Global Warming Balance Sheet: What We Really Know

By Stephen H. Schneider

IT is important for Americans to address the questions: So what if the climate changes? How much would disruption of the expected climate disrupt nature or our economy?

We've already heard from climate researchers that the earth's surface temperature has risen about 1 degree F. since the 19th century. We've been told about the potential for further warming of several degrees that may cause ecological disruption. But the tough economic – political really – question is, how much is our stewardship of nature worth? Scientists have published hundreds of papers on the potential impacts of projected climactic changes. Their estimates range from small benefits to catastrophic losses.

To try to sort this out, Yale economist William Nordhaus asked 19 economists, technologists, and natural scientists familiar with the scores of studies of "climate damages" to estimate such damage as a percentage of lost gross domestic product (GDP) for the world. Using a hypothetical scenario of 3 degrees C. warming by AD 2100, the best estimate of the group Nordhaus referred to as mainstream economists was about a 1 percent GDP loss – with fairly large uncertainty. The natural scientists estimated 10 times greater damage – but with even greater uncertainty.

Part of the difference in these professionals' world views is the higher value that natural scientists put on nature's unpriced services, like waste recycling, flood control, or biotic diversity. Economists are more optimistic that humans can invent substitutes for such ecological services. Let's suppose the economists are right. Even 1 percent of world GDP lost annually is, in today's terms, some $200 billion each year! Where do such dollar values come from?

First, consider sea level. Hurricane Andrew caused unprecedented losses, about $40 billion. Before 1987 no weather event had caused damages in excess of $1 billion. Since then, several have caused tens of billions of dollars in damages. The insurance industry is understandably very alarmed.

Although there is some theoretical reason to expect that warmer ocean temperatures could produce stronger storms, this analysis is controversial, and no one can credibly attribute some percentage of Andrew's damage to global warming. But we do know that as the earth warmed, sea levels became about 4 to 10 inches higher than a century ago, which means that any storm, natural or enhanced by global warming, will have an accompanying storm surge that penetrates farther inland and creates greater damages. Typical global warming scenarios include projections for a one-half foot to three foot greater sea level rise over the next 100 years. Those rises clearly will pose costs and risks to hundreds of millions of coastal dwellers – and even to the existence of some island states.

Now, consider hydrological extremes. By hydrological extremes I mean droughts and floods. Are the many costly floods that occurred across the United States over the past five years, or the droughts in 1988, or the heat wave in 1995 that killed hundreds of vulnerable elderly people in Chicago, merely two "snake eyes" in a row from nature, or, rather, are we "loading the climate dice?"

First, some theory. Since we add heat-trapping gases like carbon dioxide to the atmosphere, which, in turn, add energy to the earth's surface, some of that energy will be used to evaporate water. No one who is knowledgeable disputes that. More evaporation globally means more rainfall globally. Thus when the atmosphere configures itself for locally heavy rains, more evaporation means heavier rains on average. Likewise, as farmers or lawn waterers know, when the atmosphere is in a drier mode, higher temperatures suck more water from the soils.

Taken together, these physical arguments provide the rationale for forecasting increased droughts and floods from global warming. But this is physical reasoning, not proof.

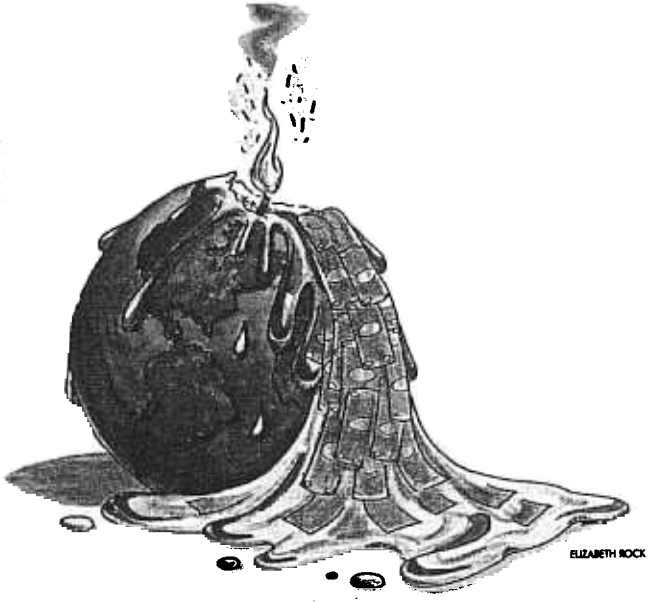
So now to some data. Tom Karl and his colleagues at the National Climate Center in Asheville, N.C., have analyzed reports from thousands of weather stations in the US over the past century and found about a 10 percent increase in precipitation since 1910. More significantly, most of this increase occurred in the top 10 percentile of extreme daily rainfall events – that is, the "gully washers" that insurance companies fear. While these observations are consistent both with theory and climate model predictions, and thus are strong circumstantial evidence for a global warming impact, certain proof will take a few more decades of performing this unplanned experiment on "laboratory Earth."

Finally, in a system as complex as the earth-atmosphere-ocean-ice biosphere system – what scientists call a "nonlinear" system – we cannot have precise forecasts that are credible. But, as the Intergovernmental Panel on Climate Change noted in concluding its 1995 assessment report, "When rapidly forced, nonlinear systems are especially subject to unexpected behavior." My free translation of this concern is that reducing the pressure that humans put on nature is an insurance policy against "nasty surprises."

NOBEL LAUREATES ON 21ST CENTURY CLIMATE

■ Professor Schneider, Stanford University climatologist and author of the adjoining column, recently joined six other natural scientists at a public briefing for President Clinton. Their message: that global warming is a real phenomenon.

Dr. Schneider adapted this article from his remarks at the briefing. His colleagues were Nobel Laureates Mario Molina of MIT and Sherwood Rowland of the University of California at Irvine, discoverers of the ozone hole; Nobel Laureate Henry Kendall of MIT, head of the Union for Concerned Scientists; ecologist Jane Lubchenco of Oregon State University; infectious disease expert Robert Shope of the University of Texas; and energy expert John Holdren of Harvard.



ELIZABETH ROCK

Stephen H. Schneider

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Twisted Revision

The most precious intangible any scientist can earn is a reputation for the courage to change directions when new evidence compels a switch. Similarly, I suspect, respectability for a journalist is the ability to sort the shallow from the deep and to ensure that all quotations have been checked for accuracy and context.

I (along with Vice President Al Gore) am branded by Charles Krauthammer ["Global Warming Fundamentalists," op-ed, Dec. 9] as being "inflexible and intolerant" for my concern over the potential seriousness of global warming. To us "global warming fundamentalists," Krauthammer asserts, "uncertainty is a foreign feeling." For a scientist, that is a pretty serious charge.

The prime evidence for this attack is a few snippets quoted from a 1971 scientific paper of which I—then a graduate student—was junior author. Krauthammer quotes me as saying carbon dioxide from industrial sources "is unlikely to produce a runaway greenhouse effect on Earth" as if that 28-year-old belief refutes my current concerns for the two dozen billion tons of carbon dioxide we humans dump annually into the air.

Ironically, though, this polluting would not have produced a "runaway greenhouse effect" in 1971—nor would it today. Krauthammer seems unaware that "runaway greenhouse" is jargon for conditions on Venus, where oven-like temperatures result from a massive carbon dioxide greenhouse effect. In the context of earth, I have never been such a catastrophist, then or now, as this quotation proves, even if the column turns it upside down to make an opposite point.

Krauthammer goes on to note that in that same paper I calculated that global increases in aerosols (i.e., hazes from industrial and agricultural activities) could cause very large-scale cooling, greater than the warming then projected.

That I did do, but Krauthammer neglects to mention that I explicitly said very little was known about the extent of these aerosols. We simply cited existing literature (not making our own predictions) that suggested that global dust content was increasing significantly. Within a few years, it became clear—in no small measure because of inquiry stimulated by this controversial paper—that aerosols were mostly a regional problem and that greenhouse gases were more significant a climate threat than I had previously calculated.

Only a few years later this shift toward warming over cooling (and the open admission of a large degree of uncertainty over details) was explicitly noted in another

Taking Exception

scientific article (Journal of the Atmospheric Sciences, 1975). This 1975 correction to the cooling hypotheses that had been current in 1971 was not published by one of today's senior "contrarians"—a group of maybe a dozen scientist-dissenters backed up by millions of dollars from the fossil fuel industry's public relations campaigns—but by me.

All I was doing then was precisely what scientists are trained to do: follow the evidence where it leads, revise our opinions as new data or theories emerge and state the conclusions with uncertainties attached. I have written dozens of scientific papers with uncertainty as a prime theme and have run several meetings on ways to quantify uncertainties so that wild opinions can be separated from more likely estimates to help the policy process proceed more rationally.

This brings me to the worst accusation that Krauthammer hurls: He alleges that I try to suppress opposing views, quoting me as believing it is "journalistically irresponsible to present both sides." This out-of-context quote is a gross distortion of my oft-published views in which I argue that it is irresponsible to cover science as if it were a political contest—that is, quote the Democrat, then get the other side, the Republican. Such balance is appropriate in covering two-party politics, but there are rarely only two sides in science and, more important, not all opinions are equally credible.

To quote a hundred-scientist assessment in one sentence and then "balance" the story by giving equal space and credibility to one of a handful of contrarian scientists who represent a tiny minority of knowledgeable opinions *is* irresponsible journalism in my opinion. Such false balance projects a distortion of the mainstream knowledge base of the scientific community because it represents all opinions as somehow being equally credible, even though thousands of scientists have worked for years to sort out the likely from the unlikely—and we're still doing that because science is never 100 percent certain of anything.

Krauthammer's column is subtitled "nuclear winter without the nukes." That's ironic, because in the actual controversy over nuclear winter, it wasn't the contrarians whose scientific work and public outreach convinced a skeptical scientific community (and an even more hostile peace activist community) that the original conception of "nuclear winter" in 1983 needed revision. Rather, it was I and my former students Curt Covey and Starley Thompson. Thompson and I not only did the revisionist science but, in a move rare for scientists, visibly explained (in Foreign Affairs, 1985) the revisions to the non-scientific world—and took the political heat for the correction that followed: "nuclear fall."

In short, I am not now and never have been in the ends-justify-the-means club.

Krauthammer ends his column with a call for "a modicum of humility before we go ahead and wreck the good life we've developed over 200 years in the name of a theory." But the vast bulk of published studies in the economics literature (save one consulting company's calculation now being ballyhooed by media ads of the polluting industries—which of course don't say that this study is based on absurdly pessimistic assumptions) suggest that most proposed policy strategies to help mitigate global warming would cost the world economy anywhere from a net benefit to only a percent or so loss of GDP.

I do believe in characterizing uncertainty and in reporting the many sides of a scientific debate, but only if the relative credibility of each position is stated. And, finally, I do believe that global warming, while not certain, is a significant potential threat that deserves some efforts to slow down the rate at which we use the atmosphere as a free sewer.

The writer is a professor of biological sciences and international studies at Stanford University.

Charles Krauthammer

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Global Warming Fundamentalists

This is nuclear winter without the nukes.

The world is meeting in Kyoto, Japan, to decide how much wreckage to visit upon the Western economies to prevent global warming. Kyoto aims to seriously reduce greenhouse gas emissions, which would seriously curtail energy use and, with it, economic growth. All under the premise that humans produce global warming and that global warming will produce a human catastrophe. Is this true?

There has been a very slight warming of the earth's atmosphere in this century (although one still has to explain why satellite and balloon data show no net temperature rise in the past 19 years). But first, it is not clear how much is caused by natural variation only. Second, even assuming a substantial human contribution, it is not clear what, say, a doubling of carbon dioxide (CO_2) emissions would do to temperatures.

You get can get answers by modeling. But scientific models are notoriously subject to the tweaking of underlying assumptions. The predictions of the Intergovernmental Panel on Climate Change have already been significantly modified. In 1990 it predicted a 6-degree (F) rise by 2100. The prediction now is down to a 3½-degree rise, a 40 percent drop. And there is a huge range of uncertainty: The lower-end estimate is less than 2 degrees F.

But uncertainty is a feeling foreign to global warming fundamentalists, many of them now gathered in Kyoto. Take that great American evangelist, Vice President Gore, a last-minute attendee. Now, Gore may turn out to be the environmentalists' villain because he fears infuriating his labor allies at home if he agrees to serious curbs on U.S. CO_2 (and thus energy) production. But whatever he ends up doing for personal political reasons, it is clear what he believes. Just two months ago, he likened those who question global warming to tobacco executives who with a "straight face" denied that smoking causes cancer. This is a serious charge: not just error, but bad faith.

This attitude is echoed by many scientists. Stephen Schneider, a Stanford scientist and participant at Clinton and Gore's Global Climate Change Roundtable last July, has said that when it comes to global warming it is "journalistically irresponsible to present both sides."

It is worth noting that 25 years ago this same Schneider was vociferously *denying* global warming. Even a tenfold increase in human production of carbon dioxide, he wrote, "which at the present rate of input is not expected within the next several thousand years" is "unlikely to produce a runaway greenhouse effect on Earth." Indeed, "the doubling of carbon dioxide"—which is what Kyoto is trying so desperately to prevent—"would produce a temperature change of less than one degree [centigrade]."

Schneider argued then that the real threat was global *cooling:* The production of aerosols screening earth from the sun could produce "a decrease of the mean surface temperature by as much as 3.5 degrees centigrade," which "if sustained over a period of several years . . . could be sufficient to trigger an ice age."

This is nuclear winter without the nukes. And this was no offhanded comment. This was a paper in the prestigious journal Science, complete with equations containing a gaudy excess of exponents and Greek subscripts.

Nor was Schneider alone. In the 1970s, which were—surprise!—cold, global cooling was the vogue. Nigel Calder, former editor of New Scientist, said in 1975 that "the threat of a new ice age must now stand alongside nuclear war as a likely source of wholesale death and misery for mankind." And Science Digest declared that "how carefully we monitor our atmospheric pollution will have direct bearing on the arrival and nature of this weather crisis"—i.e., a new "ice age."

All this doom-saying provoked J. Murray Mitchell of the National Oceanic and Atmospheric Administration to remark in 1976 that "whenever there is a cold wave, they [the media] seek out a proponent of the ice-age-is-coming school and put his theories on page one. . . . Whenever there is a heat wave . . . they turn to his opposite number [for a prediction of] a kind of heat death of the earth."

It is one thing to change your mind. It is another to then, with the zeal of the convert, write the view you have just abandoned out of polite society, as does Schneider by saying that journalists shouldn't even present the non-global warming view, and as does Gore when he makes skeptics into the moral equivalent of tobacco executives. Ironically, as climate change predictions become more malleable and contingent, climate change activists become more inflexible and intolerant.

The ease with which politicians, popularizers and even scientists can be caught up in popular enthusiasms for one doomsday or another should give us pause. This is not a call for ignoring climate change. It is a call for a modicum of humility before we go ahead and wreck the good life we've developed over 200 years in the name of a theory.

The Earth as lab

Scientists are increasingly confident that they can pinpoint the culprits of global warming, says Stephen Schneider

Awareness that pollution can degrade our environment is hardly new. That was dramatically learned centuries ago when uncontrolled coal burning fuelled the infamous London smogs. Modern environmental problems are unique in that the scale is no longer local but global, and potentially irreversible effects are likely – thus it is no longer acceptable to learn by doing. When the laboratory is the earth, we need to anticipate the outcome of our experiments before we perform them.

One of the most potentially serious problems facing the earth is the synergistic effect of changing climate and fragmentation of the environment. People fragment natural habitats for farmland, settlements, mines or other development activities. If climate changes, individual species of plants and animals will be forced to adjust if they can. In the past they typically migrated with changing climate as spruce trees did when the last ice age ended 10,000 years ago. But could all the migrating species that survived the last ice age make it across freeways, agricultural zones and cities of the 21st century?

This problem raises several controversial questions. Should we anticipate this risk and respond by setting up interconnected nature reserves as a hedge against some species going extinct if the climate changes? How much is it worth to protect the survival of a species or a habitat? What is the value of life – of humans or other species?

Good science is necessary to help answer how such biological conservation practices can take place in the most economically efficient way. What policies society should choose to respond to the advent of global change projections, however, is not a scientific question *per se*, but a political value choice about how to take risks and about who pays the "insurance" premiums to reduce risks or compensate losers.

Policy choice depends on the norms or values of the decision makers – be they consumers, voters, or cabinet ministers. Just because some economists or politicians choose not to value the preservation of biological diversity very highly, for example, does not mean that the majority of the public feels the same way, or would continue to feel the same way if they learned more about the problems.

The problem of global climate change involves a large degree of uncertainty. However, several aspects of the issue are well understood and have brought about consensus in the scientific community. Scientists agree, for example, that approximately six billion tonnes of carbon are emitted as carbon dioxide to the atmosphere every year from industrial activities, mainly the burning of fossil fuels. There is widespread consensus that the build-up of a concentration of carbon dioxide in the atmosphere, combined with build-ups of other greenhouse gases, has trapped in the lower atmosphere roughly an additional two watts per square metre of energy over the entire earth since the industrial revolution. Climatologists also generally agree that the global surface air temperature has warmed up on average approximately 0.5 +/- 0.2 degrees centigrade in the past century.

Uncertainties become more significant when we move to projections about the future. The combination of increased population and increased energy consumption per capita is expected to contribute to increased carbon dioxide and sulphate emissions over the next century, but the extent of the increase is uncertain. Central estimates of emissions imply a doubling of current carbon dioxide concentrations by the middle of the 21st century, leading to typically projected warming of the earth ranging from one degree to more than 5 degrees centigrade by the end of the 21st century.

Warming at the low end of this uncertainty range could still have significant implications for ecosystem adjustments, whereas warming of 5 degrees centigrade or more in the time frame of a century or less could have catastrophic effects on natural and managed ecosystems and produce serious coastal flooding. The overall cost of these, and other, environmental impacts could run into tens of billions of dollars annually. Since such costs are not included in the price of conventional fuels, they are called "economic externalities." Internalising such externalities is a principal goal of international climate policy advocates.

Analysts from a variety of disciplines have been attempting to gauge the impact of global climate change on agriculture, water supplies, biodiversity and economic growth; others are attempting to get a better sense of the probabilities of the different climate change scenarios. In tandem with this work, many economists have been seeking to estimate the costs in particular countries of strategies designed to reduce carbon dioxide emissions.

But, critics charge, isn't talk of abatement costs or climatic damage to nature or society premature, until we have demonstrated more confidently that climate change is indeed happening (what we call the "signal detection" problem) and, if so, what caused it to happen (the so-called "attribution" question). Data and modelling results over the past few years have, I believe, led to a sharp rise in the confidence that many climatologists worldwide now express (eg in drafts of the report from the Intergovernmental Panel on Climate Change circulating to national governments) that both real climate change has taken place and that humans are at least part of the cause. Although few would say they're certain, what has led to this recent jump in concern?

First of all, the 1980s was the warmest decade in the instrumental record of surface thermometers, and there has been a 0.5 (plus or minus 0.2) degrees centigrade century-long warming trend. But this was known in 1991, the previous record warm year (until 1995, now on an even warmer record pace). The years 1992 and 1993 were substantially cooler, and ironically, this actually increased most scientists confidence that human induced global warming was being detected. The reason is that the explosive eruption of Mount Pinatubo in the Philippines in 1991 spread a layer of sulphate dust particles in the stratosphere that filtered out a per cent or two of the sun's heat. This, our computer models predicted, would for a few years cool the surface about a quarter of a degree centigrade – very close to exactly what happened. Since the predicted cooling was made by the very same models that forecast global warming from enhancing the greenhouse effect, the credibility of the models increased as they fared well on this natural experimental test.

Sulphate particles are not only a natural phenomena, but are generated by people all over the industrialised and industrialising world where high sulphur coal and oil are burned. Up to 1991, computer models primarily considered only the effects of increased greenhouse gases in their predictions. Except for global scale temperature rise, the results did not match up well with the patterns of climate change observed over the past 30 years. Critics charged that the models could not produce a "fingerprint" of climate change that looked like the observed changes of the past few decades and that the models were thus presumed suspect. I published an article in the journal *Science* in January 1994 responding that until the models are driven by the same factors that the earth is – both the global warming from greenhouse gas increases and the regional cooling patterns from sulphate dust – no "fingerprint" matching exercise between model-predicted patterns of change and observed changes proves anything. Since then, three such model calculations have been performed – at the Hadley Centre, the German Max Planck Institute and the Lawrence Livermore National Laboratory. All three studies produced patterns of change (ie fingerprints) that are a much closer match to observed changes. So, perhaps ironically, it is the cooling effects of both natural and human produced sulfate dust that has substantially increased scientists confidence in the reality and likely cause of observed climate changes known popularly as global warming

All of this will mobilise considerable pressure from environmental groups for world leaders to rekindle the political climate of concern over human-induced climate change that marked the Earth Summit in Rio in 1992. Controversy is sure to pick up given both the new scientific results and the entrenched economic and political interests aimed at preventing curbs on carbon-emitting fossil fuels.

Investigators assessing the economic costs of reducing greenhouse gas emissions typically have considered the costs of reaching given targets for emissions reductions, or alternatively, the costs of given taxes on fuels that contribute to greenhouse gas emissions. In my view virtually all of the models suffer from an important omission – the neglect of price-induced technological change. This omission biases upward the estimation of the costs of policies to avoid climate change by reducing greenhouse gas emissions. Climate change policies, by raising the prices of conventional fuels, can stimulate more rapid development of alternative, non-fossil fuel technologies and lower the prices at which these technologies break even. Such induced technological change mitigates, perhaps substantially, the cost of climate policies. Larry Goulder, associate professor in economics at Stanford, and I have made preliminary calculations which show the possibility of a cut in the cost of policies to reduce carbon dioxide emissions as a result of possible induced innovations.

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I am not suggesting that induced technological change should become the principal basis for introducing policies such as carbon taxes that reduce greenhouse gas emissions through higher prices of carbon-based fuels. The main reason to introduce a carbon tax, for example, is its potential to internalise the carbon dioxide-related economic externalities associated with fossil fuel combustion and thus to help avert significant levels of global climate change and its potential consequences. By recognising induced technological change, however, we lower the minimal environmental benefits necessary to justify a given carbon dioxide reduction policy on overall cost-benefit grounds. Stay tuned, the climate change debate is coming back centre stage.

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