

The Earth's Deadly CO₂ Global Warming Feedback Loop

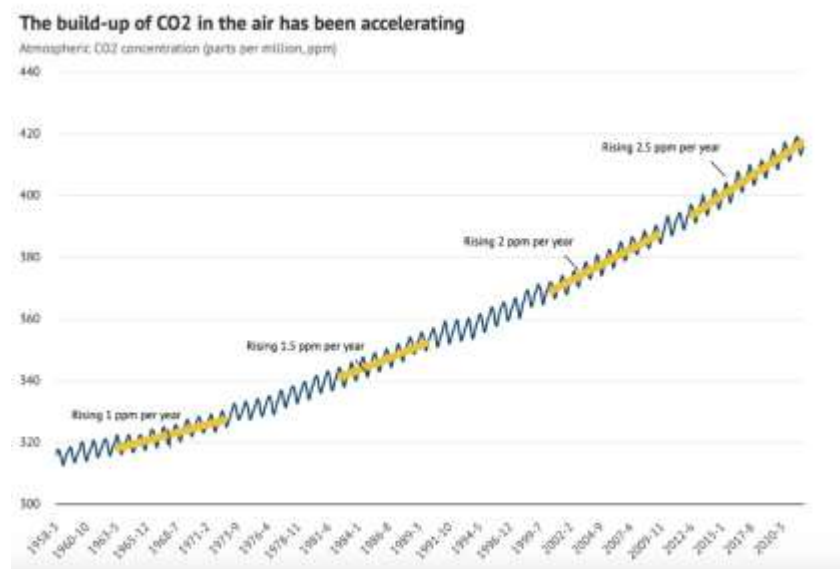
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INTRODUCTION

The purpose of this article is to bring to public's awareness some scientific observations that are rarely highlighted in the current climate change discussions but have multiple profound societal and political implications. First, the observations.

1. *The rate of increase in CO₂ into the atmosphere is increasing.* Based on the Keeling Curve, not only is the level of atmospheric CO₂ continuing to increase, as would be expected until emissions get to net zero, but the rate of this increase is also progressively increasing. The Keeling Curve is produced by the daily monitoring of atmospheric CO₂ levels based on instruments set up on Hawaii's Mauna Loa Mountain in 1958 by David Keeling. Following his death in 2005, his son Dr. Ralph Keeling of Scripps Oceanographic Institute, continued the CO₂ monitoring. Figure 1 shows some remarkable recent observations.



Data from Scripps Institution of Oceanography at UC San Diego. Permission from Creative Commons licenses. Chart by Joe Goodman for Carbon Brief. (Betts R. et al. 2022) ¹

This shows that instead of decreasing, both the amount of CO₂ and the rate of accumulation of CO₂ were increasing. For example, the following shows the rates of increase in parts per million from 1967 to 2023. The rate

in 1967 was 1.0 ppm/year,
in 1987 was 1.5 ppm/year,
in 2007 was 2.0 ppm/year,
in 2017 was 2.5 ppm/year, and
in 2023 was 2.8 ppm/yr.

Until emissions approach zero, no one expected the amount of CO₂ in the atmosphere to decrease. But it is very disturbing to see that the rate of increase in the level of atmospheric CO₂ has also been progressively increasing since 1967.

Keeling's group recently published plots that also showed an increase in the rate of increase in atmospheric CO₂ levels over time. These results (Figure 2) were based on the variable Atmospheric Growth Rate (AGR) measured in gigatons carbon per year.

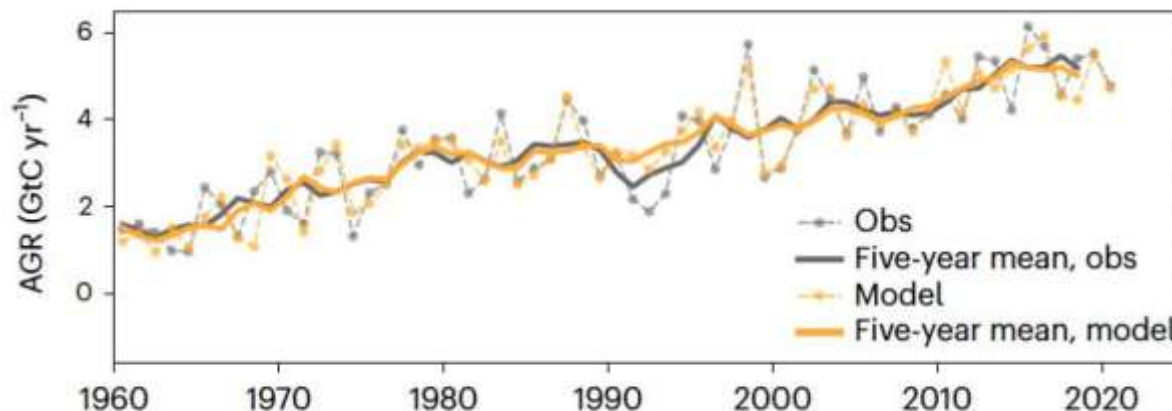


Figure 2. AGR from 1960 to 2020. Permission from creative commons licenses. (Birner B. et al 2023)².

This showed that the rate of increase in atmospheric CO₂ progressively increased from 1.8 Gigatons Carbon/year (GtC/yr) in 1960 to 5 GtC/year in 2020. These results were consistent with those in Figure 1. I found these results so disturbing that I wrote a paper suggesting an explanation for the increase in the rates of accumulation of CO₂ (Comings, D.E. 2024).³ I proposed that the high levels of greenhouse gases in the atmosphere were triggering several additional non-fossil fuel sources of CO₂. These included the massive forest fires throughout the world in temperate regions, the forest fires in the boreal regions, the burning of peat, deforestation, outgassing CO₂ from the oceans, rivers and soil, the loss of albedo due to melting polar glaciers, the melting of the permafrost, the earth's heat imbalance, die off of phytoplankton, and others. While I still believe these are contributing to the progressive increase in the rate of accumulation of CO₂ into the atmosphere, as I became more aware of the earth's massive heat imbalance, I realized this was probably the major contributor.

2. The level of the earth's heat imbalance is enormous and increasing. The earth's heat imbalance refers to the ratio of the amount of sun's heat irradiation retained by the earth versus the amount of the sun's heat irradiation reflected back into space. Ninety percent of this heat retained is adsorbed by the oceans. This has been repeatedly documented by Cheng, L. et al 2021,2022,2023,2024.³⁻⁸

Nuccitelli (2020)⁹ calculated that the magnitude of this imbalance was equivalent to five Hiroshima type Atomic Bombs exploding in the ocean per second or 432,000 Hiroshima type atom bombs going off in the ocean every day.

This heat imbalance is caused by two things. The major contributor is the effect of greenhouse gases such as CO₂ and methane in trapping the sun's heat irradiation in the earth. A second contributor is the loss of albedo due to the melting of polar glaciers and sea ice. Albedo refers to the reflection of incoming heat irradiation back into space. Glaciers and sea ice have an albedo of 70 to 90 percent, while ice free water and soil have an albedo of only 6 to 15 percent. The albedo of the whole earth is 30 percent. Clearly as glaciers and sea ice melt, the albedo significantly decreases.

Not surprisingly dumping this much heat into the ocean, heats the ocean. Currently this heat anomaly is at a level of 200 zettajoules. One zettajoule is a 1 followed by 21 zeros, i.e. 1000000000000000000000. These form a positive feedback loop (see below) such that this heat anomaly is progressively increasing. When measured in terms of watts per square meter, it has in fact increased from 0.42 in 1972 to 1993, to 0.87 in 2004 to 2010, and to 0.96 in 2011 to 2024.

According to NOAA the global ocean temperatures have increased by 2.8°F since 1901. This is an average including night and day, the different seasons and different latitudes. Locally it is a different story. For example, in 2023 the temperature off the coast of Florida exceeded 100°F. This is equivalent to the temperature of a hot tub.

3. *Oceans contain 50 times more CO₂ than the atmosphere.* Carbon dioxide in the ocean is present in three forms, dissolved gas (CO₂g), bicarbonate ions (HCO₃⁻) and carbonate ions (CO₃²⁻). These three combined are termed Dissolved Inorganic Carbon or DIC. At a level of around 38,000 gigatons (Gt) of carbon the ocean contains 16 times as much carbon as the terrestrial biosphere, that is all plant and the underlying soils on our planet. The oceans currently hold 50 times more CO₂ than the atmosphere (Ravin, J.A. and Falkowski, P.G. 1999).¹⁰

4. *The warmer the ocean temperature the less CO₂ it can contain.* This is well illustrated by the following diagram showing the solubility of CO₂ in water at different temperatures.

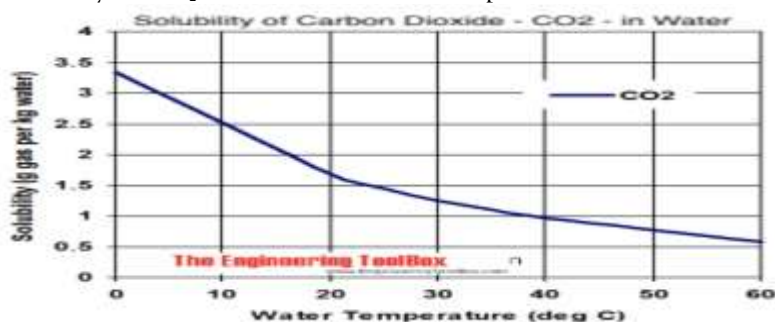


Figure 3. www.TheEngineeringToolBox.com.

As the temperature of the water increases the solubility of CO₂ decreases. Thus, as the ocean temperature increases it will release larger and larger amounts of its stored CO₂ back into the atmosphere. (See Figure 4.)

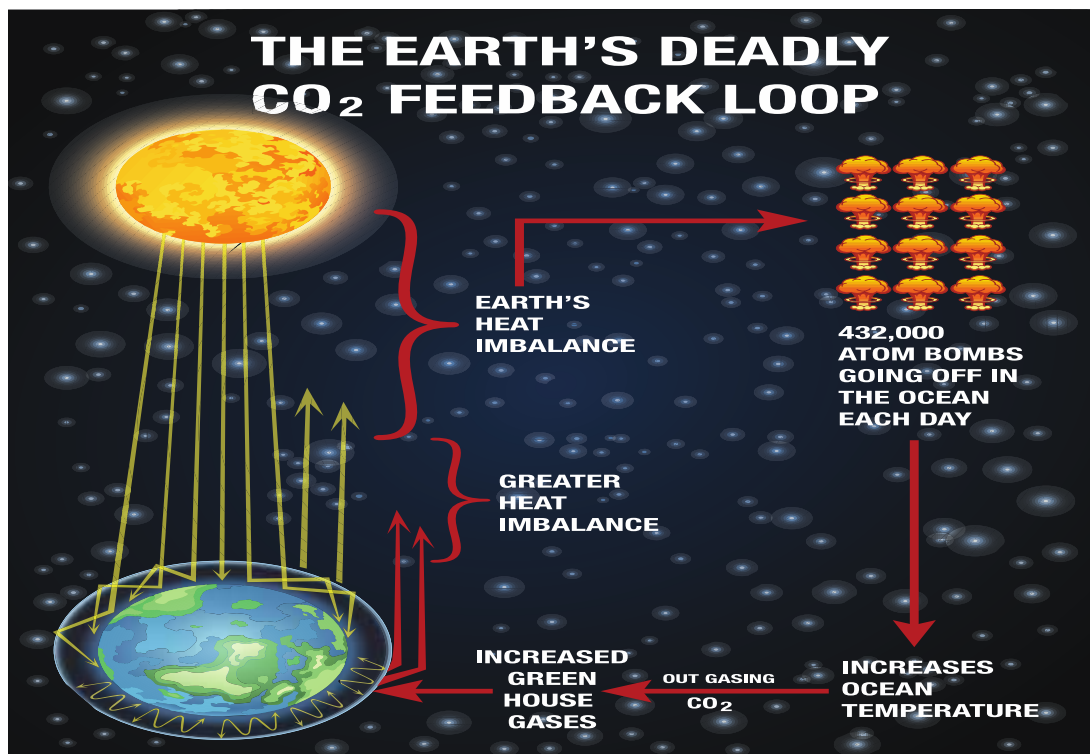


Figure 4. A positive CO₂ feedback loop by which the massive level of the earth's heat imbalance heats the ocean causing it to release its stored CO₂ which in turn increases the level of

greenhouse gases resulting in a further increase in the earth's heat imbalance. Illustration by Richard de Bose.

What are the implications of this? There are many.

First, attaining Net Zero in fossil fuel emissions would slow the accumulation of CO₂ in the atmosphere and help to prevent further increases in the earth's heat imbalance, but it will not significantly decrease the current level of that heat imbalance because the carbon dioxide causing the greenhouse effect stays in the atmosphere for hundreds to thousands of years.

Second, the only effective method of decreasing this greenhouse effect is to remove the CO₂ and safely sequester it. This is called CDR or Carbon Dioxide Removal. and NET or Negative Emission Technology. The level of CO₂ in the atmosphere in 2023 was 420 ppm. This is equivalent to 3,323 GtCO₂. In 1967 the level was approximately 320 ppm equivalent to 2,531 GtCO₂. Thus, during this 56-year period the levels increased by 79.2 gigatons or 1.41 gigatons/year.

Using the GtC/year AGR variable, in 1960 this was 1.8 and in 2020 approximately 5, indicating an increase of 3.2 over a period of 60 years or 0.53 GtC/year/year. Since one gigaton of C equals 3.67 gigatons of CO₂, using AGR the rate of CO₂ uptake into the atmosphere is increasing by 1.95 gigatons/year. This is similar to the rate of 1.41 gigatons/year based on the ppm data.

It has been recommended that to adequately combat global warming 10 Gt of CO₂ per year needs to be removed from the atmosphere until 2050 and then 20 GtCO₂/year to the end of the century.¹¹

The current emphasis for CDR is DACS (Direct Air Capture and Sequestration) with burying of the captured CO₂. While this can play a role, I have listed 10 potential problems with DACS and suggested the addition of three safer and more effective alternatives for removing gigatons of CO₂ from the atmosphere, plus a fourth consisting of repairing the earth's albedo (Comings, 2025).

Third The current Trump administration has called climate change a hoax and is adamantly opposed to undertaking any ventures to help combat global warming including defunding NOAA and NASA and other organizations contributing to the science of climate change. However, much of what conservatives complain about relates to the government regulations involved in attaining Net Zero emissions from fossil fuels. Combating the above feedback loop primarily involves a marked acceleration of CDR. This switch in emphasis from Net Zero to CDR might be far more palatable to conservatives than what is involved in pushing for Net Zero. If left alone those outside the government can handle the Net Zero part.

We should not lose sight of the fact that global warming is real and if not contained and reversed by greatly accelerating CDR and reducing emissions, continued emissions and the feedback loop described here will result in highly destructive consequences to current and future generations of humanity.

The climate change deniers in the current administration are mostly in their 60's to 70's, ages at which they will not be around to see the worst of progressive global warming. By contrast, their grandchildren will be round for another 40 to 70 years and will be severely affected. For many years we were told the world's temperature absolutely must not exceed 1.5°C over preindustrial levels. In 2024 the earth blew past that with ease. Our grandchildren are likely to see global temperatures over preindustrial levels of 3.7°C and greater, with truly dystopian effects on the earth's inhabitants. If for no other reason, the deniers need to change course to protect their grandchildren.

A final note. The heat imbalance is equivalent to 432,000 atom bombs going off in the ocean every day. This is equivalent to 153 million atom bombs going off in the ocean every year. The book, *If I Were a Billionaire, these are the Four Things....The Science of Global Warming*.¹² is devoted to four approaches to reducing this heat imbalance. The Trump administration is doing all it can to kill any efforts to combat global warming. Over the four years of this administration this would be equivalent to 613 million atom bombs set off in the ocean with no efforts made to counter the resultant heat imbalance. This total lack of action by the country that is this planet's second greatest emitter of greenhouse gases, would be devastating.

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