The Climate Surprise

Why CO_2 is good for the Earth

The New Criterion

CO2 COALITION

Contributors

Bruce M. Everett is a specialist on global energy and petroleum issues and teaches graduate students as an Adjunct Associate Professor of International Business at the Fletcher School at Tufts University.

William Happer is Professor Emeritus in the Department of Physics at Princeton University. He served as Director of Energy Research under President George H. W. Bush. He has provided congressional testimony on the subject of global warming several times.

Craig Idso is the founder, former president, and currently chairman of the Center for the Study of Carbon Dioxide and Global Change. He is a lead author of the reports of the Nongovernmental International Panel on Climate Change (NIPCC).

Roger Kimball is Editor & Publisher of *The New Criterion* and Publisher of Encounter Books. His latest book is *The Fortunes of Pemanence: Culture and Anarchy in an Age of Amnesia* (St. Augustine's Press).

Richard S. Lindzen is a dynamical meteorologist. He held the Alfred P. Sloan Professorship of Atmospheric Sciences at MIT since 1983, retiring in July of 2013. He has provided congressional testimony on the subject of global warming several times.

Patrick Moore is a co-founder of Greenpeace and served for seven years as a Director of Greenpeace International. In 2013 he published *Confessions of a Greenpeace Dropout: The Making of a Sensible Environmentalist* (Beatty Street), which outlines his vision for a sustainable future.

Roy W. Spencer is a Principal Research Scientist at the University of Alabama in Huntsville. He previously served as a Senior Scientist for Climate Studies at NASA's Marshall Space Flight Center. He has provided congressional testimony several times on the subject of global warming.

The material in this pamphlet is drawn from "The Climate Surprise: Why CO2 Is Good for the Earth," a conference organized jointly by the CO2 Coalition and *The New Criterion*. The conference took place on March 29, 2016 and was held in New York City.

The CO2 Coalition would like to thank Mr. Roger Kimball and Mr. Benjamin Riley of *The New Criterion* for their work in organizing and hosting the conference.

Reprint July 2016
The CO2 Coalition
1621 North Kent Street, Suite 603
Arlington, VA 22209
www.co2coalition.org

Earlier versions of these essays were presented at a conference on Marcy 29, 2016 in New York City. The conference was organized by the CO2 Coalition and *The New Criterion*, which first published these essays in a pamphlet to accompany its June 2016 issue.

The Climate Surprise

Why CO_2 is good for the Earth

Introduction: The politics of weather

by Roger Kimball

E pur si muove — Galileo

Are you weary of the weather wars? Are you alarmed by the extensive beachhead that "progressive" culture warriors, clad in the (borrowed) raiment of science and fired by a moral fury worthy of an early-twentieth-century temperance campaigner, have secured in the public debate? You will be grateful, then, for Mark Twain's 1892 novel *The American Claimant*, which begins with an advisory about "The Weather in This Book." "No weather will be found in this book," Twain explains. "This is an attempt to pull a book through without weather." What a relief! For it is impossible to turn anywhere in our enlightened, environmentally conscious world without being beset by lectures about one's "carbon footprint" and horror tales about "global warming," "rising seas," and imminent ecological catastrophe.

It was with this in mind that *The New Criterion* partnered this spring with the CO_2 Coalition, a Washington-based think tank dedicated to combatting misinformation about the effects of CO_2 and fossil fuels, on a conference to ponder *The Climate Surprise: Why CO_2 Is Good for the Earth*.[1] We might have added "and for you, your loved ones, and the economy," but we did not wish to appear gratuitously provocative.

Let me return to Mark Twain. It is not, he once observed, so much the things we don't know that get us into trouble. Rather, the mischief is caused by things that we "do know that ain't so."

For example, we all "know" that carbon dioxide is "bad for the environment." (In fact, it is a prerequisite for life.) We "know" that the level of carbon dioxide in the atmosphere is reaching historically unprecedented and dangerous levels. (In fact, we have, these past centuries, been living through a CO_2 famine.) We "know" that "global warming"—or, since there has been no warming for about eighteen years, that "climate change"—has caused a sudden rise in the seas. (In fact, the seas have been rising for the last 20,000 years, since the end of the last Ice Age.) We "know" that, when it comes to the subject of climate change, the "science is settled," that "97 percent of scientists" agree that global warming is anthropogenic, which is Greek for "caused by greedy corporate interests and the combustion of fossil fuels."

It's really quite extraordinary how much we do know that ain't so.

When I was growing up in the rural fastness of the moderately great state of Maine, adults were always talking about the weather. Their conversations were edged by an admirable stoicism. "If you don't like the weather," they often said, "just wait." It's too bad that Al Gore didn't spend more time in Maine. He might have learned an awesome secret, one that I will now impart to you: the weather changes. Sure, there are long-term trends. But as the following essays demonstrate, those are not nearly so alarming

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as the climate hysterics claim. In fact, they are not alarming at all.

It was about two decades ago that the Harvard philosopher Harvey Mansfield made the observation that environmentalism is "school prayer for liberals." I remember tittering when I first read that. It was an observation that had a dual advantage. It was both true—environmentalism really did seem like a religion for certain leftists—and it was also amusing. How deliciously wicked to put a bunch of white, elite, college-educated folks under the same rhetorical light as the Bible-thumpers they abominated. Ha, I thought to myself, ha!

Well, I am not laughing now. In the intervening years, the eco-nuts went from being a lunatic fringe to being lunatics at the center of power.

Item: early in March, Loretta Lynch, Attorney General of the United States, acknowledged that the Justice Department had discussed taking civil legal action against the fossil fuel industry for "denying" the "threat of carbon emissions." Item: on March 31, *Investors' Business Daily* reported that the attorneys general in sixteen states—now it's twenty—had formed a coalition to investigate and prosecute companies that don't agree with them about climate change. In other words, those dissenting from the orthodox position about climate science would be punished. Item: on April 9, *Bloomberg News* reported that the Competitive Enterprise Institute, a conservative think tank, was subpoenaed by the attorney general of the U.S. Virgin Islands to disgorge a decade's worth of documents regarding its work on climate change, a massively burdensome and expensive demand illustrating the mournful adage that when it comes to the law "the process is the punishment."

Galileo would know just how those climate dissenters feel. In 1633, he was hauled up before the Inquisition (not for the first time) for broadcasting the heterodox opinion that the earth revolves around the sun. Ninety-seven percent—maybe more—of those in charge of things in the seventeenth century *knew* that Galileo had it all wrong. The earth was the center of the universe and the sun traveled around it. Everyone knew that. Galileo was threatened with torture and prison; he recanted. The authorities settled on house arrest for the rest of his life. Tradition tells us that on his way out of court he muttered mutinously "*E pur si muove*," "And yet it moves."

When I mentioned to friends that *The New Criterion* was helping to organize a conference about climate change, a common response was, "Isn't that outside your usual area of interest?" Not really. *The New Criterion* is not a scientific journal, and the truth is that I know hardly any more about the actual science of climate change than Al Gore—i.e., very little indeed. But the contemporary obsession with climate change involves several avenues of human concern, some of them at the very center of our concerns at *The New Criterion.*

Yes, the debate over climate change does involve hard science, which is to say that it involves the historical record about what actually has happened and careful modeling about what is likely to happen later on, given what we know about the physics and biology of the eco-sphere.

Most of the following essays deal in accessible detail with this aspect of the subject. Let me mention by way of preface one fact that is often lost—or, rather, that is deliberately obscured—by many non-scientific parties weighing in on the debate. It is this: the science about mankind's influence on climate change is far from settled. Steven Koonin, who was undersecretary for science in the Energy Department during President Obama's first term, summed up this truth with pithy finality in a much-read article for *The Wall Street Journal.* The contention that the "science is settled" with respect to climate change, he wrote, is "misguided," i.e., it is wrong. "It has not only distorted our public and policy debates on issues related to energy, greenhouse-gas emissions, and the environment. But it also has inhibited the scientific and policy discussions that we need to have about our climate future."

But of course science is only part of the issue. You cannot read far into the literature on climate change before you realize that science is often dragged in as window dressing for the real issues, which are political, on the one hand, and economic, on the other.

The two hands, it is worth pointing out, belong to the same body and are working to feed the same maw.

Considered as a political movement, environmentalism may, as Harvey Mansfield said, betray a religious or cult-like aspect. But for every true believer in the religion of Gaia, there is a squadron of cynical opportunists eager to exploit the new paganism of earth-worship for decidedly secular ends. We've heard a lot about the radical community organizer Saul Alinsky these past seven plus years. A fundamental rule of thumb for a paid-up Alinskyite radical is that "the issue is never the real issue." In the present context, that means that "climate change" is largely a *pretext.* For some, it is a pretext for personal enrichment. Consider, to take but one egregious example, Al Gore, who peddles the philosophy of Chicken Little, on the one hand, and has managed to rake in hundreds of millions of dollars by exploiting various government-subsidized "green energy" initiatives, on the other.

Climate alarmism can also be a pretext for the redistribution of wealth on a global scale. You can never be green enough, Comrade, and climate change offers a potent pretext for the consolidation of governmental power: it is, as one wag put, the "killer app" for extending governmental control.

Like the House of the Lord, governmental control is a domicile of many mansions, from intrusive, prosperity-sapping regulation to the silencing, intimidation, dismissal, and even the legal prosecution of critics. Indeed, in its transformation of critics into heretics we see once again the religious or cult-like aspect of radical environmentalism. One argues with a critic. One must silence or destroy a heretic. Galileo would have understood exactly how this new Inquisition would proceed. And this brings me to one of the most frightening aspects of the gospel of climate change: its subordination of independent scientific inquiry to partisan political imperatives. Scientific inquiry depends upon the freedom to pursue the truth wherever it leads, regardless of political ideology or vested interest. Recently, climate hysterics and their political and academic enablers have begun describing those who disagree with them about the science of climate change as "climate deniers." The echo of "holocaust deniers" is deliberate and pernicious. A "holocaust denier" is someone who denies an historical enormity. But a so-called "climate denier" is merely someone who disputes an ideological construct masquerading as a scientific truth. The irony, of course, is that this farce should proceed in an era in which science and technology have remade the world for the benefit of mankind.

Climate-change hysteria takes issue with those benefits, which is why it has also been a pretext for the systematic attack on specific industries and technologies—the coal industry, for example, or fracking. The goal of the attack is, as Obama's top science advisor John Holdren put it in a book he co-authored with the climate alarmist Paul Ehrlich, "A massive campaign . . . to restore a high-quality environment in North America and to de-develop the United States."

A "massive campaign . . . to de-develop the United States": ponder that. Mr. Holdren lamented that the idea of de-development was subject to "considerable misunderstanding and resistance." I for one am happy about the resistance. Indeed, I wish it were stiffer. But as for misunderstanding what "de-development" means, I have to take issue. We know exactly what it means. It is the same thing that Luddites and anti-capitalists have always meant: the impoverishment and immiseration of the mass of mankind just so long as the perquisites for the self-appointed *nomenklatura* persist undisturbed. It was to challenge this noxious and politically motivated assault on truth, free speech, and prosperity that *The New Criterion* and the CO_2 Coalition joined hands. *E pur si muove*, indeed.

Battling this pernicious ideology is a multifaceted task. But since the evangelists for climate alarmism like to wrap themselves in the mantle of science, it is appropriate that we begin to unsettle the putatively settled consensus about climate change with a few elementary scientific lessons, illustrated in the following essays.

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The climate surprise

by William Happper

The brief reports assembled here summarize talks at the conference *The Climate Surprise: Why CO_2 Is Good for the Earth*. The Conference, jointly organized by *The New Criterion* and the CO_2 Coalition, took place at the Princeton Club in New York on March 29, 2016. The CO_2 Coalition is a new and independent non-profit organization established in 2015 to educate thought leaders, policy makers, and the public about the vital contribution made by carbon dioxide to our lives and our economy. Coalition members include climate scientists, physicists, engineers, and economists of international stature. More information about the coalition's goals and membership can be found at its website, co2coalition.org.

The mission of the Coalition is to present scientific evidence showing that the trace atmospheric gas carbon dioxide or CO_2 is a nutrient that is essential to plant life. CO_2 is not a pollutant. Increasing CO_2 levels will enable plants and agricultural crops to grow more efficiently and to be more drought resistant.

Moreover, observations show that warming from doubling the amount of CO_2 in the atmosphere is going to be about 1 degree Celsius, much less than predicted by most computer models, and beneficial to the world.

The CO_2 Coalition is in favor of cost-effective regulation of the energy sector to minimize real environmental harm. But it notes that CO_2 released by combustion of fossil fuels is actually a benefit to the world, not a pollutant. Energy sources like fossil fuels, nuclear power, hydropower, wind power, or solar power should be selected on the basis of cost, convenience, dependability, and ability to minimize real, as opposed to imaginary, environmental harm.

With proper equipment to remove genuine pollutants, like fly ash, oxides of sulfur and nitrogen, volatile organic compounds, and so on, the stack emissions of fossil fuel power plants are similar to those of human breath, as shown in *Figure 1.1*. Humans and other

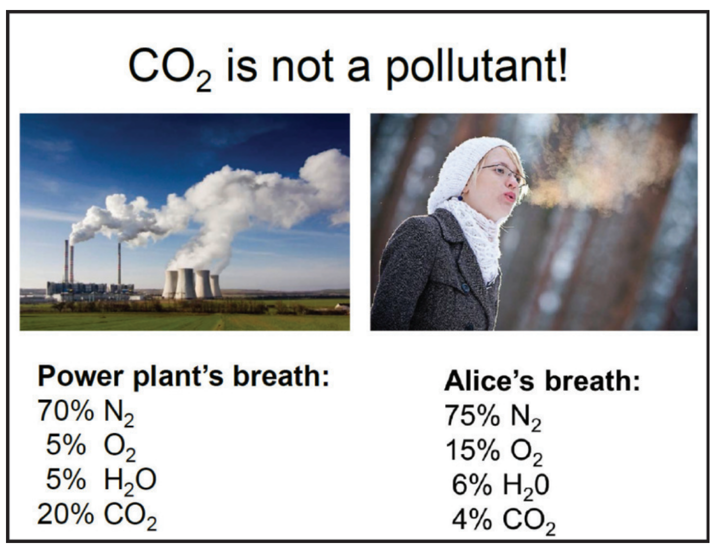


Figure 1.1: The main components of the exhaust gas of a modern power plant are similar to the components in human breath. Humans and other living things must emit large amounts of CO_2 to survive. They have a very large "carbon footprint," which is a benefi cial part of the cycle of life.

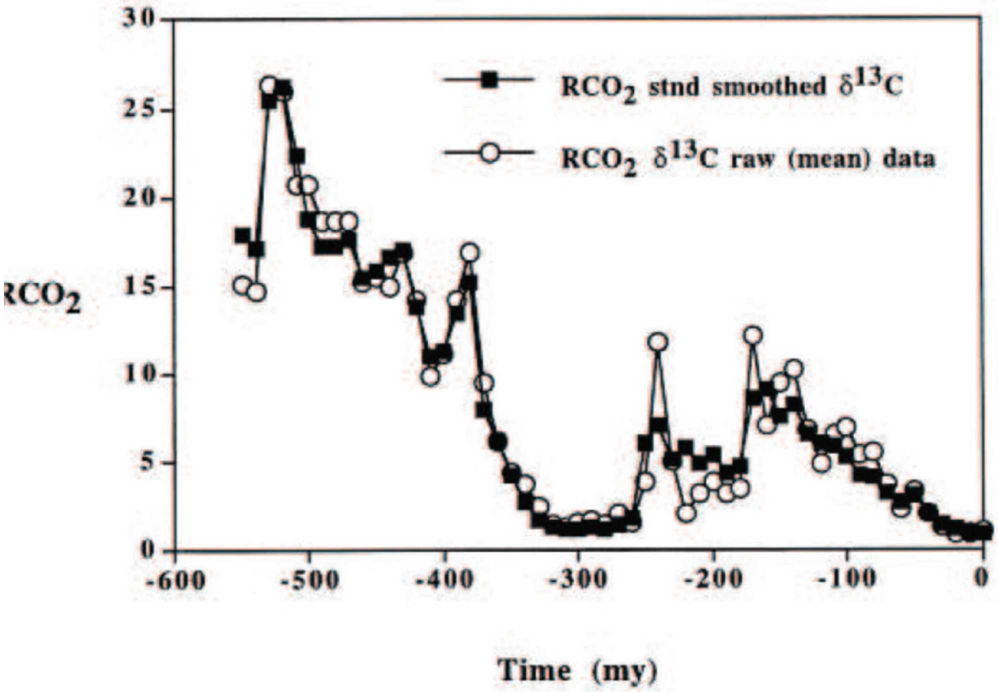


Figure 1.2: The ratio, RCO2, of past atmospheric CO_2 concentrations to those (about 300 ppm) of the past few million years. This particular proxy record comes from analyzing the fraction of the rare stable isotope 13C to the dominant isotope 12C in carbonate sediments and paleosols. Other proxies give qualitatively similar results. Only once the geological past, around 300 million years ago, were CO_2 concentrations as low as those today. From: R. A. Berner and C. Kothavala, Geocarb:III, "A revised model of atmospheric CO2 over the Phanerozoic time," American Journal of Science, 301, 182 (2001).

living things must emit large amounts of CO_2 to survive. They have a very large "carbon footprint," which is a beneficial part of the cycle of life.

The first report, by the Coalition member Dr. Craig Idso, shows that green plants grow faster and need less water as a result of increasing levels of CO_2 in the atmosphere. Few people realize that current CO_2 levels are far lower than the optimum levels for photosynthesis, and that plants have been coping with a "CO_2 famine" for many tens of millions of years, as illustrated in *Figure 1.2*.

The second report, *"*Global warming: the science in three nutshells," by the Coalition member Professor Richard Lindzen, gives a sobering analysis of three "narratives" on climate: that of the supportive scientists, that of the so-called skeptics, and that of the politicians, environmental activists, and the media.

Along with the other participants, Professor Lindzen is a strong supporter of the second narrative, that climate change

> is not an especially serious problem . . . there are many reasons why the climate changes—the sun, clouds, oceans, the orbital variations of the earth, as well as myriad other inputs. None of these is fully understood, and there is no

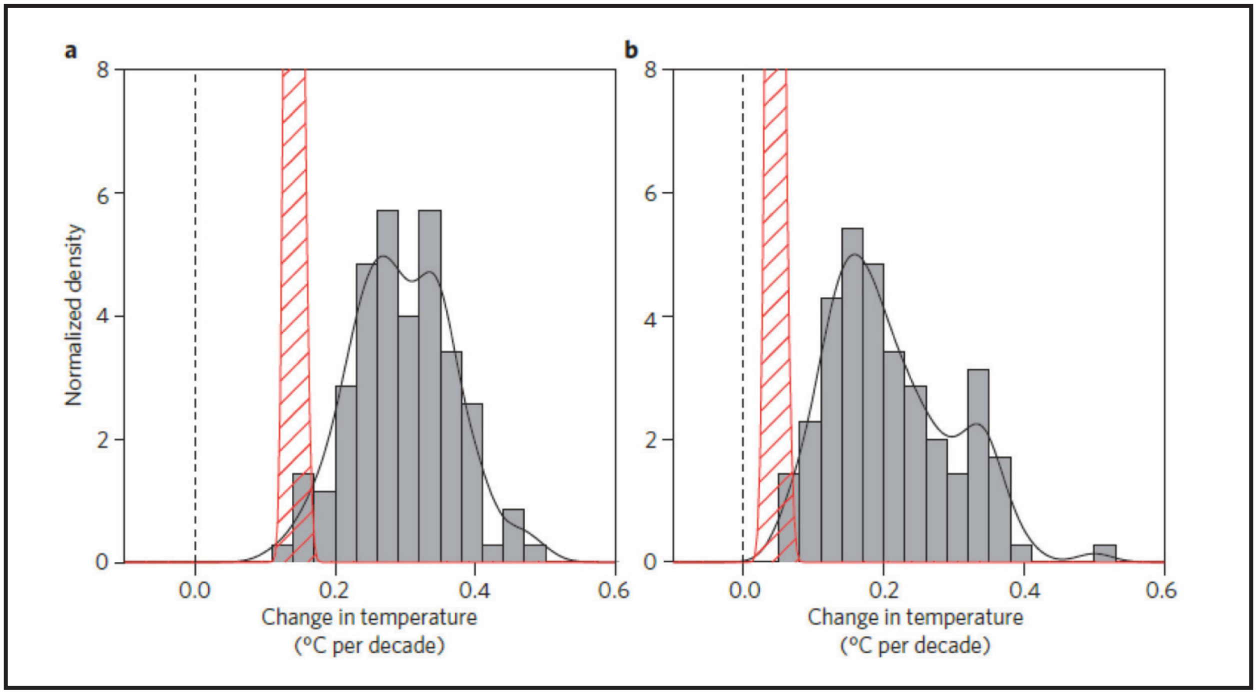


Figure 1.3: A comparison of the surface warming predicted by climate models with observed warming. Trends in global mean surface temperature. a: 1993–2012. b: 1998–2012.

evidence that CO_2 emissions are the dominant factor.

For many thoughtful scientists, the most persuasive evidence that climate change due to more CO_2 is not an especially serious problem is that the warming over the past few decades has been much less than that predicted by most climate models, as illustrated in *Figure 1.3*.

The third report, by Dr. Roy Spencer, is a review of temperature measurements, the narrow red bars shown in *Figure 1.3*, which came from networks of surface stations. It is also possible to use satellites and balloons to measure the temperature of the lower atmosphere by satellites. Climate models invariably predict more warming of the lower atmosphere than of the surface. This is because a warming surface should evaporate more water vapor, which releases additional heat of condensation in the lower atmosphere. And yet measured rates of temperature rise in the troposphere are *less* than on the surface. Dr. Spencer was unable to attend the conference but fortunately was able to provide the written report on measurements included here.

The fourth report, by the Coalition member Dr. Patrick Moore, "The truth about ocean 'acidification,' " assesses one of the many scare stories about increasing levels of CO_2: that the ocean will turn to acid and dissolve the poor living creatures who live there. Dr. Moore shows why this is nonsense. The slow decrease in ocean pH over the next century will be smaller than day-to-day fluctuations in the most biologically productive parts of the ocean, and much smaller than variations of pH with depth or latitude.

The last report, by the Coalition member Professor Bruce Everett, "Rethinking climate economics," is a precautionary tale of Germany's experience with "renewable energy." This brings to mind the ancient advice: "first do no harm." One would hope that the lessons learned from experiments with "green" energy policies in Germany, the United Kingdom, Spain, and elsewhere will help us avoid similar mistakes in the United States of America.

Benefits of atmospheric CO_2

by Craig Idso

We on Earth benefit from the rise of atmospheric CO_2. But we seldom hear this important fact and its critical implications. Studying the biological impacts of rising atmospheric CO_2 has occupied my professional life for nearly three decades now.

Time and again, governments, non-governmental organizations, international agencies, societal think tanks, and even respectable scientific organizations undertake to spend multiple millions of dollars writing and promoting large reports about climate change. Yet in nearly all of these endeavors they have failed by not properly evaluating, or even *acknowledging*, the manifold real and measurable benefits of the ongoing rise in the air's CO_2 content. As a result, the positive impacts of atmospheric CO_2 enrichment remain largely ignored.

There are three main benefits of atmospheric CO_2 enrichment: more CO_2 increases plant productivity, enhances plant water use efficiency, and helps plants to withstand and better endure various environmental and resource limitations and stresses.

Regarding plant productivity, carbon dioxide is the primary raw material utilized by plants during the process of photosynthesis to build and construct their tissues. It is the "food" that sustains essentially all plants on the face of the Earth. And the more CO_2 they "eat" or take in from the air, the bigger and better they grow, a fact that has been conclusively demonstrated in *thousands* of laboratory and field experiments.

Figure 2.1 illustrates this truly amazing benefit. As the atmosphere's CO_2 concentration increases to six times above that of its current value, this extra "food," if you will, induces a growth enhancement in most plants that reaches upwards of 160 percent.

In *Figure 2.2* we see the growth-enhancing effects of atmospheric CO_2 enrichment on pea plants. All plants in the figure were grown under identical conditions except atmospheric CO_2 content. Grown under three different atmospheric CO_2 concentrations, the effects

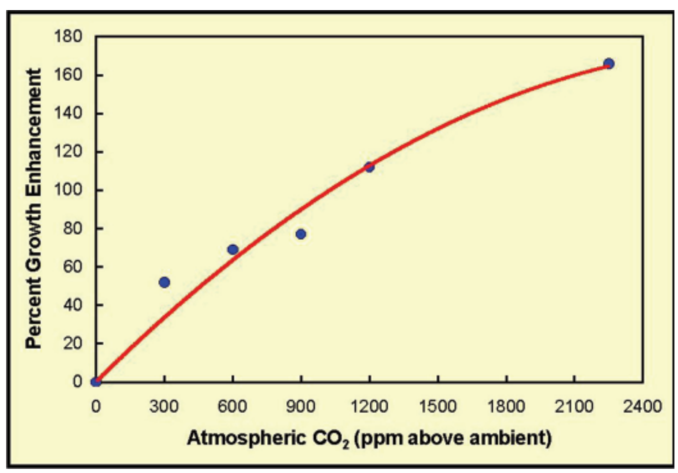


Figure 2.1: Adding CO_2 to the atmosphere enhances plant growth. Source: adapted from Idso, K.E. 1992. Plant responses to rising levels of atmospheric carbon dioxide: a compilation and analysis of the results of a decade of international research into the direct biological effects of atmospheric CO_2 enrichment. Climatological Publications Scientific Paper No. 23, Office of Climatology, Arizona State University, Tempe, Ariz.

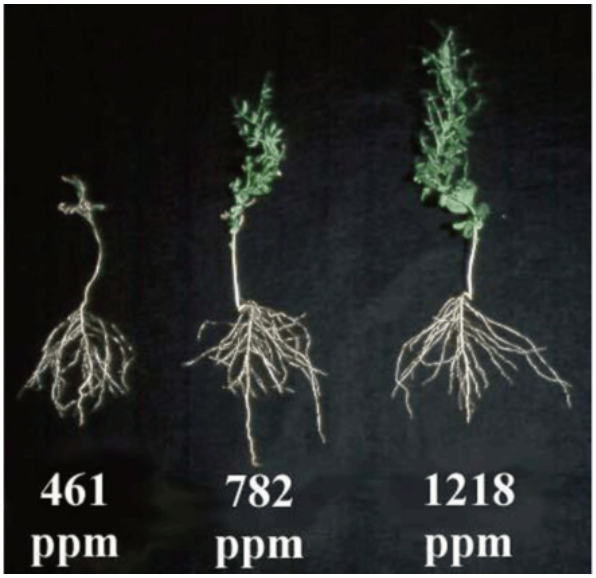


Figure 2.2: The only difference in growing conditions for these plants is the parts per million of atmospheric CO2 as noted beneath each specimen.

of CO_2 fertilization are readily apparent in the leaf, stem, and root biomass. The plant on the left is clearly deficient on all counts.

My employer, the Center for the Study of Carbon Dioxide and Global Change, has studied the effects of atmospheric CO_2 on plants for decades. On its website, www.co2science.org is a Plant Growth database, where the results of thousands of laboratory and field CO_2 enrichment studies are archived.

Based on the numerous experiments listed there, we have determined that a 300 parts per million (ppm) increase in the air's CO_2 content will typically raise the productivity of most herbaceous plants by about one third. This stimulation is generally manifested by an increase in the number of branches and tillers, more and thicker leaves, more extensive root systems, plus more flowers and fruit.

A study I conducted several years ago found that a 300 ppm increase in atmospheric CO_2 enrichment leads to yield increases of 15 percent for CAM crops, 49 percent for C3 cereals, 20 percent for C4 cereals, 24 percent for fruits and melons, 44 percent for legumes, 48 percent for roots and tubers, and 37 percent for vegetables, on average.

Although much less studied than terrestrial plants, many aquatic plants are also known to be responsive to atmospheric CO_2 enrichment, including unicellular phytoplankton and bottom-rooted macrophytes of both freshwater and saltwater species. Hence, there is probably no category of photosynthesizing plant that does not respond positively to atmospheric CO_2 enrichment and that is not likely to benefit from the ongoing rise in the air's CO_2 content.

It should come as no surprise, therefore, that the father of modern research in this area—Dr. Sylvan H. Wittwer—has stated that "it should be considered good fortune that we are living in a world of gradually increasing levels of atmospheric CO_2," and that "the rising level of atmospheric CO_2 is a universally free premium, gaining in magnitude with time, on which we can all reckon for the future."

So what does the growth-enhancing benefit of atmospheric CO_2 enrichment portend for the biosphere? One obvious consequence is greater crop productivity. Many researchers have acknowledged the yield-enhancing benefits of the historical and still-ongoing rise in the air's CO2 content on past, present, and future crop yields, yet scientists are only scratching the surface of the potential benefits such yield enhancements can bring.

Consider rice, at 9.4 percent of global food production. Based upon data presented in our *CO_2 Science* Plant Growth Database, the average growth response of rice to a 300 ppm increase in the air's CO_2 concentration is positive 37.5 percent. However, data obtained from

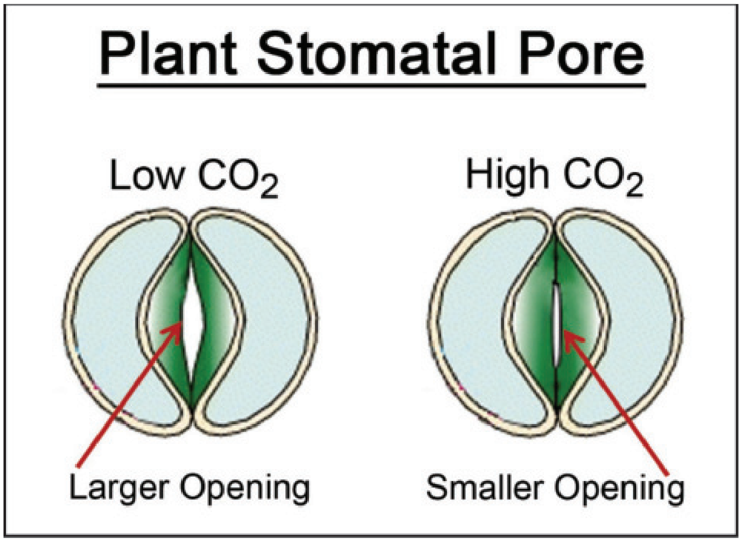


Figure 2.3: The wide-open Low CO2 stomatal pore allows more H2O to escape from the plant compared to the High CO2 pore, if other factors are held constant. This causes more water-loss plant stress in arid regions.

De Costa *et al*. (2007), who studied the growth responses of sixteen different rice genotypes, revealed CO_2-induced productivity increases ranging all the way from negative 7 percent to positive 263 percent. Therefore, if farmers identified which genotypes provided the largest yield increases per unit of CO_2 rise, and then grew those genotypes, global food supply would continue to expand rapidly.

The second major benefit of atmospheric CO_2 enrichment is increased plant water use efficiency—the amount of biomass produced by a plant per unit of water lost via transpiration. *Figure 2.3* represents two typical stomatal pore configurations. Plants exposed to elevated levels of atmospheric CO_2 generally do not open their leaf stomatal pores as wide as they do at lower CO_2 concentrations. The result is a reduction in most plants' rates of water loss by transpiration. The amount of carbon they gain per unit of water lost therefore typically rises for a doubling of CO_2 on the order of 70 to 100 percent.

Thus, at higher atmospheric CO_2 concentrations it has been observed that plants need less water to produce the same—or an even *greater*—amount of biomass.

With smaller stomatal openings, plants exposed to elevated levels of atmospheric CO_2 are generally less susceptible to drought. As such, they will be able to grow and reproduce where it has previously been too dry for them to exist. Consequently, Earth's terrestrial vegetation should become more robust as the air's CO_2 concentration rises, and should begin to win back lands previously lost to desertification. Simultaneously, the greater vegetative cover of the land produced by this phenomenon should reduce the adverse effects of wind and rain soil erosion.

With respect to the third major benefit of atmospheric CO_2 enrichment—the amelioration of environmental stresses and resource limitations—atmospheric CO_2 has been shown to help reduce the detrimental effects of high soil salinity, high air temperature, low light intensity, and low levels of soil fertility. Elevated levels of CO_2 also reduce the severity stresses of low temperature, of oxidation, and of herbivory. What is more, the *percentage* growth enhancement produced by an increase in the air's CO_2 content is often *greater* under stressful and resource-limited conditions than under optimal growing conditions.

Retuning to water resources to illustrate this third benefit, the percent growth enhancement due to atmospheric CO_2 enrichment increases when water availability is less than ideal, as shown in *Figure 2.4*. For example, a

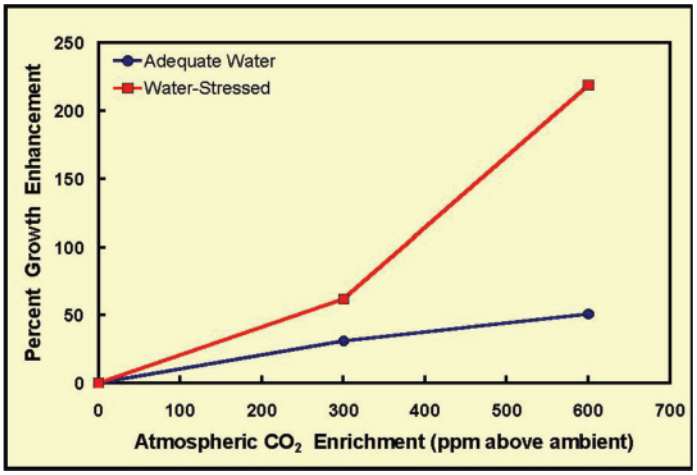


Figure 2.4: Higher levels of atmospheric CO_2 support greater plant growth in dry conditions. This is a cause of the global greening of arid regions as documented by space photographs.

plant growing in adequate water conditions will experience about a 35 percent increase in productivity for a 300 ppm increase in CO_2. But that same plant growing in a water-stressed environment would experience a much greater 65 percent increase in productivity for a 300 ppm increase in CO_2. That benefit becomes even larger as the CO_2 concentration rises.

Further, research shows that a doubling of the air's CO_2 concentration typically boosts the optimum temperature for plant photosynthesis by several degrees centigrade, and it raises the temperature at which plants experience heat-induced death by about the same amount. Therefore, most types of vegetation, with the help of the extra CO_2, will likely be able to tolerate much warmer living conditions than they do currently, even if temperatures were to rise as high as is unrealistically predicted by the most pessimistic climate models.

Based on a multitude of real-world observations, *the future is now.* Evidence from all across the globe indicates that the terrestrial biosphere is already experiencing a great planetary greening, likely in large measure due to the approximate 40 percent increase in atmospheric CO_2 since the beginning of the Industrial Revolution.

Perhaps most surprising about these observations is the fact that this great greening of the Earth has occurred despite many assaults of both man and nature on Earth's vegetation over this time period, including fires, disease, pest outbreaks, deforestation, war, and climatic changes in temperature and precipitation.

In considering each of the CO_2 enrichment benefits discussed above, instead of being shunned like the plague, the ongoing rise in atmospheric CO_2 should be welcomed with open arms. Carbon dioxide is not a pollutant—it is the very elixir of life.

Recent global temperature trends

by Roy W. Spencer

Our measurements of global average temperature are fundamental to establishing whether global warming is occurring, how strong it is, and whether its magnitude agrees with global warming theory as embodied in computer climate model predictions. Since those model predictions are the basis for energy policy, it is important that they be tested with actual observations.

But scientific measurements always have errors. And the main reason why global temperature measurements are so controversial—and sometimes even contradictory—is that none of our temperature monitoring systems were designed to measure the small signal of global warming, which is expected to be on the order of 0.2 degrees centigrade per decade. That is only 0.02 degrees centigrade per year.

In contrast, most of us are used to experiencing tens of degrees of temperature variation, from day to night, and from season to season. Our backyard thermometers can be off by one or two degrees and it really doesn't matter to us when we are used to tens of degrees of variation. But for global warming, one to two degrees is the entire warming that has been alleged to have occurred over the last century.

Despite the uncertainties in the measurements, the importance of the global warming issue to energy policy, agricultural productivity, ecosystem health, and so on necessitates that we use whatever data we have in order to determine whether climate really is changing.

Three Temperature Measurement Methods

The only truly global measurement strategy is with Earth-orbiting satellites. Satellite instruments measure the intensity of microwave radiation emitted by oxygen in the atmosphere, and that intensity is directly proportional to temperature. The satellite instruments are continuously calibrated with views of the cosmic background radiation (near absolute zero in temperature) and on-board precision platinum resistance thermometers that have themselves been calibrated in a laboratory. While using radiation to measure temperature might seem rather indirect, this is how the nurse now takes your body temperature—by the intensity of infrared radiation, usually measured in your ear.

The second and most familiar method of monitoring global temperatures is with ground-based thermometers. Many years ago these instruments were liquid-in-glass (either alcohol or mercury), which required a person to estimate the temperature visually and record the data manually. These have been largely replaced with electronic thermometers, called thermistors, which measure electrical resistance, which is then converted to a temperature—like radiation, an indirect measure. Most thermometer measurements are made on land, and tend to be located where people have replaced natural vegetation with buildings and pavement, leading to a spurious long-term warming signal (the "urban heat island" effect) that is difficult to correct for. There are large land areas of the world with very few thermometer measurements, while Europe and the United States have dense coverage by thermometer measurements, albeit with varying quality. Thermistors are also used on ships, moored ocean buoys, and the relatively new Argo buoys that float around the world autonomously and dive down taking vertical temperature profiles in the deep ocean.

Finally, weather balloons (also called radiosondes) are launched from a relatively small number of stations around the world, and provide thermistor-based vertical profiles of temperature measurements up through the atmosphere. These measurements can be directly compared to the satellite microwave measurements, since both measure fairly deep layers of the atmosphere.

None of our temperature measurements, whether satellites, surface-based thermometers, or weather balloons, is perfect. All must be adjusted for known sources of error over time in order to measure the very small signal of global warming, not the least of which is due to newer instrumentation being different in design than, say, that of thirty years ago.

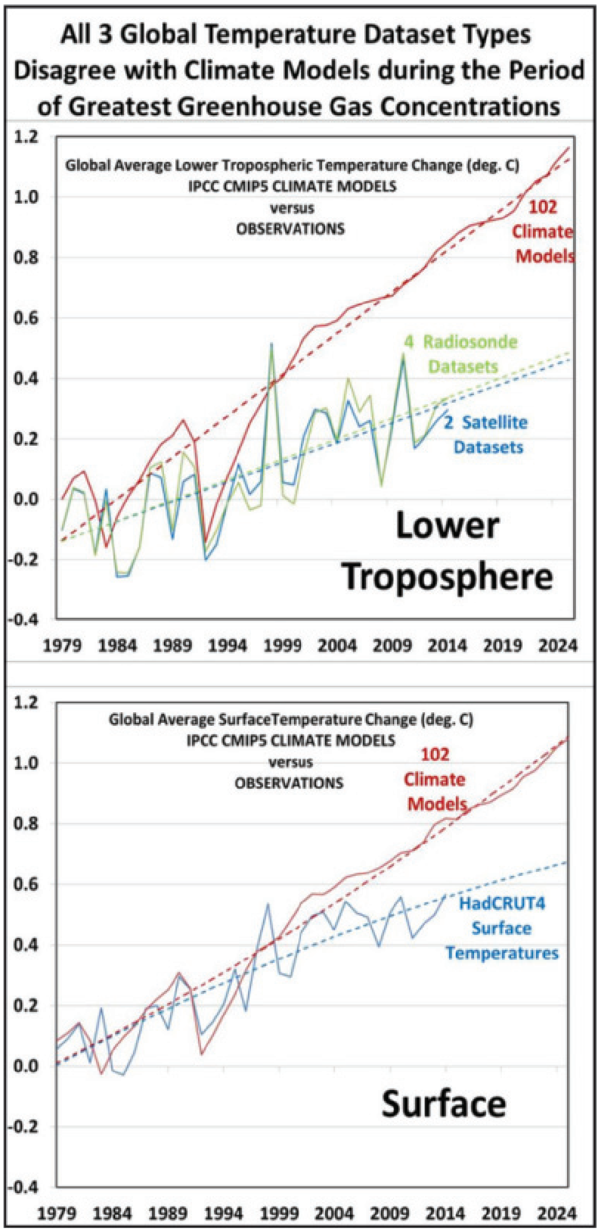


Figure 3.1: Observations of global average temperature since 1979 suggest that climate models are warming about twice as fast as the real world, in both the lower atmosphere (top panel) and at the surface (bottom panel).

What do the measurements tell us?

Generally speaking, whether we use satellites, thermometers, or weather balloons, the measurements suggest that warming in recent decades has been weaker than expected by the climate models. This is summarized in *Figure 3.1*, the top panel of which shows satellite and weather balloon measurements of the lower atmosphere versus the corresponding forecasts of climate models, while the lower panel shows surface thermometer measurements versus climate model forecasts.

As seen in *Figure 3.1*, observations of global average temperature since 1979 suggest that climate models are warming about twice as fast as the real world, in both the lower atmosphere (top panel) and at the surface (bottom panel).

Why do we measure the deep-atmospheric temperatures, even though no one lives at those altitudes? There are a couple of reasons. First, as the sun warms the surface of the Earth, the lower atmosphere (the troposphere) is also warmed as the atmosphere overturns, producing clouds and precipitation. The surface and deep-atmosphere are thus coupled together, and as the surface warms, so should the troposphere. This gives us an important check on whether surface warming really is occurring.

Second, the amount of warming in the troposphere compared to the surface tells us something about feedbacks in the climate system, and thus about climate sensitivity. The climate models suggest that the troposphere should be warming more quickly than the surface. Instead, the observations suggest that troposphere is warming more slowly than the surface. We don't yet know why this is the case, but it might well be related to errors in the climate models that need to be corrected.

As can be seen in *Figure 3.1*, the discrepancy between models and observations seems to be growing with time. Unfortunately, there is no way to know if this discrepancy will continue. A few scientists even dispute whether a discrepancy exists, pointing to uncertainties in the observations. I tend to believe the observations are largely correct, and that the discrepancy is real. The tendency of the climate models to warm too much is due to highly uncertain tunings that have been made in those models, especially in how clouds respond to warming. Since clouds are the Earth's natural sunshade, a small change in how the model handles clouds can lead to a large change in global warming predictions from the models.

Is recent warming natural or man-made?

It is commonly assumed that "climate change" means "human-caused climate change." Yet we know from historical records that humanity has experienced prolonged periods of abnormally warm or cool temperatures. For example, as seen in *Figure 3.2*, the Roman Warm Period, the Medieval Warm period, and the Little Ice Age all show up in temperature proxy estimates of Northern Hemispheric temperature estimates.

Proxy average temperature reconstruction for the Northern Hemisphere over the last 2,000 years reveals that most centuries experienced natural episodes of warming or cooling.

This evidence demands the question: if most centuries in the last two millennia experienced either warming or cooling, how do we know

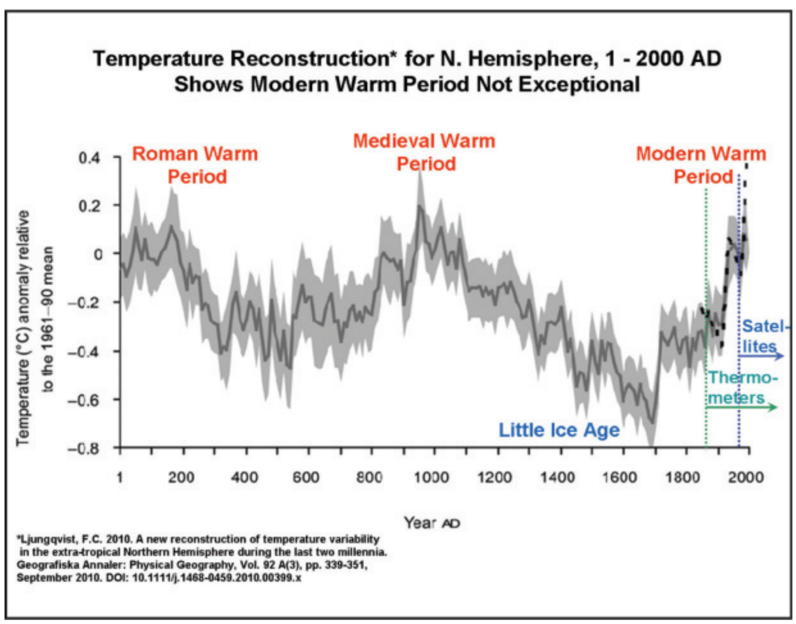


Figure 3.2: Proxy average temperature reconstruction for the Northern Hemisphere over the last 2,000 years reveals that most centuries experienced natural episodes of warming or cooling.

that the warming of the last 100 years is all human-caused?

The answer is that we don't.

While the theory supporting some warming from our carbon dioxide emissions is reasonably sound, the magnitude of that warming is very uncertain. This distinction between the mere existence of some warming versus its magnitude is usually lost in the global warming debate, where people are often believers in either no human effect or a catastrophic human effect.

The temperature estimates in *Figure 3.2* suggest that humans routinely had to deal with fairly large temperature changes, some of which lasted for centuries. The idea that those natural climate changes no longer exist, and that we now are experiencing only human-caused changes, seems speculative at best.

The truth is, no one really knows. Climate science unavoidably deals with large uncertainties. Even if we had perfect temperature measurements over the last 2,000 years, there would still be disagreements over the cause of the observed temperature variations, which remain largely unknown.

What we do know, though, is that the climate models continue to predict rapid warming for our future. As those predictions either succeed or fail as more measurements are made in the coming years, we will very gradually gain more confidence in our understanding of the effects of humans on climate.

Global warming: The science in three nut shells

by Richard S. Lindzen

A peculiar aspect of the global warming issue is the popular attempt to characterize the underlying science as transparently trivial—presumably to make the layman feel stupid if he should question the alarm surrounding this issue.

To quote Secretary of State John Kerry on the science of climate:

> I know sometimes I can remember from when I was in high school and college, some aspects of science or physics can be tough. But this is not tough. This is simple. Kids at the earliest age can understand this.

Alas, climate brings together some of the hardest problems in physics despite Secretary Kerry's peculiar (though common) view.

Obviously, I will not be able to review fully the physics in any detail (though some attention to this will be given at the conclusion of this piece). Rather, I will describe the three narratives that cover the bulk of the public discourse. I use the word "narrative" advisedly, and will eventually explain why we are dealing with story lines rather than with serious discourses. It goes without saying that narratives can have a powerful influence.

The three narratives are perpetrated by the supportive scientists, the so-called skeptics, and the politicians, environmental activists, and media. The third narrative is also favored by scientists who are not involved with the physics of climate but who explicitly profit from alarm.

The first narrative is that commonly associated with the scientific part of the United Nation's International Panel on Climate Change, or IPCC (Working Group 1). Its main position is that recent (since the 1960s) climate change is primarily due to man's burning of fossil fuels—oil, coal, and natural gas—leading to the release of CO_2 into the atmosphere, which the IPCC believes might eventually dangerously heat the planet. Although warming per se is assumed to be bad, little attention is given as to what constitutes the danger. For over thirty years, however, the issue of potentially rising sea levels has provided the primary graphic illustration of danger, though little evidence is on offer.

The second narrative holds that warming is not an especially serious problem. It holds that there are many reasons why the climate changes—the sun, clouds, oceans, the orbital variations of the earth, as well as myriad other inputs. None of these is fully understood, and there is no evidence that CO_2 emissions are the dominant factor. Furthermore, the fact that computer model projections of climate, where CO_2 is made to dominate, have consistently overestimated observed warming strongly suggests that the alleged climate response to CO_2 is greatly exaggerated.

In summary, the skeptics find that climate is a remarkably complex system that cannot be reduced to a CO_2 knob, something you turn up or down like your house thermostat, to control global temperature.

Despite these differences, the first two narratives actually share quite a few positions: first that the climate is always changing and second that CO_2 is a greenhouse gas without which life on earth is not possible. They also agree that adding it to the atmosphere should lead to some warming. Moreover, the narratives agree that atmospheric levels of CO_2 have been increasing since the end of the Little Ice Age in the nineteenth century and that over this period (the past two centuries) the global mean temperature has increased slightly and erratically by about 1.8 degrees Fahrenheit or one degree Celsius—but only since the 1960s have man's greenhouse emissions been sufficient to play a role. Finally, both narratives agree that given the complexity of climate, no confident prediction about future global mean temperature or its impact can be made. The IPCC acknowledged in its own 2007 report that "The long-term prediction of future climate states is not possible."

The most important commonality, however, is that neither of the first two narratives asserts that the burning of fossil fuel leads to catastrophe. This important point has often been made by scientists closely associated with the first narrative.

The situation may have been best summarized by Mike Hulme, director of the Tyndall Centre at the University of East Anglia (a center of concern for global warming): "To state that climate change will be 'catastrophic' hides a cascade of value-laden assumptions which do not emerge from empirical or theoretical science."

Here is an exchange from John Humphry's BBC4 interview of Ralph Cicerone (President of the National Academy of Sciences) in July 2012.

> John Humphrys: You don't sound, if I can use this word, apocalyptic. I mean, you're not saying "If we don't do these things, we're going to go to hell in a handbasket, we're going to fry, in a few years."
>
> Ralph Cicerone: Well, there are people who are saying those things, John.
>
> Humphrys: But not you.
>
> Ralph Cicerone: No. I don't think it's useful, I don't think it gets us anywhere, and we don't have that kind of evidence.

Even Gavin Schmidt, Jim Hansen's successor as head of NASA's Goddard Institute of Space Studies, whose website, realclimate.org, is a major advocate of the global warming claim, does not agree with claims of extremes:

> General statements about extremes are almost nowhere to be found in the literature but seem to abound in the popular media. . . . It's this popular perception that global warming means all extremes have to increase all the time, even though if anyone thinks about that for ten seconds they realize that's nonsense.

The third narrative is substantially divorced from either of the first two narratives.

The take of Senators McCain and Lieberman (The Boston Globe, February 13, 2007) illustrates a common approach to pretending that there is a connection between the first and third narratives:

> The recent report by the Intergovernmental Panel on Climate Change concluded there is a greater than 90 percent chance that greenhouse gases released by human activities like burning oil in cars and coal in power plants are causing most of the observed global warming. This report

> puts the final nail in denial's coffin about the problem of global warming.

Of course, the IPCC WG1 wisely avoided making the claim that 51 percent of a small change in temperature constituted a "problem." This, they left to the politicians.

More commonly, no attempt is made to relate the "scare" scenario to the first narrative. Here is President Obama's constant refrain:

> Climate change is contributing to extreme weather, wildfires, and drought, and rising temperatures can lead to more smog and more allergens in the air we breathe, meaning more kids are exposed to the triggers that can cause asthma attacks.

Pope Francis, President Hollande, and virtually all state leaders have chimed in with similar "learned" proclamations.

To be sure, the advocates of the third narrative attempt to cloak their bizarre views with claims of "science." The following quotes from Secretary Kerry are characteristic:

> When I think about the array of global climate—of global threats—think about this: terrorism, epidemics, poverty, the proliferation of weapons of mass destruction, all challenges that know no borders, the reality is that climate change ranks right up there with every single one of them. And it is a challenge that I address in nearly every single country that I visit as Secretary of State, because President Obama and I believe it is urgent that we do so.

> . . . it's compelling us to act. And let there be no doubt in anybody's mind that the science is absolutely certain. . . .

> First and foremost, we should not allow a tiny minority of shoddy scientists and science and extreme ideologues to compete with scientific fact.

> This is not opinion. This is about facts. This is about science. The science is unequivocal. And those who refuse to believe it are simply burying their heads in the sand. Now, President Obama and I believe very deeply that we do not have time for a meeting anywhere of the Flat Earth Society.

As usual, political figures improperly associate science as a source of unquestionable authority rather than as a successful mode of inquiry. In addition, they cynically assert that science is the source of their authority. Sometimes, the ignorance of the politician becomes painfully evident, as when the former Speaker of the House Nancy Pelosi famously intoned: "Natural gas is a good, cheap alternative to fossil fuels." Then-senator Hillary Clinton, at a Senate Hearing, more modestly acknowledged her ignorance of climate science, but, nonetheless, confidently asserted that "CO_2 can't be good for kids with asthma."

At least some political figures don't bother referring to "the science." People like Christiana Figueres, the executive secretary of the U.N. Framework Convention on Climate Change, make clear the purely political motivation.

> This is the first time in the history of mankind that we are setting ourselves the task of intentionally, within a defined period of time, to change the economic development model that has been reigning for at least 150 years, since the Industrial Revolution.

Despite such occasional outbursts of honesty, the third narrative is generally defended as being due to those in the first narrative, with the usual mantras of "97 percent," "everyone knows," etc. With increases in funding by over an order of magnitude, there is little incentive for those in the first narrative to complain, and this third narrative clearly dominates the public discourse. Indeed, those associated with the first narrative have ample incentive to keep the third narrative in play. While it is clear that the third narrative consists in a story line divorced from actual science, it is less clear why this is the case for the first two narratives, both of which are nominally closer to the actual science.

First, both of these narratives assume that we are dealing with a problem. In point of fact, as others at this meeting have pointed out, increasing levels of CO_2 per se are beneficial to all plant life on earth, and realistically modest levels of warming are beneficial as well. That most people prefer the sunbelt to the Northwest Territories is perfectly obvious. So too is the fact that warming will substantially extend growing seasons. Indeed, polling results consistently show that most people assign minimal priority to "fighting" global warming, but the concern permeates "elite" opinion. As Orwell sagely noted, "Some ideas are so stupid that only intellectuals believe them." However, one hesitates to include the media and Hollywood as "intellectual."

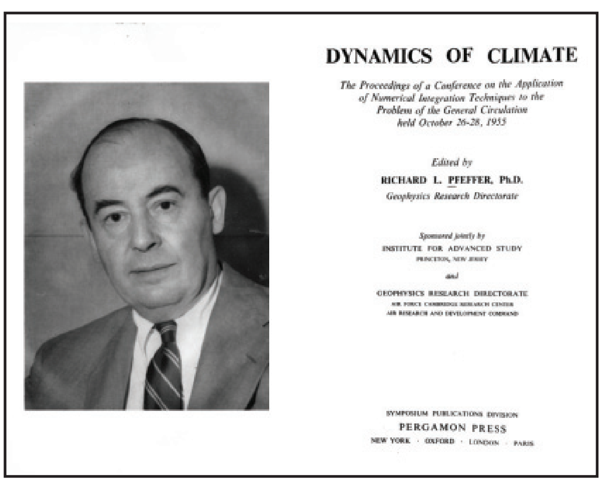


Figure 4.1: Cover page of a 1955 conference dealing with climate dynamics and involving virtually all the leading figures in meteorology. The portrait on the left is of John von Neumann.

The second (and far more subtle) point wherein the first two narratives deviate from reality is in their focus on a zero dimensional picture of climate (i.e., greenhouse warming of the global mean temperature). This leads to a view of climate sensitivity that bears little resemblance to past climate change. A standard part of these narratives is that the greenhouse effect has been known since the work of John Tyndall in the nineteenth century, with additional references to Svante Arrhenius and Guy Stewart Callendar. The clear implication is that the zero-dimensional approach had always been accepted as the fundamental approach to climate, and, more importantly, to climate change. This is, however, far from true. While we don't wish to minimize the role of the greenhouse effect, it has long been recognized that other processes are likely to have played a more important role in the Earth's climate history. Moreover, the relative stability of the tropical temperature points to a strong negative radiative feedback that stabilizes climate with respect to radiative perturbations.

Figure 4.1 is the cover page of an important volume from 1955.The portrait is of John von Neumann. As the head of the Institute for Advanced Study in Princeton, he formed the first group to undertake the numerical prediction of weather. The contributors to this volume included Charney, Phillips, Lorenz, Smagorinsky, Starr, Bjerknes, Mintz, Kaplan, Eliassen, among others (with an introduction by J. Robert Oppenheimer). Only one article dealt with radiative transfer, and it did not focus on the greenhouse effect, though increasing CO_2 was briefly mentioned. The contributors were the leading figures in atmospheric physics from the mid-1950s until at least the early 1980s, and they clearly did not emphasize greenhouse warming.

The main reason for this was probably the recognition that major climate changes were characterized by large changes in the temperature difference between the tropics and the poles, with very little change at the equator. The following are rough values for this difference at different periods in earth history: Today:ΔT≈40K; Major glacial periods: ΔT≈60K; Eocene (fifty million years ago): ΔT≈20K.

Such changes imply changes in heat flow between low and high latitudes. (It is probably worth noting that during the '60s and '70s when global cooling was the focus of climate alarm, the popular climate model was the Budyko-Sellers model that emphasized the role of equator-to-pole heat transport in enabling the possibility of an ice-covered earth.) Given the rather small changes in tropical temperatures, the changes in global mean temperature were regarded as simply the residues of the changes in ΔT.

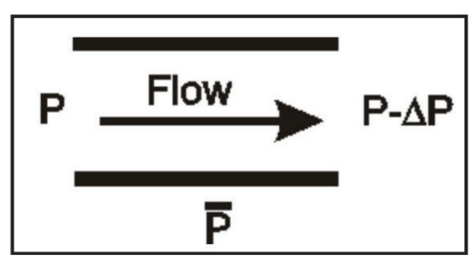
The following admittedly naïve analogy illustrates the problem with much current thinking about climate. Few of us would question Figure 4.2 for determining P, pressure (subject to forcing, F, acting on a piston). By focusing on P as the determinant of everything else, however, we are implicitly assuming that mean pressure rather than ΔP determines flow, which is patently absurd (see Figure 4.3). In the present discourse, this absurdity is subsumed under the need to explain "polar amplification."

The above illustrates the insidious power of a narrative to corrupt rational assessment. Misunderstanding the nature of past climate change, has, for example, led paleoclimatologists to exaggerate grossly climate sensitivity. As we have seen, past climate change was primarily characterized by changes in the equator-to-pole temperature difference, accompanied by only small changes in equatorial temperature. Although the changes in equator-to-pole temperature difference need not be tied causally to changes in greenhouse forcing, they do lead to changes in the mean temperature, and attributing these changes in mean temperature to greenhouse forcing can lead to greatly exaggerated estimates of sensitivity to greenhouse forcing. Indeed, for climate change in the absence of greenhouse forcing, this can lead to the absurd conclusion that sensitivity is infinite.

In brief, even those of us associated with the second narrative (including me) have focused on the greenhouse picture despite the fact that this is probably not the major factor in climate change. That is to say, we have accepted the basic premise of the first narrative. Mea culpa.

Figure 4.2 (left): Illustration of the force on a piston determining the pressure in a cylinder.

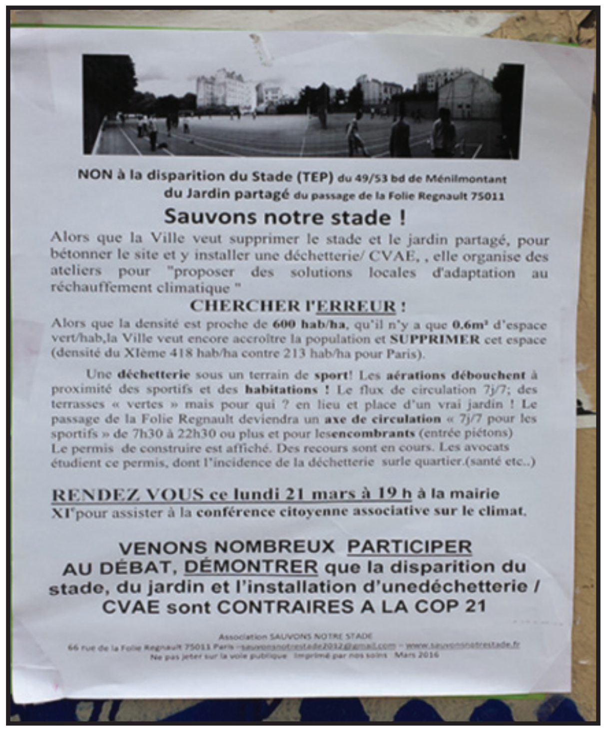
Figure 4.3 (right: Illustration of the pressure difference across a pipe determining the flow through the pipe.



Capturing the narrative is a crucial element in a political battle. So far, the alarmists have succeeded. Indeed, the matter of global warming has become a mindless part of the discussion of almost anything. The following two posters that I have seen recently in my Paris neighborhood, illustrated in Figures 4.4 and 4.5, show this.

The poster on the right begins with the statement that the climate is deteriorating, and that everyone knows this, and that the time has come to stop talking and to begin doing something. And what do they propose that one do? Why, one should obviously deposit one's money with his Crédit Cooperatif. The poster on the right is protesting the plan to pave over a part of a park and playing field in the Belleville neighborhood of Paris. What is the objection? Obviously, the paving will contribute to climate change in violation of the agreement at the 2015 U.N. Cimate Change Conference.

Clearly, the return of sanity to this discourse will require great effort, but, for the sake of our societal wellbeing, it is an essential effort.



Figures 4.4 & 4.5: The poster on the left begins with the statement that the climate is deteriorating, and that everyone knows this, and that the time has come to stop talking and to begin doing something. And what do they propose that one do? Why, one should obviously deposit one's money with their Crédit Cooperatif. The poster on the right is protesting the plan to pave over a part of a park and playing eld in the Belleville neighborhood of Paris. What is the objection? Obviously, the paving will contribute to climate change in violation of the agreement at the 2015 U.N. Cimate Change Conference.

The truth about ocean "acidification"

by Patrick Moore

This paper will focus on what has been dubbed "global warming's evil twin": the specter of "ocean acidification" and the extinction of marine calcifying species (including the most important species of phytoplankton), which, if true, would threaten the entire life-cycle of the world's seas.

First a little background on how I managed the trick of transforming from a radical Greenpeace activist into a sensible humanitarian environmentalist and a committed skeptic of catastrophic human-caused climate change. I was born and raised in a tiny floating village in Winter Harbour on the northwest tip of Vancouver Island. There was no road to my village and I went to a one-room schoolhouse by boat every day until I was fourteen. Then I was sent to boarding school in Vancouver, where I excelled in science. Later I did my undergraduate studies at the University of British Columbia, gravitating to the life sciences —biology, biochemistry, genetics, and forestry: the environment and the industry my family has been in for more than one hundred years. Then, before the word was known to the general public, I discovered the science of ecology, the science of how all living things are interrelated, and how we are related to them. At the height of the Cold War, the Vietnam War, with the threat of all-out nuclear war and the newly emerging consciousness of the environment, I was transformed into a radical environmental activist.

While doing my Ph.D. in ecology in 1971, I joined a group of activists who had begun to meet in the basement of the Unitarian Church to plan a protest voyage against U.S. hydrogen bomb testing in Alaska. We proved that a somewhat rag-tag looking group could sail an old fishing boat across the North Pacific Ocean and help change the course of history. We created a focal point for the media to report on public opposition to the tests.

When that H-bomb exploded in November 1971, it was the last hydrogen bomb the United States ever detonated. Even though there were four more tests planned in the series, President Nixon canceled them due to the public opposition we had helped to create. That was the birth of Greenpeace.

Flushed with victory, we were made brothers of the Namgis Nation in their Big House at Alert Bay near my northern Vancouver Island home on our return from Alaska. For Greenpeace, this began the tradition of the Warriors of the Rainbow, after a Cree Indian legend that predicted the coming together of all races and creeds to save the Earth from destruction. We named our ship the Rainbow Warrior, and I spent the next fifteen years in the top committee of Greenpeace, on the front lines of the environmental movement around the world as we evolved from that church basement into the world's largest environmental activist organization.

Next we took on French atmospheric nuclear testing in the South Pacific. They proved a bit more difficult than the U.S. nuclear tests. It took years to drive these tests underground at Mururoa Atoll in French Polynesia. In 1985, under direct orders from President Mitterrand, French commandos bombed and sank the Rainbow Warrior in Auckland Harbour, killing our photographer.

Going back to 1975, I drove a small inflatable boat into the first encounter with the Soviet factory whaling fleet in the North Pacific. We confronted the whalers, putting ourselves in front of their harpoons in our little rubber boats, to protect the fleeing whales. This got us on television news around the world, bringing the Save the Whales movement into people's living rooms for the first time. After four years of voyages, factory whaling was finally banned in the North Pacific in 1979, and by 1981 in all the world's oceans.

Why did I leave Greenpeace after fifteen years in the leadership? When Greenpeace began, we had a strong humanitarian orientation, to save civilization from destruction by all-out nuclear war. Over the years the "peace" in Greenpeace was gradually lost, and my organization, along with much of the environmental movement, drifted into a belief that humans are the enemies of the earth. I promote humanitarian environmentalism, because we are part of nature, not separate from it. This means including the social and economic priorities with the environmental ones. The first principle of ecology is that we are all part of the same ecosystem—as Barbara Ward put it, "One human family on spaceship Earth"—and to preach otherwise teaches that the world would be better off without us. There is very good reason to see humans as essential to the survival of life on this planet.

In the mid-1980s, I found myself the only director of Greenpeace International with a formal education in science. My fellow directors proposed a campaign to "ban chlorine worldwide," naming it "The Devil's Element." I pointed out that chlorine is one of the elements in the Periodic Table, one of the building blocks of the universe, and the eleventh most common element in the Earth's crust. I argued the fact that chlorine is the most important element for public health and medicine. Adding chlorine to drinking water was the biggest advance in the history of public health, and the majority of our synthetic medicines are based on chlorine chemistry. This fell on deaf ears, and for me this was the final straw. I had to leave.

When I left Greenpeace, I vowed to develop an environmental policy that was based on science and logic, rather than sensationalism, misinformation, anti-humanism, and fear.

The supposed smoking gun of catastrophic climate change is the Keeling curve of CO_2 concentration in the Earth's atmosphere since 1959. We presume CO_2 was at 280 ppm at the beginning of the Industrial Revolution, before human activity could have caused a significant impact. I believe that most of the rise from 280 to today's 400 ppm was caused by human CO_2 emissions, mainly from burning fossil fuels, with the possibility that some of it is due to outgassing from warming of the oceans.

It is widely known that the biomass of Earth's vegetation is increasing rapidly due to the additional CO_2 humans have put back into the atmosphere, increasing food crop and tree growth as well as all wild vegetation, on a global basis. This is largely ignored or illogically explained away by the believers of "dangerous human-caused climate change."

Even NASA tells us that "Carbon Dioxide Controls Earth's Temperature," in child-like denial of the many other factors involved in climate change. This is parallel with NASA's contention that there might be life on Mars. Decades after it was demonstrated that there was no life on Mars, NASA continues to use it as a hook to raise public funding for more expeditions to the Red Planet. The promulgation of fear of Climate Change now serves the same purpose.

It is clear to anyone who analyzes the graph of CO_2 and temperature over the past 600 million years that they are not strongly correlated, if at all. Even factors that have zero correlation with each other sometimes move in the same direction. During the evolution of modern life, CO_2 and temperature have been out of sync most of the time.

In 2003 an explosion of journal articles, media reports, and glossy publications from environmental groups on ocean acidification began to appear. A paper published in the journal Nature said human emissions of carbon dioxide (CO_2) "may result in larger pH changes [in the oceans] over the next several centuries than during the geological record of the past 300 million years."

The best estimate of CO_2 in the atmosphere 150 million years ago was 2000–2500 ppm, compared to today's 400 ppm. Yet shellfish and corals thrived at that time. One can only brand this kind of exaggeration as sensationalism—certainly not science. By 2009, the Natural Resources Defense Council (NRDC) was saying that "by mid-century, . . . coral reefs will cease to grow and even begin to dissolve," and ocean acidification will "impact commercial fisheries worldwide, threatening a food source for hundreds of millions of people as well as a multi-billion dollar industry." Therefore, not only are calcifying species threatened, but the entire web of life in the seas is too.

Let's examine this hypothesis and test its assumptions against real-world observations and scientific knowledge.

The term "ocean acidification" is, in itself, very misleading. The scale of pH runs from 0 to 14 where 7 is neutral, below 7 is acidic, and above 7 is basic, or alkaline. The pH of the world's oceans varies from 7.5 to 8.3, well into the alkaline scale. It is incorrect to state that the oceans are acidic or that they will ever become acidic under any conceivable scenario. The term "acidification" implies that oceans will actually become acidic. It is perhaps just short of propaganda to use the language in this manner, as it is well known that the terms "acid" and "acidic" have strong negative connotations for most people. It should also be noted that nearly all "fresh water," including the water we drink and fish live in, is slightly acidic.

More than 500 million years ago, at the beginning of the Cambrian Period, many marine species of invertebrates evolved the ability to control calcification, a form of biomineralization, and build armor-plating to protect their soft bodies. Shellfish such as clams and snails, corals, coccolithophores (phytoplankton), and foraminifera (zooplankton) began to combine carbon dioxide with calcium and thus to remove carbon from the life cycle as the shells sank into sediments—100 million billion tons of carbonaceous sediment which became chalk, limestone, and marble (see Figure 5.1).

Coral reefs are widely distributed across the tropics with the highest biodiversity centered in

Figure 5.1: Representatives of marine calcifying species. Clockwise from left: coccolithophores (phytoplankton), bivalves and gastropods, foraminifera (zooplankton) and corals.

Indonesia and the Philippines. Deep-water corals are also found in the colder seas of the northern and southern oceans.

There are five key reasons why the "ocean acidification" narrative is a fabrication with no basis in reality.

First, it is widely accepted that the concentration of CO_2 was much higher in the Earth's atmosphere when modern-day life forms evolved during the Cambrian Period, which began 544 million years ago. Early shellfish such as clams arose more than 500 million years ago, when atmospheric CO_2 was 10 to 15 times higher than it is today. Clearly, the lower pH of the oceans at that time did not cause the extinction of corals or shellfish, or they would not be here today.

Second, there is a tendency to assume that it takes thousands or millions of years for species to adapt to changes in the environment. This is not the case. Most of the invertebrates that have developed the ability to produce calcium carbonate armor are capable of relatively rapid adaptation to changes in their environment due to two distinct factors. Firstly, they reproduce at least annually and sometimes more frequently. This means their progeny are tested on an annual basis for suitability to a changing environment. Secondly, these species produce thousands to millions of offspring every time they reproduce. This greatly increases the chance that genetic mutations that are better suited to the changes in environmental conditions will occur in some offspring.

Third, two distinct physiological mechanisms exist whereby adaptation to environmental change can occur much more rapidly than by change in the genotype through genetic mutation.

The first of these is called phenotypic plasticity, which is the ability of one genotype to produce more than one phenotype when exposed to different environments. In other words, a specific genotype can express itself differently due to an ability to respond in different ways to variations in environmental factors. Examples of this in humans are the ability to acclimatize to different temperature regimes and different altitudes. There is no change in the genotype, but there are changes in physiology.

The second and more fascinating factor is transgenerational plasticity, which is the ability of parents to pass their adaptations to their offspring. Experiments with marine species of fish demonstrate that initial exposure to considerably lower-pH seawater reduced fish survival by 54 percent (2012) and 33 percent (2013) relative to ambient conditions. Yet they found that "offspring from parents collected later in the season became increasingly CO_2-tolerant until, only two months later, offspring survival was equally high at all CO_2 levels."

Third, the salt content of seawater provides it with a powerful buffering capacity, the ability to resist change in pH when an acidic or basic compound is added to the water. For example, one micromole of hydrochloric acid added to one kilo of distilled water at pH 7.0 (neutral) causes the pH to drop to nearly 6.0. If the same amount of hydrochloric acid is added to seawater at pH 7, the resulting pH is 6.997, a change of only 0.003 of a pH unit. Thus, seawater has approximately 330 times the buffering capacity of freshwater.

The proponents of ocean acidification say that the ocean's pH was 0.1 pH units higher in 1750 before industrialization. No one measured pH in 1750 and there is no "average" pH for the oceans as pH varies greatly with both place and time. Their number is typically the result of a computer model.

A 16-decade measure of pH in the South China Sea, inferred from isotopes of Boron, shows that pH has fluctuated greatly, more than twice as much as the alarmists claim will destroy most marine

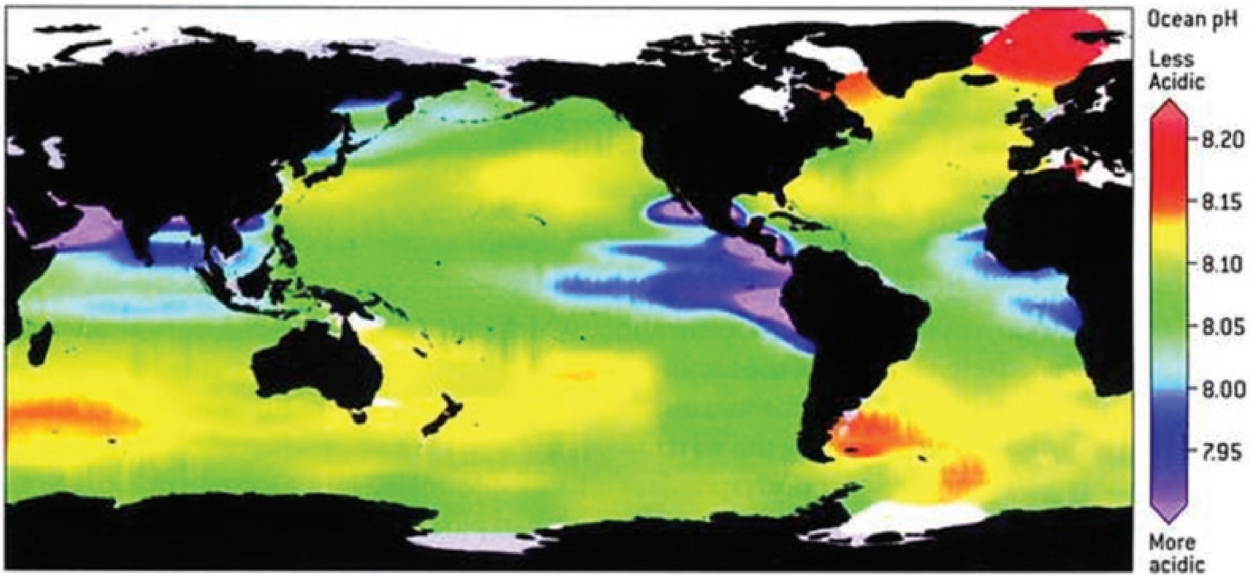


Figure 5.2: World map depicting the pH of the oceans, including the large area of lower pH seawater off the west coast of South America. To be correct, the scale of ocean pH on the right should read "More Basic" and "Less Basic." From Scientifi c American, March 2006.

life, and that there has been no detectable trend from 1850 into the twentieth century.

There is every reason to believe that computer models are exaggerating the "sensitivity" of ocean pH to CO_2 levels in the same way as the models purporting to predict global temperature from increasing levels of CO_2 have done.

The most "acidic" (that is, least alkaline) area of the world's oceans produces 20 percent of all the world's wild fish catch. In the Humboldt Current off Peru 5 million tons of anchovies are brought aboard in a good year. The pH of this cold, upwelling water, rich in CO_2, is 7.7, lower than the probably inflated prediction for 2100. The source of this high productivity are the tiny coccolithophores, phytoplankton that lap up the dissolved CO_2 and turn it into food for zooplankton that feed the fish and whales and everything else in the sea. It turns out that seawater high in CO_2 with a lower pH is the perfect environment for phytoplankton and corals, and, contrary to the alarmism touted by publicly funded scientists, CO_2 is fertilizing the oceans just like it is greening the earth (see Figure 5.2).

Fourth, all organisms are able to control the chemistry of their internal organs and biochemical functions. The term "homeostasis" means that an organism can maintain a desirable state of chemistry, temperature, etc., within itself under a wide range of external conditions. This is especially necessary in a marine environment because the salinity of the ocean is too high to allow the metabolic processes that take place in an organism. The general term for an important part of homeostasis is "osmoregulation."

And fifth, if the present 300-year warming trend continues and the oceans warm, they will tend to release CO_2 into the atmosphere because warm seawater at 30 degrees Celsius can dissolve only about half as much CO_2 as cold seawater at 4 degrees Celsius. This would be balanced against the tendency of increased atmospheric CO_2 to result in more absorption of CO_2 by the oceans.

It does not appear as though anyone has done the calculation of the net effect of these two competing factors under varying circumstances. Perhaps funding could be found for this important research!

The media does not report a balanced perspective on climate and CO_2 issues. In fact, the only comprehensive meta-analysis of ocean "acidification" concludes that "Active biological processes and small-scale temporal and spatial variability in ocean pH may render marine biota more resistant to ocean acidification than hitherto believed."

And finally, Craig Idso of the CO2Science website provides a surprising insight. Beginning with 1,103 results from a wide range of studies, the results are narrowed down to those up to 0.3 reduction in pH units, what the alarmists predict for 2100 (see Figure 5.3).

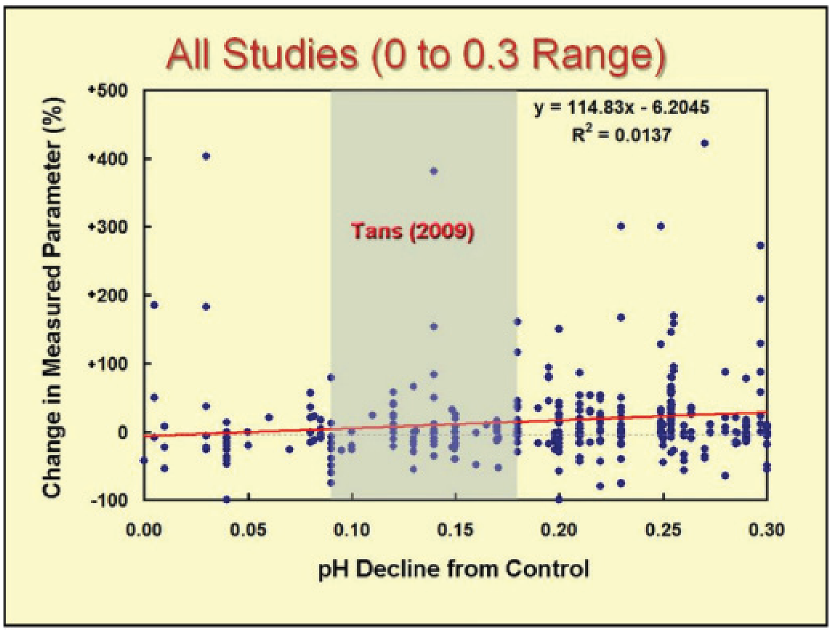


Figure 5.3: All peer-reviewed experimental results for pH decrease of 0.0 to 0.3 from present value. (Prediction of range of actual expected pH change in gray). Five parameters are included: calcifi cation, metabolism, growth, fertility and survival. Note that the overall trend is positive for all studies up to 0.30 units of pH reduction.

A review of these many studies, all of which use direct observation of measured parameters, indicates that the overall predicted effect of increased CO_2 on marine species would be positive rather than negative for calcification, metabolism, growth, fertility, and survival (what else is there to worry about?). This further reinforces the fact that CO_2 is essential for life, that CO_2 is at an historically low concentration during this Pleistocene Ice Age, and that more CO_2 rather than less would be generally beneficial to all life on Earth. Please join me to celebrate CO_2.

Rethinking climate economics

by Bruce M. Everett

Climate policy is primarily a scientific issue, but economics has an important role to play, too. To climate activists, economic analysis means cataloguing the inevitable disasters of an increasingly unlivable planet. The best available science, however, suggests that carbon dioxide in fact contributes to human well-being.

If economics is to make a useful contribution to the climate discussion, economic analysis should be aligned with science by following two principles: first, establish the appropriate base case for analysis and, second, reflect honestly and accurately the costs of carbon reduction.

The key parameter in the scientific discussion is climate sensitivity, defined as the temperature increase that would result from doubling the atmospheric concentration of CO_2. Carbon dioxide is a greenhouse gas, and basic physics indicates that the sensitivity of CO_2 by itself would be about 1 degree Celsius. In its Fifth Assessment Report from 2014, however, the UN Intergovernmental Panel on Climate Change (IPCC) estimated equilibrium climate sensitivity in the range of 1.5 to 4.5 degrees Celsius. The hypothesis of high climate sensitivity was established several decades ago by climate models that incorporate feedback effects that amplify warming, often with higher humidity assumed to occur at higher temperatures.

The essence of science, however, is the testing of hypotheses against data. Climate models have been making high sensitivity predictions for a long time, but actual experience to date shows a sensitivity below the bottom of the IPCC range. In other words, the models have consistently overpredicted temperature.

Nonetheless, much of the economic analysis currently available is not only based on the IPCC range but on the high end of the IPCC range. Using an extreme case as a starting point supports the narrative of climate activists, but severely distorts the analysis.

Macroeconomic forecasts are naturally subject to a wide range of uncertainty, but it is important to center the analysis on the most reasonable and likely set of assumptions. For example, we do not do our economic planning on the basis of worldwide depression or nuclear war. Assuming catastrophe effectively eliminates the discipline of cost-benefit analysis. If we are all going to fry and drown from man-made climate change, we don't have to worry about the costs of reducing carbon or the impacts of climate policies on peoples' lives. Yet economic policy is about costs and trade-offs.

Consider the case of Germany. Among climate activists, Germany and Chancellor Angela Merkl are nothing short of rock stars. In 2015, the noted author and columnist Thomas Friedman wrote in *The New York Times* that Germany would be Europe's first "green solar-powered superpower." National Geographic magazine, always a reliable supporter of climate activism, seconded Friedman's claim, telling its readers that Germany could be a model for how to generate electric power. What exactly have the Germans done to earn these accolades?

The left-hand side of Figure 6.1 shows the installed electric power generation capacity in Germany in 2015. Wind and solar energy account for about 45 percent of installed capacity, and these two big green slices of the pie are the basis for Germany's honored status among climate activists. But capacity is just a list of available machinery and doesn't tell us very much. What really counts is the actual generation of kilowatt-hours, and that looks very different, as shown on the right side of Figure 6.1.

Note that the coal and nuclear plants, which can produce power whenever it's needed, are working overtime, generating 60 percent of the kilowatt-hours from less than a third of the capacity. Wind and solar generators, however, provide only 22 percent of the power from 45 percent of the capacity, and then only when nature makes it available.

The nuclear plants operate at 92 percent of their capacity and the coal plants at about 60 percent, while the wind turbines operate at only 22 percent of their capacity and the solar arrays at only 11 percent. In a sense, Germany is receiving international praise for building machines that stand idle most of the time. This is rather like buying a Prius and leaving it in your driveway for your neighbors to admire while you drive around in your SUV.

So how does the United States compare with the German green miracle? As shown in Figure 6.2, solar and wind contribute 22 percent of power generation in Germany, but a measly 6 percent in the United States. No wonder the Germans are feeling so smug. It's interesting to note, however, that, while the United States has less wind and solar, we also have proportionately less coal in our power generation mix and a greater contribution from nuclear, hydroelectric, and particularly natural gas. In total, although Germany generates nearly four times as much power from wind and solar as the United States does, Germany emits only about 15 per-

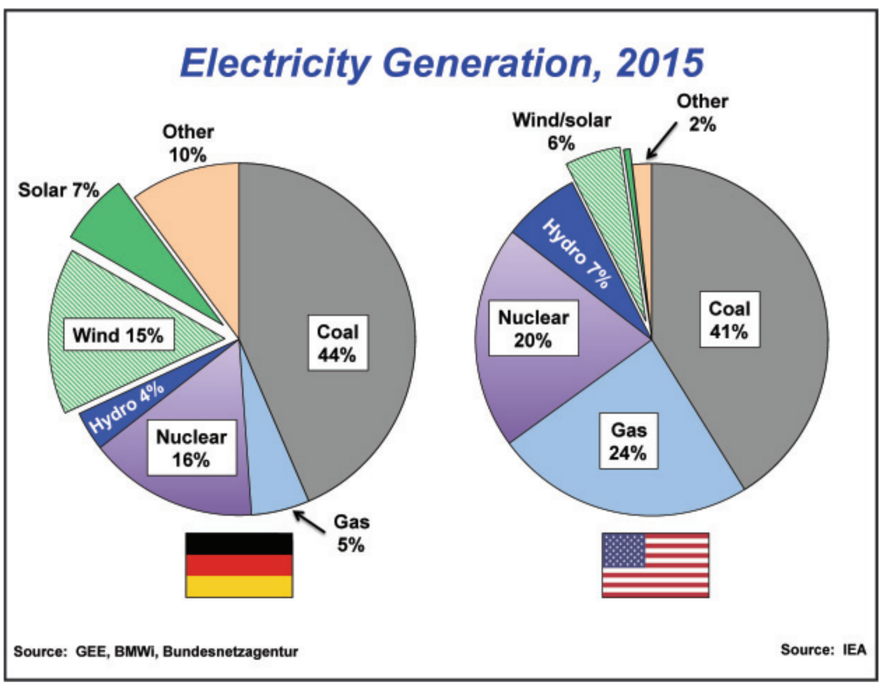


Figure 6.1: German Electric Power Generation Capacity and Generation. Forty-five percent of Germany's power generation capacity is wind and solar, but these units generate only 22 percent of the electricity. While the wind and solar units are idle most of the time, the coal and nuclear units produce most of the power.

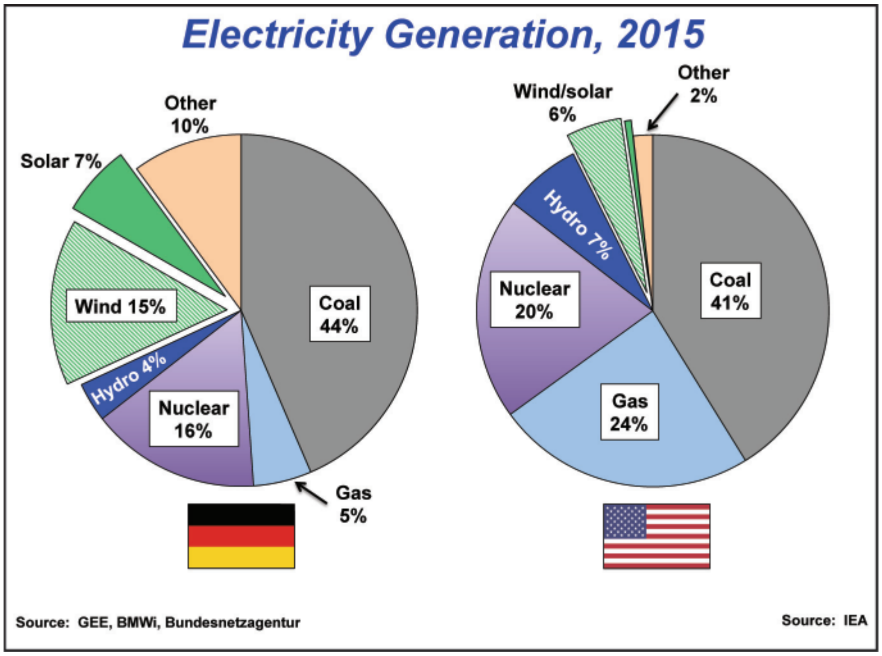


Figure 6.2: Electric Power Generation, Germany versus the United States. Germany produces 22 percent of its electricity from wind and solar compared to only 6 percent in the United States. The United States, however, has a smaller share of coal and a much larger contribution from clean nuclear and natural gas.

cent less CO_2 per kWh than the US does (0.39 kg for Germany versus 0.46 for the United States).

Rather than swooning over the marvels of Germany's wind and solar program, economists should look at power generation with a critical and analytical eye.

In particular, what does all this green power actually means for German consumers? Let's look at the energy prices consumers pay.

As shown in Figure 6.3, New York State residential customers currently pay $2 per gallon for gasoline, $11 per thousand cubic feet (MCF) for natural gas, and 18¢ per kWh for electricity. We should note that these prices are on the high side for Americans, since New York is at the far end of the supply chain for many energy sources and imposes relatively high taxes on residential energy. Prices in Texas, for example, are lower at $1.90 per gallon for gasoline, $9.00 per MCF for natural gas, and 11.3¢ per kWh for electricity.

German consumers, however, pay $5 per gallon for gasoline, $22 per thousand cubic feet of natural gas, and 31¢ per kWh for electricity, roughly double what New York consumers pay. These prices do not include the tax burden required to support the extensive subsidy system for renewables. In fairness, some of the high prices are not the fault of the German government. Germany, for example, lacks the huge natural gas resources we have in the States. Much, however, is the result of deliberate policy choices.

There are 7.2 million households in New York State with an average household income of about $60,000 per year. After taxes, take-home pay averages about $50,000. As shown in Figure 6.4, a typical New York family uses about 700 gallons of gasoline per year at a cost of $1,400, sixty thousand cubic feet of natural gas at a cost of $660, and 6,800 kWh of electricity at a cost of $1,225. The total residential energy bill is thus $3,285 per year, roughly 6.5 percent of take-home pay. We should note that the average New York family consumes and pays for again as much energy embodied in the manufactured goods and services it buys. What would happen if New York consumers had to pay German prices for energy?

Figure 6.3: Consumer Energy Prices in Germany and the United States

	New York State	Germany
Gasoline (per gallon)	$2.00	$5.00
Natural gas (per MCF)	$11	$22
Electricity (per kWh)	18¢	31¢

Figure 6.4: Consumer Energy Expenditures for New York Households

	Quantity	Price	Expenditure
Gasoline	700 gallons	$2.00/gal	$1,400
Natural gas	60 MCF	$11/MCF	$ 660
Electricity	6,800 kWh	18¢/kWh	$1,225
Total			$3,285

Figure 6.5: New York Household Energy Expenditures at German Prices

	Quantity	Price	Expenditure
Gasoline	700 gallons	$5.00/gal	$3,500
Natural gas	60 MCF	$22/MCF	$1,320
Electricity	6,800 kWh	30¢/kWh	$2,040
Total			$6,860

As shown in Figure 6.5, the answer is that their energy costs would more than double to $6,860, or almost 14 percent of take-home pay. The burden would be even greater if we included indirect energy costs, which are also much higher in Germany.

Wealthy people, particularly those who fly around the world on private jets demanding that other people use less energy, are not affected much by energy costs. Rich climate activists like Leonardo DiCaprio probably don't care what their monthly electricity or natural gas bills are, but working people do care. German government officials and climate activists receive praise for imposing high prices on the German public, but what do German consumers actually get in return for paying such high energy prices?

In a recent European Union survey, over 90 percent of Germans responded that climate change is either a "fairly serious" or a "very serious" problem. German government surveys indicate that 74 percent of Germans support their government's current nuclear/renewables policy. Germans apparently are willing to tolerate the current situation because they believe they are at the forefront of the global fight against climate change.

Climate activists often point to Germany's low "carbon footprint," the average amount of CO_2 emitted per person each year. The typical American emits about 16 metric tonnes of CO_2 annually—including both direct and indirect energy use, while the average German emits only ten tonnes per year. A 60 percent difference appears on the surface to be substantial, but is it meaningful?

The IPCC says that avoiding the dreaded two degree Celsius temperature increase would require a 40 to 60 percent reduction in global CO_2 emissions by 2050 from the 2010 emissions level. Although there is no scientific basis for this number, such a reduction would mean that every country in the world would have to cut its per capita emissions to less than two metric tonnes per year, about the emissions of the average Indian today.

The current German green energy program is utterly inadequate to meet this target, which would require German consumers to reduce their carbon emissions by another 80 percent. Another recent poll indicated that 88 percent of Germans, although supportive of their government's energy policy, believe the costs are already too high. The energy cost required to reduce consumption by another 80 percent would be astronomical. Germany is already trying to cope with their higher energy costs and their nuclear plant shutdowns by building new coal plants, an economically sensible but rather ironic decision for a green superpower.

The point here is not to disparage the Germans, but simply to take a hard look at the consequences of climate policies for real people. Even modest carbon reductions would be economically painful for the middle class and fatal for the poor. People who believe that buying an electric vehicle, putting solar cells on their roof, or using compact fluorescent light bulbs make them steely-eyed climate warriors just haven't done the math. These actions are costly, yet have a negligible impact on atmospheric carbon concentrations. Prevailing climate policies are "all pain, no gain." As economists, we should demand honesty about the costs of carbon reduction.

An analytical approach to climate economics suggests not catastrophe, but a world in which the benefits of CO_2 dominate the calculation. Looking analytically at the problem will allow us to abandon our single-minded and destructive obsession with carbon dioxide reduction and allow us to focus on the truly important issues faced by people around the world.

For example, we need to address actual pollution, like sulfur, lead, nitrogen oxides, and particulates, which are serious health hazards, particularly in emerging market countries.

We also need to feed the two-and-a-half billion people who will be added to the global population by the year 2050.

And we need to allow the people of the world to choose the forms of energy they think are best suited to bringing them out of poverty and improving their living standard.

In 1988, the great economist and Nobel Laureate Friedrich Hayek said, "The curious task of economics is to demonstrate to men how little they really know about what they imagine they can design." In other words, economists should be conscientious critics, not blind followers.

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1621 North Kent Street, Suite 603 • Arlington, Virginia 22209 • 571-970-3180
www.co2coalition.org • info@co2coalition.org

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