The Real Truth about Greenhouse Gases and Climate Change:
Paragraph-by-Paragraph Comments on an Article by Dr. William Happer

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Dr. William Happer, the Cyrus Fogg Brackett Professor of Physics at Princeton University, who also serves as Chairman of the Board of Directors of the Marshall Institute in Washington DC, has been a prominent and outspoken critic of the science of climate change, its impacts, and proposed policies to deal with it. In the June/July 2011 issue of *First Things*, Dr. Happer published a summary of his views: "The Truth About Greenhouse Gases: The dubious science of the climate crusaders" (see http://www.firstthings.com/article/2011/05/the-truth-about-greenhouse-gases). The paper is so misleading that, in my view, it merits a paragraph-by-paragraph response. Indeed, being an alumnus of Princeton University and having devoted my career to study of climate change science, preparing a response almost seemed an obligation.

In offering these comments, my intent is to present the findings and perspectives of the national and international science community, illuminated with insights gained over more than four decades of seeking to improve understanding of how the Earth system works and is affected by natural and human events. In contrast to Dr. Happer's view that the science of climate change is like a house of cards (i.e., find one flaw and the whole sense of understanding will fall), I have tried to give a sense of why, as Professor Henry Pollack of the University of Michigan has put it, the science of climate change is like a rope hammock (i.e., with lots of interconnections and linkages, such that weaknesses or failure of any particular detailed finding does not weaken the overall strength of scientific understanding).

Unless footnoted, the views I have offered are primarily drawn from IPCC's Fourth Assessment Report and/or from perspectives on climate change that are summarized at http://www.climate.org/topics/climate-change/science-in-six-findings.html and references, including a review paper, that can be downloaded from that site.

The full set of points made by Dr. Happer is included below, in paragraph-by-paragraph order, with my comments on each paragraph immediately following. To assist in referring to Dr. Happer's various paragraphs, I have numbered the paragraphs sequentially, and my response is provided in italics. To provide a sense of the issues

covered, the table gives a sense of the questions that an independent moderator might ask that would lead to the exchange regarding each paragraph, and the reader may want to use this to jump to comments and responses on a topic of particular interest.

A key to Will Happer's assertions and Mike MacCracken's responses:

1. Is the climate change community really off on a "climate crusade"?

2. Is CO_2 a pollutant or a vital molecule for life on Earth—or both?

3. On what basis is EPA moving to regulate CO_2?

4 through 7. Isn't CO_2 a nutrient for plants? Don't we really want to have a higher CO_2 concentration? Wasn't the CO_2 level actually nearly too low? Won't more CO_2 be beneficial?

8 and 9. How high can the CO_2 level be without impacting human health? What is the optimal range for the CO_2 concentration?

10 and 11. Is the increasing CO_2 concentration really having adverse impacts?

12 and 13. Will increasing CO_2 really cause warming? Is it really human activities causing the warming?

14 through 17. What does the history of Earth's climate tell us over centuries to tens of millions of years? Hasn't the Earth's climate always been changing? So what makes the present warming significant?

18, 19, and 20. Has the IPCC really considered what has been learned from the study of Earth's climatic history?

21 and 22. Is the "hockey stick" curve indicating recent warming really solid? Don't the hacked emails show that climate data were manipulated?

23, 24 and 25. Has peer-review been compromised? Isn't it biased?

26. Will the warming in response to the rising CO_2 concentration be significant? How fast will these changes be occurring?

27. Will shifting to renewables enrich a few with political ties at the expense of the majority?

28, 29 and 30. Are computer models reliable enough to depend on? Aren't they tuned and therefore unreliable? Can they really be used to project into the future?

31, 32, and 33. What has led to climate change being seen as so controversial? Has the science been co-opted by politics? How large is the funding for climate change research?

34 and 35. Are the views of those who are critical of the climate change results being suppressed? Aren't their reputations being impugned?

36, 37, and 38. Are professional societies being corrupted by the climate change proponents? Has the American Physical Society misrepresented the views of its members?

39, 40 and 41. Is the public getting a balanced picture of climate change science? What is the trend in public understanding and viewpoint? Is the public just being rushed to judgment?

42 and 43. Aren't there other environmental problems more deserving of emphasis than climate change? Where should the attention lie?

The Real Truth About
Greenhouse Gases and Climate Change

Comments by Michael MacCracken (MCM) on the article by Will Happer (the Author)

1. The object of the Author in the following pages has been to collect the most remarkable instances of those moral epidemics which have been excited, sometimes by one cause and sometimes by another, and to show how easily the masses have been led astray, and how imitative and gregarious men are, even in their infatuations and crimes," wrote Charles Mackay in the preface to the first edition of his *Extraordinary Popular Delusions and the Madness of Crowds*. I want to discuss a contemporary moral epidemic: the notion that increasing atmospheric concentrations of greenhouse gases, notably carbon dioxide, will have disastrous consequences for mankind and for the planet. The "climate crusade" is one characterized by true believers, opportunists, cynics, money-hungry governments, manipulators of various types—even children's crusades—all based on contested science and dubious claims.

   Comment (MCM): *At least we can agree that the issue of climate change raises issues that have a moral dimension. With respect to Dr. Happer's last sentence, his view must be obscured by the fellow objectors that seem to crowd around whenever a highly educated scientist takes objection to climate change science. Where in his list, for example, does he place the Intergovernmental Panel on Climate Change with its hundreds of leading scientists and thousands of expert reviewers, the 190+ governments that participate and have unanimously endorsed its findings through four rounds of international science assessments, the national academies of science of all the leading nations, the many dozens of leading professional societies, and more? Are all of these entities somehow more opportunistic, cynical, money-hungry, and manipulative than the leaders of the fossil fuel companies that had a hidden strategy to sow uncertainties, than the supposedly independent individuals and organizations that get major support from the fossil fuel companies and have as a major purpose the critiquing climate change science, than the non-scientific believers that climate change cannot be man-made, and than the coal companies funding curricula and the teaching of the benefits of coal to elementary school children. Of course excessive comments are made, on both sides, but for Dr. Happer to suggest that the entire set of nations and international scientific organizations has been corrupted and is off on a crusade is insulting demagoguery and not at all the opening basis for the type of rational discussion that the public deserves and expects from those in the scientific community.*

2. I am a strong supporter of a clean environment. We need to be vigilant to keep our land, air, and waters free of real pollution, particulates, heavy metals, and pathogens, but carbon dioxide (CO_2) is not one of these pollutants. Carbon is the stuff of life. Our bodies are made of carbon. A normal human exhales around 1 kg of CO_2 (the simplest chemically stable molecule of carbon in the earth's atmosphere) per day. Before the industrial period, the concentration of CO_2 in the atmosphere was 270

ppm. At the present time, the concentration is about 390 ppm, 0.039 percent of all atmospheric molecules and less than 1 percent of that in our breath. About fifty million years ago, a brief moment in the long history of life on earth, geological evidence indicates, CO_2 levels were several thousand ppm, much higher than now. And life flourished abundantly.

Comment (MCM): *First, when a scientist asserts we know a value from the past with more accuracy than at present (i.e., "was 270 ppm," and with no specified time reference given, versus "about 390 ppm" at present), it is good to be cautious. Generally, air bubbles trapped in glacial ice indicate that the CO_2 concentration in the nearly 10,000 years of the Holocene (the era since the end of the last glacial period) has been in the range of roughly 270 to 280 ppm, being closer to 280 ppm just before the start of the Industrial period in about 1750. Second, with respect to Dr. Happer's citing of much higher CO_2 concentrations many tens of millions of years ago, that is widely agreed (although timing and values are still quite uncertain), but he neglects to add that the global climate then was very different, being warm enough for what is now tropical vegetation in polar latitudes. In addition, all indications are that those very high concentrations of CO_2 contributed strongly to the much higher global average temperature that existed at the time. Over the next century or two, continued use of fossil fuels and the resulting emissions of CO_2 have the potential to very rapidly increase the CO_2 concentration, to significantly increase temperatures around the world, and for this to occur so rapidly that natural processes cannot work fast enough to neutralize the acidification of the oceans that is likely to seriously disrupt marine ecosystems.*

On the issue of whether or not CO_2 is a pollutant (as opposed to just a climate-changing agent), Dr. Happer is on the one hand stating the obvious (CO_2 is vital to plant life, which is vital to sustain human and animal life. However, he is also, by inter-mixing colloquial and legal terminology, seeking to justify taking exception to a very important conclusion in the 2007 Supreme Court ruling that he discusses in the next paragraph. In making the point that humans exhale CO_2 to justify that it is not a pollutant, he fails to add that this occurs because humans can die from their blood carrying too much CO_2. As for many other substances, too little is a problem (in this case, not enough for plants to grow), too much is a problem (in this case, humans and animals die from too much), and we are dependent on the atmospheric CO_2 concentration being within a safe range.

3. Now the Environmental Protection Agency wants to regulate atmospheric CO_2 as a "pollutant." According to my *Webster's New Collegiate Dictionary*, to pollute is "to make or render unclean, to defile, to desecrate, to profane." By breathing are we rendering the air unclean, defiling or desecrating it? Efforts are underway to remedy the old-fashioned, restrictive definition of pollution. The current Wikipedia entry on air pollution, for example, now asserts that pollution includes: "carbon dioxide (CO_2)—a colorless, odorless, non-toxic greenhouse gas associated with ocean acidification, emitted from sources such as combustion, cement production, and respiration."

Comment (MCM): *The Environmental Protection Agency does what the law says, and given the many lawsuits against it by environmental groups, the problem is generally that it moves too slowly rather than too fast. In the particular matter Dr. Happer is referring to, the Clean Air Act was first enacted by Congress about 40 years ago and it underwent major reworking about 20 years ago—it is the well-established law of the land and has been the basis for air quality improvement over the past four decades. In defining what was to be regulated, the Act defined what characteristics would lead to a substance being called a "pollutant," and then used that word throughout the Act. After a number of years in the courts, a case filed by Massachusetts and a number of other states and environmental groups describing how CO2-induced climate change was harming them rose to the Supreme Court, the question at issue was whether the characteristics of a pollutant, as defined in the law (and not the dictionary), applied to fossil-fuel related emissions of CO2 [disclosure: I was the author of the declaration on the science and impacts of CO2-induced climate change in support of the plaintiffs' (i.e., the states') argument for standing in Massachusetts et al. vs. EPA]. Justice Stevens, writing for the majority, ruled that the states had standing to file their complaint and that, under the legal language in the law, CO2 should be regulated in the same way as traditional pollutants.*

Even though recent leaders of EPA have asked Congress to enact provisions that would better apply to CO2 than existing provisions, this has not happened (likely in part due to the misleading representation of the science by Dr. Happer and those offering similar views). Without such language, EPA is ***required*** *to apply the Clean Air Act's provisions to CO2, and they have been slowly starting to do this [disclosure: I am author of a declaration in support of EPA's Endangerment Finding and, in a separate case, calling for EPA to take action to limit CO2 emissions from cement plants, the third largest stationary source category and one for which technologies exist to limit emissions]. In seeming to suggest that there is no difference between the fossil-fuel-related emissions of CO2, which increase the atmospheric CO2 concentration, with the CO2 that we breathe out, which does not because that CO2 comes from food that pulled CO2 out of the atmosphere. Dr. Happer is really being misleading, rather like suggesting that there is no difference between depositing a check from your employer and depositing cash from your wallet that had earlier been taken out at an ATM.*

4. As far as green plants are concerned, CO2 is not a pollutant, but part of their daily bread—like water, sunlight, nitrogen, and other essential elements. Most green plants evolved at CO2 levels of several thousand ppm, many times higher than now. Plants grow better and have better flowers and fruit at higher levels. Commercial greenhouse operators recognize this when they artificially increase the concentrations inside their greenhouses to over 1000 ppm.

Comment (MCM): *For the concentrations likely to be reached this century and perhaps the next, at least some categories of plants do have the potential to grow significantly better with a higher CO2 concentration. To really grow better, however, these plants require a balanced diet, not too much or too little water, sunlight, nitrogen, and other essential elements. Commercial greenhouse operators*

not only increase the amount of CO2, but also the supply of other nutrients, and they keep the temperature and other factors in optimal ranges. With CO2-induced climate change, other factors important to plants also change: the temperature increases and so optimal climatic conditions may well come at times of the year with sub-optimal levels of sunlight and water, and, to the extent their range shifts, less than optimal soil conditions. Simply saying that a higher CO2 level makes the situation better for plants is thus a misleading oversimplification.

5. Wallis Simpson, the woman for whom King Edward VIII renounced the British throne, supposedly said, "A woman can't be too rich or too thin." But in reality, you can get too much or too little of a good thing. Whether we should be glad or worried about increasing levels of CO2 depends on quantitative numbers, not just qualitative considerations.

   Comment (MCM): *Agreed—and not just the CO2 concentration. The success of crops, trees, and other plants will also depend on what happens to the pests, diseases, and predators they face; on the competition from other species that are responding; on changes in the populations of soil organisms that fix nitrogen for use by plants; on the rate of climate change, which will determine how rapidly they will have to respond or shift ranges; and more. It is important to be quantitative, but also to consider all sorts of interconnections and linkages.*

6. How close is the current atmosphere to the upper or lower limit for CO2? Did we have just the right concentration at the preindustrial level of 270 ppm? Reading breathless media reports about CO2 "pollution" and about minimizing our carbon footprints, one might think that the earth cannot have too little CO2, as Simpson thought one couldn't be too thin—a view which was also overstated, as we have seen from the sad effects of anorexia in so many young women. Various geo-engineering schemes are being discussed for scrubbing CO2 from the air and cleansing the atmosphere of the "pollutant." There is no lower limit for human beings, but there is for human life. We would be perfectly healthy in a world with little or no atmospheric CO2—except that we would have nothing to eat and a few other minor inconveniences, because most plants stop growing if the levels drop much below 150 ppm. If we want to continue to be fed and clothed by the products of green plants, we can have too little CO2.

   Comment (MCM): *Agreed, having less than 150-200 ppm of CO2 in the atmosphere would be problematic for plants, and so for food. And when these low levels have occurred over the past million years (concentrations derived from bubbles in Antarctic ice cores), the average temperature of the Earth has been roughly 6°C (roughly 11°F) colder with continental scale ice sheets and sea level lower by 120 meters (almost 400 feet). So, yes, CO2 is important for food supplies, and for the environmental conditions that we face.*

7. The minimum acceptable value for plants is not that much below the 270 ppm preindustrial value. It is possible that this is not enough, that we are better off with our current level, and would be better off with more still. There is evidence that

California orange groves are about 30 percent more productive today than they were 150 years ago because of the increase of atmospheric CO_2.

Comment (MCM): *Were the effects of increased CO_2 only to enhance plant growth, then Dr. Happer's comments make a useful point. But, as he well knows as a physicist, he is presenting a partial derivative as if it were the total derivative (that is, he is considering only how plants might change with a change in the CO_2 concentration, and ignoring the total array of dependencies of ecological well-being on climate, ocean acidification, ecosystem interactions, and other factors). For the health of the global environment, from which society draws many ecological services, there needs to be a balance among a quite broad range of variables, and given that plants and animals have evolved based on particular niches in the prevailing climate and environment, it should not be surprising that rapidly changing the set of variables in disparate ways might have the potential for very significant disruption.*

8. Although human beings and many other animals would do well with no CO_2 at all in the air, there is an upper limit that we can tolerate. Inhaling air with a concentration of a few percent, similar to the concentration of the air we exhale, hinders the diffusional exchange of CO_2 between the blood and gas in the lung. Both the United States Navy (for submariners) and NASA (for astronauts) have performed extensive studies of human tolerance to CO_2. As a result of these studies, the Navy recommends an upper limit of about 8000 ppm for cruises of ninety days, and NASA recommends an upper limit of 5000 ppm for missions of one thousand days, both assuming a total pressure of one atmosphere. Higher levels are acceptable for missions of only a few days.

   Comment (MCM): *Health-related limits on atmospheric "pollutants" (i.e., substances that have the potential to have harmful effects on people) are not set based on the level that some of the healthiest people in society (i.e., submariners and astronauts) can withstand in situations where their health is frequently monitored and there is a significant cost for carrying equipment that could keep concentrations lower. Instead, health-related levels are set based on the situation facing the most vulnerable in our society, typically meaning babies, the sick, and the elderly. The reason some need oxygen for breathing is, at least in part, so that there is enough oxygen to make up for the slow removal of CO_2 from a person's system. Already, ventilation systems of buildings are designed to ensure that a harmful build-up will not occur for sensitive people, and that concentration is fortunately well below the levels for the most healthy among us.*

9. We conclude that atmospheric CO_2 levels should be above 150 ppm to avoid harming green plants and below about 5000 ppm to avoid harming people. That is a very wide range, and our atmosphere is much closer to the lower end than to the upper end. The current rate of burning fossil fuels adds about 2 ppm per year to the atmosphere, so that getting from the current level to 1000 ppm would take about 300 years—and 1000 ppm is still less than what most plants would prefer, and much less than either the NASA or the Navy limit for human beings.

Comment (MCM): *Dr. Happer's proposed upper limit is far too high, as explained above—perhaps Dr. Happer should try living at that CO2 level for a while, and take an elderly person with him. On the rate of rise that he cites, the rate has already moved to above 2 ppm/year and will increase further if increasing amounts of fossil fuels are used to meet the energy needs of the world's poor. For the time period to get to 1000 ppm to be 300 years, as Dr. Happer suggests, not only would emissions have to be no higher than they were in the year 2000, but the carbon-uptake rates for the oceans and biosphere would also have to be unaffected by the increase in CO2 and climate change, and there are a number of reasons that this is unlikely to be the case. A more likely time to get to 1000 ppm is 150 years if emissions continue to increase as is projected without emissions controls.*

A much more stringent upper bound to the atmospheric concentration also results from concerns about ocean acidification—the second carbon problem. As the atmospheric CO2 concentration rises, CO2 is forced into the ocean to maintain a chemical equilibrium. This has the effect of changing ocean chemistry, just as injecting CO2 into sodas lowers their pH, making them more acidic. These chemical changes are important because they affect the ability of fish and shellfish to make their skeletons and shells and the chemical stability of calcium carbonate deposits and coral reefs. The decrease in pH being induced by the rising CO2 concentration is most important initially in colder waters (warm waters hold less CO2, though it still rises as the atmospheric concentration rises). Observations indicate that the depth at which shells and sediments dissolve has been rising toward the surface as the CO2 concentration has risen. Already, deeper waters with a reduced pH are pushing up onto the continental shelf in the Pacific Northwest and the more acidic waters are adversely impacting aquaculture farming (e.g., production of clams, etc.).

At the preindustrial CO2 level, virtually all near-surface coral was located in regions defined primarily by a relatively high ocean pH. With a continuing rise of the CO2 concentration, there will be no ocean areas with suitably favorable oceanic pH by the latter half of the 21st century. That coral survived the very high concentrations tens of millions of years ago was likely mainly a result of the lower pH if the precipitation having eroded enough of the exposed rock to provide chemical buffering of ocean waters (basically, over very long times, the low pH rain slowly provided enough antacids to the oceans to relieve their acidity). The problem with what is occurring is that the change in the CO2 concentration is occurring so fast that this is not possible, nor does it appear possible for some geoengineering approach to emerge that could buffer anything close to the global ocean. It may well be that some species of coral can adapt to the changing conditions, but, based on the risks from ocean acidification, the upper limit for the atmospheric CO2 would best be no more than about 400-450 ppm—and we are, unfortunately, very nearly at those levels.

10. Yet there are strident calls for immediately stopping further increases in CO2 levels and reducing the current level. As we have discussed, animals would not even notice a doubling of CO2 and plants would love it. The supposed reason for limiting it is to stop global warming—or, since the predicted warming has failed to be nearly as large

as computer models forecast, to stop climate change. Climate change itself has been embarrassingly uneventful, so another rationale for reducing CO2 is now promoted: to stop the hypothetical increase of extreme climate events like hurricanes or tornados. But this does not necessarily follow. The frequency of extreme events has either not changed or has decreased in the 150 years that CO2 levels have increased from 270 to 390 ppm.

Comment (MCM): *Dr. Happer needs to take a trip to the Arctic, to Greenland, to the Antarctic, to low-lying islands, to the changing limits of many plant and animal species, and more to see how climate change is altering conditions around the world. Sea ice retreat is leading to increased erosion of the barrier islands where Indigenous Peoples have lived safely for thousands of years—the amount of retreat is unprecedented in at least historical times. Despite model-based projections summarized by the IPCC in its third and fourth assessments that the Greenland and Antarctic ice sheets would not start losing significant mass during the 21st century, both are already losing mass at surprisingly large rates. Loss of mass of ice from mountain glaciers and ice sheets along with expansion of the warming oceans have roughly doubled the average rate of sea level rise during the 20th century, and the recent rapid movement of some glacial outflows suggests that the rate will rise further as climate change increases, further accelerating sea level rise and creating increasingly severe problems for low lying islands.*

The ranges of plant and animal species are shifting, predominantly due to factors consistent with climate change being the driving factor. And with respect to extremes, an increasing fraction of precipitation is coming as heavy precipitation, which can create flooding problems when precipitation zones shift into geographic regions not suited to downpours. During the periods between precipitation events, warmer temperatures are leading to greater evaporation and more rapid transition to dry conditions, especially as the subtropics expand.

With respect to the amount of observed warming as compared to model projections, there is actually quite good agreement when one accounts for all of the factors that can affect the climate and how emissions have changed with respect to those projected when the model simulations were done. For example, in the 1980s and early 1990s, model projections assumed that the emissions of CFCs would be continuing—something that changed with the international approval of the Montreal Protocol and subsequent amendments. Many early simulations also were interpolations between equilibrium simulations without properly accounting for the thermal inertia of the ocean. The range of estimates among model projections is now primarily due to differences in assumptions about how the world's future energy system will develop—heavily or modestly based on use of fossil fuels.

11. Let me turn to some of the problems the non-pollutant CO2 is supposed to cause. More CO2 is supposed to cause flooded cities, parched agriculture, tropical diseases in Alaska, etc., and even an epidemic of kidney stones. It does indeed cause some warming of our planet, and we should thank Providence for that, because without the greenhouse warming of CO2 and its more potent partners, water vapor and clouds, the earth would be too cold to sustain its current abundance of life.

Comment (MCM): *Dr. Happer makes very light of some very serious studies, and gives no indication of the time scales for such impacts. Estimates of sea level rise taking account of the potential for ice stream dynamics suggest an increase of sea level of 1 meter (about 3 feet), plus or minus 50%, by 2100 and continuing thereafter. There are quite a number of coastal cities where this would be very problematic, especially when this amount of rise is added to current high water situations (high tides, storm surges, etc.). Perhaps Dr. Happer would like to live in southern Florida, the underlying rock for which is limestone, so building levees will not prevent seawater from channeling in underneath. Or perhaps on an island in the Sacramento-San Joaquin delta, or in southern Louisiana, or even in New York City where high-water situations currently reach near subway entrances, or many other places along the US coastline, not to mention low lying locations around the world.*

Or perhaps he'd like to buy up the farms being lost due to severely dry conditions in western Texas or southern Australia. Calling such situations drought is optimistic, for the dry conditions are going to become the norm and wet years the exception. And Dr. Happer presumably does not visit the pine forests of the west, which are being killed off because the pine bark beetle and other pests can now survive the warmer winters, overwhelming the natural defenses of trees that have made up western forests for millennia.

Tropical disease may not yet have reached Alaska, but such diseases are starting to expand their ranges. It will take the careful diligence of the public health community, with funds to cover their defensive measures, to keep such diseases at bay.

12. Other things being equal, more CO2 will cause more warming. The question is how much warming, and whether the increased CO2 and the warming it causes will be good or bad for the planet.

Comment (MCM): *No one questions that the planet will survive or that some forms of life will continue. The question is if, in response to geologically and historically very rapid climate change and ocean acidification, the environment and society will continue in ways that sustain human populations and provide the necessary and sufficient ecological services for this to occur, for those living today and for future generations. Whether New York City or London or Bangladesh is lost to rising sea level has little bearing on the planet, but would have tremendous implications for those living there, especially if the rate of change is nearly as fast as projected.*

13. The argument starts something like this. CO2 levels have increased from about 280 ppm to 390 ppm over the past 150 years or so, and the earth has warmed by about 0.8 degree Celsius during that time. Therefore the warming is due to CO2. But correlation is not causation. Roosters crow every morning at sunrise, but that does not mean the rooster caused the sun to rise. The sun will still rise on Monday if you decide to have the rooster for Sunday dinner.

Comment (MCM): *That a supposedly well-informed scientist would say this is astounding, or perhaps unethical—a student being so ignorant of the very careful analyses that have been done would get a failing grade. Specifically, the results of increasingly detailed 'fingerprint' analyses have been described in each of the last three IPCC assessments. These analyses carefully analyze and decompose the temporal, altitudinal, latitudinal, and, increasingly, geographic patterns of change into the most likely contributions from each of the potentially important natural and human-induced causes of change, and then compare observed changes with those that are expected.*

As just the simplest example, were an increase in solar radiation causing the warming, the expectation would be that the stratosphere and surface-troposphere layers would warm. That is not the case—the stratosphere is cooling! A warming surface/troposphere and a cooling stratosphere turns out to be the fingerprint of an increase in the concentrations of greenhouse gases. The fingerprints of volcanic eruptions, tropospheric aerosols, and increasingly ozone depletion have each been identified. Their comparative roles can then be determined over time by quantitatively relating observations to how, for example, solar radiation is changing, volcanic eruptions are occurring, greenhouse gas concentrations are rising, etc. These fingerprint analyses are being carried out not only for temperature amounts and patterns, but also for water vapor and other climatic variables. It is the coherence of all of these analyses and the quantitative relationships that are used to determine comparative roles of natural and human-induced factors. It is these very careful studies that give high confidence that the observed changes (which are far more detailed than that the global average temperature has increased about 0.8°C) are predominantly due to human activities, primarily the increasing use of fossil fuels.

14. There have been many warmings and coolings in the past when the CO_2 levels did not change. A well-known example is the medieval warming, about the year 1000, when the Vikings settled Greenland (when it *was* green) and wine was exported from England. This warm period was followed by the "little ice age" when the Thames would frequently freeze over during the winter. There is no evidence for significant increase of CO_2 in the medieval warm period, nor for a significant decrease at the time of the subsequent little ice age. Documented famines with millions of deaths occurred during the little ice age because the cold weather killed the crops. Since the end of the little ice age, the earth has been warming in fits and starts, and humanity's quality of life has improved accordingly.

Comment (MCM): *It is true that the climate has been quite different at different times in Earth history. Independent of the causes of the changes, that the climate has changed so much should imbue a great sense of caution, for it means that the climate can change, and to very different conditions. During the coldest extremes over the last million years, an ice sheet a mile or more thick covered North America down to south of the Great Lakes; during warm extremes tens of millions of years ago, there is evidence that palm trees grew in arctic regions. That climatic variations over the last 8,000 years were more modest played an important role in allowing societies to become productive enough to devote some of their resources to*

improving human well-being instead of having to devote all of a society's resources to continually adjusting to rapidly changing conditions.

Even with global conditions being fairly stable, with global average temperatures likely varying by less than about 1°C, there have been important regional fluctuations in climate over the last 8,000 years that not all civilizations survived. For example, not only did the colonies on Greenland die off because they were unable to adapt, but so did societies in Latin America and the southwestern U.S. and others around the world. So, history clearly teaches that climate can change, that even small changes in the global climate can lead to very disruptive regional changes, and that successful adaptation can require resources and is not guaranteed.

Extensive research into Earth's climatic history has started to reveal the factors that have caused changes in the climate and how sensitive the climate is to changes in these factors. Over periods of tens to hundreds of millions of years, the continents have moved across the face of the Earth, widening and shrinking oceans, and raising and lowering mountain chains. Evidence derived from changes in the types of minerals being deposited indicates that changes in atmospheric composition were also occurring, and as Dr. Happer indicated, the CO2 concentration was several times higher than at present several tens of millions of years ago, especially during the period greater than 65,000,000 years ago when dinosaurs roamed jungle covered continents up toward the poles.

Over periods from 10,000 to several million years, there are additional factors that are well correlated with changes in the climate. Cores derived from ocean sediments and ice sheets are now yielding considerable information about changes over nearly the last million years, and ocean cores and geological information are providing information back a hundred million years and more. Over the last couple of million years, the Earth has cycled between glacial and interglacial conditions with periodicities that quite well match seasonal and geographic shifts in solar radiation reaching the top of the atmosphere as a result of cyclic changes in the Earth's orbit around the Sun. These cycles are caused by the changing ellipticity (circularity) of the Earth's orbit (cycle of about 413,000 years with a major subcycle at about 100,000 years) that shortens some seasons and lengthens others, the tilt of the Earth's axis (cycle of about 41,000 years) that latitudinally redistributes incoming solar radiation and thus alters the intensity of the seasons, and the precession of the Earth's orbit (cycle of about 21,000 years), which affects the time of year when the Earth is closest to the Sun, changes seasonal contrasts and affects the relative amount of energy going to the Northern and Southern Hemispheres.

But there must be more to this cycling (which has caused the Earth to be colder than at present roughly 90% of the time) or it would have caused glacial cycling back many tens of millions of years. Such cycles, however, are not evident over time scales of hundreds of millions of years, during which the Earth has been warmer than at present roughly 90% of the time. Ice cores indicate that one contributing factor appears to be changes in the atmospheric concentrations of CO2 and CH4, both of which are greenhouse gases. That the changes in the concentrations of these gases lag the changes in solar radiation (driven by orbital element cycling) suggests that, on these time scales, the changes in atmospheric

composition are serving as amplifying (or positive) feedbacks. That colder oceans hold more CO2 than warmer is very likely one contributor to the positive feedback; changes in the rates of ocean overturning, biological activity on land and in the ocean, capping of polar seas by sea ice, and other processes are also likely contributing, although much remains to be worked out. Other processes that appear likely to be contributing to overall glacial-interglacial cycling include the slow up and down movement of the land surface as the glacial thickness atop the land changes, and changes in the distribution of vegetation, which can affect surface reflectivity and other factors.

For the last 8,000 years, the relative stability of the climate suggests that fluctuations in solar radiation (exhibited, for example, by the sunspot cycle), in the frequency of volcanic eruptions, and in internal oscillations and feedbacks have a pretty limited ability to change the climate compared to the factors contributing to glacial-interglacial cycling. Asserting that changes in these influences are the primary explanation for recent climate change would seem to necessitate explaining how Nature decided to exert these influence just during the Industrial Revolution and not for the preceding 8,000 years.

Over the last century or two, and quite possibly longer, human influences have gradually become the dominant influence. Release of CO2 as a result of deforestation, agricultural expansion and particularly combustion of fossil fuels has become the dominant influence since the start of the Industrial Revolution, with additional contributions resulting from changes in the concentrations of CH4 and N2O and the loading of aerosols from SO2, black carbon, and other emissions. While the detection-attribution analyses of recent climate change do show an influence from variations in natural factors, observational and climate model analyses indicate that these natural forcings are too small to be causing the strong warming over the last four decades.

With respect to the Medieval Warm Period and the Little Ice Age mentioned by Dr. Happer, both of which were apparently most strongly expressed in the North Atlantic basin, the causes are not yet well established. While the presumption is that the fluctuations were due to natural factors, human activities, particularly changes in the CH4 concentration and land cover may well also have contributed. For example, reconstruction of the methane record indicates that there was a significant decrease in the methane concentration during the Little Ice Age that may have resulted from the sharp reduction in agriculture and biomass burning as a result of the deaths of most Native peoples in North and South America by contagious disease following the European conquest.[1]

Finally, with regard to Dr. Happer's suggestion that warm climates are better for society than cold ones: while this is a defensible position for countries surrounding the North Atlantic, there is no basis for thinking that several times greater warming over coming decades would also be beneficial. Were the development of societies mainly determined by warmth, one would expect that

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[1] Ferretti, et al., 2005: Unexpected Changes to the Global Methane Budget over the Past 2000 Years, *Science* **309**, 1714.

countries in the tropics would have been and would be the world's economic leaders.

15. A rare case of good correlation between CO_2 levels and temperature is provided by ice-core records of the cycles of glacial and interglacial periods of the last million years or so. But these records show that changes in temperature preceded changes in CO_2 levels, so that the levels were an effect of temperature changes. This was probably due to outgassing of CO_2 from the warming oceans and the reverse effect when they cooled.

Comment (MCM): *Dr. Happer has the timing right—and he is correct that the changes in temperature correlated with (and very likely caused by) the cyclic changes in orbital parameters occurred prior to the changes in the CO_2 concentration, and that the rise in the CO_2 concentration was likely caused by out-gassing of CO_2 from the warming ocean. What he fails to note is that analyses of the factors contributing to the glacial cycling find that the warming influence of the increase in CO_2 is an essential amplifying feedback needed to explain the magnitude of the glacial to interglacial shift, just as a decrease in the CO_2 concentration is essential to explaining the transition from interglacial to glacial conditions.*

With respect to the situation that we face at present, these lessons are both confirmatory and disturbing. The confirmatory lesson is that an increase in the CO_2 concentration contributes to warming—that the present increase occurs due to injection of fossil fuel CO_2 rather than outgassing from the ocean makes no difference in the climatic influence, and the responsiveness of the climate system would be expected to be (and is calculated to be) about the same for the glacial-interglacial transition and the present warming.

The disturbing aspect about the ice cores showing the strong CO_2 variations is that this makes clear that there is a quite strong, natural, amplifying (positive) CO_2 feedback and that we can expect that it will kick in as the world warms; indeed, there are early signs that this is starting to occur.

So, rather than contradict current understanding and models, as Dr. Happer infers, the paleo-evidence not only confirms the level of concern, but also the existence of a strong natural, positive CO_2 feedback that will further amplify the climate change risk the world faces.

16. The most recent continental ice sheets began to melt some twenty thousand years ago. During the "Younger Dryas" some 12,000 years ago, the earth very dramatically cooled and warmed by as much as 10 degrees Celsius in fifty years.

Comment (MCM): *Well, yes, there was a Younger Dryas—basically as the world was warming up from the Last Glacial Maximum 20,000 years ago, there was a period when the cold returned. As to the amount, Dr. Happer's number is not the global number—after all, the global estimate for the entire glacial-interglacial transition is about 6°C, and the Younger Dryas occurred within the bounds of present and glacial climates. What Dr. Happer is presumably confused about is that for the North Atlantic region, there was a larger change, which is not*

surprising as that region is pretty sensitive because the Gulf Stream can shift in location, and there may have been a major release of glacial meltwater that had built up on the continents. Such a freshwater outbreak would have tended to slow down the ocean overturning circulation that draws tropical ocean warmth up to middle latitudes and provides energy to warm Europe, etc.

17. The earth's climate has always been changing. Our present global warming is not at all unusual by the standards of geological history, and it is probably benefiting the biosphere. Indeed, there is very little correlation between the estimates of CO2 and of the earth's temperature over the past 550 million years (the "Phanerozoic" period). The message is clear that several factors must influence the earth's temperature, and that while CO2 is one of these factors, it is seldom the dominant one. The other factors are not well understood. Plausible candidates are spontaneous variations of the complicated fluid flow patterns in the oceans and atmosphere of the earth—perhaps influenced by continental drift, volcanoes, variations of the earth's orbital parameters (ellipticity, spin-axis orientation, etc.), asteroid and comet impacts, variations in the sun's output (not only the visible radiation but the amount of ultraviolet light, and the solar wind with its magnetic field), variations in cosmic rays leading to variations in cloud cover, and other causes.

Comment (MCM): *A lot of this has been addressed in earlier responses, but more does need to be said. Indeed, changes and variations in quite a number of factors, each with their characteristic time scale and strength, have very likely influenced the Earth's climate, and it is true that we understand these roles to varying degrees. That the climate of the Holocene, so roughly the last 8,000 years, has been quite stable, allowing cities and civilizations to develop, suggests that what we need to be most concerned about right now is disturbing this stable state (i.e., global average temperatures have likely varied by less than 1°C from the mean). Instead, Dr. Happer seems to advocate interpreting the fact that the Earth's climate has changed over the last four billion years to justify totally ignoring any effect that humans are having on the climate, no matter how large or how rapid.*

Reconstructions of the CO2 concentration over Earth's history indicate that Dr. Happer is being pretty loose in describing the existing evidence. Reconstructing conditions back a few hundred million years, so before most of the coal, oil, and natural gas were formed, there was a lot more CO2 in the active reservoirs (i.e., the atmosphere, upper ocean, and terrestrial biosphere), suggesting that the CO2 concentration was over ten times its preindustrial level. Back about 300 million years when the Earth went through a major glacial epoch, the evidence suggests the CO2 concentration was near the preindustrial level, and that the concentration rebounded to about 5 times the preindustrial level from 100-200 million years ago. Since roughly that time, the CO2 concentration has been trending down. Simulations by a simplified model that can simulate ice age cycling in response to changes in the Earth's orbital elements suggest that the cycling depends on the CO2 concentration being less than about 400 ppm (so roughly 50% above the preindustrial level). With a higher CO2 concentration, winters are apparently just not cold enough to allow the multiyear snow buildups that likely initiate glaciation to occur over near-Arctic mountainous areas.

Regarding Dr. Happer's suggestion that the cycling might be driven by "spontaneous variations of the complicated fluid flow patterns in the oceans and atmosphere of the earth—perhaps influenced by" a host of other causes, Dr. Happer seems to have things backwards. He lists a number of forcings (e.g., orbital variations, motion of the continental plates, trends in overall solar luminosity) that are quite long-term and for which there is evidence they cause climate change, but he fails to include changes in atmospheric composition, particularly CO2 and, in some situations, CH4 for which there is also very strong evidence. He also includes a number of forcings that are short-term (e.g., volcanic eruptions, sunspot variations) that are fairly well understood—and that just do not match the timing and pattern of changes that are being observed. In addition to not fitting observed changes, Dr. Happer also provides no explanation for why these factors were not causing climatic changes as large as we are seeing over the past 8,000 years, but then just happened to start having effects at the start of the Industrial Revolution. For a physicist to offer such an ad hoc, non-quantitative explanation in opposition to one that is quantitatively based, and to claim the latter is a result of some sort of conspiracy or failing of the international scientific system is a very long reach.

18. The existence of the little ice age and the medieval warm period were an embarrassment to the global-warming establishment, because they showed that the current warming is almost indistinguishable from previous warmings and coolings that had nothing to do with burning fossil fuel. The organization charged with producing scientific support for the climate change crusade, the Intergovernmental Panel on Climate Change (IPCC), finally found a solution. They rewrote the climate history of the past 1000 years with the celebrated "hockey stick" temperature record.

Comment (MCM): *Nonsense. The Little Ice Age and Medieval Warm Period reflect the climatic conditions that were being experienced primarily in the North Atlantic basin and adjacent land areas. The evidence that few-hundred year periods were simultaneously as intense all around the globe is quite limited and merits very close analysis, and even outright skepticism. As indicated earlier, the North Atlantic basin region appears to experience larger variations in the climate than elsewhere, likely partly due to the ocean reaching further north than in the Pacific due to the continental locations, partly due to the fact that a large fraction of the land of the Northern Hemisphere drains into the Atlantic, and partly due to how Latin American mountains separate the Atlantic and Pacific basins, which affects the salinity of the Atlantic and thereby affects ocean circulation.*

As to the Medieval Warm Period being as warm as today, that conclusion, if it applies at all, is mainly again constrained to the North Atlantic region—there is just not much data on what the conditions were around the world. In addition, if one is going to draw results from particular regions, one has to make sure that all additional forcings are being considered. In this regard, additional ones to consider would likely include, for example, land clearing and marsh draining in Europe and then in North America over the last thousand years. Thomas Jefferson noted, for example, that the clearing of forests in eastern North America during colonial times seemed to affect the inland penetration of the sea breeze.

With respect to the role of the Intergovernmental Panel on Climate Change (IPCC), it is charged with summarizing the science using the process that is traditional in science: have experts write a review paper and then subject it to an intense peer review--likely the most extensive and open in the world. The IPCC is not on a "crusade," and indeed a number of countries like Saudi Arabia and other Middle Eastern nations would argue even with this terminology. For each of the IPCC's four assessment reports (issued in 1990, 1995, 2001, 2007), the assembly of the involved nations, now exceeding 190, has ***unanimously*** *endorsed the reports that have emerged from the IPCC's very careful development and review process. To suggest that the IPCC findings are somehow not mainstream and their process is leading to far-out conclusions bespeaks a very paranoid view of the international community of nations; if anything, the IPCC's findings have been too cautious, as indicated by each IPCC assessment strengthening the overall findings, bringing them into accord with what were at the time the cutting edge findings of leading scientists.*

On Dr. Happer's charge regarding the "hockey stick," the role of the IPCC is to summarize the science that is available, and it has done that. In carefully reviewing the literature and bringing in new analyses, the IPCC has tread quite cautiously, especially regarding such issues as to the shortcomings of older data sets and the spatial representativeness of the newer data sets. From the moaning of Dr. Happer about relying on new approaches, does this mean that medically he would choose to stick with use of leeches? It is fine for there to be controversy about how the analysis was done, but the way to do this is to do what roughly a dozen other scientific groups have done—go out, assemble the data sets that they think are most accurate and useful, use the information to reconstruct past changes in the climate, combine the results into a temporal and spatial mosaic of the patterns, check the consistency of the results, and then combine into a global (or hemispheric) estimate of the changes that have occurred. What Dr. Happer fails to mention is that this has been done, and there is large-scale agreement on the results. Basically, the climate 2000 years ago started off with slow cooling that continued to a couple of centuries ago, at which time a dramatic warming roughly coinciding with the start of the Industrial Revolution began. That warming, with some hesitations, has continued to the present. This is science, not mythology.

19. The first IPCC report, issued in 1990, showed both the medieval warm period and the little ice age very clearly. In the IPCC's 2001 report was a graph that purported to show the earth's mean temperature since the year 1000. A yet more extreme version of the hockey stick graph made the cover of the Fiftieth Anniversary Report of the United Nation's World Meteorological Organization. To the surprise of everyone who knew about the strong evidence for the little ice age and the medieval climate optimum, the graph showed a nearly constant temperature from the year 1000 until about 150 years ago, when the temperature began to rise abruptly like the blade of a hockey stick. The inference was that this was due to the anthropogenic "pollutant" CO2.

Comment (MCM): *In the IPCC's first assessment, the curve that was presented was based on data available at that time, so mainly data coming from the countries*

bordering the North Atlantic. Being about periods long ago and so not necessarily closely relevant to the IPCC's interests in its First Assessment Report, the focus was mainly on including a qualitative representation to give a sense of context for the other scientific results. By the time of the later assessments, there was a much greater incentive to pull data sets together, both to test model simulations and to provide context and information to underpin projections. The result was to prompt a number of groups to start working together to really build up the paleoclimatic record, drawing together and reconciling records from different types of observations and from different regions.[2]

Because of the expectation that a wide range of proxy data sources could be found (e.g., tree rings, coral layering, lake sediments, historical records, and more), quite intensive efforts have focused on reconstructing climatic changes over the past 500-2000 years. Attention has focused on documenting the timing, spatial patterns and extent of fluctuations and trends and then quantitatively calibrating these records using available instrumental records. These records indicated that the Northern Hemisphere (as opposed to just over Europe) was experiencing a slow cooling, albeit with fluctuations in various parts of the hemisphere, until the early stages of the Industrial Revolution.

Dr. Happer seems hung up on early and limited reconstructions of what was happening—it would be like a physicist not accepting the transformative work of Einstein. There were famous scientists who took a while to come around, so it happens, and this seems to be the case for him.

20. This *damnatia memoriae* of inconvenient facts was simply expunged from the 2001 IPCC report, much as Trotsky and Yezhov were removed from Stalin's photographs by dark-room specialists in the later years of the dictator's reign. There was no explanation of why both the medieval warm period and the little ice age, very clearly shown in the 1990 report, had simply disappeared eleven years later.

Comment (MCM): *The IPCC presents (and has room to present) a summary of the most relevant and up-to-date science. If Dr. Happer wants to understand the details of how the transition occurred in this field, he needs to go back and read the underlying literature. And while he is at that task, he should also read all the articles that have also confirmed the hockey-stick-like appearance of the resulting data. Every one of IPCC's chapters has an extensive underpinning set of references and not everything can be fit into IPCC's page limits—that is why there are extensive references and why IPCC has, as more and more paleoclimatic information has developed, devoted more and more attention to the findings.*

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[2] For an early start at this that turned out not to be covered in IPCC's First Assessment Report, see MacCracken, M. C., M. I. Budyko, A. D. Hecht, and Y. A. Izrael (Eds.), 1990: *Prospects for Future Climate: A Special US/USSR Report on Climate and Climate Change*. Lewis Publishers, Boca Raton, FL, 270 pp.

21. The IPCC and its worshipful supporters did their best to promote the hockey-stick temperature curve. But as John Adams remarked, "Facts are stubborn things, and whatever may be our wishes, our inclinations, or the dictates of our passion, they cannot alter the state of facts and evidence." The hockey-stick curve caught the attention of two Canadians, Steve McIntyre, a mining consultant, and an academic statistician, Ross McKitrick. As they began to look more carefully at the original data—much of it from tree rings—and at the analysis that led to the hockey stick, they became more and more puzzled. By hard, remarkably detailed, and persistent work over many years, consistently frustrated in their efforts to obtain original data and data-analysis methods, they showed that the hockey stick was not supported by observational data. An excellent, recent history of this episode is A. W. Montford's *The Hockey Stick Illusion*.

Comment (MCM): *Dr. Happer's is one view—the one he seems to have a dogged near-religious faith in. It is not the conclusion of the 190-plus nations that have endorsed the IPCC's findings. The literature underpinning the 'hockey stick' finding is extensive and has been reviewed also by the National Academy of Sciences, among other groups. While insights gained over time and careful independent studies by a range of other scientists have improved the statistics of the analyses and provided insight into the strengths and weaknesses of the various interpretations, there has been no significant shift away from the original finding that the world was cooling and then started warming subsequent to the start of the Industrial Revolution.*

It is particularly ironic that Dr. Happer so strongly criticizes the development of the temperature record for the last 500 years, but then does not discuss the much more serious problems with the record of changes in upper tropospheric temperature. This record, which is derived from satellite-based observations taken by the Microwave Sounding Unit (MSU), was touted for over a decade by the Marshall Institute and other global warming skeptics as showing that the upper troposphere was cooling, in contradiction to the warming trend derived from observations of surface temperatures. That there was an apparent contradiction brought extensive scientific attention (just as had been the case for the paleoclimatic record). This time, however, a series of serious problems was found with the data set, including biases due to the decaying altitudes of satellites, to changes in the time of day of measurement as the orbit drifted, to the techniques used for cross-calibration across satellites, to inadequate solar shielding for the sensor used for radiosonde observations needed for cross-calibration, and on and on. Now, with a record finally exceeding three decades long, the record indicates that the tropospheric temperatures are climbing along with surface temperatures.

For more than a decade, the touting of an early record that had really not been reconciled with other observational records was used by lobbyists and others to create doubt about the importance of Congress moving forward to deal with climate change. With the record now found to be giving the opposite result, there has not been any significant apology by all those who played a part in this. Instead, they are focusing their criticism on the "hockey stick" record that has been confirmed over and over by independent studies of other scientists. Somehow this

smacks of the critics having an agenda other than seeking to learn what science can tell us.

22. About the time of the Copenhagen Climate Conference in the fall of 2009, another nasty thing happened to the global-warming establishment. A Russian server released large numbers of e-mails and other files from computers of the Climate Research Unit (CRU) of the University of East Anglia. Among the files released were e-mails between members of the power structure of the climate crusade, "the team." These files were, or should have been, very embarrassing to their senders and recipients. A senior scientist from CRU wrote, for example: "PS, I'm getting hassled by a couple of people to release the CRU station temperature data. Don't any of you three tell anybody that the UK has a freedom of information act."

    Comment (MCM): *Personally, I have always been in favor of data being openly available; that has been the policy of the interagency U. S. Global Change Research Program since it first organized the issue nearly 20 years ago. There are, however, other perspectives that merit at least some consideration, including that scientists may work for many years to assemble data sets on which their careers and jobs are based, and just giving the data sets away can be like asking Coca-Cola to just give out its recipe. In addition, not all countries subscribe to open data exchange; for example, countries having invested in the taking of the observations might not want scientists in some big, well-funded country to take and use their observations before their own scientists can do so, so some records may be provided on a do-not-further-release basis. Or there might be concerns that the observations might reveal information of national economic importance or about national security (e.g., it took quite a while for the US Navy to release its records of the depth of sea ice, for if one knew when and where observations were taken, deciphering sonic records might make it possible to figure out how to detect the locations of US submarines in the future). In addition, different countries have different perspectives on the roles of government and the private sector. In the US, for example, weather forecast results, which are based on a huge set of observations from around the world, are released free for use by the private sector to promote economic development and in exchange for the private sector broadcasting warnings about severe weather so as to reduce death, injury, and damage. In other countries, however, weather forecasts are sold, and the price may even include a contribution to the taking of the observations. So, it is not nearly as simple as Dr. Happer is suggesting, even though we are in agreement that information on which important decisions is being based should be widely available.*

    With respect to the specific situation that Dr. Happer was referring to, the underlying information was, at least in principle, virtually all available to the public from groups around the world—that is how the data set was assembled. If those requesting the information thus really wanted to confirm the results of the calculations that were done, then they really should have gone back to the original sources of information and gotten that information and then gone through the whole assembly of information, quality checking, corrections, and analysis themselves. That is what, for example, those at the NOAA Climatic Data Center and the NASA Goddard Institute for Space Studies have done over the past 20 years,

and that is what a new, independent group at the University of California Berkeley has done. Instead, in the case that Dr. Happer refers to, the requester chose not to go through all that effort and put in what became hundreds of requests for information that the other scientists had gone through all the effort to gather and refine. Given human nature, it should not be surprising that this seemed rather unfair, not to mention that there were constraints on some of the data sets, that it was a Canadian asking for work carried out by a scientist with support from the British government, and that it was going to require a lot of unpaid work to make the data available. And all of this to meet the requests of someone who was not really doing the checking in a complete manner, but instead seemed to be out to find a flaw, no matter how minor.

In addition, the requests also raise even broader issues. Can anyone from around the world use the Freedom of Information provisions of any country around the world to get at very low or no cost all the efforts that a scientist or lab in that country has assembled at significant cost? Do Freedom of Information provisions apply to basically everything that anyone or any company working for the government or with any contract support from the government does in their everyday job, whether it has to do with a decision that matters or not (this is how the provisions are seeming to be interpreted in some case in the US)? Can anyone make the request for any purpose or must there be some justification in terms of whether the information will be used in a legitimate scientific study? Basically, could I, for example, request all of Dr. Happer's information on any of his activities that have received even a single dollar of governmental support, and require a search of his personal email to be sure he has complied? This is a much more complex issue than Dr. Happer indicates, getting into all sorts of issues of privacy, the value of information, intellectual property rights, and more.

In any case, for the records of changes in temperature around the globe, the results of the four groups that have sought out the data and assembled and processed it are all in quite good agreement—the world is warming substantially. This is not to say, however, that there are not still biases in the observations that need to be looked into. For example, ocean surface temperatures from the years during World War II are generally higher than for surrounding periods. So, did World War II warm the oceans or are there some biases or neglected forcings? This is n important question because, in comparing model results and observations over the 20th century, the only large domain for which there is statistically significant disagreement between observations and model simulations seems to be over the oceans during World War II. To date, analyses indicate that a much greater share of the observations during those years were from US Navy ships and the way in which they made the measurements was somewhat different than the techniques used by ships of other nations, so there is reason to think that this may contribute to the model-observation differences

Similarly, over the last ten years there have been some questions about ocean temperature measurements and the amount of heat stored in the ocean. Close examination is suggesting that there are likely some biases in observations taken with particular types of instruments and appropriate adjustments and corrections will need to be determined. Such independent verifications are important to do—and when done they should be completely independent instead of through

harassing attacks on the work of particular scientists, as was the case for the situation that Dr. Happer highlights.

23. A traditional way to maintain integrity in science is through peer review, the anonymous examination of a scientific paper by qualified, competing scientists before publication. In a responsible peer review, the authors may be required to make substantial revisions to correct any flaws in the science or methodology before their paper is published. But peer review has largely failed in climate science. Global warming alarmists have something like Gadaffi's initial air superiority over rag-tag opponents in Libya.

Comment (MCM): *First, peer review is indeed helpful, it can and does generally lead to improvements in submitted papers before publication. Second, however, just because a paper has been through peer review and published does not guarantee its validity forever—the published paper is just better than the draft, at least if the peer review is reasonably rigorous. Third, peer review also does not mean that an author has to accept every comment—it might be that a point should be better defended or argued or referenced. And fourth, reviewers can make mistakes too. What a peer review should be expected to do is to ensure that a paper is well and clearly presented and argued.*

Dr. Happer offers no evidence here that there has been a failure of the international peer review system. The typical publishers of the leading scientific literature include the national academies of various countries and the professional societies around the world—is Dr. Happer really asserting that all of these organizations have failed in their responsibilities?

Now, it is true that some of the scientists with differing views on climate change have not had their papers accepted in leading journals. First, that has happened to a lot of scientists, whatever their views, so just because someone has a paper rejected proves nothing. Second, the understanding of science is tightly linked and intercoupled—if a paper is going to claim it proves something different than well-developed and reinforced findings, then it really needs to not only provide a self-consistent alternative hypothesis for the situation at hand, but for linked situations. For example, claims that changes in the atmospheric CO_2 concentration have virtually no effect on the temperature of Earth need to explain not only Earth history, but also how it can then be that present understanding explains the temperatures of both Venus and Mars, both of which have atmospheres where CO_2 plays a major role—otherwise, it might well be shortcomings in the argument being made that is the explanation. While this asks a lot of the author, a claim that decades of well-argued and confirmed scientific findings coupling across to many other disciplines are flawed does not merit being loosely granted—and trying to substitute whining about being rejected for good, sound reasoning and presentation will only make the examination of the arguments put forth more intense.

24. Consider this comment from one of the most respected IPCC leaders, as revealed in the CRU e-mails: "I can't see either of these papers being in the next IPCC report. Kevin and I will keep them out somehow—even if we have to define what the peer-

review literature is." And consider the CRU e-mail comment on a journal that committed the mortal sin of publishing one of the heretical papers: "I think we have to stop considering *Climate Research* as a legitimate peer-reviewed journal. Perhaps we should encourage our colleagues in the climate research community to no longer submit to, or cite papers in, this journal." Peer review in climate science means that the "team" recommends publication of each other's work, and tries to keep any off-message paper from being accepted for publication.

Comment (MCM): *Dr. Happer has here taken some quotes out of context. There is peer review and there is peer review. In championing peer review, as he did earlier, Dr. Happer is apparently in favor of stringent peer review. Well, so is the scientific community. But not all journals conduct a serious peer review—just asking a few other scientists who tend to agree with the author or are not experts in the field does not meet the high standards appropriate to this well-developed field. So lines may well need to get drawn regarding which journals are carrying through with a high quality peer review process.*

A few examples illustrate the situation. First, when a scientist requests and gets another scientist's data and then submits a paper with strikingly different results, it is generally viewed as appropriate for the journal editor, if not before that the author, to send the paper for comment to the scientist who did the original analysis and to make sure the reasons for the difference are substantive rather than an error of some type (e.g., making an error in the transfer of the information, etc.). Progress in science comes from reconciling different findings and interpretations, so the peer review process should, at the very least, make sure that the reasons for the differences are clearly presented and described, with the original author offered an opportunity to respond. If a journal does not bore in when there is such a difference and just publishes different results to get attention for being different, it really is not carrying out peer review in a serious way. Journal publication is not free speech—that is for op-ed pages; journal publication is for measured and well-documented analysis and the deepening of understanding.

Second, when a detailed review paper comes in, it should be sent to a number of experts in the field to look at and return comments. Such a review will inevitably take weeks to months. If there is a journal that publishes a submitted review paper within a few days and just before a Congressional hearing where its results are touted as completely over-turning the results of a major assessment by others, that pretty clearly smacks of a sham peer review process. Neither conducting a thorough peer review nor allowing time for publication of responses given the supposed significance of the new result is seeking headlines (and potentially sowing confusion) rather than advancing understanding.

Third, when the editor of a journal openly seeks to publish papers that are controversial and differ from the prevailing understanding, apparently without serious peer review by those whose views are being overturned to ensure an adequate explanation, it should not be surprising that that journal is not considered of a rank commensurate with the leading journals that the IPCC would be expected to be relying on. And what is the appropriate response when a journal editor, through their choice of reviewers of papers, basically favors one perspective over

another with the intent of getting a positive review, or when co-editors are so unhappy with how a lead editor handles a paper that they resign?

I assume that Dr. Happer goes to doctors that actually have a license and don't just claim to have one—he chooses. Well, in doing a major scientific review, choices have to be made. Taking comments about the credentials of various journals out of context can sound inappropriate, but maintaining excellence requires making choices and frank discussion about serious matters.

25. James Madison reminds us in *The Federalist Papers* that "no man is allowed to be a judge in his own cause, because his interest would certainly bias his judgment, and, not improbably, corrupt his integrity. With equal, nay with greater reason, a body of men are unfit to be both judges and parties at the same time." Madison goes on to observe that the smaller the community, the more likely that parties and judges will be one and the same.

Comment (MCM): *James Madison is also a Princeton alum, so I am pleased to consider his words. When, as in the time of Madison, the brightest could be experts in many fields because the knowledge in individual fields was not as deep as today, his statement made eminent sense. Today, with the extensive knowledge being developed by the international set of scientists, it is particularly challenging for someone with no or little training and knowledge of an issue, so supposedly no bias, to come in and learn enough about a field to make authoritative statements and judgments—and to do so in very little time (so as to meet publication deadlines) and at no cost (because any source of money a person gets is thought to create a bias). The IPCC has faced this challenge in selecting the authors of the review chapters. If they choose an expert in the field, there is a good chance that individual's perspective on the topic will be given a prominent position in the chapter, and this may well be appropriate; if they choose a highly qualified expert from outside the field, there will be charges that the individual is not qualified, especially by those whose perspectives are not made the central conclusion of the chapter.*

It may not be a perfect solution, but what IPCC has done is to select a set of authors (generally two convening lead authors and several lead authors) who then invite input from a broader group that can become contributing authors. Chapters thus typically have many authors, which can sometimes broaden the findings so much that they become over-qualified. In any case, once the authors agree, the chapter texts are then subjected to a multi-stage international peer review process, overseen by a pair of independent review editors that are not allowed to submit materials or comments on the particular chapter for which they are responsible. In the multi-stage review process, the report first goes to a set of considered experts in the field (so for example, to the authors of the articles being cited); then, after revision, to a broader range of experts nominated by the national members of IPCC and organizations with an interest in the IPCC process. After these expert reviews, the further revised text goes out to the experts again, to the national members (and each nation can choose whatever experts and process it thinks appropriate to generate their review comments), and to participating organizations (e.g., environmental groups, industry associations, etc.). The review comments at each

stage of the process are made public, along with author response on how the comments were handled. That any scientists are willing to serve as authors is amazing, given the effort and dedication that this takes.

The final draft is submitted for acceptance at a plenary meeting of IPCC's national members and the convening lead authors of the chapters. By 'accepting,' the IPCC's members are confirming that the chapters and technical summary have gone through the prescribed preparation and review process, which has been designed to ensure that the perspectives offered represent the consensus views of the international scientific community.

Based on the acceptance of the chapters and technical summary, the attendees then consider, review and edit the draft summary for policymakers on a line-by-line basis, with the government representatives seeking clarity and the scientists seeking accuracy in presentation of what is understood and how well and with what limitations. Both groups are essentially able to veto what they think is not acceptable. This process has been very actively undertaken, requiring many, many hours, but in the end has led to the unanimous concurrence of all of the national members for each IPCC's four assessment reports. This multi-tiered and consensus-building effort has been an impressive international achievement, earning IPCC the 2007 Nobel Peace Prize (along with former vice-president Al Gore, who has devoted significant effort to outreach and building public understanding).

For the scientific community, the assessments, particularly preparation of the summaries for policymakers, have not been without some controversy, and it is important to understand why. First, science advances by focusing on differences rather than on common understanding, so finding text representing the consensus of the scientific community is not a natural undertaking. Second, for such a complicated topic spanning time from the distant past to future and space from local to global, it should not be surprising that there is a range of perspectives and interpretations among scientists, even among just those intimately involved with the research, much less with those from related fields. Third, because scientists and experts have a tradition of wanting there to be a clear demonstration of high statistical significance before agreeing to a finding (and even then provisionally), the limits in data collection and in projection into the future can make gaining such high confidence difficult. A corollary to this point is that different fields of science have different traditions regarding what is needed to gain confidence. Fourth, there is a reluctance among scientists to translate their levels of confidence and uncertainty into the relative likelihood framing that is required in order to communicate in the paradigm used in public and commercial sectors. And fifth, the media have not particularly helped in describing the process, mainly basing the credibility of the IPCC assessments on the number of scientific participants (and implying all agree with everything) whereas scientists agree findings need to be based on solid evidence and are not appropriately decided by voting.

Admittedly, IPCC's process is not a perfect system, but, paraphrasing from Winston Churchill:" [IPCC's peer review system] is the worst form [possible] except [for] all the others that have been tried." In addition, by redoing its assessments every 5-6 years, with each new assessment having a strong input of new authors and leaders, IPCC aims for the process to iteratively lead to better and better summaries of the science through repeated examination and evaluation. If Dr.

Happer does not find the process authoritative, it would have been helpful if he could at least have offered some constructive suggestion for improvements.

26. Let me summarize how the key issues appear to me, a working scientist with a better background than most in the physics of climate. CO2 really is a greenhouse gas and other things being equal, adding the gas to the atmosphere by burning coal, oil, and natural gas will modestly increase the surface temperature of the earth. Other things being equal, doubling the CO2 concentration, from our current 390 ppm to 780 ppm will directly cause about 1 degree Celsius in warming. At the current rate of CO2 increase in the atmosphere—about 2 ppm per year—it would take about 195 years to achieve this doubling. The combination of a slightly warmer earth and more CO2 will greatly increase the production of food, wood, fiber, and other products by green plants, so the increase will be good for the planet, and will easily outweigh any negative effects. Supposed calamities like the accelerated rise of sea level, ocean acidification, more extreme climate, tropical diseases near the poles, and so on are greatly exaggerated.

Comment (MCM): *First, the high degree of confidence that Dr. Happer exhibits in his own views is greater than that of IPCC and others in the community typically have in their summaries of the science; given the limits of available information and understanding and Dr. Happer's supposedly skeptical mindset, it seems surprising that he is not more skeptical of his own assertions. Second, most scientists in the climate change area have peer-reviewed publications in their field, and many have a quite extensive background in physics and strongly disagree with his conclusions—authority needs to be illustrated by accurate and cogent explanation and argument; authority based on expertise in a related field needs to be earned rather than asserted.*

Regarding the temperature response to a doubling of the atmospheric CO2 concentration, Dr. Happer's use of the phrase "other things being equal" hides a great deal. First, for the response to be only a bit over 1 degree Celsius, would require the absolute humidity (so the absolute amount and distribution of water vapor in the atmosphere) to stay the same, which seems highly unlikely. For example, given that water vapor builds up in the atmosphere until removed by precipitation (which occurs when the relative humidity exceeds 100%), then the absolute humidity is going to end up being proportional to the temperature at which clouds start to form, and in the summer, those temperatures are far above those in winter. The same would be the case with a 1-degree warming; warmer air temperatures would lead to there being more water vapor in the atmosphere.

Based on the way that water vapor mixing ratio is controlled by the up and down motions of the atmosphere, observations indicate that it is far more likely that the relative humidity rather than the absolute humidity would stay roughly constant--Dr. Happer's assumption is simply not justified. The relationship that governs the change in water vapor pressure with temperature is called the Clausius-Clapeyron relationship. This well tested relationship indicates that the saturation water vapor pressure rises exponentially with temperature. As a result, as the temperature goes up, maintaining a constant relative humidity (the ratio of actual humidity to its saturation value) leads to a significant increase in

atmospheric water vapor, and therefore substantial additional warming. Accepting this empirically supported assumption, the global average temperature increase would be at least double the value Dr. Happer suggests (so well over 2 degrees Celsius).

Second, once warming starts, snow cover and sea ice will start melting. Because the surface is not as dark as the snow, more solar radiation will be absorbed and this will lead to more warming, which in turn leads to more atmospheric water vapor and warming, as indicated above.

Third, there is a range of views about how clouds will respond as the climate changes. In considering cloud responses, it is first important to understand that more water vapor in the atmosphere will not necessarily make for an increase in cloud cover; were the amount of water vapor in the atmosphere what determined cloud cover, there would be no clouds in the Arctic or at altitude because the water vapor mixing ratio is much lower than near the surface, and there would be no clear days in low latitudes because the amount of water vapor is highest there. What matters is the relative humidity, and it is determined by the atmospheric circulation. As the atmosphere circulates, as much air will be rising (creating clouds and precipitation that remove water vapor from the atmosphere) as there is air descending (having the low water vapor mixing ratio of the cold air coming out of the tops of clouds). This dry, descending air then starts to gain back water vapor as it gets near the surface where evaporation will load it up with moisture, perhaps even creating low lying stratus clouds near the surface. While climate change will likely somewhat alter the distributions of cloud type and extent, the various effects on solar and infrared radiation seem likely to be relatively small as compared to the warming effects of the higher greenhouse gas concentrations on infrared radiation and of snow and ice melting on solar radiation.

Regarding the rate of rise of the CO_2 concentration, while it is rising at a bit over 2 ppm per year now, projections are that the concentration will rise much more rapidly in the future if the energy needs of the many people around the world that now have so much less than we do in the US rise and are met using fossil fuels, which seems likely. In addition (repeating earlier comments here as Dr. Happer is repeating his claims), the rates at which the oceans and the marine biosphere take up CO_2 are projected to decrease, so a larger fraction of the emissions will go into increasing the CO_2 concentration as opposed to being removed from the atmosphere. The reasons for these changes are pretty clearly based on the physics of the climate system: less CO_2 can be dissolved in warmer ocean waters; and with the upper ocean becoming warmer, there is likely to be less transfer of cold surface waters to the deep ocean (i.e., less downwelling). As a secondary consequence, with less downwelling, there will be less upwelling of nutrients for marine organisms to use in creating waste and skeletons that carry carbon to the deep ocean as they sink. Thus, Dr. Happer's projection that it will take nearly two centuries to double the CO_2 concentration is very implausible. Accounting for the terms mentioned in my comments, a doubling of the preindustrial CO_2 concentration, which is the baseline being used in the calculation of human-induced climate change, is projected to occur near the middle of the 21st century unless strong actions are taken to stop and then reverse the increases in emissions that are occurring.

As for Dr. Happer's assertion that increases in the CO2 concentration and in global average temperature will all be good for the planet, his conclusion is at complete variance with a tremendous amount of scientific research. While crops may grow better in some regions of the world, in many regions the impacts of changes in the climate and the increased competition by weeds and pests are very likely to more than offset the CO2 gain. For forests (and their significant biodiversity), there are already clear indications that many forests are being over-stressed, which is the first stage of their destruction. For coastal communities and wetland ecosystems, rising sea level, more intense storms, reduced presence of sea ice, and more will create significant difficulties, ranging from erosion to salination to inundation. With respect to human health, warmer wintertime temperatures will increase the range of key disease vectors and longer and more intense heat waves will seriously stress the young and old. There is more, all taking the climate away from the baseline that society and nature's species have become accustomed to. There is also emerging evidence that the projected warming over the next several decades could initiate very serious, even dangerous, impacts (e.g., release of methane from thawing permafrost, accelerated loss of ice from the Greenland and Antarctic ice sheets that raises the rate of sea level rise to over a meter per century, etc.). Because of the increasing risks of dangerous impacts from climate change, international leaders have agreed that the global average temperature should not be allowed to exceed 2 C above preindustrial levels, a level that an increasing number of scientists think may be too high to avoid many serious impacts from climate change.

27. "Mitigation" and control efforts that have been proposed will enrich a favored few with good political ties—at the expense of the great majority of mankind, including especially the poor and the citizens of developing nations. These efforts will make almost no change in earth's temperature. Spain's recent experiment with green energy destroyed several pre-existing jobs for every green job it created, and it nearly brought the country to bankruptcy.

Comment (MCM): *For those defending use of coal, oil, and natural gas through tax breaks and overwhelming contributions to political candidates to charge that moving to use of distributed renewable energy sources will enrich the favored few seems a criticism beyond the pale. Renewable energy systems, with their great variety, have the potential to provide jobs in countries around the world, ending the dependence on importing fuel from the few countries blessed with oil reserves. While there is a higher initial cost for at least some types of renewable energy systems, that cost is coming down, and then the cost of energy becomes much less, if not quite free.*

With respect to the benefits of cutting emissions, it matters a great deal what is done. If only the US did a little, then indeed the global effect would be small. But if the world takes strong action, a lot can be accomplished. As to the emissions that must be cut, cutting CO2 emissions is essential to limit long-term warming that is expected the second half of the 21st century and beyond. To limit near-term warming, the emissions of short-lived species must also be cut sharply, including especially the emissions of methane, black carbon, and the precursors of

tropospheric ozone. The United Nations Environment Programme and the World Meteorological Organization have just completed a major international assessment indicating how a reasonable set of such actions could reduce the projected temperature increase between the present and 2050 by almost 50%, or just over a half degree Celsius. It is possible to make a difference—we just have to commit to it and take the appropriate actions.

Finally, Dr. Happer does not seem to know the basics of economics—if the developed countries use less petroleum, then (assuming the same amount is produced), the price in developing nations should go down as overall global demand goes down. Spain's problems have been due to a lot more than trying to initiate green energy technologies, paying for the oil they import being just one example of the costs of traditional approaches for deriving energy.

28. The frightening warnings that alarmists offer about the effects of doubling CO2 are based on computer models that assume that the direct warming effect of CO2 is multiplied by a large "feedback factor" from CO2-induced changes in water vapor and clouds, which supposedly contribute much more to the greenhouse warming of the earth than CO2. But there is observational evidence that the feedback factor is small and may even be negative. The models are not in good agreement with observations—even if they appear to fit the temperature rise over the last 150 years very well.

Comment (MCM): *This is more unsupported nonsense. As mentioned above, the water vapor feedback is quite well understood; after all, it is the water vapor feedback that helps to raise the global average temperature from being below freezing up to the moderate conditions that we experience. Somehow, Dr. Happer has the water vapor effect stopping just where the climate is now; his position raises the question of how the climate in the geological past could have been as much warmer as it was if water vapor feedback were not strongly positive.*

With respect to observational evidence, the water vapor feedback effect is pretty well confirmed by observations from the surface (e.g., the water vapor loading of the atmosphere is going up with global average temperature) and from satellites (evident in the change in the radiative emissions from the Earth). So, observations confirm the models, and that the models are consistent with observations helps to confirm that our theoretical understanding is also in good accord.

Whether changes in cloud cover in response to a warming climate will tend to slightly amplify or moderate the warming due to the increases in the atmospheric loadings of CO2 and water vapor does remain an open question. The range of possibilities, however, is not all that large, as explained in the response to paragraph 26 above.[3] *Dr. Happer also seems to ignore the positive feedback effect of the snow and sea ice melting back, which is actually happening—and not just*

[3] Just to be really clear, there is also no possibility that negative cloud feedback could cause the global average temperature to decrease--that would be a thermodynamic absurdity—by trapping more energy, the higher concentrations of greenhouse gases have to lead to warming.

some model conjecture—the notion that cloud feedback could offset water vapor and snow/ice albedo feedbacks is just wishful conjecture.

With respect to model performance versus observations, there is generally good agreement over the last 150 years, and over shorter and longer periods. The one exception shown in IPCC's Fourth Assessment detection-attribution analysis is over the oceans during WW II where biases seem to remain due to the very large proportion of measurements taken by US Navy ships and the engine-room intake observation technique that they used.

What is actually most unsettling about model performance is that the models generally ***underestimate*** *the magnitude of changes in climate that have occurred over Earth history, both in the coldness of the ice ages and the warmth during the time of the dinosaurs. Dr. Happer offers no evidence to suggest that the models are greatly overestimating climate sensitivity.*

29. Indeed, the computer programs that produce climate change models have been "tuned" to get the desired answer. The values of various parameters like clouds and the concentrations of anthropogenic aerosols are adjusted to get the best fit to observations. And—perhaps partly because of that—they have been unsuccessful in predicting future climate, even over periods as short as fifteen years. In fact, the real values of most parameters, and the physics of how they affect the earth's climate, are in most cases only roughly known, too roughly to supply accurate enough data for computer predictions. In my judgment, and in that of many other scientists familiar with the issues, the main problem with models has been their treatment of clouds, changes of which probably have a much bigger effect on the temperature of the earth than changing levels of CO2.

Comment (MCM): *While there are some parameters that are based on observations rather than on fundamental physics, firmly basing the models in fundamental physics has been an issue that has received a great deal of research attention, including tests of the sensitivity of the model results to the choices that are made. When a parameterization is put together (that is, a representation of processes occurring at a spatial scale finer than the can be resolved in the models), the parameter choices made have to be applicable at all locations over the globe. This is tested as the models simulate the evolution of the weather and run through the diurnal and seasonal cycles—there is no local scale tuning of model parameters.*

The models do not specify cloud cover, but seek to represent the various factors and processes that determine the functioning of cloud processes. In that some of these processes are occurring on the micro-scale, there is really no alternative to parameterizing sub-grid scale processes—simulation models in all fields need to make such approximations in order to be able to represent physics on scales from atomic to global. For aerosols, there are several types of representations in the models, and some have specified aerosol loadings (generally based on observations), but increasingly they are now representing both atmospheric and aerosol chemistry. Many aspects of the aerosol physics can also be represented, but some processes do require approximations. Without making approximation, we would not even have the fuzzy projections of the future that we do, in this field or any other, and that would be an abdication of the human power to reason.

On Dr. Happer's statements on predicting the climate, he makes some pretty fundamental mistakes. First, the Earth system is not like an automobile engine with all its interconnected cylinders and gears—it is fluid, and in a nonlinear system such as this, turbulent eddies cause fluctuations that we call the weather. Analogous to the seemingly random bubbles in a pot of boiling water, we can pretty well determine that uniformly adding heat will create more bubbles, even if we do not know exactly where they will occur, and that adding heat on one side of the pot will cause more bubbles on that side. What Dr. Happer is proposing as a test of scientific understanding (as did the late author Michael Crichton before him) is that models be able to predict exactly where each bubble occurs. That is just not possible in what are called chaotic systems (or in stock markets, economic systems), or in life generally—what matters overall is the rate at which the boiling is occurring, not the location of each bubble. The IPCC and climate change scientists are quite careful in making all of this clear. The useful data sets from models are those that define changes in the statistics of the conditions at various locations and over various time intervals.

In making their calculations of what the future will bring, the models also make projections, not predictions—that is, the models are used to estimate what will happen on average ***if*** *certain other factors change. Thus, model projections of climate change are conditional, being based on the model responses to different presumptions (i.e., scenarios) of how the emissions will change (equivalent to projecting what will happen if varying amounts of heat are added to one side of the pot or another and at prescribed times).*

Again, on the effects of clouds, it is not the effects of clouds that are important—it is how much their effects will change as the climate changes, and there are limits on the extent of these changes (after all, even with clouds, the Earth's surface is much warmer than it would be without an atmosphere). Clouds cannot be everywhere or nowhere; clouds occur where rising air leads to saturation and not where descending air leads to drying. Geologically, the Earth has experienced very large changes in climate due to forcings, some as a result of changes in the CO2 concentration. If cloud feedbacks were as negative as Dr. Happer suggests, this feedback would prevent the global climate from changing as much as it has, as Dr. Happer himself makes clear. His qualitative arm-waving just does not stand up in the face of all the quantitative studies that have been done, and much more should be expected from such a prominent physicist.

30. What, besides the bias toward a particular result, is wrong with the science?
Scientific progress proceeds by the interplay of theory and observation. Theory explains observations and makes predictions about what will be observed in the future. Observations anchor our understanding and weed out the theories that don't work. This has been the scientific method for more than three hundred years. Recently, the advent of the computer has made possible another branch of inquiry: computer simulation models. Properly used, computer models can enhance and speed up scientific progress. But they are not meant to replace theory and observation and to serve as an authority of their own. We know they fail in economics. All of the proposed controls that would have such a significant impact on the world's economic future are based on computer models that are so complex and

chaotic that many runs are needed before we can get an "average" answer. Yet the models have failed the simple scientific test of prediction. We don't even have a theory for how accurate the models should be.

Comment (MCM): *Dr. Happer surely knows the difference between modeling economics, which is governed in large part by social decisions, perceptions, and different perspectives on self-interest, and the Earth system, which is governed to a very large extent by the fundamental conservations laws for mass, momentum, and energy. Indeed, both are complex systems, but physical and social sciences provide very different constraints.*

In physical systems, we do have a theory—make a change and there will be a response in largely understandable and calculatable ways. Models don't replace theory; their very structure is based on our theoretical understanding, which is why they are called theoretical models. All that the computers do is to very rapidly make the calculations in accord with their theoretical underpinnings, doing so much, much faster than scientists could with pencil and paper. It is the same way with models for nuclear bombs, plasma physics, lasers, astrophysics—all that is different are the temperatures, pressures, and scales, etc.—the underpinning theoretical principles are exactly the same.

As indicated earlier, for all nonlinear systems, the limits to actual prediction of detailed conditions require careful consideration of nonlinear behavior (not unlike that in physics relating to the specific location of an electron at the atomic level). Model results provide a statistical representation of the chaotic behavior of the Earth system and the response of the system to an external perturbation, such as a changing rate of concentration of CO2. To refine the estimate, the models are run more than one time and the results of the ensemble are then combined. This is no different than flipping a coin more than once to get at the chances of one outcome or another.

Finally, there are theoretical limits to predictability in non-linear systems—studies of this are done to better understand the accuracy and potential outer limits to weather forecasting. This is all apparently a field that Dr. Happer has not yet studied.

31. There are many honest, hardworking climate scientists who are trying to understand the effects of CO2 on climate, but their work has fallen under suspicion because of the hockey-stick scandal and many other exaggerations about the dangers of increasing CO2. What has transformed climate science from a normal intellectual discipline to a matter of so much controversy?

Comment (MCM): *For one perspective on the question of the causes of the controversy that is now going on, I refer the reader to four books by those who have looked into this issue closely: "Merchants of Doubt: How a Handful of Scientists Obscured the Truth on Issues from Tobacco Smoke to Global Warming" by Naomi Oereskes and Erik M. M. Conway; "The Republican War on Science" by Chris Mooney; and "Boiling Point: How Politicians, Big Oil and Coal, Journalists, and Activists Have Fueled a Climate Crisis--And What We Can Do to Avert*

Disaster" and "The Heat is On: The Climate Crisis, The Cover-up, The Prescription" by Ross Gelbspan.

Although there has been much muddying of the waters by the actions of special interests, there are many reasons that the climate change issue is difficult to address politically. These include its global nature, its long-term nature, the importance of reliable and low-cost energy for the public, and the broad set of actions needed to seriously address the findings. There are also a number of scientific issues that make the issue difficult to provide the expert information that is needed to support decision-making, including that: (1) the Earth system is exceedingly complex, with spatial scales from microphysical to global and time scales from microseconds to millennia; (2) the problem being examined is closely intertwined with very important human activities; (3) scientific tradition is to seek very high confidence before coming to a conclusion, which is in conflict with the need to get an early indication of likely results so that political actions can be taken with sufficient time to make a difference; and (4) the complexity, long time scales, and inherent uncertainties make the issue difficult to explain to the public and politicians, and to raise to the front level of policy consideration.

32. A major problem has been the co-opting of climate science by politics, ambition, greed, and what seems to be a hereditary human need for a righteous cause. What better cause than saving the planet? Especially if one can get ample, secure funding at the same time? Huge amounts of money are available from governments and wealthy foundations for climate institutes and for climate-related research.

    Comment (MCM): *Having been on assignment with the interagency Office of the United States Global Change Research Program from 1993 to 2002, and having kept up with the USGCRP level of activities since, I believe Dr. Happer is simply incorrect on this. Research funding is not at all abundant—in fact, there have been significant reductions in the funding made available for research. The lower and lower ratio of funded proposals to qualified submissions has also been striking. Because the grant success ratio for qualifying proposals has sunk to well below 25%, and in many cases below 10%, the chance of winning an award has been less than in games of gambling—funding is hardly secure. And to suggest that more funding is going to the pro-climate camp from foundations than the anti-climate camp—well, that is not at all clear (see references to books in response to paragraph 31).*

33. Funding for climate studies is second only to funding for biological sciences. Large academic empires, prizes, elections to honorary societies, fellowships, and other perquisites go to those researchers whose results may help "save the planet." Every day we read about some real or contrived environmental or ecological effect "proven" to arise from global warming. The total of such claimed effects now runs in the hundreds, all the alleged result of an unexceptional century-long warming of less than 1 degree Celsius. Government subsidies, loan guarantees, and captive customers go to green companies. Carbon-tax revenues flow to governments. As the great Russian poet Pushkin said in his novella *Dubrovsky*, "If there happens to be a

trough, there will be pigs." Any doubt about apocalyptic climate scenarios could remove many troughs.

Comment (MCM): *Well, Dr. Happer can't seem to count. In the rollout of the FY-2010 budget proposal, at least, it is said that, of the $147.6 billion the government spends on research and development, the Department of Defense gets about $80 billion and then the Department of Health and Human Services gets $31 billion. Then come DOE and NASA (mostly for energy and space research, respectively) at about $11 billion each. According to the annual compilation prepared for Congress by the US Global Change Research Program (http://downloads.globalchange.gov/ocp/ocp2011/ocp2011.pdf), the total enacted global change research budget for all agencies combined in FY-10 was $2.178B, so about 1.5% of the Federal Government's total research budget (and this budget includes research for study of ozone depletion, effects of land cover change, and natural variability—so a scope wider than just climate change). This amount is down from $2.654B in FY-09, so a drop of nearly a half billion dollars. Quite clearly, Dr. Happer is significantly misrepresenting the federal budget for climate studies, even being generous in the definition of what climate studies includes.*

Next, Dr. Happer maligns all the societies and organizations that give out awards, and apparently all scientists who work to "save the planet"—as opposed, I presume, to those who favor destroying the planet. This set of institutions presumably starts with the National Academy of Sciences and other academies of science around the world that have given recognition to climate change scientists. This is indeed quite a conspiracy that Dr. Happer is proposing.

Dr. Happer then talks about the range of impacts that are occurring, and here he significantly understates--there are actually many more than hundreds of impacts. For example, IPCC's Working Group II contribution to the Fourth Assessment Report cites tens of thousands of ecosystem impacts. Dr. Happer apparently finds this hard to accept due to the limited warming that has occurred, but the nearly 1°C warming is already a significant fraction of the 6°C warming from the glacial maximum 20,000 years ago to the present. This near 1°C change is also the value for the global average—for well-established physical reasons, the warming has been greater over land and in high latitudes. Already, Arctic ice cover, the Greenland and Antarctic ice sheets, and most of the world's terrestrial ecosystems are experiencing warming that is larger than the global average. While the change is small compared to seasonal variations to which systems are accustomed, the reasonably well-defined boundaries in vegetation and fisheries make clear that small differences matter. Just because humans can survive in a wide range of conditions (with help like clothing and shelter) does not mean that flora and fauna will not be impacted.

Finally, for Dr. Happer to point to the relatively small amounts of money going toward green technologies without acknowledging the much larger subsidies going to the fossil fuel industry with its great profitability does smack of a really one-sided analysis (or bias).

34. What about those who doubt the scientific basis of these claims, or who simply don't like what is being done to the scientific method they were taught to apply and

uphold? Publications of contrary research results in mainstream journals are rare. The occasional heretical article is the result of an inevitable, protracted battle with those who support the dogma and who have their hands on the scales of peer review. As mentioned above, we know from the Climategate emails that the team conspired to prevent contrary publications from seeing the light of day and even discussed getting rid of an editor who seemed to be inclined to admit such contentious material.

Comment (MCM): *I actually agree that a wider range of articles should be published so that all can have access to them—having discussions of criticisms of specific scientific points in op-eds and other such informal settings is unfortunate. I would, however, like to have some sort of commentaries printed with papers so that shortcomings of papers identified in the peer review process can also be made available (and I actually am in favor of the reviewers identifying themselves, as is done with the IPCC process; it makes everyone be really thoughtful and careful in describing their criticisms).*

Dr. Happer, it appears, seems to think that just because a paper is written, it should be published in a major journal. When the various papers he is talking about have been submitted, they have generally gone through peer review and been found seriously flawed (much like the many shortcomings in this article). Douglass et al. (2007) is an example of the "occasional heretical paper" that did get published; since that time it has been found to be seriously flawed due to a fundamental conceptual error made in their statistical analysis that should have been caught by a rigorous peer review process (see Santer et al., 2008), suggesting a weak per review process. Rather than critique the publication of that paper, which is in accord with his views, Dr. Happer chooses to critique the supposedly poor statistical techniques in Mann et al.'s "hockey stick" paper that (despite a vanishingly small problem in the initial statistical analysis) has been verified by roughly a dozen independent analyses. The peer review process of Dr. Mann et al.'s paper has worked well, with active responses and exchanges—it can work on papers with critical views as well if the authors will engage rather than think they have a right to publish poorly argued papers.

To provide some experience in participating in the review process, it would also be good practice for those critical of global warming science to also be critiquing each other's work. Interestingly, their perspectives and findings often differ from each other, often significantly, but one would never know this from the their own literature. By contrast, the IPCC assessments describe the ranges of views in the mainstream literature and specifically identify differences and uncertainties.

35. Skeptics' motives are publicly impugned; denigrating names are used routinely in media reports and the blogosphere; and we now see attempts to use the same tactics that Big Brother applied to the skeptical hero, Winston Smith, in Orwell's *1984*. In 2009 a conference of "ecopsychologists" was held at the University of West England to discuss the obvious psychological problems resident in those who do not adhere to the global warming dogma. The premise of these psychologists was that scientists and members of the general population who express objective doubt about the propagated view of global warming are suffering from a kind of mental illness. We

know from the Soviet experience that a society can find it easy to consider dissidents to be mentally deranged and act accordingly.

Comment (MCM): *I wholeheartedly agree the discussion should be on the scientific issues and not based on name-calling. However, Dr. Happer, in the first paragraph of this paper, hardly sets the high tone for the discussion that he is apparently calling for:*

> "I want to discuss a contemporary moral epidemic: the notion that increasing atmospheric concentrations of greenhouse gases, notably carbon dioxide, will have disastrous consequences for mankind and for the planet. The "climate crusade" is one characterized by true believers, opportunists, cynics, money-hungry governments, manipulators of various types—even children's crusades—all based on contested science and dubious claims."

If Dr. Happer and his colleagues with similar views want respect in exchange, they need to be high-minded and give respect as well rather than saying such things about, presumably, all who represent the international scientific community through the IPCC process, the leadership of all the nations of the world (all of whom have endorsed the IPCC assessment findings), many dozens of national academies of science, and many others who have endeavored to learn about climate change.

What particularly frustrates climate scientists that I know is that those that Dr. Happer refers to as "Skeptics" (actually all scientists are taught to be skeptical, and, as a result, the IPCC chapters devote a lot of their attention to describing uncertainties, etc.) seem totally one-sided in their presentations, never seeming to have any doubt in their interpretations and the data sets they use. I earlier referred to the many adjustments that have been made in the Microwave Sounding Unit estimates of trends in tropospheric average temperature. I have not heard any admission that the conclusions that were widely touted by "Skeptics" and their sponsors and supporters throughout the 1990s have proven totally wrong—instead of cooling, the layer was warming and it was problems in the Spencer-Christy analysis (essentially all identified by those critiquing their approach) that caused the mistaken result.

Similarly, I have not heard any admission of the very serious conceptual error made in the Douglass et al. (2007) paper, from those authors or other "Skeptics." This has happened a lot—an analysis is done by one of the "Skeptics" that contradicts a reasonably well-established finding, a lot of publicity is given to the result before the author has looked closely at what could be causing this, the result is presented to Congress, and then over the following few years other scientists looking closely at the analysis figure out what the problem is with the critique. It is not that the "Skeptics" arrive at a different result, it is that there is very little, if any, effort to try to figure out what might be causing the differences—and research into reconciling differences is the way in which science really advances. Thus, the "Skeptics" are not seen as carrying their weight—all they do is attack, expressing themselves as absolutely sure they are right. And then when their results are looked at closely and found wanting, there is no admission or apology; instead, they are on to the next attack.

Fairly applied skepticism involves having an open, but questioning, mind, even-handedly considering all the evidence and developing hypotheses without a bias

about what the outcome turns out to be, and then being willing to consider that they just might be wrong. Science is an endeavor to find the explanation most consistent with observations and all that we have learned from the conduct of science over many centuries, including the fundamental conservation laws and their application to a very wide range of situations and problems. Criticisms have to be considered in the grander context of the whole scientific enterprise. For example, questioning how the atmospheric radiation equations are applied to calculate the change in the greenhouse effect also raises, at least implicitly, questions about their application to derivation of MSU temperatures, to explaining the temperatures of Mars and Venus, and to the physics of a nuclear explosion. In their criticisms, my experience is that the objections of Happer's "Skeptics" have failed to consider the implications of their criticisms beyond their very narrow issue with global change science.

With the many shortcomings in past analyses and insulting name-calling, it seems to me the "Skeptics" have a lot of cleaning up to do before complaining about the treatment they receive.

36. The management of most scientific societies has enthusiastically signed on to the global warming bandwagon. This is not surprising, since governments, as well as many states and foundations, generously fund those who reinforce their desired outcomes under the cover of saving the planet. Certain private industries are also involved: those positioned to profit from enacted controls as well as financial institutions heavily invested in "green technologies" whose rationale disappears the moment global warming is widely understood to be a non-problem. There are known connections and movements of people involved in government policy, scientific societies, and private industry, all with the common thread of influencing the outcome of a set of programs and investments underpinned by the supposed threat of global warming.

Comment (MCM): *For a person wanting the debate to be about the science, this type of comment questioning the motives of virtually the entire scientific community and many in industry is just what generates the type of reaction Dr. Happer then complains about. And to say this without similarly examining the funding and motives of those criticizing climate change science (e.g., much of the fossil fuel industry) is the type of one sidedness that really takes away from Dr. Happer's credibility. Enough said.*

37. My own trade union, the American Physical Society (APS), is a good example, but hardly the worst. An APS Council statement issued on November 18, 2007 states: "The evidence is incontrovertible: Global warming is occurring. If no mitigating actions are taken, significant disruptions in the Earth's physical and ecological systems, social systems, security, and human health are likely to occur. We must reduce emissions of greenhouse gases beginning now." This is pretty strong language for physicists, for whom skepticism about evidence was once considered a virtue, and nothing was incontrovertible.

Comment (MCM): *For physicists talking to physicists, this is pretty strong language. If Dr. Happer goes and reads the chapters of the IPCC assessments, he won't find that type of language, for those chapters are aimed at the experts in the field and quite carefully go over the uncertainties. These chapters typically are 50-100 pages long and use a small font—and each assessment has 40-50 such chapters, with lead authors of many of the chapters wanting even more material to be included. So, read the appropriate document and a great deal, if not all, detail, with descriptions of uncertainties, will be there.*

In contrast, the APS statement was aimed at the public, and communicating with the public requires a lot of boiling down, simplifying, and speaking in terms of the relative likelihood of an outcome—not the scientific jargon of statistical significance. Personally, I likely would have expressed the findings a bit differently, but then the statement would likely have been a good bit longer as I tend to write for those willing to devote significant time to learning about the issues in some detail. If Dr. Happer is going to complain about the statement language, he needs to focus on whether the statement, in any way, misled the intended audience, namely the public. My conclusion is that it did not.

38. In the fall of 2009 a petition, organized by Fellow of the American Physical Society, Roger Cohen, and containing the signatures of hundreds of distinguished APS members was presented to the APS management with a request that at least the truly embarrassing word "incontrovertible" be taken out of the statement. The APS management's response was to threaten the petitioners, while grudgingly appointing a committee to consider the request. It was exactly what James Madison warned against. The committee included members whose careers depended on global warming alarmism, and the predictable result was that not one word was changed. Bad as the actions of the APS were, they were far better than those of most other scientific societies, which refused to even reconsider extreme statements on climate.

Comment (MCM): *In the panel's review of the statement, I was asked how I would have rewritten it—and I would have said it all a good bit differently. But, just looking at the quote above in paragraph 37, while the word "incontrovertible" is objectionable to Dr. Happer (and most public communication experts would have crossed it out as well given the word has six syllables), my objection would have been to the phrasing "significant disruptions … are likely to occur." Given that the condition set before this was "if no mitigating actions are taken," the "are likely" merits being changed to "are virtually certain to occur." For example, the Greenland and West Antarctic ice sheets are losing mass now, Arctic sea ice is greatly reduced in summer now, drier conditions are prevailing in southwestern North America and southern Australia now, and so on. With unlimited future emissions, a lot more will occur and I would have urged that the statement about impacts be significantly stronger.*

My understanding is that the review panel felt that if they opened the statement up for changes, they would have had to open it all up for changes. They thus concluded that it would be better not to change this statement, and to express their views differently the next time. In any case—human activities are changing the CO2

concentration and this will change the climate and this will have impacts, so none of the major findings in this very qualitative statement really needs to be revisited.

39. The situation is even more lamentable for the general public, which is fed a constant stream of propaganda by specialists in environmental issues from the mainstream media and well-funded alarmist blogs. Not unlike functionaries of Orwell's Ministry of Truth in *1984*, with its motto "Ignorance is Strength," many members of the environmental news media dutifully and uncritically promote the party line of the climate crusade.

Comment (MCM): *In that the science of climate change and likely impacts, as summarized by IPCC, is strongly supported by the national academies of science and many professional societies, the real problem with media coverage is when they have an anti-global warming lawyer from a non-profit supported mainly by fossil fuel companies be the responder to a scientist reporting on their research, just so they have offered an opportunity to respond to someone opposed. To give a balanced and informed portrayal of the strengths and weaknesses of research findings, the media should be talking to scientists about the science—not lawyers. The problem the media is having is that, as in the case of tobacco smoking and health, they can't find independent scientists who disagree with the key findings on climate change science, so they go to lawyers, for example, with the intent of trying to generate more controversy and confusion than there really is (or perhaps they resort to this rather than devoting enough time to really get to the bottom of things and indicate which viewpoint really represents the strongest case).*

I might also just note that if Dr. Happer wants the media to provide fair coverage, then he should set the example of how this could be done. Instead, all we get is innuendo, attacks on the motives of scientists, and very limited and biased descriptions of the science.

40. However, the situation is slowly getting better. Skeptics are more numerous and better organized than before. In a few cases, leading former adherents have publicly and courageously spoken out against the dogma and its core of establishment promoters. The IPCC itself has come under severe criticism by the international scientific establishment for its series of bizarre errors and organizational failings. Under pressure from a dissident group of Fellows, the Royal Society moved to meaningfully moderate its former radically alarmist position on global warming. And perhaps most important of all, public skepticism has increased significantly, and with it has come a major drop in support of the climate crusade's attempt to seize control of the "pollutant," CO2.

Comment (MCM): *What is disturbing about this paragraph is how it portrays the situation as essentially a two-sided war with neither side willing to modify its view as new scientific findings emerge. What all scientists should be doing is pursuing a better understanding of the very complex Earth system on which we live, wherever our investigation may take us. It is fine to raise new issues, offer tough criticisms if justified, and seek deeper insight—but it is also important to be taking an even-*

handed look at all information, be willing to adjust one's views as further scientific findings emerge, and not question motives of those that disagree with you.

41. I began with a quotation from the preface of the first edition of Mackay's *Extraordinary Popular Delusions and the Madness of Crowds*, and it is worth recalling now a quotation from the preface of the second edition: "Men, it has been well said, think in herds; it will be seen that they go mad in herds, while they only recover their senses slowly, one by one."

Comment (MCM): *Interesting quote, especially given today's political environment. And who is to say to which group or groups it applies? How is it that, instead of making their presentations and interpretations in open science meetings where all can make their presentations, the "Skeptics" convene their own 'science' meetings (e.g., June 30 and July 1, 2011—see http://climateconference.heartland.org/), apparently not wanting to listen to anyone who might disagree with their view? As the announcement for the meeting says:*

> "Sen. James Inhofe, R-OK, among the biggest critics of global warming alarmism in Congress, confirmed this week he will kick off The Heartland Institute's sixth International Conference on Climate Change (ICCC-6) with a breakfast keynote address….
>
> "Inhofe will be joined at the Marriott Wardman Park in Washington, DC by dozens of state and federal legislators, Heartland's think tank cosponsors, and scientists who dispute the claim that "the science is settled" on the causes, consequences, and policy implications of climate change."

Very strange phrasing. I don't know any scientists in the IPCC process who claim the "science is settled"--indeed that would be a very poor strategy if their intent is to gain more research funds to support them, as Dr. Happer (very unfairly and insultingly) charges. One would think that if one wants to learn about the differences in results, their meeting would present viewpoints from both sides rather than just those who agree to be criticizing the IPCC results, but, No, they want to have only those who agree with them so they can talk without having to face up to the international consensus views.

42. In our efforts to conserve the created world, we should not concentrate our efforts on CO2. We should instead focus on issues like damage to local landscapes and waterways by strip mining, inadequate cleanup, hazards to miners, and the release of real pollutants and poisons like mercury, other heavy metals, and organic carcinogens. Much of the potential harm from coal mining can be eliminated, for example, by requirements that land be restored to a condition that is at least as good as, and preferably better than, when the mining began.

Comment (MCM): *Well, glad to find out that Dr. Happer agrees that fossil fuels are causing a lot of environmental problems. I am confused, however, how it is that Dr. Happer is fully supportive of the science for all of these other problems, but the science for climate change is globally corrupted—seems rather selective to me.*

On the notion of restoring coal mines, just how is this going to work when the mining companies blast away the hilltops (e.g., in West Virginia) and dump the

debris in streams, seriously polluting them and leaving dangerous piles of tailings that it is estimated will cost many, many billions of dollars for taxpayers to clean up. Just whose "propaganda" (to use his word from earlier) is Dr. Happer listening to and apparently accepting without question?

43. Life is about making decisions, and decisions are about trade-offs. We can choose to promote investment in technology that addresses real problems and scientific research that will let us cope with real problems more efficiently. Or we can be caught up in a crusade that seeks to suppress energy use, economic growth, and the benefits that come from the creation of national wealth.

MCM Comment: *Ah, finally, here is Dr. Happer's agenda. In my view, the global science community and the community of nations, with the exception of a noisy set in the US Congress, have chosen the former, and that is what the green revolution is all about. It is about using energy much more efficiently (no sense wasting it), deriving energy from sources and in ways that do not disrupt the environment, and assisting the world community in their efforts to create a better situation for all of the world's people.*

As happened in the US through the 20th century, environmental regulation of the very dirty power plants that had been built has brought a healthier and wealthier population. Transforming our energy system to one based on non-carbon sources can bring about a similar advance in the 21st century, and there are many industrial leaders who are very enthusiastic about the potential for reworking the global energy system and getting much more efficient and abundant services from the energy we do generate. Staying with the polluting technologies of the past makes no sense when we can do much better, and, indeed, we must do much better to ensure that our children and grandchildren have at least the same opportunities to derive services and sustenance from the natural world as we have.

Building a better future can only be accomplished by facing up to the impacts that increasing CO2 emissions are having on the climate, on sea level, and on ocean acidification. That Dr. Happer is slowing this down by putting forth scientific statements that indicate so little understanding (presumably, because of reading too narrowly or with too closed a mind) is very disappointing. In the years that I was at Princeton and the grading system went from 1 (high) to 7 (low), I regret to say that Dr. Happer would have earned the 7. This grade was actually hard to get because it indicated "flagrant neglect" in one's studies. For his generally uninformed and limited discussion and understanding of climate change science, however, I very much regret to say that Dr. Happer seems clearly to have earned that designation.