Carbon Dioxide Benefits the World:

See for Yourself

CO2 COALITION

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Preface

This white paper summarizes the views of the CO_2 Coalition, a new and independent, non-profit organization that seeks to engage thought leaders, policy makers, and the public in an informed, dispassionate discussion of how our planet will be affected by CO_2 released from the combustion of fossil fuel. Available scientific facts have persuaded Coalition members that additional CO_2 will be a net benefit. Rather than immediately setting this document aside for promoting such a politically incorrect view, readers would do well to act on the ancient motto of Britain's prestigious Royal Society—*nullius in verba*, "don't take anyone's word for it," or more simply, "see for yourself."

Claims that "97 percent of scientists" agree that a climate catastrophe is looming because of the emission of CO_2 should be greeted with skepticism. Traditional science has advanced by comparing observations or experiments with theoretical predictions. If there is agreement with theory, confidence in the theory is increased. If there is disagreement, the theory is abandoned or it is modified and tested again against observations.

Scientific truth has *never* been established by consensus, for example, by "97 percent agreement." History reveals many instances when the scientific consensus of the day was later discredited. The widespread embrace and practice of eugenics in the early 1900s; opposition to the theory of plate tectonics in geology; and the dominance of Lysenkoist biology in the Soviet bloc, are a few recent examples. Given the frequency of mistaken consensus, citizens everywhere should heed the Royal Society's motto and learn as much as they can about how increasing CO_2 levels in the atmosphere will affect the planet.

Overview

Green plants grow faster with more CO_2. Many also become more drought-resistant because higher CO_2 levels allow plants to use water more efficiently. More abundant vegetation from increased CO_2 is already apparent. Satellite images reveal significant greening of the planet in recent decades, especially at desert margins, where drought resistance is critical. This remarkable planetary greening is the result of a mere 30% increase of CO_2 from its preindustrial levels. Still higher CO_2 levels will bring still more benefits to agriculture.

Plants use energy from sunlight to fuse a molecule of CO_2 to a molecule of water, H_2O, to form carbohydrates. One molecule of oxygen O_2 is released to the air for each CO_2 molecule removed. Biological machinery of plants reworks the carbohydrate polymers into proteins, oils and other molecules of life. Every living creature, from the blooming rose, to the newborn baby, is made of carbon from former atmospheric CO_2 molecules. Long-dead plants used CO_2 from ancient atmospheres to produce most of the fossil fuels, coal, oil, and natural gas that have transformed the life of most humans —moving from drudgery and near starvation before the industrial revolution to the rising potential for abundance today.

The fraction of the beneficial molecule CO_2 in the current atmosphere is tiny, about 0.04% by volume. This level is about 30% larger than pre-industrial levels in 1800. But today's levels are still much smaller than the levels, 0.20% or more, that prevailed over much of geological history. CO_2 levels during the past tens of millions of years have been much closer to starvation levels, 0.015%, when many plants die, than to the much higher levels that most plants prefer.

Basic physics implies that more atmospheric CO_2 will increase greenhouse warming. However, atmospheric processes are so complicated that the amount of warming cannot be reliably predicted from first principles. Recent observations of the atmosphere and oceans, together with geological history, point to very modest warming, about 1 C (1.8 F) if atmospheric CO_2 levels are doubled.

Observations also show no significant change in extreme weather, tornadoes, hurricanes, floods, or droughts. Sea levels are rising at about the same rate as in centuries past. A few degrees of warming will have many benefits, longer growing seasons and less winter heating expenses. And this will be in addition to major benefits to agriculture.

More CO_2 in the atmosphere is not an unprecedented experiment with an unpredictable outcome. The Earth has done the experiment many times in the geological past. Life flourished abundantly on land and in the oceans at much larger CO_2 levels than those today. Responsible use of fossil fuels, with cost-effective control of genuine pollutants like fly ash or oxides of sulfur and nitrogen, will be a major benefit for the world.

Introduction

Around the year 1861, John Tyndall, a prominent Irish physicist, discovered that water vapor (H_2O), carbon dioxide (CO_2), and many other molecular gases that are transparent to visible light can absorb invisible heat radiation—such as that given off by a warm tea kettle, the human body, or the Earth itself. Tyndall recognized that water vapor is the dominant greenhouse gases in the Earth's atmosphere, with CO_2 a less important contributor.[1]

Tyndall's discovery came as the combustion of coal in the Industrial Revolution was beginning to release substantial amounts of CO_2. These emissions have coincided with a steady increase of atmospheric CO_2, from around 285 ppm (parts-per-million) in the 1860s to around 400 ppm today.

Increased CO_2 levels have likely produced some warming of the Earth and will continue to do so in the future, although with ever decreasing efficiency because of the "logarithmic" dependence of warming on CO_2 concentrations, an important detail discussed more extensively below. At the same time, more CO_2 will have a hugely beneficial effect on agriculture, forests and plant growth in general. The benefits of more CO_2 will greatly exceed any harm.[2]

Key Findings

Mainstream warming forecasts have been wrong. Over the past two decades, the global warming predicted by climate models has mostly failed to materialize. The real "equilibrium climate sensitivity"—the amount of global warming to be expected for a doubling of atmospheric CO_2—is likely to be about three times smaller than what the models have assumed. Observational data suggest that doubling atmospheric CO_2 levels will increase the surface temperature by about 1 C, not the much larger values that were originally assumed in mainstream models. Using these much smaller, observationally based climate sensitivities, the projected warming from continued use of fossil fuels will be moderate and benign for the foreseeable future.

Negative effects of more CO_2 have been exaggerated. Readily available data from governmental and reliable non-governmental sources confirm that extreme weather events in recent years have not occurred more frequently or with greater intensity. Such data also refute claims of ecologically damaging ocean acidification, accelerating sea-level rises, and disappearing global sea ice and other alleged dangers. If further observations confirm a small climate sensitivity, these realities will not change.

Higher carbon-dioxide levels will be beneficial. CO_2 is an essential nutrient for land-based plants. The Earth's biosphere has also experienced a relative CO_2 famine for many millennia—the recent increase in CO_2 levels has thus had a measurable, positive effect on plant life. Future CO_2 increases will boost agricultural productivity and improve drought resistance, thereby bolstering food security and contributing to a greener, lusher planet.

Global Warming: The Neglected Facts

Most research that tries to project future climate has focused on developing and applying complex computer models that attempt to simulate the Earth's climate system. These models have sought to explain past climate and have been used to calculate various future global and regional climate scenarios. These future climate scenarios have, in turn, prompted policy proposals that would reduce future emissions—thereby, according to the models, limiting future global warming, though admittedly at the cost of reducing future global economic development.

This emphasis on computer model forecasts has been very costly, with many tens of billions of dollars invested but has failed to accurately *predict* the Earth's climate: the United Nations Intergovernmental Panel on Climate Change's (IPCC) estimates of the critical parameter, the equilibrium climate sensitivity, for example, have not become more precise over the past 25 years. **Figure 1** summarizes the IPCC's findings, as documented in its five comprehensive research reports released over more than three decades, as well as the findings of two major pre-IPPC research reports. Since scientific research is generally aimed at reducing uncertainty, the lack of progress over more than three decades is extremely unusual.

Figure 1. Key Findings, IPCC and Pre-IPCC Climate Reports*

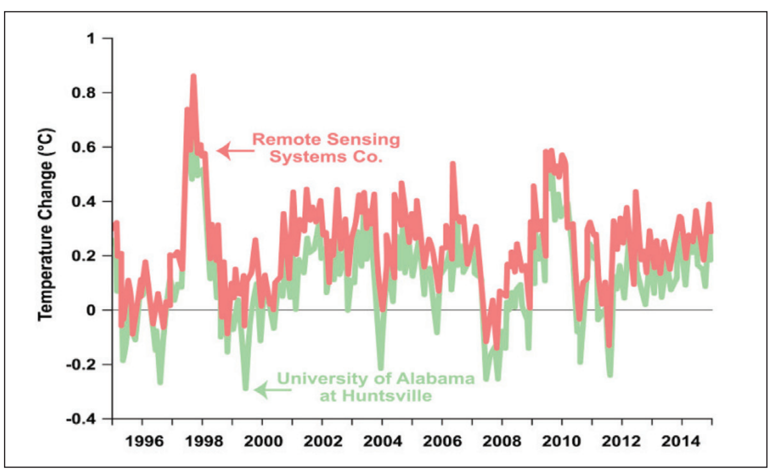
Date	Source	Confidence in Attribution	Equilibrium Climate Sensitivity (C)
1896 & 1938	Arrhenius / Callendar	------	2 – 5.5
1979	Charney Report	------	1.5 – 4.5
1990	IPCC FAR	No quantification of anthropogenic contribution to warming	1.5 – 4.5 (best guess = 2.5)
1996	IPCC SAR	*The balance of evidence suggests a discernible human influence on climate.*	1.5 – 4.5 (best guess = 2.5)
2001	IPCC TAR	*Human-emitted greenhouse gases are likely (67-90% chance) responsible for more than half of Earth's temperature increase since 1951.*	1.5 – 4.5
2007	IPCC AR4	*Human-emitted greenhouse gases are very likely (at least 90% chance) responsible for more than half of Earth's temperature increase since 1951.*	2 – 5.5 (>66% chance correct)
2013	IPCC AR5	*Human-emitted greenhouse gases are extremely likely (at least 95% chance) responsible for more than half of Earth's temperature increase since 1951.*	1.5 – 4.5

*In Figure 1, the far-right column lists successive estimates of the range of the equilibrium climate sensitivity (the "doubling sensitivity," in IPCC reports and two pre-IPCC reports). The range remains unchanged despite costly efforts to invest in reliable computer models. In science—where extensive research over time nearly always reduces uncertainty—this lack of progress is rare.

Source: American Physical Society Climate Change Statement Review framing document (2015), http://www.aps.org/policy/statements/upload/climate-review-framing.pdf.

In science, observational data are the ultimate test of theory and modeling. Climate data show significant divergence between computer predictions and the Earth's actual climate record. **Figure 2** shows average global temperature changes during 1995–2015, as provided by NASA satellite data: despite a 13 percent increase in atmospheric CO_2 levels during this period, there is no statistically discernible warming trend.[3] The climate record is thus at odds with the IPCC's Third (2001) and Fourth (2007) Assessment Reports' forecasts.[4] During this 20-year period, the Earth's atmosphere warmed by only 0.05 C;[5] but computer models predicted a far more dramatic 0.4 C rise in global temperature.[6]

Figure 2. Global Temperature Change as Measured by Satellite, 1995–2015*

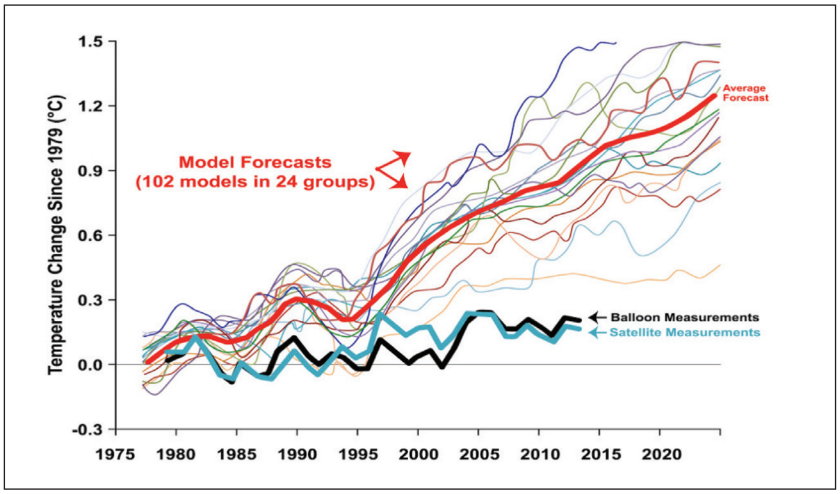


*NASA satellite data for the temperature of the Earth's lower troposphere for the 20-year period 1995-2014. Monthly global temperature is shown relative to the 1981–2010 base-period average. Despite month-to-month volatility, there has been little—or zero—global warming during this period. For more, see Appendix.

Source: Roy W. Spencer, Earth Systems Science Center, University of Alabama at Huntsville.

Figure 3 compares various climate forecasts—specifically, 102 computer climate models used by the IPCC—with the actual change in average tropical atmospheric temperature during 1979–2013, as measured by balloon and satellite. Why focus on tropical atmospheric temperature? Because the Earth's tropical surface and troposphere, the lowest layer of the atmosphere, receive a major portion of the planet's incoming solar energy. The rising warm, humid air from the oceans and rain-forests that cover much of the tropics should lead to especially large warming of the middle troposphere. As Figure 3 demonstrates, actual temperature changes differ dramatically from those predicted by models: the average computer model forecast warming of a full 1 C for the period 1979–2013; in reality, only 0.2 C (at most) has been observed.

Figure 3. Average Change in Tropical Atmospheric Temperature, Forecasts v. Actual, 1979–2013*

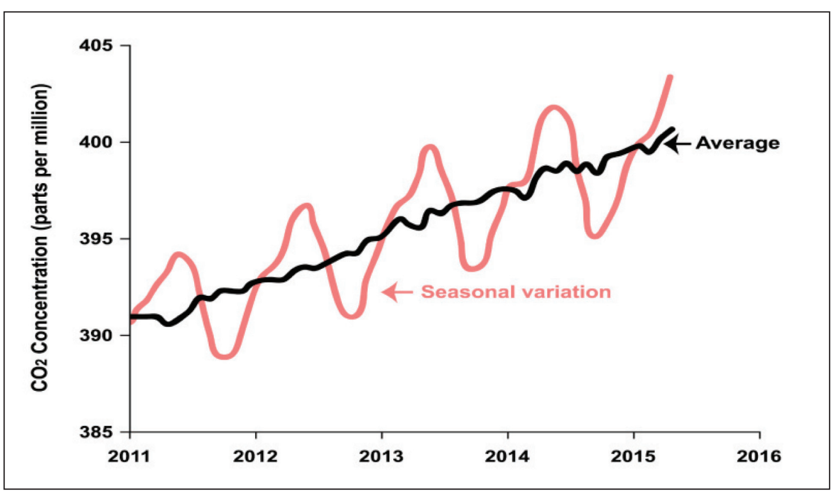


*As measured by satellite and balloon, from the Earth's surface to an altitude of 50,000 feet. Forecasts extend to 2024. For more, see Appendix.

Source: http://docs.house.gov/meetings/II/II00/20150513/103524/HHRG-114-II00-Wstate-ChristyJ-20150513.pdf

Figure 4 shows CO2 concentration measured at Hawaii's Mauna Loa: the long-term rise in CO_2 has seasonal oscillations caused mostly by removal of CO_2 from the air of the northern hemisphere by growing land plants during the summer; and by release of CO_2 during the winter, when respiration of CO_2 by the biosphere exceeds its removal by photosynthesis.

Figure 4. Atmospheric Concentration of CO2, 2011–15*



*Annual CO_2 oscillations represent seasonal variations in the biosphere. The annual growth rate (black line) averages about 2 ppm annually. Annual growth, according to the IPCC, accounts for only about half of CO_2 emissions from human activities; the other half is naturally absorbed by oceans and land. For more, see Appendix.

Source: National Oceanic and Atmospheric Administration

The failure of computer models to reliably predict future temperatures has created a growing awareness that such models are fundamentally flawed—and have greatly exaggerated past and future anthropogenic (man-made) global warming.[7] Indeed, there is good reason to believe that any future anthropogenic warming will be far smaller than projected by the IPCC's models. The best available evidence suggests that the equilibrium doubling sensitivity, the final warming of the surface in response to doubling atmospheric CO_2, is closer to 1 C than to the "most likely" 3 C of mainstream climate models.

The best available evidence also suggests that—despite two periods of 20th century warming, as well as a steady increase in atmospheric CO_2—the frequency of extreme weather events has not risen. And the rise in sea levels has been modest. "Ocean acidification," a slight decrease of the alkalinity of the oceans by a few tenths of a pH unit, will be much less than variations of pH with location, depth and time in today's oceans. Such facts do not support widespread predictions of imminent planetary catastrophe from rising CO_2 levels. Numerous studies suggest that a modestly warmer Earth with more atmospheric CO_2 will be good for all living things.[8]

Benefits of More Carbon Dioxide

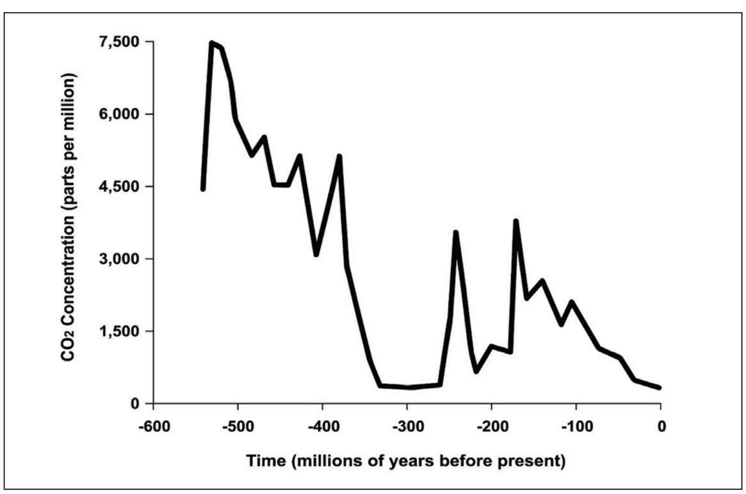
Pure CO_2 gas is chemically inert, transparent, colorless, and odorless. On a cold winter day, chilled air often condenses the water vapor of human breath—of which 4 to 5 percent is CO_2—into visible fog. Such fog, however, is not CO_2. Similarly, water vapor often condenses into clouds of steam over fossil-fuel power plants, creating the impression of smoke. Such steam clouds are not CO_2, either.

Of every million air molecules in today's atmosphere, 400 are CO_2. This average masks wide variation. For example, without strong ventilation, CO_2 levels in crowded indoor spaces, such as classrooms, courtrooms, and trains, commonly reach 2,000 ppm—with no clinically documented ill effects to people. The U.S Navy strives to keep CO_2 levels in its submarines below 5,000 ppm.[9]

On a calm summer day, CO_2 concentrations in a cornfield can drop to 200 ppm, as the growing corn consumes the available CO_2.[10] At a concentration of about 150 ppm or less, many plants die of CO_2 starvation.[11] The differences between the peak winter CO_2 levels and minimum summer CO_2 levels, measured at Hawaii's Mauna Loa volcano (Fig. 4), have increased over the past 50 years. This is believed to be due a global expansion of forests and other plant life.

That Earth has experienced a CO_2 "famine" for millions of years is also not widely known. As illustrated in **Figure 5**, in the 550 million years since the Cambrian period—when abundant fossils first appeared in the sedimentary record—CO_2 levels have averaged many thousands of ppm, that is, much larger than the CO_2 level of 400 ppm today.[12]

Figure 5. CO_2 Levels on Earth: A Long View*



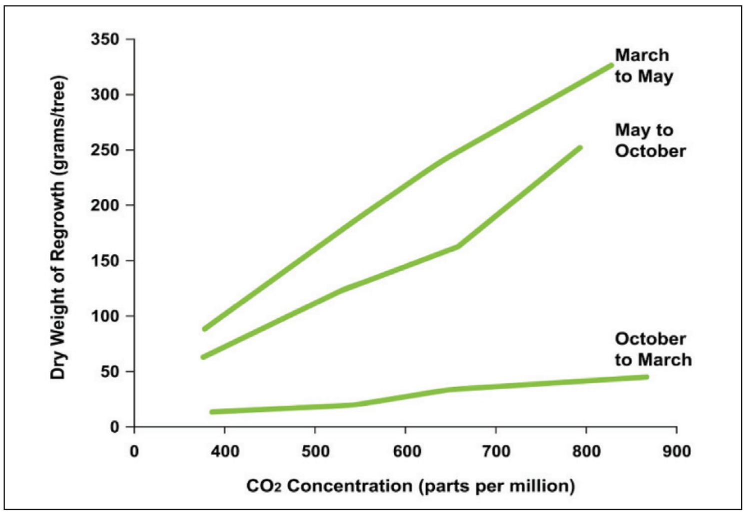
***CO_2 estimates during the Earth's Phanerozoic era are derived from fossil records in sedimentary rocks. A typical Phanerozoic CO_2 level is about 1,500 ppm, considerably higher than today's 400 ppm. For more, see Appendix.

Source: Berner and Kothavala

All animals, including humans, owe their existence to green plants that use energy from sunlight to convert CO_2 and water molecules into carbohydrates, releasing oxygen into the atmosphere in the process. Land plants get the carbon they need from CO_2 in the air, and they obtain other essential nutrients from the soil. Just as plants grow better in fertilized, well-watered soils, they grow better with CO_2 concentrations several times higher than the Earth's current level.[13] For this reason, additional CO_2 is often pumped into greenhouses to enhance plant growth.[14]

Figure 6 illustrates the effect of various levels of CO_2 on the growth of sour orange trees. Because the growth rate of plants is proportional, on average, to the square root of CO_2 concentration, doubling atmospheric CO_2 will increase green plant growth by 40 percent—a boon for crop productivity and, thus, for global food security.

Figure 6. CO_2's Effect on Growth of Sour Orange Trees*



*Measured dry weight of above-ground biomass produced by sour orange trees between specified sequential coppicing dates; and mean atmospheric CO_2 concentration. Figure 6 is a particularly dramatic example of the CO_2 fertilization effect. For more, see Appendix.

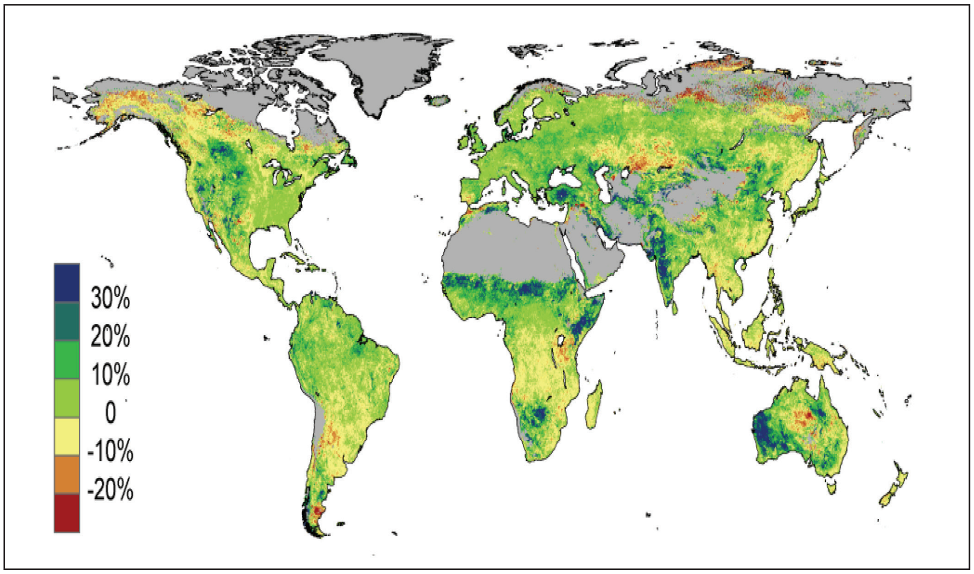
Source: Idso and Kimbal

CO_2's nutritional value is only part of its benefit for plants. No less important is CO_2's contribution to making plants more drought-resistant: plant leaves are perforated by stomata, surface holes that allow CO_2 to diffuse from the atmosphere into the leaf's interior, where they are photosynthesized into carbohydrates. Depending on the relative humidity of the outside air, as many as 100 H_2O molecules can diffuse out of the leaf for each CO_2 molecule that diffuses in. This is why most land plants need at least 100 grams of water to produce one gram of carbohydrate.

The 30% increase in atmospheric CO_2 during the 20th century boosted crop productivity by around 15 percent. Continued improvements in crop variety, fertilizer, and water management—coupled with higher CO_2 levels—will strengthen food security in large parts of Africa and Asia where hunger remains widespread.

Figure 7 shows how the Earth is getting greener. The study from which the image is drawn analyzed plant growth at desert margins and other semi-arid areas and found an 11 percent net growth in foliage ground cover during 1982–2006—growth attributed to improved water-use efficiency arising from higher atmospheric CO_2 levels.[15] The study's authors conclude: "Our results confirm that the anticipated CO_2 fertilization effect is occurring alongside ongoing anthropogenic perturbations to the carbon cycle and that the fertilization effect is now a significant land surface process." As CO_2 levels continue to rise, the Earth will grow greener and agricultural yields will continue to increase, with additional contributions from better varieties, improved cropping practices, more efficient use of fertilizer, and other factors.

Figure 7. Greening of the Earth, 1982–2006*



*Percentage change in foliage cover as revealed by satellite.
Source: Donohue et al

The Developing World

Developing nations in Asia, Africa, and Latin America will need enormous increases in low-cost energy to power their economic development and lift their citizens out of poverty. Fossil fuels—notably coal, natural gas, and oil—which currently supply more than 80 percent of the world's energy, will remain indispensable. As countries grow more affluent, they will also acquire greater means to reduce pollution. Indeed, it is precisely the wealth unleashed by industrialization that enables societies to invest in modern technologies and other practices that clean up the environment.

Further, the best available evidence suggests that current levels—and forseeable future increases—of carbon dioxide are not only harmless, but are indeed beneficial to plants and humans. Quixotic policies to supposedly limit global warming, by making fossil fuels prohibitively expensive, would condemn much of humanity to wretched conditions unimaginable in developed nations.

Initial Members of the CO2 Coalition

BELL, Larry: Launched the research and education program in space architecture at the University of Houston; author of *Climate of Corruption: Politics and Power Behind the Global Warming Hoax.*

COHEN, Roger: PhD in physics, Rutgers University; Fellow of the American Physical Society; former Senior Scientist, ExxonMobil.

EVERETT, Bruce: Faculty, Tufts University's Fletcher School; over forty years of experience in the international energy industry.

HAPPER, William: Cyrus Fogg Brackett Professor of Physics (emeritus), Princeton University; former Director, Office of Energy Research; Director of Research, U.S. Department of Energy; Member, National Academy of Sciences.

HARTNETT-WHITE, Kathleen: Distinguished Senior Fellow in Residence and the Director of the Armstrong Center for Energy and the Environment (CEE) at the Texas Public Policy Foundation.

IDSO, Craig: Founder and Chairman of the Center for the Study of Carbon Dioxide and Global Change; Member of the American Association for the Advancement of Science, American Geophysical Union, and the American Meteorological Society.

LINDZEN, Richard: Emeritus, Alfred P. Sloan Professor of Meteorology; Member, National Academy of Sciences; author of numerous papers on climate and meteorology.

MICHAELS, Pat: Director of the Center for the Study of Science at the Cato Institute; a past president of the American Association of State Climatologists; former Virginia state climatologist; program chair, Committee on Applied Climatology of the American Meteorological Society.

MILLS, Mark: Senior Fellow, Manhattan Institute; Chief Executive Officer, Digital Power Group, a tech-centric capital advisory group; Faculty Fellow, McCormick School of Engineering and Applied Science, Northwestern University.

MOORE, Patrick: Co-founder, Chair, and Chief Scientist, Greenspirit Strategies, a Vancouver-based consulting firm on environmental and sustainability issues; founding member of Greenpeace (nine years as president of Greenpeace Canada and seven years as a director of Greenpeace International).

NICHOLS, Rodney: Former President and Chief Executive Officer of the New York Academy of Sciences; Scholar-in-Residence at the Carnegie Corporation of New York; Executive Vice President of The Rockefeller University; R&D Manager, Office of the Secretary of Defense.

O'KEEFE, William: Chief Executive Officer of the George C. Marshall Institute; founder of Solutions; Executive Vice President and Chief Operating Officer, American Petroleum Institute; Chief Administrative Officer of the Center for Naval Analyses.

ROGERS, Norman: Founder of Rabbit Semiconductor Company; Policy Advisor to The Heartland Institute; member of the American Geophysical Union and the American Meteorological Society.

SCHMITT, Harrison: PhD in Geology from Harvard University; Astronaut and last man to walk the moon (Apollo 17); Adjunct Professor of Physics at the University of Wisconsin-Madison; former U.S. Senator from New Mexico.

SPENCER, Roy: Climatologist, Principal Research Scientist at the University of Alabama in Huntsville; served as Senior Scientist for Climate Studies at NASA's Marshall Space Flight Center; Co-Developer of satellite temperature measurement system.

STEWARD, Leighton: Geologist; Environmentalist; Author; Chairman of Plants Need CO2.org; Chairman of the Board of The Institute for the Study of Earth and Man at SMU; past Chairman of the National Wetlands Coalition; twice Chairman of the Audubon Nature Institute.

YAPPS-COHEN, Lorraine: M.S. in chemistry and an M.B.A. in marketing; former Communications & Marketing Manager, ExxonMobil; columnist for the Examiner newspapers.

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