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Regulation

Global Warming: The Origin and Nature of the Alleged Scientific Consensus

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Most of the literate world today regards "global warming" as both real and dangerous. Indeed, the diplomatic activity concerning warming might lead one to believe that it is the major crisis confronting mankind. The June 1992 Earth Summit in Rio de Janeiro, Brazil, focused on international agreements to deal with that threat, and the heads of state from dozens of countries attended. I must state at the outset, that, as a scientist, I can find no substantive basis for the warming scenarios being popularly described. Moreover, according to many studies I have read by economists, agronomists, and hydrologists, there would be little difficulty adapting to such warming if it were to occur. Such was also the conclusion of the recent National Research Council's report on adapting to global change. Many aspects of the catastrophic scenario have already been largely discounted by the scientific community. For example, fears of massive sea-level increases accompanied many of the early discussions of global warming, but those estimates have been steadily reduced by orders of magnitude, and now it is widely agreed that even the potential contribution of warming to sea-level rise would be swamped by other more important factors.

To show why I assert that there is no substantive basis for predictions of sizeable global warming due to observed increases in minor greenhouse gases such as carbon dioxide, methane, and chlorofluorocarbons, I shall briefly review the science associated with those predictions.

Summary of Scientific Issues

Before even considering "greenhouse theory," it may be helpful to begin with the issue that is almost always taken as a given--that carbon dioxide will inevitably increase to values double and even quadruple present values. Evidence from the analysis of ice cores and after 1958 from direct atmospheric sampling shows that the amount of carbon dioxide in the air has been increasing since 1800. Before 1800 the density was about 275 parts per million by volume. Today it is about 355 parts per million by volume. The increase is generally believed to be due to the combination of increased burning of fossil fuels and before 1905 to deforestation. The total source is estimated to have been increasing exponentially at least until 1973. From 1973 until 1990 the rate of increase has been much slower, however. About half the production of carbon dioxide has appeared in the atmosphere.

Predicting what will happen to carbon dioxide over the next century is a rather uncertain matter. By assuming a shift toward the increased use of coal, rapid advances in the third world's standard of living, large population increases, and a reduction in nuclear and other nonfossil fuels, one can generate an emissions scenario that will lead to a doubling of carbon dioxide by 2030--if one uses a particular model for the chemical response to carbon dioxide emissions. The Intergovernmental Panel on Climate Change Working Group I's model referred to that as the "business as usual" scenario. As it turns out, the chemical model used was inconsistent with the past century's record; it would have predicted that we would already have about 400 parts per million by volume. An improved model developed at the Max Planck Institute in Hamburg shows that even the "business as usual" scenario does not double carbon dioxide by the year 2100. It seems unlikely moreover that the indefinite future of energy belongs to coal. I also find it difficult to believe that technology will not lead to improved nuclear reactors within fifty years.

Nevertheless, we have already seen a significant increase in carbon dioxide that has been accompanied by increases in other minor greenhouse gases such as methane and chlorofluorocarbons. Indeed, in terms of greenhouse potential, we have had the equivalent of a 50 percent increase in carbon dioxide over the past century. The effects of those increases are certainly worth studying--quite independent of any uncertain future scenarios.

The Greenhouse Effect.

The crude idea in the common popular presentation of the greenhouse effect is that the atmosphere is transparent to sunlight (apart from the very significant reflectivity of both clouds and the surface), which heats the Earth's surface. The surface offsets that heating by radiating in the infrared. The infrared radiation increases with increasing surface temperature, and the temperature adjusts until balance is achieved. If the atmosphere were also transparent to infrared radiation, the infrared radiation produced by an average surface temperature of minus eighteen degrees centigrade would balance the incoming solar radiation (less that amount reflected back to space by clouds). The atmosphere is not transparent in the infrared, however. So the Earth must heat up somewhat more to deliver the same flux of infrared radiation to space. That is what is called the greenhouse effect.

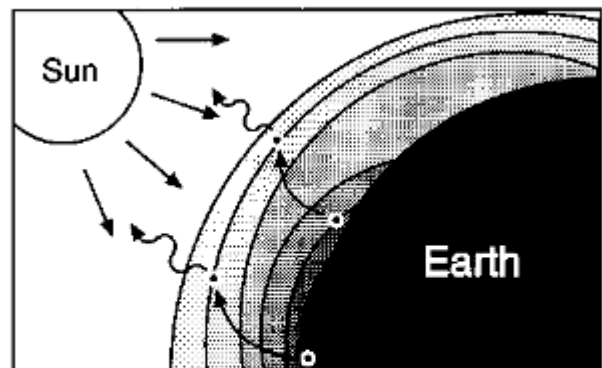
The fact that the Earth's average surface temperature is fifteen degrees centigrade rather than minus eighteen degrees centigrade is attributed to that effect. The main absorbers of infrared

in the atmosphere are water vapor and clouds. Even if all other greenhouse gases (such as carbon dioxide and methane) were to disappear, we would still be left with over 98 percent of the current greenhouse effect. Nevertheless, it is presumed that increases in carbon dioxide and other minor greenhouse gases will lead to significant increases in temperature. As we have seen, carbon dioxide is increasing. So are other minor greenhouse gases. A widely held but questionable contention is that those increases will continue along the path they have followed for the past century.

The simple picture of the greenhouse mechanism is seriously oversimplified. Many of us were taught in elementary school that heat is transported by radiation, convection, and conduction. The above representation only refers to radiative transfer. As it turns out, if there were only radiative heat transfer, the greenhouse effect would warm the Earth to about seventy-seven degrees centigrade rather than to fifteen degrees centigrade. In fact, the greenhouse effect is only about 25 percent of what it would be in a pure radiative situation. The reason for this is the presence of convection (heat transport by air motions), which bypasses much of the radiative absorption.

What is really going on is schematically illustrated in Figure 1. The surface of the Earth is cooled in large measure by air currents (in various forms including deep clouds) that carry heat upward and poleward. One consequence of this picture is that it is the greenhouse gases well above the Earth's surface that are of primary importance in determining the temperature of the Earth. That is especially important for water vapor, whose density decreases by about a factor of 1,000 between the surface and ten kilometers above the surface. Another consequence is that one cannot even calculate the temperature of the Earth without models that accurately reproduce the motions of the atmosphere. Indeed, present models have large errors here—on the order of 50 percent. Not surprisingly, those models are unable to calculate correctly either the present average temperature of the Earth or the temperature ranges from the equator to the poles. Rather, the models are adjusted or "tuned" to get those quantities approximately right.

Figure 1: The Role of Dynamic Heat Transport in Modifying Greenhouse Warming



Note: Infrared opacity is greatest at the ground over the tropics and diminishes as one goes poleward and upward. Air currents bodily carry heat to regions of diminished infrared opacity where the heat is radiated to space—balancing absorbed sunlight. Lighter shading represents reduced opacity due to diminishing water vapor density.

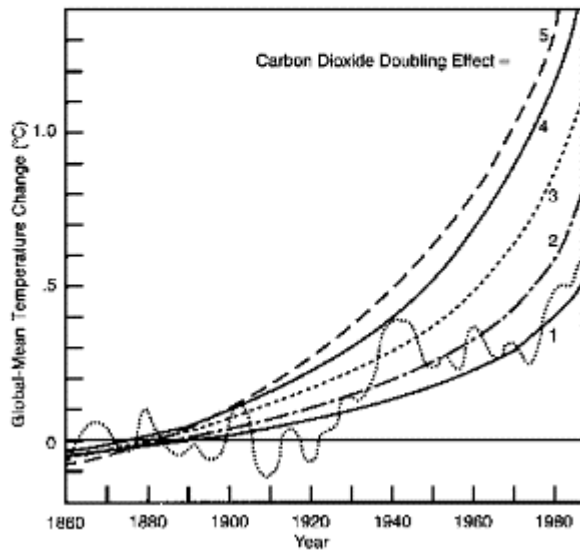
It is still of interest to ask what we would expect a doubling of carbon dioxide to do. A large number of calculations show that if this is all that happened, we might expect a warming of from .5 to 1.2 degrees centigrade. The general consensus is that such warming would present few, if any, problems. But even that prediction is subject to some uncertainty because of the complicated way the greenhouse effect operates. More important, the climate is a complex system where it is impossible for all other internal factors to remain constant. In present models those other factors amplify the effects of increasing carbon dioxide and lead to

predictions of warming in the neighborhood of four to five degrees centigrade. Internal processes within the climate system that change in response to warming in such a manner as to amplify the response are known as positive feedbacks. Internal processes that diminish the response are known as negative feedbacks. The most important positive feedback in current models is due to water vapor. In all current models upper tropospheric (five to twelve kilometers) water vapor--the major greenhouse gas--increases as surface temperatures increase. Without that feedback, no current model would predict warming in excess of 1.7 degrees centigrade--regardless of any other factors. Unfortunately, the way current models handle factors such as clouds and water vapor is disturbingly arbitrary. In many instances the underlying physics is simply not known. In other instances there are identifiable errors. Even computational errors play a major role. Indeed, there is compelling evidence for all the known feedback factors to actually be negative. In that case, we would expect the warming response to carbon dioxide doubling alone to be diminished.

It is commonly suggested that society should not depend on negative feedbacks to spare us from a "greenhouse catastrophe." What is omitted from such suggestions is that current models depend heavily on undemonstrated positive feedback factors to predict high levels of warming. The effects of clouds have been receiving the closest scrutiny. That is not unreasonable. Cloud cover in models is poorly treated and inaccurately predicted. Yet clouds reflect about seventy-five watts per square meter. Given that a doubling of carbon dioxide would change the surface heat flux by only two watts per square meter, it is evident that a small change in cloud cover can strongly affect the response to carbon dioxide. The situation is complicated by the fact that clouds at high altitudes can also supplement the greenhouse effect. Indeed, the effects of clouds in reflecting light and in enhancing the greenhouse effect are roughly in balance. Their actual effect on climate depends both on the response of clouds to warming and on the possible imbalance of their cooling and heating effects.

Similarly, factors involving the contribution of snow cover to reflectivity serve, in current models, to amplify warming due to increasing carbon dioxide. What happens seems reasonable enough; warmer climates presumably are associated with less snow cover and less reflectivity--which, in turn, amplify the warming. Snow is associated with winter when incident sunlight is minimal, however. Moreover, clouds shield the Earth's surface from the sun and minimize the response to snow cover. Indeed, there is growing evidence that clouds accompany diminishing snow cover to such an extent as to make that feedback factor negative. If, however, one asks why current models predict that large warming will accompany increasing carbon dioxide, the answer is mostly due to the effect of the water vapor feedback. Current models all predict that warmer climates will be accompanied by increasing humidity at all levels. As already noted, such behavior is an artifact of the models since they have neither the physics nor the numerical accuracy to deal with water vapor. Recent studies of the physics of how deep clouds moisturize the atmosphere strongly suggest that this largest of the positive feedbacks is not only negative, but very large.

Figure 2: Observed Behavior of Globally Averaged Temperatures since 1860 and Expected Behavior from Models Whose Equilibrium Response to a Doubling of Carbon Dioxide Is Indicated on the Curves



Not only are there major reasons to believe that models are exaggerating the response to increasing carbon dioxide, but, perhaps even more significantly, the models' predictions for the past century incorrectly describe the pattern of warming and greatly overestimate its magnitude. The global average temperature record for the past century or so is irregular and not without problems. It does, however, show an average increase in temperature of about .45 degree centigrade plus or minus .15 degree centigrade with most of the increase occurring before 1940, followed by some cooling through the early 1970s and a rapid (but modest) temperature increase in the late 1970s. As noted, we have already seen an increase in "equivalent" carbon dioxide of 50 percent. Thus, on the

basis of models that predict a four degree centigrade warming for a doubling of carbon dioxide we might expect to have seen a warming of two degrees centigrade already. If, however, we include the delay imposed by the oceans' heat capacity, we might expect a warming of about one degree centigrade--which is still twice what has been observed. Moreover, most of that warming occurred before the bulk of the minor greenhouse gases were added to the atmosphere. Figure 2 shows what might have been expected for models with differing sensitivities to a doubling of carbon dioxide. What we see is that the past record is most consistent with an equilibrium response to a doubling of about 1.3 degrees centigrade--assuming that all the observed warming was due to increasing carbon dioxide. There is nothing in the record that can be distinguished from the natural variability of the climate, however.

If one considers the tropics, that conclusion is even more disturbing. There is ample evidence that the average equatorial sea surface has remained within plus or minus one degree centigrade of its present temperature for billions of years, yet current models predict average warming of from two to four degrees centigrade even at the equator. It should be noted that for much of the Earth's history, the atmosphere had much more carbon dioxide than is currently anticipated for centuries to come. I could, in fact, go on at great length listing the evidence for small responses to a doubling of carbon dioxide; there are space constraints, however.

Consensus and the Current "Popular Vision"

Many studies from the nineteenth century on suggested that industrial and other contributions to increasing carbon dioxide might lead to global warming. Problems with such predictions were also long noted, and the general failure of such predictions to explain the observed record caused the field of climatology as a whole to regard the suggested mechanisms as suspect. Indeed, the global cooling trend of the 1950s and 1960s led to a minor global cooling hysteria in the 1970s. All that was more or less normal scientific debate, although the cooling hysteria had certain striking analogues to the present warming hysteria including books such as *The Genesis Strategy* by Stephen Schneider and *Climate Change and World Affairs* by

Crispin Tickell--both authors are prominent in support of the present concerns as well-- "explaining" the problem and promoting international regulation. There was also a book by the prominent science writer Lowell Ponte (*The Cooling*) that derided the skeptics and noted the importance of acting in the absence of firm, scientific foundation. There was even a report by the National Research Council of the U.S. National Academy of Sciences reaching its usual ambiguous conclusions. But the scientific community never took the issue to heart, governments ignored it, and with rising global temperatures in the late 1970s the issue more or less died. In the meantime, model calculations--especially at the Geophysical Fluid Dynamics Laboratory at Princeton--continued to predict substantial warming due to increasing carbon dioxide. Those predictions were considered interesting, but largely academic, exercises--even by the scientists involved.

The present hysteria formally began in the summer of 1988, although preparations had been put in place at least three years earlier. That was an especially warm summer in some regions, particularly in the United States. The abrupt increase in temperature in the late 1970s was too abrupt to be associated with the smooth increase in carbon dioxide. Nevertheless, James Hansen, director of the Goddard Institute for Space Studies, in testimony before Sen. Al Gore's Committee on Science, Technology and Space, said, in effect, that he was 99 percent certain that temperature had increased and that there was some greenhouse warming. He made no statement concerning the relation between the two.

Despite the fact that those remarks were virtually meaningless, they led the environmental advocacy movement to adopt the issue immediately. The growth of environmental advocacy since the 1970s has been phenomenal. In Europe the movement centered on the formation of Green parties; in the United States the movement centered on the development of large public interest advocacy groups. Those lobbying groups have budgets of several hundred million dollars and employ about 50,000 people; their support is highly valued by many political figures. As with any large groups, self-perpetuation becomes a crucial concern. "Global warming" has become one of the major battle cries in their fundraising efforts. At the same time, the media unquestioningly accept the pronouncements of those groups as objective truth.

Within the large-scale climate modelling community--a small subset of the community interested in climate--however, the immediate response was to criticize Hansen for publicly promoting highly uncertain model results as relevant to public policy. Hansen's motivation was not totally obvious, but despite the criticism of Hansen, the modelling community quickly agreed that large warming was not impossible. That was still enough for both the politicians and advocates who have generally held that any hint of environmental danger is a sufficient basis for regulation unless the hint can be rigorously disproved. That is a particularly pernicious asymmetry, given that rigor is generally impossible in environmental sciences.

Other scientists quickly agreed that with increasing carbon dioxide some warming might be expected and that with large enough concentrations of carbon dioxide the warming might be significant. Nevertheless, there was widespread skepticism. By early 1989, however, the popular media in Europe and the United States were declaring that "all scientists" agreed that warming was real and catastrophic in its potential.

As most scientists concerned with climate, I was eager to stay out of what seemed like a public circus. But in the summer of 1988 Lester Lave, a professor of economics at Carnegie

Mellon University, wrote to me about being dismissed from a Senate hearing for suggesting that the issue of global warming was scientifically controversial. I assured him that the issue was not only controversial but also unlikely. In the winter of 1989 Reginald Newell, a professor of meteorology at the Massachusetts Institute of Technology, lost National Science Foundation funding for data analyses that were failing to show net warming over the past century. Reviewers suggested that his results were dangerous to humanity. In the spring of 1989 I was an invited participant at a global warming symposium at Tufts University. I was the only scientist among a panel of environmentalists. There were strident calls for immediate action and ample expressions of impatience with science. Claudine Schneider, then a congressman from Rhode Island, acknowledged that "scientists may disagree, but we can hear Mother Earth, and she is crying." It seemed clear to me that a very dangerous situation was arising, and the danger was not of "global warming" itself.

In the spring of 1989 I prepared a critique of global warming, which I submitted to *Science*, a magazine of the American Association for the Advancement of Science. The paper was rejected without review as being of no interest to the readership. I then submitted the paper to the *Bulletin of the American Meteorological Society*, where it was accepted after review, rereviewed, and reaccepted--an unusual procedure to say the least. In the meantime, the paper was attacked in *Science* before it had even been published. The paper circulated for about six months as samizdat. It was delivered at a Humboldt conference at M.I.T. and reprinted in the *Frankfurter Allgemeine*.

In the meantime, the global warming circus was in full swing. Meetings were going on nonstop. One of the more striking of those meetings was hosted in the summer of 1989 by Robert Redford at his ranch in Sundance, Utah. Redford proclaimed that it was time to stop research and begin acting. I suppose that that was a reasonable suggestion for an actor to make, but it is also indicative of the overall attitude toward science. Barbara Streisand personally undertook to support the research of Michael Oppenheimer at the Environmental Defense Fund, although he is primarily an advocate and not a climatologist. Meryl Streep made an appeal on public television to stop warming. A bill was even prepared to guarantee Americans a stable climate.

By the fall of 1989 some media were becoming aware that there was controversy (*Forbes* and *Reader's Digest* were notable in that regard). Cries followed from environmentalists that skeptics were receiving excessive exposure. The publication of my paper was followed by a determined effort on the part of the editor of the *Bulletin of the American Meteorological Society*, Richard Hallgren, to solicit rebuttals. Such articles were prepared by Stephen Schneider and Will Kellogg, a minor scientific administrator for the past thirty years, and those articles were followed by an active correspondence mostly supportive of the skeptical spectrum of views. Indeed, a recent Gallup poll of climate scientists in the American Meteorological Society and in the American Geophysical Union shows that a vast majority doubts that there has been any identifiable man-caused warming to date (49 percent asserted no, 33 percent did not know, 18 percent thought some has occurred; however, among those actively involved in research and publishing frequently in peer-reviewed research journals, none believes that any man-caused global warming has been identified so far). On the whole, the debate within the meteorological community has been relatively healthy and, in this regard, unusual.

Outside the world of meteorology, Greenpeace's Jeremy Legett, a geologist by training, published a book attacking critics of warming---especially me. George Mitchell, Senate majority leader and father of a prominent environmental activist, also published a book urging acceptance of the warming problem (World on Fire: Saving an Endangered Earth). Sen. Gore recently published a book (Earth in the Balance: Ecology and the Human Spirit). Those are just a few examples of the rapidly growing publications on warming. Rarely has such meager science provoked such an outpouring of popularization by individuals who do not understand the subject in the first place.

The activities of the Union of Concerned Scientists deserve special mention. That widely supported organization was originally devoted to nuclear disarmament. As the cold war began to end, the group began to actively oppose nuclear power generation. Their position was unpopular with many physicists. Over the past few years, the organization has turned to the battle against global warming in a particularly hysterical manner. In 1989 the group began to



circulate a petition urging recognition of global warming as potentially the great danger to mankind. Most recipients who did not sign were solicited at least twice more. The petition was eventually signed by 700 scientists including a great many members of the National Academy of Sciences and Nobel laureates. Only about three or four of the signers, however, had any involvement in climatology. Interestingly, the petition had two pages, and on the second page there was a call for renewed consideration of nuclear power. When the petition was published in the New York Times, however, the second page was omitted. In any event, that document helped solidify the public perception that "all scientists" agreed with the disaster scenario. Such a disturbing abuse of scientific authority was not unnoticed. At the 1990 annual meeting of the National Academy of Sciences, Frank Press, the academy's president, warned the membership against lending their credibility to issues

about which they had no special knowledge. Special reference was made to the published petition. In my opinion what the petition did show was that the need to fight "global warming" has become part of the dogma of the liberal conscience--a dogma to which scientists are not immune.

At the same time, political pressures on dissidents from the "popular vision" increased. Sen. Gore publicly admonished "skeptics" in a lengthy New York Times op-ed piece. In a perverse example of double-speak he associated the "true believers" in warming with Galileo. He also referred, in another article, to the summer of 1988 as the Kristallnacht before the warming holocaust.

The notion of "scientific unanimity" is currently intimately tied to the Working Group I report of the Intergovernmental Panel on Climate Change issued in September 1990. That panel consists largely of scientists posted to it by government agencies. The panel has three working groups. Working Group I nominally deals with climate science. Approximately 150 scientists contributed to the report, but university representation from the United States was relatively small and is likely to remain so, since the funds and time needed for participation are not available to most university scientists. Many governments have agreed to use that report as the authoritative basis for climate policy. The report, as such, has both positive and negative features. Methodologically, the report is deeply committed to reliance on large models, and within the report models are largely verified by comparison with other models. Given that models are known to agree more with each other than with nature (even after "tuning"), that approach does not seem promising. In addition, a number of the participants have testified to the pressures placed on them to emphasize results supportive of the current scenario and to suppress other results. That pressure has frequently been effective, and a survey of participants reveals substantial disagreement with the final report. Nonetheless, the body of the report is extremely ambiguous, and the caveats are numerous. The report is prefaced by a policymakers' summary written by the editor, Sir John Houghton, director of the United Kingdom Meteorological Office. His summary largely ignores the uncertainty in the report and attempts to present the expectation of substantial warming as firmly based science. The summary was published as a separate document, and, it is safe to say that policymakers are unlikely to read anything further. On the basis of the summary, one frequently hears that "hundreds of the world's greatest climate scientists from dozens of countries all agreed that...". It hardly matters what the agreement refers to, since whoever refers to the summary insists that it agrees with the most extreme scenarios (which, in all fairness, it does not). I should add that the climatology community, until the past few years, was quite small and heavily concentrated in the United States and Europe.

While the International Panel on Climate Change's reports were in preparation, the National Research Council in the United States was commissioned to prepare a synthesis of the current state of the global change situation. The panel chosen was hardly promising. It had no members of the academy expert in climate. Indeed, it had only one scientist directly involved in climate, Stephen Schneider, who is an ardent environmental advocate. It also included three professional environmental advocates, and it was headed by a former senator, Dan Evans. The panel did include distinguished scientists and economists outside the area of climate, and, perhaps because of this, the report issued by the panel was by and large fair. The report concluded that the scientific basis for costly action was absent, although prudence might indicate that actions that were cheap or worth doing anyway should be considered. A subcommittee of the panel issued a report on adaptation that argued that even with the more severe warming scenarios, the United States would have little difficulty adapting. Not surprisingly, the environmentalists on the panel not only strongly influenced the reports, but failing to completely have their way, attempted to distance themselves from the reports by either resigning or by issuing minority dissents. Equally unsurprising is the fact that the New York Times typically carried reports on that panel on page 46. The findings were never subsequently discussed in the popular media--except for claims that the reports supported the catastrophic vision. Nevertheless, the reports of that panel were indicative of the growing skepticism concerning the warming issue.

Indeed, the growing skepticism is in many ways remarkable. One of the earliest protagonists of global warming, Roger Revelle, the late professor of ocean sciences at Scripps Institution of Oceanography who initiated the direct monitoring of carbon dioxide during the International Geophysical Year (1958), coauthored with S. Fred Singer and Chauncy Starr a paper recommending that action concerning global warming be delayed insofar as current knowledge was totally inadequate. Another active advocate of global warming, Michael McElroy, head of the Department of Earth and Planetary Sciences at Harvard, has recently written a paper acknowledging that existing models cannot be used to forecast climate.

One might think that such growing skepticism would have some influence on public debate, but the insistence on "scientific unanimity" continues unabated. At times, that insistence takes some very strange forms. Over a year ago, Robert White, former head of the U.S. Weather Bureau and currently president of the National Academy of Engineering, wrote an article for Scientific American that pointed out that the questionable scientific basis for global warming predictions was totally inadequate to justify any costly actions. He did state that if one were to insist on doing something, one should only do things that one would do even if there were no warming threat. Immediately after that article appeared, Tom Wicker, a New York Times columnist and a confidant of Sen. Gore, wrote a piece in which he stated that White had called for immediate action on "global warming." My own experiences have been similar. In an article in Audubon Stephen Schneider states that I have "conceded that some warming now appears inevitable." Differences between expectations of unmeasurable changes of a few tenths of a degree and warming of several degrees are conveniently ignored. Karen White in a lengthy and laudatory article on James Hansen that appeared in the New York Times Sunday Magazine reported that even I agreed that there would be warming, having "reluctantly offered an estimate of 1.2 degrees." That was, of course, untrue.

Most recently, I testified at a Senate hearing conducted by Sen. Gore. There was a rather arcane discussion of the water vapor in the upper troposphere. Two years ago, I had pointed out that if the source of water vapor in that region in the tropics was from deep clouds, then surface warming would be accompanied by reduced upper level water vapor. Subsequent research has established that there must be an additional source--widely believed to be ice crystals thrown off by those deep clouds. I noted that that source too probably acts to produce less moisture in a warmer atmosphere. Both processes cause the major feedback process to become negative rather than positive. Sen. Gore asked whether I now rejected my suggestion of two years ago as a major factor. I answered that I did. Gore then called for the recording secretary to note that I had retracted my objections to "global warming." In the ensuing argument, involving mostly other participants in the hearing, Gore was told that he was confusing matters. Shortly thereafter, however, Tom Wicker published an article in the New York Times that claimed that I had retracted my opposition to warming and that that warranted immediate action to curb the purported menace. I wrote a letter to the Times indicating that my position had been severely misrepresented, and, after a delay of over a month, my letter was published. Sen. Gore nonetheless claims in his book that I have indeed retracted my scientific objections to the catastrophic warming scenario and also warns others who doubt the scenario that they are hurting humanity.

Why, one might wonder, is there such insistence on scientific unanimity on the warming issue? After all, unanimity in science is virtually nonexistent on far less complex matters. Unanimity on an issue as uncertain as "global warming" would be surprising and suspicious.

Moreover, why are the opinions of scientists sought regardless of their field of expertise? Biologists and physicians are rarely asked to endorse some theory in high energy physics. Apparently, when one comes to "global warming," any scientist's agreement will do.

The answer almost certainly lies in politics. For example, at the Earth Summit in Rio, attempts were made to negotiate international carbon emission agreements. The potential costs and implications of such agreements are likely to be profound for both industrial and developing countries. Under the circumstances, it would be very risky for politicians to undertake such agreements unless scientists "insisted." Nevertheless, the situation is probably a good deal more complicated than that example suggests.

The Temptation and Problems of "Global Warming"

As Aaron Wildavsky, professor of political science at Berkeley, has quipped, "global warming" is the mother of all environmental scares. Wildavsky's view is worth quoting. "Warming (and warming alone), through its primary antidote of withdrawing carbon from production and consumption, is capable of realizing the environmentalist's dream of an egalitarian society based on rejection of economic growth in favor of a smaller population's eating lower on the food chain, consuming a lot less, and sharing a much lower level of resources much more equally." In many ways Wildavsky's observation does not go far enough. The point is that carbon dioxide is vitally central to industry, transportation, modern life, and life in general. It has been joked that carbon dioxide controls would permit us to inhale as much as we wish; only exhaling would be controlled. The remarkable centrality of carbon dioxide means that dealing with the threat of warming fits in with a great variety of preexisting agendas--some legitimate, some less so: energy efficiency, reduced dependence on Middle Eastern oil, dissatisfaction with industrial society (neopastoralism), international competition, governmental desires for enhanced revenues (carbon taxes), and bureaucratic desires for enhanced power.

The very scale of the problem as popularly portrayed and the massive scale of the suggested responses have their own appeal. The Working Group I report of the Intergovernmental Panel on Climate Change suggested, for example, that a 60 percent reduction in carbon dioxide emissions might be needed. Such a reduction would call for measures that would be greater than those that have been devoted to war and defense. And just as defense has dealt with saving one's nation, curbing "global warming" is identified with saving the whole planet! It may not be fortuitous that this issue is being promoted at just the moment in history when the cold war is ending.

Major agencies in the United States, hitherto closely involved with traditional approaches to national security, have appropriated the issue of climate change to support existing efforts. Notable among those agencies are NASA, the Department of Defense, and the Department of Energy. The cold war helped spawn a large body of policy experts and diplomats specializing in issues such as disarmament and alliance negotiations. In addition, since the Yom Kippur War, energy has become a major component of national security with the concomitant creation of a large cadre of energy experts. Many of those individuals see in the global change issue an area in which to continue applying their skills. Many scientists also feel that national security concerns formed the foundation for the U.S. government's generous support of science. As the urgency of national security, traditionally defined, diminishes, there is a

common feeling that a substitute foundation must be established. "Saving the planet" has the right sort of sound to it. Fundraising has become central to environmental advocates' activities, and the message underlying some of their fundraising seems to be "pay us or you'll fry."

Clearly, "global warming" is a tempting issue for many very important groups to exploit. Equally clearly, though far less frequently discussed, are the profound dangers in exploiting that issue. As we shall also see, there are good reasons why there has been so little discussion of the downside of responding to "global warming."

A parochial issue is the danger to the science of climatology. As far as I can tell, there has actually been reduced funding for existing climate research. That may seem paradoxical, but, at least in the United States, the vastly increased number of scientists and others involving themselves in climate as well as the gigantic programs attaching themselves to climate have substantially outstripped the increases in funding. Perhaps more important are the pressures being brought to bear on scientists to get the "right" results. Such pressures are inevitable, given how far out on a limb much of the scientific community has gone. The situation is compounded by the fact that some of the strongest proponents of "global warming" in Congress are also among the major supporters of science (Sen. Gore is notable among those). Finally, given the momentum that has been building up among so many interest groups to fight "global warming," it becomes downright embarrassing to support basic climate research. After all, one would hate to admit that one had mobilized so many resources without the basic science's being in place. Nevertheless, given the large increase in the number of people associating themselves with climatology and the dependence of much of that community on the perceived threat of warming, it seems unlikely that the scientific community will offer much resistance. I should add that as ever greater numbers of individuals attach themselves to the warming problem, the pressures against solving the problem grow proportionally; an inordinate number of individuals and groups depend on the problem's remaining.

In addition to climatologists, are there other groups that are at risk? Here, one might expect that industry could be vulnerable, and, indeed, it may be. At least in the United States, however, industries seem to be primarily concerned with improving their public image, often by supporting environmental activists. Moreover, some industries have become successful at profiting from environmental regulation. The most obvious example is the waste management industry. Even electric utility companies have been able to use environmental measures to increase the base on which their regulated profits are calculated. It is worth noting that about 1.7 trillion dollars have been spent on the environment over the past decade. The environment, itself, qualifies as one of our major industries.

If Wildavsky's scenario is correct, the major losers would be ordinary people. Wealth that could have been used to raise living standards in much of the world would be squandered. Living standards in the developed world would decrease. Regulatory apparatuses would restrict individual freedom on an unprecedented scale. Here too, however, one cannot expect much resistance to proposed actions--at least not initially. Public perceptions, under the influence of extensive, deceptive, and one-sided publicity, can become disconnected from reality. For example, Alabama has had a pronounced cooling trend since 1935. Nevertheless, a poll among professionals in Alabama found that about 95 percent of the participants believed that the climate had been warming over the past fifty years and that the warming was due to

the greenhouse effect. Public misperceptions coupled with a sincere desire to "save the planet" can force political action even when politicians are aware of the reality.

What the above amounts to is a societal instability. At a particular point in history, a relatively minor suggestion or event serves to mobilize massive interests. While the proposed measures may be detrimental, resistance is largely absent or coopted. In the case of climate change, the probability that the proposed regulatory actions would for the most part have little impact on climate, regardless of the scenario chosen, appears to be of no consequence.

Modelling and Societal Instability

So far I have emphasized the political elements in the current climate hysteria. There can be no question, however, that scientists are abetting this situation. Concerns about funding have already been mentioned. There is, however, another perhaps more important element to the scientific support. The existence of modern computing power has led to innumerable modelling efforts in many fields. Supercomputers have allowed us to consider the behavior of systems seemingly too complex for other approaches. One of those systems is climate. Not surprisingly, there are many problems involved in modelling climate. For example, even supercomputers are inadequate to allow long-term integrations of the relevant equations at adequate spatial resolutions. At presently available resolutions, it is unlikely that the computer solutions are close to the solutions of the underlying equations. In addition, the physics of unresolved phenomena such as clouds and other turbulent elements is not understood to the extent needed for incorporation into models. In view of those problems, it is generally recognized that models are at present experimental tools whose relation to the real world is questionable.

While there is nothing wrong in using those models in an experimental mode, there is a real dilemma when they predict potentially dangerous situations. Should scientists publicize such predictions since the models are almost certainly wrong? Is it proper to not publicize the predictions if the predicted danger is serious? How is the public to respond to such predictions? The difficulty would be diminished if the public understood how poor the models actually are. Unfortunately, there is a tendency to hold in awe anything that emerges from a sufficiently large computer. There is also a reluctance on the part of many modellers to admit to the experimental nature of their models lest public support for their efforts diminish. Nevertheless, with poor and uncertain models in wide use, predictions of ominous situations are virtually inevitable--regardless of reality.

Such weak predictions feed and contribute to what I have already described as a societal instability that can cascade the most questionable suggestions of danger into major political responses with massive economic and social consequences. I have already discussed some of the reasons for this instability: the existence of large cadres of professional planners looking for work, the existence of advocacy groups looking for profitable causes, the existence of agendas in search of saleable rationales, and the ability of many industries to profit from regulation, coupled with an effective neutralization of opposition. It goes almost without saying that the dangers and costs of those economic and social consequences may be far greater than the original environmental danger. That becomes especially true when the benefits of additional knowledge are rejected and when it is forgotten that improved technology and increased societal wealth are what allow society to deal with environmental

threats most effectively. The control of societal instability may very well be the real challenge facing us.