



This is the print version of the [Skeptical Science](http://sks.to/evidence) article '[There's no empirical evidence](http://sks.to/evidence)', which can be found at <http://sks.to/evidence>.

# Empirical evidence that humans are causing global warming

## What The Science Says:

Less energy is escaping to space: Carbon dioxide (CO<sub>2</sub>) acts like a blanket; adding more CO<sub>2</sub> makes the 'blanket' thicker, and humans are adding more CO<sub>2</sub> all the time.

## Climate Myth: There's no empirical evidence

"There is no actual evidence that carbon dioxide emissions are causing global warming. Note that computer models are just concatenations of calculations you could do on a hand-held calculator, so they are theoretical and cannot be part of any evidence." ([David Evans](#))

The proof that man-made CO<sub>2</sub> is causing global warming is like the chain of evidence in a court case. CO<sub>2</sub> keeps the Earth warmer than it would be without it. Humans are adding CO<sub>2</sub> to the atmosphere, mainly by burning fossil fuels. And there is empirical evidence that the rising temperatures are being caused by the increased CO<sub>2</sub>.

## The Earth is wrapped in an invisible blanket

It is the Earth's atmosphere that makes most life possible. To understand this, we can look at the moon. On the surface, the moon's temperature during daytime can reach 100°C (212°F). At night, it can plunge to minus 173°C, or -279.4°F. In comparison, the coldest temperature on Earth was recorded in Antarctica: -89.2°C (-128.6°F). According to the WMO, the hottest was 56.7°C (134°F), measured on 10 July 1913 at Greenland Ranch (Death Valley).

Man could not survive in the temperatures on the moon, even if there was air to breathe. Humans, plants and animals can't tolerate the extremes of temperature on Earth unless they evolve special ways to deal with the heat or the cold. Nearly all life on Earth lives in areas that are more hospitable, where temperatures are far less extreme.

Yet the Earth and the moon are virtually the same distance from the sun, so why do we experience much less heat and cold than the moon? The answer is because of our atmosphere. The moon doesn't have one, so it is exposed to the full strength of energy coming from the sun. At night, temperatures plunge because there is no atmosphere to keep the heat in, as there is on Earth.

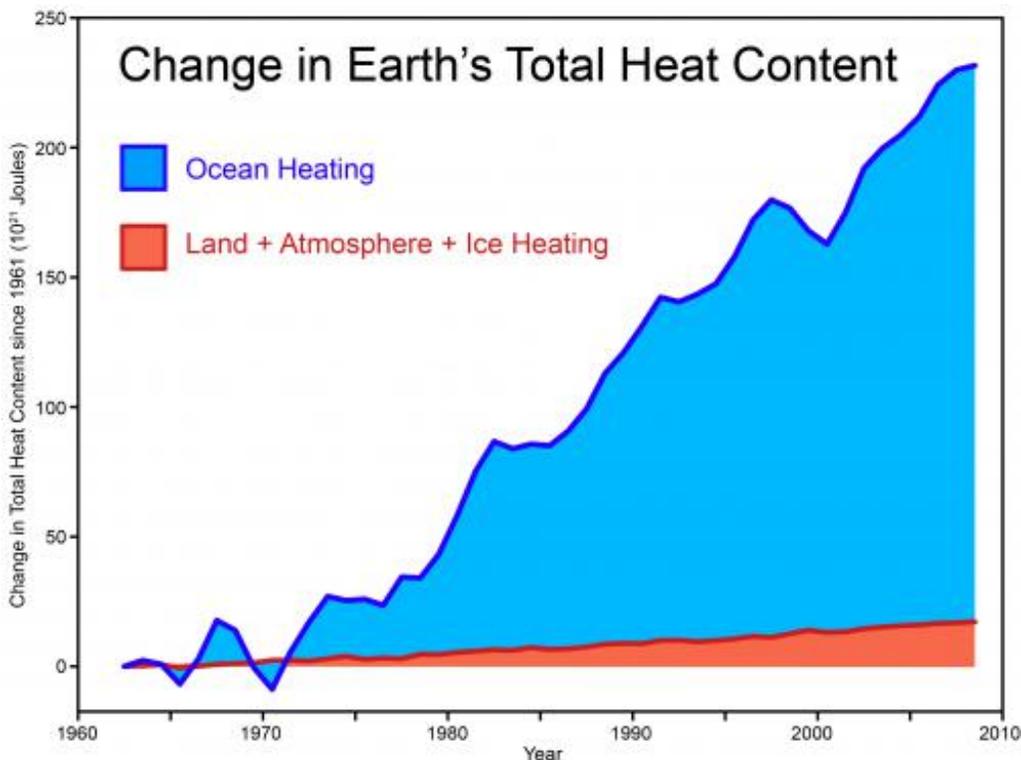
The laws of physics tell us that without the atmosphere, the Earth would be approximately 33°C (59.4°F) cooler than it actually is.

This would make most of the surface uninhabitable for humans. Agriculture as we know it would be more or less impossible if the average temperature was -18 °C. In other words, it would be freezing cold even at the height of summer.

The reason that the Earth is warm enough to sustain life is because of greenhouse gases in the atmosphere. These gases act like a blanket, keeping the Earth warm by preventing some of the sun's energy being re-radiated into space. The effect is exactly the same as wrapping yourself in a blanket - it reduces heat loss from your body and keeps you warm.

If we add more greenhouse gases to the atmosphere, the effect is like wrapping yourself in a thicker blanket: even less heat is lost. So how can we tell what effect CO<sub>2</sub> is having on temperatures, and if the increase in atmospheric CO<sub>2</sub> is really making the planet warmer?

One way of measuring the effect of CO<sub>2</sub> is by using satellites to compare how much energy is arriving from the sun, and how much is leaving the Earth. What scientists have seen over the last few decades is a gradual decrease in the amount of energy being re-radiated back into space. In the same period, the amount of energy arriving from the sun has not changed very much at all. This is the first piece of evidence: **more energy is remaining in the atmosphere.**

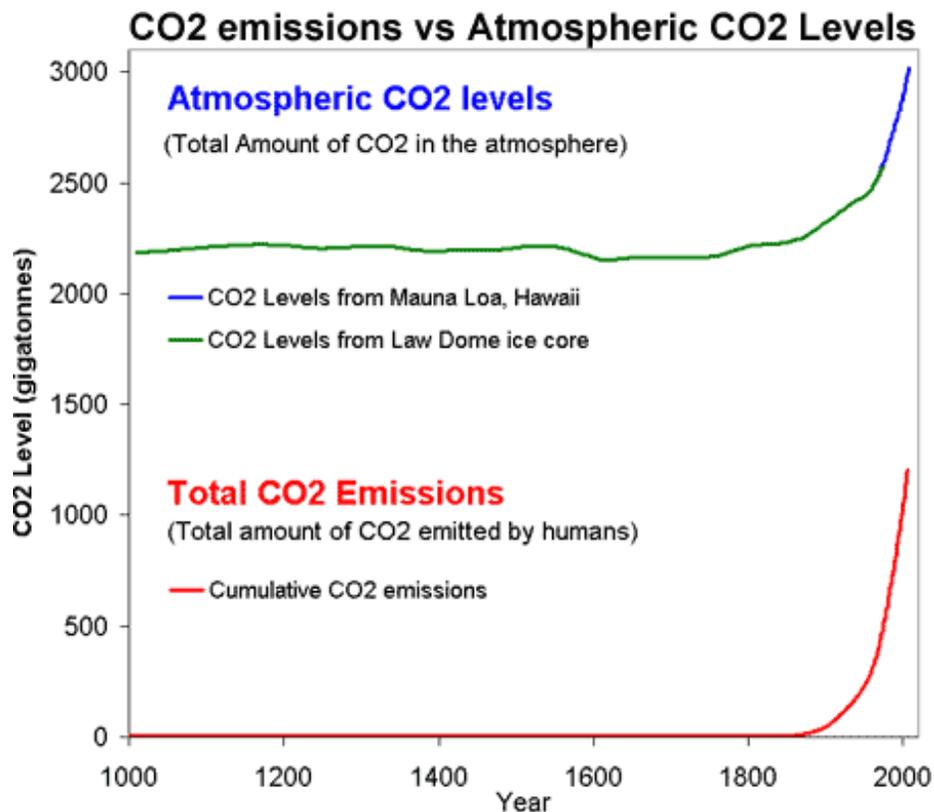


Total Earth Heat Content from [Church et al. \(2011\)](#)

What can keep the energy in the atmosphere? The answer is greenhouse gases. Science has known about the effect of certain gases for over a century. They 'capture' energy, and then emit it in random directions. The primary greenhouse gases - carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), water vapour, nitrous oxide and ozone - comprise around 1% of the air.

This tiny amount has a very powerful effect, keeping the planet 33°C (59.4°F) warmer than it would be without them. (The main components of the atmosphere - nitrogen and oxygen - are not greenhouse gases, because they are virtually unaffected by long-wave, or infrared, radiation). This is the second piece of evidence: **a provable mechanism by which energy can be trapped in the atmosphere.**

For our next piece of evidence, we must look at the amount of CO<sub>2</sub> in the air. We know from bubbles of air trapped in ice cores that before the industrial revolution, the amount of CO<sub>2</sub> in the air was approximately 280 parts per million (ppm). In June 2013, the NOAA Earth System Research Laboratory in Hawaii announced that, for the first time in thousands of years, the amount of CO<sub>2</sub> in the air had gone up to 400ppm. That information gives us the next piece of evidence; **CO<sub>2</sub> has increased by nearly 43% in the last 150 years.**

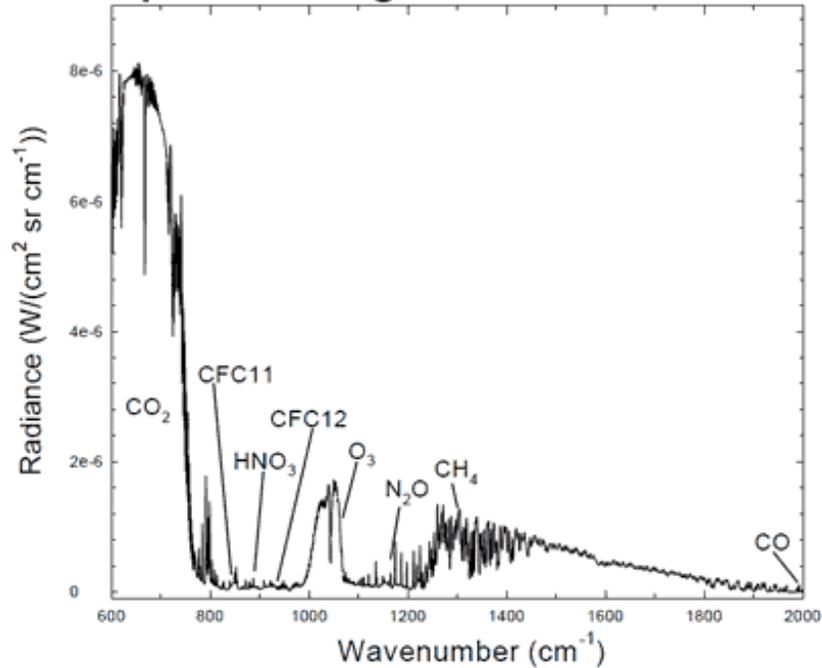


Atmospheric CO2 levels (Green is [Law Dome ice core](#), Blue is [Mauna Loa, Hawaii](#)) and Cumulative CO2 emissions ([CDIAC](#)). While atmospheric CO2 levels are usually expressed in parts per million, here they are displayed as the amount of CO2 residing in the atmosphere in gigatonnes. CO2 emissions includes fossil fuel emissions, cement production and emissions from gas flaring.

### The Smoking Gun

The final piece of evidence is 'the smoking gun', the proof that CO2 is causing the increases in temperature. CO2 traps energy at very specific wavelengths, while other greenhouse gases trap different wavelengths. In physics, these wavelengths can be measured using a technique called spectroscopy. Here's an example:

## Spectrum of greenhouse radiation



*Spectrum of the greenhouse radiation measured at the surface. Greenhouse effect from water vapor is filtered out, showing the contributions of other greenhouse gases ([Evans 2006](#)).*

The graph shows different wavelengths of energy, measured at the Earth's surface. Among the spikes you can see energy being radiated back to Earth by ozone ( $O_3$ ), methane ( $CH_4$ ), and nitrous oxide ( $N_2O$ ). But the spike for  $CO_2$  on the left dwarfs all the other greenhouse gases, and tells us something very important: **most of the energy being trapped in the atmosphere corresponds exactly to the wavelength of energy captured by  $CO_2$ .**

### Summing Up

Like a detective story, first you need a victim, in this case the planet Earth: **more energy is remaining in the atmosphere.**

Then you need a method, and ask how the energy could be made to remain. For that, you need **a provable mechanism by which energy can be trapped in the atmosphere**, and greenhouse gases provide that mechanism.

Next, you need a 'motive'. Why has this happened? Because  **$CO_2$  has increased by nearly 50% in the last 150 years and the increase is from burning fossil fuels.**

And finally, the smoking gun, the evidence that proves 'whodunit': **energy being trapped in the atmosphere corresponds exactly to the wavelengths of energy captured by  $CO_2$ .**

The last point is what places  $CO_2$  at the scene of the crime. The investigation by science builds up empirical evidence that proves, step by step, that man-made carbon dioxide is causing the Earth to warm up.

Basic rebuttal written by [GPWayne](#)

**Addendum:** the opening paragraph was added on 24th October 2013 in response to a criticism by Graeme, a participant on the [Coursera Climate Literacy course](#). He pointed out that the rebuttal did not make explicit that it was man-made  $CO_2$  causing the warming, which the new paragraph makes clear. The statement "...and humans are adding more  $CO_2$  all the time" was also added to the 'what the science says section'.

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### Update July 2015:

Here is a related lecture-video from [Denial101x - Making Sense of Climate Science Denial](#)

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Skeptical Science explains the science of global warming and examines climate misinformation through the lens of peer-reviewed research. The website won the Australian Museum 2011 Eureka Prize for the Advancement of Climate Change Knowledge. Members of the Skeptical Science team have authored peer-reviewed papers, a [college textbook on climate change](#) and the book [Climate Change Denial: Heads in the Sand](#). Skeptical Science content has been used in university courses, textbooks, government reports on climate change, television documentaries and numerous books.



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