THE POSITIVE IMPACT OF HUMAN CO_2 EMISSIONS ON THE SURVIVAL OF LIFE ON EARTH

BY PATRICK MOORE

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EXECUTIVE SUMMARY

This study looks at the positive environmental effects of carbon dioxide (CO_2) emissions, a topic which has been well established in the scientific literature but which is far too often ignored in the current discussions about climate change policy.

All life is carbon based and the primary source of this carbon is the CO_2 in the global atmosphere.

As recently as 18,000 years ago, at the height of the most recent major glaciation, CO_2 dipped to its lowest level in recorded history at 180 ppm, low enough to stunt plant growth. This is only 30 ppm above a level that would result in the death of plants due to CO_2 starvation.

It is calculated that if the decline in CO_2 levels were to continue at the same rate as it has over the past 140 million years, life on Earth would begin to die as soon as two million years from now and would slowly perish almost entirely as carbon continued to be lost to the deep ocean sediments.

The combustion of fossil fuels for energy to power human civilization has reversed the downward trend in CO_2 and promises to bring it back to levels that are likely to foster a considerable increase in the growth rate and biomass of plants, including food crops and trees.

Human emissions of CO_2 have restored a balance to the global carbon cycle, thereby ensuring the long-term continuation of life on Earth.

This extremely positive aspect of human CO_2 emissions must be weighed against the unproven hypothesis that human CO_2 emissions will cause a catastrophic warming of the climate in coming years.

The one-sided political treatment of CO_2 as a pollutant that should be radically reduced must be corrected in light of the indisputable scientific evidence that it is essential to life on Earth.

INTRODUCTION

There is a widespread belief that CO_2 emissions from the burning of fossil fuels for energy are a threat to the Earth's climate and that the majority of species, including the human species, will suffer greatly unless these emissions are drastically curtailed or even eliminated.[1]

This paper offers a radically different perspective based on the geological history of CO_2. CO_2 is one of the most essential nutrients for life on Earth. It has been approaching dangerously low levels during recent periods of major glaciation in the Pleistocene Ice Age, and human emissions of CO_2 may stave off the eventual starvation and death of most life on the planet due to a lack of CO_2.[2] This is not primarily a discussion of the possible connection between CO_2 and global warming or climate change, although some mention must be made of it. There has been a great deal of discussion on the subject, and it is hotly contested in both scientific and political spheres. There is no question that the climate has warmed during the past 300 years since the peak of the Little Ice Age. There is also no question that CO_2 is a greenhouse gas and *all else being equal*, the emissions would result in some warming if CO_2 rose to higher levels in the atmosphere. Yet, there is no definitive scientific proof that CO_2 is a major factor in influencing climate in the real world. The Earth's climate is a chaotic, non-linear, multi-variant system with many unpredictable feedbacks, both positive and negative. Primarily, this is a discussion about the role of atmospheric CO_2 in the maintenance of life on Earth and the positive role of human civilization in preventing CO_2 from trending downward to levels that threaten the very existence of life.

THE HISTORY OF CO_2 IN THE GLOBAL ATMOSPHERE

It is an undisputed fact that all life on Earth is carbon based and that the source of this carbon is CO_2, which cycles through the global atmosphere. The original source of CO_2 in the atmosphere is thought to be massive volcanic eruptions during the Earth's early history, the extreme heat of which caused the oxidation of carbon in the Earth's interior to form CO_2.[3] Today, as a minor gas at 0.04 per cent, CO_2 permeates the entire atmosphere and has been absorbed by the oceans and other water bodies (the hydrosphere), where it provides the food for photosynthetic species such a phytoplankton and kelp. If there were no CO_2 or an insufficient level of CO_2 in the atmosphere and hydrosphere, there would be no life as we know it on our planet.

On a relatively short-term basis (years to hundreds of years), the carbon cycle is a complex series of exchanges among the atmosphere, the hydrosphere, living species and decomposing organic matter in soils and sediments. Over the long term (millions to billions of years), the majority of the carbon that has been absorbed from the atmosphere by plants has been lost to the cycle into deep deposits of fossil fuels and carbonaceous rock (minerals) such as chalk, limestone, marble and dolomite. By far the majority of the carbon sequestered over the long term is in the form of carbonaceous rock.

We do not have a good estimate of the total amount of CO_2 that has been emitted from volcanic activity into the global atmosphere. We do not know the total amount of carbon that has been lost to long-term sequestration in fossil fuels and carbonaceous rock, but we do have order-of-magnitude estimates. We do have quantitative estimates of the level of CO_2 in the atmosphere going back more than 600 million years, i.e., the net result of additions from volcanic events, losses to deep deposition in carbonaceous rocks and fossil fuels, the biomass of living species and decomposing organic matter. These estimates become more accurate the closer they are to the present. This paper will focus on the past 540 million years and in particular the past 140 million years.

The best estimate of CO_2 concentration in the global atmosphere 540 million years ago is 7,000 ppm, with a wide margin of error. (See Figure 1). For the sake of discussion, we will accept that number, which indicates a mass of more than 13,000 billion tonnes (Gt) of carbon in the atmosphere, 17 times the present level, during the Cambrian Explosion, when multicellular life evolved. This is considered the advent of modern life, when both plant and animal species diversified rapidly in warm seas and later colonized the land during a warm terrestrial climate.[4] Prior to this, for more than three billion years, life was largely unicellular, microscopic and confined to the sea.

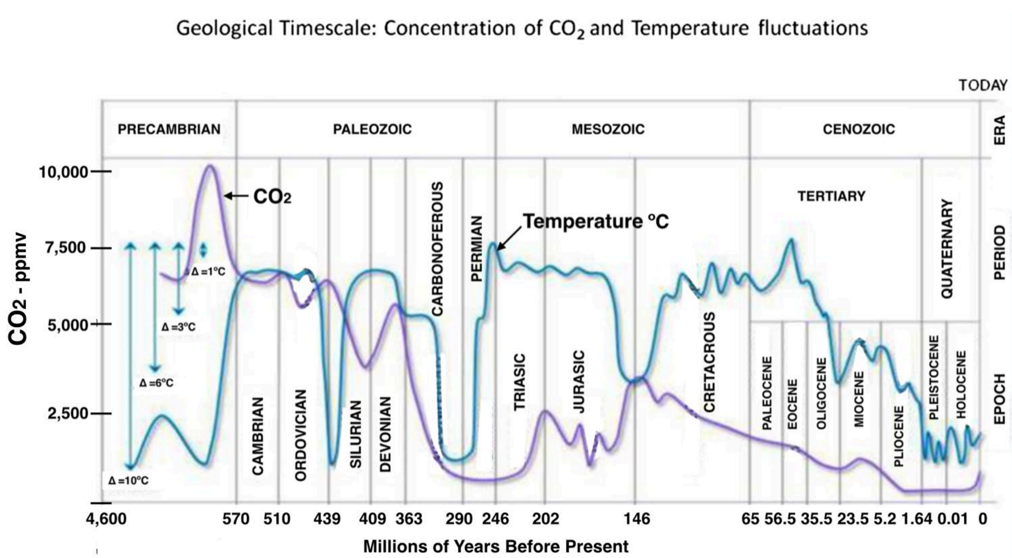

Figure 1. Graph of global temperature and atmospheric CO_2 concentration over the past 600 million years. Note both temperature and CO_2 are lower today than they have been during most of the era of modern life on Earth since the Cambrian Period. Also, note that this does not indicate a lock-step cause-effect relationship between the two parameters.[5]

The Rise of Terrestrial Woody Plants

One of the most significant developments during the establishment of terrestrial plant species was the evolution of wood, a complex of cellulose and lignin that provided a rigid stem. This allowed plants to place their photosynthetic structures higher toward the sun, thus providing a competitive advantage. The evolution of lignin also provided protection against attack from bacteria and fungi, as no species had yet evolved enzymes that could digest lignin. There followed in the Devonian Period the spread of vast forests of tree ferns, trees and shrubs, resulting in a massive increase in living biomass compared with the low-lying vegetation prior to the woody era. This orders-of-magnitude increase in biomass came with an inevitable drawing down of CO_2 from the atmosphere, as wood is almost 50 per cent carbon. From that time until the present day, the biomass of trees and other woody plants far surpasses the sum of all other species combined.[6]

It could be expected that once living biomass had reached a much higher but relatively stable state that the net withdrawal of CO_2 would end and would level off at a concentration somewhat lower than the approximately 4,000 ppm (7,600 Gt of carbon) in the mid-Devonian. However, this was not the case. CO_2 levels continued to drop, with minor fluctuations perhaps caused by volcanic activity, for the next 80 million to 100 million years into the mid-Carboniferous Period until they reached a level of about 400 ppm (760 Gt of carbon), similar to present-day levels. Therefore, during this era, the level of CO_2 in the atmosphere was reduced by about 90 per cent. Many of the massive coal deposits we are mining today were formed during this period.

There are two competing hypotheses regarding the formation of coal during these ancient times. One hypothesis postulates that coal deposits came about as trees died and fell into vast swamps where they were preserved, eventually buried by deep sediments, and over time transformed into coal by heat and pressure.[7] An alternative explanation is that the decomposer species of bacteria, fungi and insects had not yet developed the complex set of digestive enzymes necessary to digest wood. Therefore, the dead trees in forests simply piled up on top of one another and new trees grew upon an ever-deepening layer of dead trees until eventually they were buried, and heat and pressure converted them into coal.[8]

The end of the Carboniferous and the beginning of the Permian marked a reversal of the downward trend in CO_2, and over the next 125 million years, CO_2 rose to about 2,500 ppm in the Jurassic Period. During this period, species of

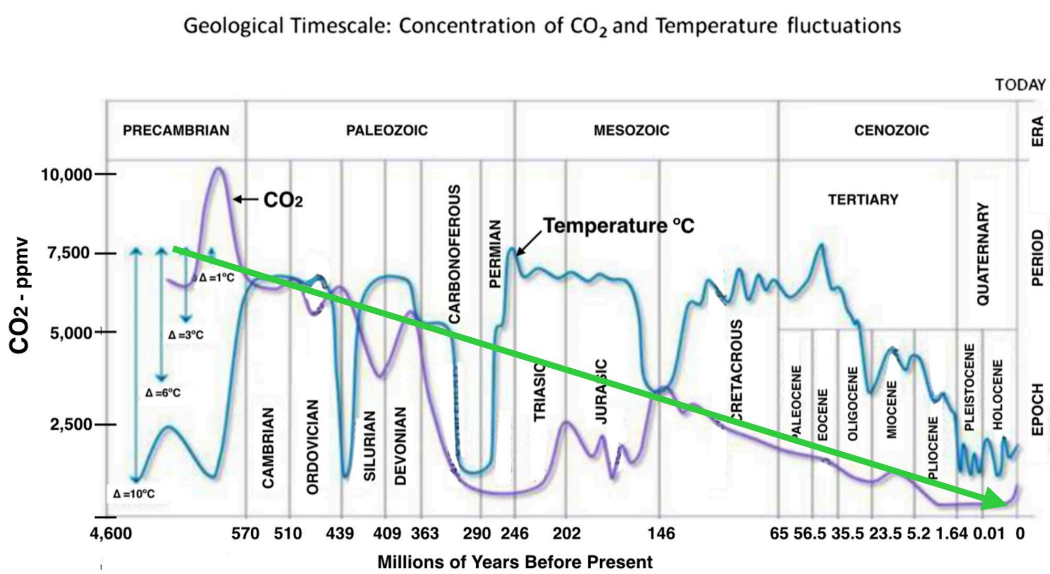

Figure 2. The graph of CO_2 and temperature shown in Figure 1 with the trend in CO_2 concentration in the global atmosphere represented by the green arrow. Note the uptick at the far right of the graph representing the reversal of the 600 million-year downward trend due primarily to emissions of CO_2 from the use of fossil fuels for energy. Note that even today, at 400 ppm, CO_2 is still far lower than it has been during the most of this 600 million history.

fungi developed enzymes that could digest the lignin in wood.[9] It is plausible that these species consumed vast stores of dead wood near the surface, with the attendant release of CO_2 into the atmosphere. Coincident with the development of decomposers that could digest lignin was a significant reduction of coal formation. Volcanic activity and outgassing of CO_2 from the oceans may also have played a role in bringing CO_2 levels higher.

Regardless of which coal-forming hypothesis one favours, and a combination of the two is plausible, if fungi and other species had not evolved to produce the enzymes necessary to digest lignin, it is likely that atmospheric CO_2 would have continued to decline until it reached the 150 ppm threshold for the survival of plant life. At that point, species of plants would begin to die for lack of CO_2, and as more carbon was sequestered as wood and as calcium carbonate in marine deposits, living biomass would begin to shrink steadily until most or all of it died. It was therefore most fortuitous that white rot fungi and other species evolved the enzymes to digest lignin, or the history of life on Earth would have been considerably shorter.

The Second Long Decline of CO_2

With this historical background, we will now focus on the period from 140 million years ago to the present. Having recovered to approximately 2,500 ppm, CO_2 concentrations gradually and steadily fell to what is likely the lowest level it has been in the history of the Earth. The ice cores drilled at Vostok Station in Antarctica indicate that at the height of the last major glaciation event, 18,000 years ago, CO_2 dropped to roughly 180 ppm (See Figure 3).[10] This is only 30 ppm above the level of starvation for most plant species, which is 150 ppm.[11]

One hundred and forty million years ago at 2,500 ppm, the atmosphere held 4,750 Gt of carbon as CO_2. At 180 ppm, the atmosphere held 342 Gt of carbon as CO_2, which over the 140-million-year period represented a loss of 4,530 Gt of carbon or 92.8 per cent of atmospheric CO_2. While we do not have accurate estimates of volcanic emissions of CO_2 or of deep ocean sequestration of CO_2 over this period, we do have a very good representation of the net effect on atmospheric levels of CO_2. Because of this decline, on a number of occasions during the present Pleistocene Ice Age, CO_2 has dropped during major glaciations to dangerously low levels relative to the requirements of plants for their growth and survival. At 180 ppm, there is no doubt that the growth of many plant species was substantially curtailed.[12]

The solubility pump and the biological pump continuously remove carbon dioxide from the atmosphere.[13] The

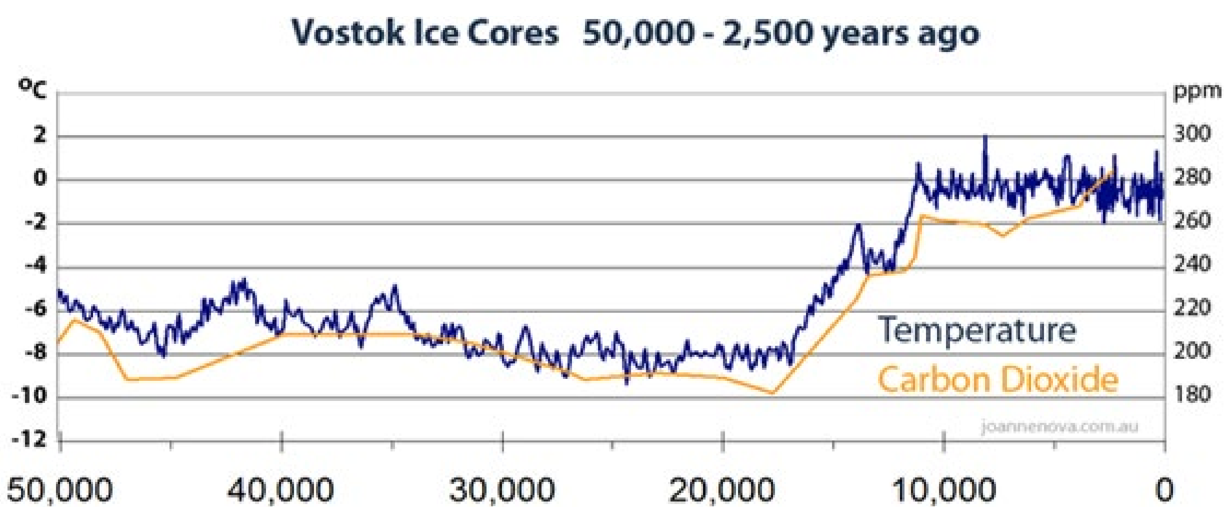

Figure 3. Graph of temperature and CO_2 concentration from the Vostok ice cores in Antarctica showing that atmospheric CO_2 concentration descended close to 180 ppm at 18,000 YBP (years before present). Note that CO_2 levels tend to lag behind changes in temperature.[14]

solubility pump refers to the high solubility of CO_2 in cold ocean water at higher latitudes where sinking cold seawater carries it into the depths of the ocean. The biological pump refers to the sequestration of carbon from biomass and calcium carbonate ($CaCO_3$) from planktonic shells, corals and shellfish into the deep ocean sediments. During the past 140 million years, these processes have removed more than 90 per cent of the CO_2 in the atmosphere.

The steady reduction of CO_2 in the atmosphere over the past 140 million years from 2,500 ppm to 180 ppm, prior to the Holocene interglacial period and prior to significant human emissions of CO_2, amounts to a net loss from the global atmosphere of 32 thousand tonnes (Kt) of carbon every year. We can reasonably surmise that the primary cause of this downward trend was $CaCO_3$ deposition from plankton and coral reefs in marine sediments.[15] During the major glaciations, cooling oceans may also have absorbed additional CO_2.

CO_2 Rises from the Brink

After the most recent major glaciation peaked 18,000 years ago, CO_2 levels began to rise in the atmosphere, reaching 260 ppm 10,000 years ago and 280 ppm prior to the Industrial Revolution when fossil fuels became dominant for energy production. The most plausible explanation for the majority of this rise is outgassing of CO_2 from the oceans as they warmed with a warming climate.[16] Since then, human emissions of CO_2 have contributed to raising the level to about 400 ppm, a level perhaps not experienced during the past 10 million to 20 million years. Since the onset of the Industrial Age, CO_2 has risen by 120 ppm or approximately 230 Gt of carbon in a little more than 100 years, whereas the lesser “natural” increase from 180 ppm to 280 ppm took about 15,000 years. The increase during the Industrial Age is likely due to a combination of fossil fuel combustion, land-use change, cement production and possibly outgassing of CO_2 from the oceans due to rising global temperature. This latter point is the subject of much discussion and contention but is not of principal concern in the context of this paper.

THE DISTRIBUTION OF CARBON TODAY

The global atmosphere today, at about 400 ppm CO_2, contains approximately 850 Gt of carbon compared with the oceans, which contain approximately 38,000 Gt of carbon, most of which was initially absorbed as CO_2 from the atmosphere. (See Figure 4) Therefore, the emission or absorption of 1 per cent of CO_2 from or into the oceans would make a 45 per cent change to the CO_2 level in the atmosphere at the present concentration of CO_2.

The truly astounding figure is the estimate of 100,000,000 Gt (one hundred million billion tons, also known as 100 quadrillion tons) of carbon in carbonaceous rocks, all or most of which originated from CO_2 in the global atmosphere. If all that CO_2 had remained in the atmosphere, it would represent approximately 70 current global atmospheres by weight at 100 per cent CO_2. This highlights the fact that during the Earth's early times, vast quantities of CO_2 were outgassed from volcanism. During the past 3.5 billion years, the vast majority (about 99.5 per cent) of the carbon in that CO_2 has been sequestered in carbonaceous rocks and to a much lesser extent, fossil fuels.

It is interesting to note that our closest neighbouring planets, Venus and Mars, have atmospheres that are dominated by CO_2, likely from early volcanic eruptions. Neither of them evolved life that could convert the CO_2 to $CaCO_3$ to be buried in marine sediments.

CO_2 in the Oceans

The solubility of CO_2 in the oceans is dependent on the salinity and temperature of the oceans and on CO_2 concentration in the atmosphere. Salinity varies among oceans between 30 parts per thousand and 38 parts per thousand and is relatively constant over time. The oceans have warmed since the height of the Little Ice Age, so it is likely there has been a net outgassing from them during the past 300 years, at least until human-caused emissions of CO_2 began in earnest. From the literature, it appears that we do not have definitive quantitative data for the fate

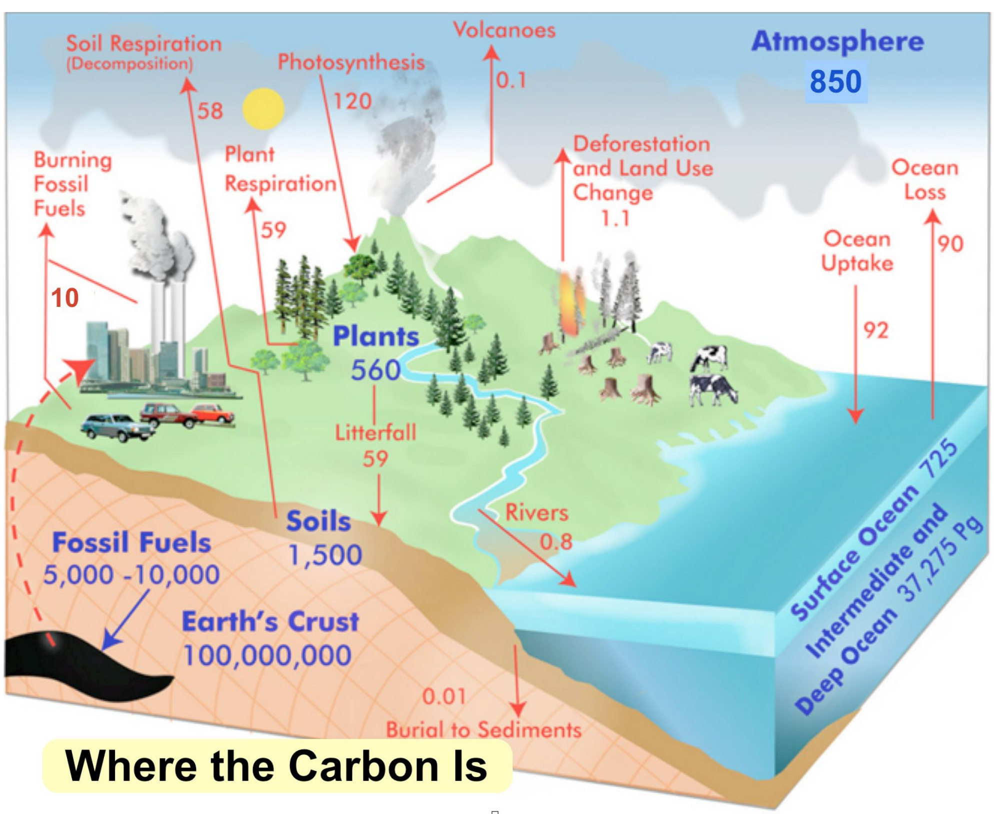

Figure 4. Depiction of the global carbon budget in Gt of carbon. Values in blue are stocks of carbon while values in red are annual flows. Note that the ocean contains nearly 50 times as much carbon as the atmosphere does, and the ocean and atmosphere are in constant flux.[17]

of the current 10 Gt of carbon emitted annually due to human activities. We can measure the increase in the CO_2 concentration in the atmosphere, but some of this may be due to outgassing from the warming oceans rather than from human-caused emissions. Many scholars conclude that the oceans are absorbing roughly 25 per cent of the human CO_2 emissions, therefore negating the possibility of a net outgassing of CO_2. It is generally recognized that global plant biomass is increasing because of increased CO_2 in the atmosphere, but quantifying this accurately is difficult. One recent paper concluded that most of the short-term CO_2 uptake is by terrestrial plants and that very little, if any, is absorbed by the oceans.[18]

In recent years there has been an outpouring of papers warning that if CO_2 emissions continue, and CO_2 levels in the atmosphere continue to rise, that a phenomenon called "ocean acidification" will occur that will threaten the entire marine food chain. Some postulate that the decrease in the pH of the oceans will render it impossible for calcifying species such as corals, shellfish, and calcifying species of plankton such as coccolithophores and foraminifera to produce their shells from $CaCO_3$. The author has recently published an in-depth paper on this subject. The paper concludes that "ocean acidification" is a fabrication and provides five key factors that make such an outcome impossible.[19]

CO_2 in the Modern Era

The most important question facing a species on Earth today is how long would it have been in the absence of human-caused CO_2 emissions until the gradual depletion of CO_2 in the atmosphere fell to levels that began to decrease biomass due to starvation, thus signaling the beginning of the end of life on Earth?

It is commonly believed that volcanic activity results in massive emissions of CO_2 comparable to or greater than human-caused emissions. This is not the case. Whereas the original atmospheric CO_2 was the result of massive outgassing from the Earth's interior, there is no evidence that large volumes of new CO_2 were added to the atmosphere during the 140-million-year decline leading to the present era. The eruption of Mount Pinatubo, the largest in recent history, is estimated to have released the equivalent of 2 per cent of the annual human-caused CO_2 emissions. Therefore, in the absence of human-caused emissions, it could reasonably be presumed that CO_2 levels would have continued to fall as they had done for the previous 140 million years.[20]

Judging by the timing of the many glacial and interglacial periods during the Pleistocene Ice Age, the next major glaciation period could begin any time. Interglacial periods have generally been of 10,000 years' duration, and this Holocene interglacial period began nearly 12,000 years ago. In the absence of human-caused CO_2 emissions and other environmental impacts, there is no reason to doubt that another major glaciation would have occurred, following the pattern that has been established for at least the past 800,000 years, as established by the European Project for Ice Coring in Antarctica (EPICA),[21] and presumably for the past 2.5 million years of the Pletstocene Ice Age. These glaciations have coincided with the Milankovitch cycles.[22] (See Figure 5) The Milankovitch cycles are determined by oscillations in the Earth's orbit and by cycles of the tilt of the Earth toward the sun. The strong correlation between the onset of major periods of glaciation during the past 800,000 years and the Milankovitch cycles has led the majority of earth scientists and climatologists to accept the hypothesis that the major glaciations are tied to the Milankovitch cycles in a cause-effect relationship.

For 90 million years from the late Jurassic Period to the Early Tertiary Period, global temperature rose considerably while CO_2 levels steadily declined.

Then after the Paleocene-Eocene Thermal Maximum, there began a 50-million-year cooling trend in global temperature to the current era. (See Figure 6) The Paleocene-Eocene Thermal Maximum saw an average global temperature

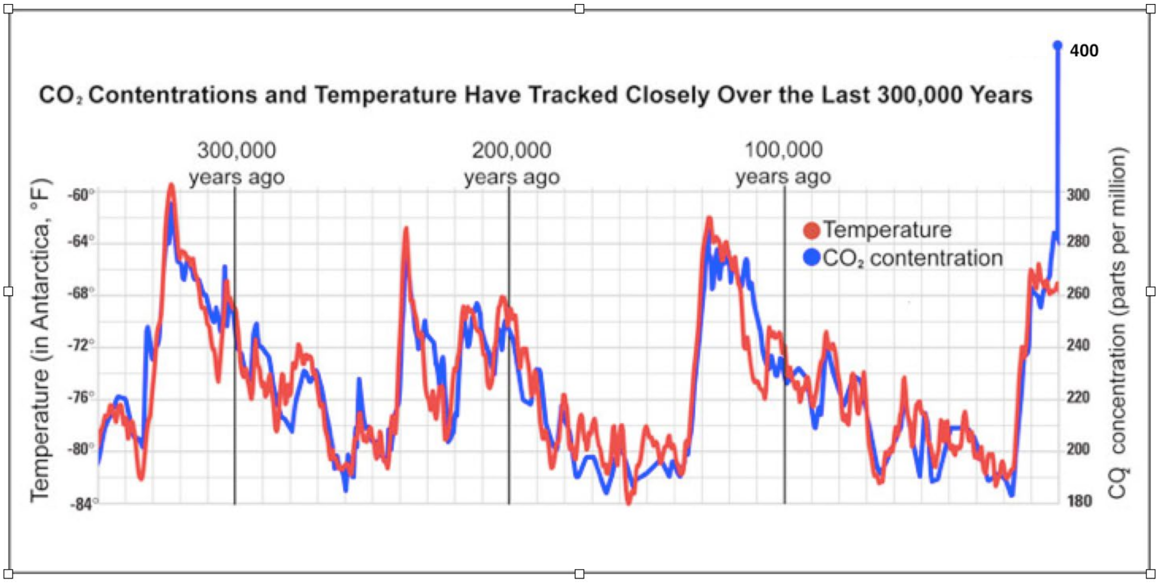

Figure 5. Graph showing the atmospheric CO_2 concentration and temperature from Antarctica for the most recent four interglacial periods, closely tied to the Milankovitch cycles of 100,000 years. This graph is based on data from the 420,000 year record obtained from the Vostok ice cores drilled by Russian scientists.[23] Note the gradual nature of the onset of colder temperatures and the rapid warming at the end of the cycle. Note that the peak warming during the most recent interglacial period (the Holocene) is lower than during the previous three interglacial periods.[24]

as much as 16°C higher than the temperature today. Yet, the ancestors of every species living today must have survived through this period, as they had also survived through previous much colder climates. It is instructive to note that despite the numerous periods of extreme climatic conditions and cataclysmic events, every species alive today is descended from species that survived those conditions. This leads one to question the predictions of mass species extinction and the collapse of human civilization if the average global temperature exceeds a rise of 2°C above today's level.[25]

It may seem surprising that the average global temperature could have been 16°C higher in previous ages, as this

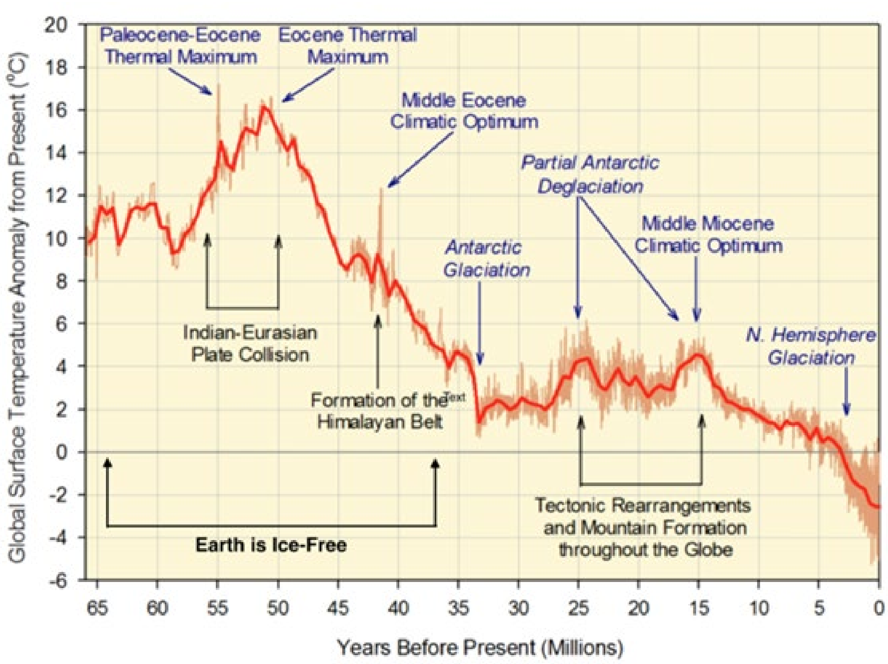

Figure 6. Global surface temperature from 65 million YBP showing the major cooling trend over the past 50 million years. While the poles were considerably warmer than they are today, there was much less warming in the tropics, which remained habitable throughout. The Earth is in one of the coldest periods during the past 600 million years.[26]

would appear to render parts of the Earth that are warm today virtually uninhabitable. The key to understanding this is that when the Earth warms, it does so disproportionally, depending on the latitude. While the Arctic and Antarctic experience considerable warming, there is much less warming in the tropics. Thus, the tropical regions remain habitable while the high latitudes shift from polar to temperate, and during the warmest ages, they shift to a tropical climate.

It is clear from the 800,000-year Antarctic ice core record that the coldest periods during major glaciations coincide with the lowest levels of CO_2 in the atmosphere. (see Figure 5) The correlation is certainly strong enough during this period to suggest a causal relationship between CO_2 and temperature. However, there is disagreement in the literature about which is the cause and which is the effect. Those who ascribe the warming over the past century to greenhouse gas emissions, CO_2 in particular, also tend to agree with the position set forth in Al Gore's *An Inconvenient Truth: The Planetary Emergency of Global Warming and What We Can Do about It,* that the warming during the interglacial periods is caused by rising CO_2 levels.[27] However, it is problematic to postulate how the Milankovitch cycles could cause an increase or decrease in atmospheric CO_2 levels, whereas it *is* plausible that the Milankovitch cycles could cause a fluctuation in global temperature due to changes in solar radiation, which in turn could cause either CO_2 outgassing from or absorption into the oceans. Indeed, both sets of ice core data from Antarctica show that changes in temperature usually precede changes in CO_2 levels, suggesting that temperature change is the cause of change in the level of CO_2.[28] Some have suggested that although the onset of warming after a glaciation is caused by the Milankovitch cycles, the subsequent outgassing of CO_2 from the ocean then becomes the predominant driver of further warming.[29] Presumably, it would also be postulated that the cooling leading to glaciation is triggered by the Milankovitch cycle and then driven by reduced CO_2 levels due to ocean absorption. This hypothesis is not proven.

It is extremely unlikely or perhaps impossible to imagine how CO_2 could have increased from a pre-industrial 280 ppm to 400 ppm in the absence of human-caused emissions. No other species, existing or imagined in the near future, is capable of digging and drilling into the massive deposits of fossil fuels and then burning them so as to release CO_2 back into the atmosphere from where it had come in the first place. Many scientists think this increase in atmospheric CO_2 is the dominant cause of the slight warming (0.5C) of the atmosphere over the past 65 years. Only time will tell if this is the case. Since the Little Ice Age peaked around 1700, the climate has been warming in fits and starts for about 300 years. It is possible that the most recent warming is a continuation of the longer period of warming that had already begun long before human-caused CO_2 emissions could have been a factor.

HIGHER CO_2 CONCENTRATIONS WILL INCREASE PLANT GROWTH AND BIOMASS

It has been well demonstrated that the increase in CO_2 in the atmosphere is responsible for increased plant growth on a global scale. Many studies suggest that nearly 25 per cent of human-caused CO_2 emissions, or 2.5 Gt of carbon annually, are absorbed by plants, thus increasing global plant biomass. A recent study postulates that up to 50 per cent of human CO_2 emissions are absorbed by increased plant growth.[30] This has been described as a "greening of the Earth" as CO_2 reaches concentrations well above the near-starvation levels experienced during the major glaciations of the Pleistocene.[31] The most prestigious Australian science body, the Commonwealth Scientific and Industrial Research Organisation (CSIRO), has shown that CO_2 particularly benefits plants that are adapted to dry climates. In higher CO_2 environments, they become more efficient at photosynthesis, growing faster without using more water.[32]

One of the most impressive records comes from an experimental forest in Germany where there is a continuous

Figure 7. Craig Idso,expert on CO2 and author of the CO2Science website[34] demonstrating the growth-rate of pine trees under ambient conditions versus the addition of 150 ppm, 300 ppm and 450 ppm CO2. In a higher CO2 world there will be a great increase in the growth of food crops, forests, and wild landscapes around the world. Studies also demonstrate that higher CO2 levels in the oceans will result in increased growth of phytoplankton and other marine plants.[35]

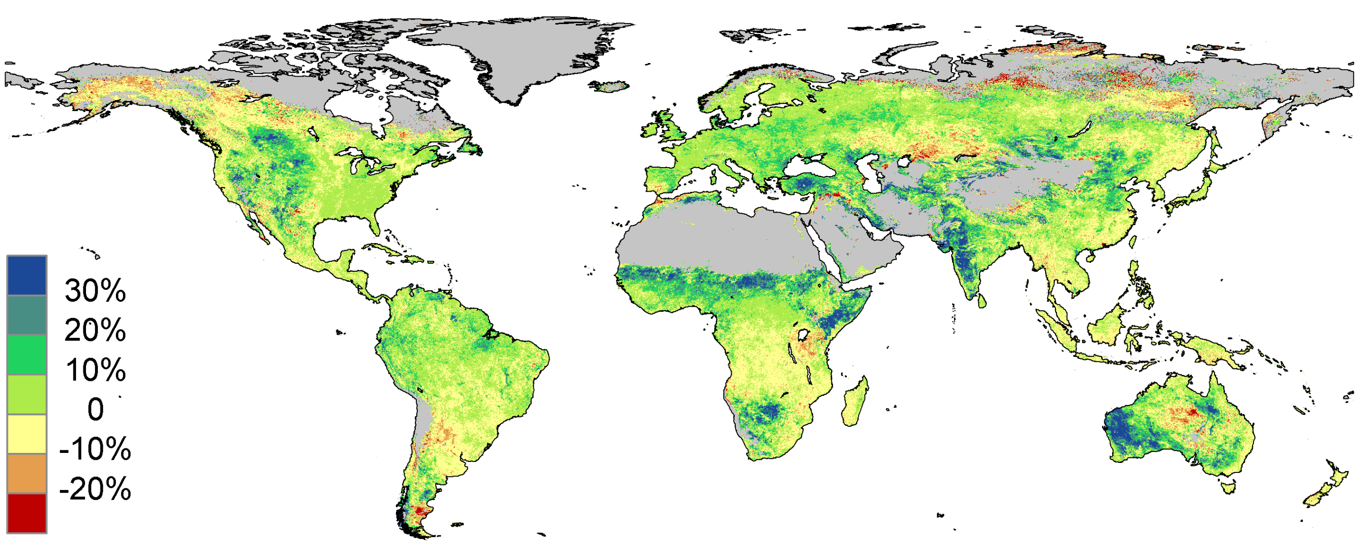

Figure 8. Change in net primary productivity of vegetation 1982 to 2010. The driest regions, such as Western Australia, sub-Saharan Africa, western India and the Great Plains of North America, show the greatest increase in plant growth.[36]

record of forest growth since 1870. Since 1960, as CO_2 emissions began to rise rapidly, the growth rate of individual trees has increased by 32 per cent to 77 per cent. While some of this may be due to the slight increase in temperature since 1960, the much higher growth rate is consistent with laboratory and field studies on the effect of increased CO_2 levels on plants.[33]

It is not widely known that greenhouse operators worldwide inject additional CO_2 into their greenhouses in order to increase the growth and yield of their crops. Among horticulturalists, it is well known that this practice can increase growth by 40 per cent or more. This is because the optimum level of CO_2 for plant growth is between 1,000 ppm and 3,000 ppm in air, much higher than the 400 ppm in the global atmosphere today.[37] Every species on Earth, including our own, is descended from ancestors that thrived in climates with much higher levels of CO_2 than are present today.

Discussion

The debate about climate change has one side insisting that the "science is settled." Yet, there is no scientific proof that increased CO_2 will result in disaster, as CO_2 has been higher during most of the history of life on Earth than it is today. On the other hand, it can be stated without a doubt that if CO_2 once again falls to the level it was only 18,000 years ago, or lower, there would be a catastrophe unlike any known in human history. We are advised by many scientists that we should be worried about CO_2 levels climbing higher when, in fact, we should actually be worried about CO_2 levels sinking lower.

Atmospheric CO_2 Concentrations in the Future

If humans had not begun to use fossil fuels for energy, it is reasonable to assume that atmospheric CO_2 concentration would have continued to drop as it has done for the past 140 million years. It is also reasonable to assume that the Earth's climate would continue to fluctuate between relatively long periods of glaciation and relatively short periods of interglacial climate similar to the present climate. Given continued withdrawal of carbon from the atmosphere into the ocean sediments, it would only be a matter of time before CO_2 dropped to 150 ppm or lower during a period of glaciation. At the average rate of 32 Kt of carbon lost annually, this would occur in less than two million years from now. In other words, the beginning of the end of most life on planet Earth would begin in fewer years into the future than our genus of primates, Homo, has existed as a distinct taxonomic unit.

It is instructive to note that our species is a tropical species that evolved at the equator in ecosystems as warm or warmer than today's. We were only able to leave the warmth of the tropical climate due to harnessing fire, wearing clothing and building shelters. This allowed us to settle in temperate climes and even Arctic conditions by the sea where domesticated dogs as well as marine mammals made life possible for a very small population. However, we cannot grow food crops in abundance on glaciers or in frozen soil. Moreover, we would not be able to grow much of anything anywhere if the level of CO_2 went below 150 ppm. There is a distinct possibility that no amount of additional CO_2 will shift the climate out of the next major period of glaciation. This is not a reason to abandon hope but rather to marvel at the fact that we can actually put some of the CO_2 needed for life back into the atmosphere while at the same time enjoying abundant, reasonably priced energy from fossil fuels.

There has been a gradual net loss of CO_2 from the atmosphere during the past 550 million years from approximately 14,000 Gt to approximately 370 Gt at the lowest level during the height of the last glaciation. This is a reduction of nearly 98 per cent of one of the most essential nutrients for life on Earth. In the absence of human CO_2 emissions over the past century, it is difficult to imagine how this process of continuous removal of CO_2 would be interrupted. Massive volcanism on a scale not seen for more than 200 million years would be required to

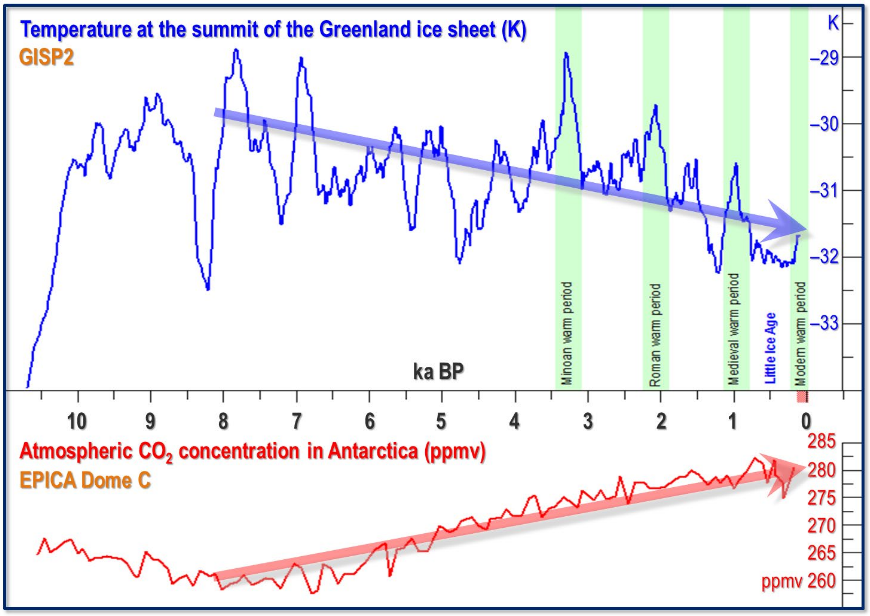

Figure 9. Reconstructed Greenland mean temperature anomalies (top) and Antarctic CO_2 concentration (bottom). Halving the temperature anomalies to allow for polar amplification gives a reasonable approximation of global temperature change in the Holocene. Since the Holocene Optimum began about 9,000 years before present (ka BP), global temperature has fallen by ~1°C, though CO_2 concentration rose throughout.[38]

bring about a reversal in the long-term CO_2 trend that has now been achieved by human CO_2 emissions. There is no doubt the Earth's interior has cooled substantially over its roughly 4.6-billion-year existence. This makes massive volcanism an ever-decreasing likelihood. There is no other plausible natural mechanism to return carbon to the global atmosphere in the form of CO_2.

The present Holocene interglacial has already endured longer than some previous interglacial periods. The Holocene is also somewhat cooler than previous interglacial periods. Of more urgent concern than the possible starvation of life two million years from now is what would happen at the onset of the next glaciation, possibly a relatively short time from now. In the absence of human CO_2 emissions, both temperature and CO_2 would have dropped to levels that would result in a continuous reduction in plant growth, bringing in climatic conditions similar to or perhaps even more severe than those that occurred in previous glaciations. This would certainly lead to widespread famine and likely the eventual collapse of human civilization. This scenario would not require two million years but possibly only a few thousand. Even if the conditions of the Little Ice Age reoccurred in the next hundreds of years with a human population of nine billion or more, we can be sure the population would not be nine billion for long.

There is a strong argument to be made that the Earth is already in a cooling trend that is descending into the next 100,000-year cycle of major glaciation. See Figure 5 and note that in the three preceding interglacial periods, there was a sharp peak followed by a steady downward trend in temperature. The peak temperature in this Holocene interglacial period was during the Holocene Optimum between 5,000 and 9,000 years ago. Since then, the warming peaks have been diminishing, and the cool periods have been colder. The Little Ice Age, which peaked about 300 years ago, was possibly the coldest period of climate since the Holocene Optimum.[39]

A Paradigm Shift in the Perception of CO_2

Independent scientist James Lovelock provides an interesting example of both these contrasting predictions of future catastrophe versus salvation regarding CO_2

emissions. He is undoubtedly one of the foremost experts in atmospheric chemistry,[40] which is why NASA retained him to design part of the life-detection equipment for the first U.S. Mars landers.[41] He concluded from the results that there is no life on Mars.

Since publishing his first book on the Gaia hypothesis in 1979, Lovelock became concerned with human civilization's impact on the global atmosphere.[42] He became a strong advocate for reducing CO_2 emissions, stating that humans had become a "rogue species" against Gaia (the Earth). He went so far as to state in 2006, '"Before this century is over, billions of us will die, and the few breeding pairs of people that survive will be in the Arctic where the climate remains tolerable . . . a broken rabble led by brutal warlords."'[43]

Only four years later, in a public speech at London's Science Museum in 2010, Lovelock recanted, stating,

> *'It is worth thinking that what we are doing in creating all these carbon emissions, far from something frightful, is stopping the onset of a new ice age.*
>
> *If we hadn't appeared on the earth, it would be due to go through another ice age and we can look at our part as holding that up.*
>
> *I hate all this business about feeling guilty about what we're doing.'*[44]

This abrupt reversal of Lovelock's interpretation of CO_2 is precisely what is required universally to avoid the tragedy of depriving billions of people of reasonably priced, reliable energy, especially those with a need to lift themselves out of poverty. There must be a total paradigm shift from demonizing fossil fuels and fearing CO_2 as a toxic pollutant to celebrating CO_2 as the giver of life that it is while continuing to use fossil fuels ever-more efficiently. Like Lovelock, we should be hopeful that CO_2 will prove to be the moderate warming influence that it is predicted to be in theory. A somewhat warmer world with a higher level of CO_2 in the atmosphere would result in a greener world with more plant biomass, higher yields of food crops and trees, a more hospitable climate in high northern latitudes and a possible reduction in the likelihood of another major glaciation.

It is highly probable, and ironic, that the existence of life itself may have predetermined its own eventual demise due mainly to the development of $CaCO_3$ as armour plating in marine organisms.[45] The fact that humans appear able to reverse this fate temporarily due to our recycling of CO_2 back into the atmosphere by burning fossil fuels for energy verges on the miraculous. Nevertheless, there is only so much fossil fuel, and once burned, it is not renewable in the short to medium term. The vast bulk of carbon is sequestered into carbonaceous rocks, mainly as $CaCO_3$. Today, about 5 per cent of human CO_2 emissions are derived from converting $CaCO_3$ with heat into CO_2 and CaO (lime) to manufacture cement. Therefore, when fossil fuels become scarce in future centuries, and if CO_2 again begins to dwindle, we will have the option of producing additional CO_2 by burning limestone with nuclear or solar energy, with lime for cement as a useful by-product. This has the potential to extend the existence of a highly productive living Earth into the far distant future.

It is clear from the preceding discussion that rather than bringing on a catastrophic climate condition, human CO_2 emissions are serving to reinstate a balance to the global carbon cycle. By reversing the 140-million-year decline in atmospheric CO_2, we are helping to ensure the continuation of carbon-based life on Earth.

CONCLUSION

CO_2 is essential for life, and twice in the history of modern life there have been periods of steep decline in the concentration of CO_2 in the global atmosphere. If this decline were to have continued at the same rate into the future, CO_2 would eventually fall to levels insufficient to support plant life, possibly in less than two million years. More worrisome is the possibility in the nearer future that during a future glaciation, CO_2 may fall to 180 ppm or lower, thus greatly reducing the growth of food crops and other plants. Human CO_2 emissions have staved off this possibility so that at least during a period of glaciation, CO_2 would be high enough to maintain a productive agricultural industry.

A 140 million year decline in CO_2 to levels that came close to threatening the survival of life on Earth can hardly be described as "the balance of nature". To that extent human emissions are restoring a balance to the global carbon cycle by returning some of the CO_2 back to the atmosphere that was drawn down by photosynthesis and $CaCO_3$ production and subsequently lost to deep sediments. This extremely positive aspect of human CO_2 emissions must surely be weighed against the unproven hypothesis that human CO_2 emissions are mainly responsible for the slight warming of the climate in recent years and will cause catastrophic warming over the coming decades. The fact that the current warming began about 300 years ago during the Little Ice Age indicates that it may at least in part be the continuation of the same natural forces that have caused the climate to change through the ages.

Despite a great deal of evidence to the contrary, much of Western society has been convinced that a global warming and a climate change crisis is upon us. The idea of catastrophic climate change is a powerful one, as it encompasses everything and everywhere on Earth. There is nowhere to hide from "carbon pollution." There is also the combination of fear and guilt: we are fearful that driving our cars will kill our grandchildren, and we feel guilty for doing so.

A powerful convergence of interests among key elites supports and drives the climate catastrophe narrative. Environmentalists spread fear and raise donations; politicians appear to be saving the Earth from doom; the media has a field day with sensation and conflict; scientists and science institutions raise billions in public grants, create whole new institutions, and engage in a feeding frenzy of scary scenarios; businesses want to look green and receive huge public subsidies for projects that would otherwise be economic losers, such as large wind farms and solar arrays. Even the Pope of the Catholic Church has weighed in with a religious angle.

Lost in all these machinations is the indisputable fact that the most important thing about CO_2 is that it is essential for all life on Earth and that before humans began to burn fossil fuels, the atmospheric concentration of CO_2 was heading in a very dangerous direction for a very long time. Surely, the most "dangerous" change in climate in the short term would be to one that would not support sufficient food production to feed our own population. The current "pause" in global warming recorded by two satellites and thousands of weather balloons, now nearly two decades on, does give pause to the hypothesis that higher CO_2 will inevitably lead to higher temperatures.[46] During this period of no significant warming, about one-third of all human CO_2 emissions since the beginning of the Industrial Age has been emitted into the atmosphere. The best outcome would be that CO_2 does cause some measure of warming, but somewhat lower than that suggested by extreme predictions.[47]

We should ask those who predict catastrophic climate change, including the UN's Intergovernmental Panel on Climate Change, some pressing questions regarding the outcome if humans had not intervened in the carbon cycle.

- What evidence or argument is there that the global climate would not revert to another glacial period in keeping with the Milankovitch cycles as it has done repeatedly during at least the past 800,000 years?

- What evidence is there that we are not already past the maximum global temperature during this Holocene interglacial period?

- How can we be certain that in the absence of human emissions the next cooling period would not be more severe than the recent Little Ice Age?

- Given that the optimum CO_2 level for plant growth is above 1,000 ppm and that CO_2 has been above that level for most of the history of life, what sense does it make to call for a reduction in the level of CO_2 in the absence of evidence of catastrophic climate change?

- Is there any plausible scenario, in the absence of human emissions, that would end the gradual depletion of CO_2 in the atmosphere until it reaches the starvation level for plants, hence for life on earth?

These and many other questions about CO_2, climate and plant growth require our serious consideration if we are to avoid making some very costly mistakes.

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