry and changes in land use. (Some analysts apportion energy-related emissions into the sectors where the energy is used; using this method, total emissions from industry account for almost one-third of overall emissions, and from buildings, nearly one-fifth.)

Carbon dioxide accounts for about 80% of the UK's total greenhouse gas emissions, with the main sectors being energy and transport. Nearly 40% of the CO2 comes from energy, and about 25% from transport.

Between 2000 and 2010, GHG emissions globally rose at about 2.2% per year – faster than in previous decades.



## What else is important?

Aerosols are tiny particles of dust. They are naturally present in the atmosphere – for example, when dry soil is whipped into the air by strong winds. But the amount in the atmosphere has increased due to factors including the removal of tree cover and the burning of fossil fuels. Aerosol 'clouds' from the rapidly industrialising countries of Asia are so marked that they can be seen from space. Conversely, clean air legislation in more developed regions such as Western Europe and North America has reduced the amount going into the atmosphere, 'brightening' the sky.

Aerosols generally have a cooling effect as they reflect sunlight back into space. But in some cases their impact is to warm; for example, soot ('black carbon') deposited on ice darkens the surface, making it absorb more of the Sun's energy. Aerosols also affect cloud formation, which can also have a warming impact. In contrast to carbon dioxide, aerosols remain in the lower atmosphere for short periods, often measured in days.

**Amplifiers and dampeners**

The impact of greenhouse gases can be amplified or dampened by a range of factors. For example, warmer air can hold more water vapour – and water vapour is itself a greenhouse gas. In Europe at least, this 'water vapour feedback' is amplifying the effect of greenhouse gases.

Another issue is the melting of ice. Higher temperatures mean that ice melts; and whereas white ice reflects solar energy back into space, the darker surface of land or ocean absorbs more solar energy, increasing the temperature. The formation of clouds can act either to amplify or to reduce greenhouse warming, because clouds can either act as an extra insulating 'blanket' or a bright reflective sheet that sends more solar energy back into space.

**Natural changes**

Ultimately, virtually all of the energy in the Earth system comes from the Sun. So changes to the Sun's energy output will warm or cool the Earth. However, the Sun releases energy at a very consistent rate, varying by only about 0.1% over its various cycles (such as the 11-year 'sunspot' cycle). Over periods longer than about a decade, solar variability has a much smaller effect on the climate than greenhouse gases.

Volcanoes release dust particles ('aerosols') into the atmosphere; and big eruptions produce enough to change the climate for several years. The eruptions of El Chichón in Mexico in 1982 and Mount Pinatubo in The Philippines in 1991 each reduced the average temperature by about 0.2°C for several years.

Heat is constantly being exchanged between the ocean and atmosphere. In some years, there is a net transfer from ocean to atmosphere; in other years, the reverse occurs. The most familiar example of this cycling is the El Niño Southern Oscillation (ENSO), which has warm and cold phases. In warm years, warm water comes to the top of the eastern Pacific Ocean. The heat it transfers to the atmosphere causes higher than average air temperatures measured on a global basis. The strong El Niño event of 1998 warmed the atmosphere globally by about 0.15°C. In colder La Niña conditions, the net transfer of heat from atmosphere to ocean lowers the average temperature across the Earth's surface.

Other natural cycles involving heat transfer between ocean and atmosphere include the Atlantic Multidecadal Oscillation (AMO), the Pacific Decadal Oscillation (PDO) and the Indian Ocean Dipole (IOD), among others. While ENSO can lead to warmer or colder years, the other cycles occur over longer time periods and can influence surface temperature for periods of a decade or longer. These natural cycles are not perfectly understood, and may in any case be influenced by man-made climate change. On timescales of several decades and longer, the influence of greenhouse gas emissions is projected to dominate natural variability.

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