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ABSTRACT

Due to the injection of carbon dioxide and various other gasses into the atmosphere, the world of the 21st century may well have a climate that is beyond the parameters of human existence. Physical science produces information regarding the physical effects of increasing concentrations of "greenhouse" gasses. Once this information is developed, it is transferred to social scientists who evaluate the effects of physical changes on individual and social behavior, and economic and political systems. Information from both physical and social scientists is then transferred to policymakers and their advisors. This picture of the relationship between science and policy consorts with what may be regarded as a "positivist" view of science and value--a view deeply entrenched in U.S. science and public life. An analysis of the use of such a model reveals several problems, showing that it provides a distorted picture of the situation. Some salient considerations should be taken into account when developing policy related to the greenhouse effect. There will continue to be substantial increases in atmospheric carbon dioxide. This will lead to climate change and will have a biological and ecological impact. The possible political and economic effects of climactic change must also be considered. Policymakers must realize that the usual techniques of policy analysis are not adequate to managing a problem of this magnitude. By focusing on the possibilities of producing positive incremental changes, incorporating global concerns in national environmental impact policies, and accelerating scientific research into this complex problem, the nation may begin to solve this global dilemma. A 27-item bibliography is included. (GEA)

MANAGING THE FUTURE

PUBLIC POLICY, SCIENTIFIC UNCERTAINTY, AND GLOBAL WARMING:

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In every society people have speculated about the future and modulated their behavior in the light of their speculations. Today, however, we are in a novel position. We are in the process of racically altering the fundamental planetary systems that produced life on Earth. As a result the world we bequeath to our children and grandchildren will be very different from the one in which we live. Since the changes we are instituting are global in scope, it will not be possible for our descendents to move on to greener pastures across the seas or mountains. Escape cannot be to another continent or hemisphere, only to another planet or solar system.

The atmosphere is one area which is undergoing dramatic changes due to human activity. Due to our injection of carbon dioxide and various other gases into the atmosphere, the world of the twenty-first century may well have a climate regime that is outside the parameters of what humans have experienced in the entire course of their evolution. According to a report issued by the National Aeronautics and Space Administration, the Commission of the European Community, and the World Meteorological Organization, We are conducting one giant experiment on a global scale by increasing the concentration of trace gases in the atmosphere without knowing the environmental consequences (WMO, 1985).

Some of the consequences of this experiment are clear. The Earth's mean temperature will increase, sea levels will rise, and extreme climatic events will become more frequent. Much remains unclear, however. The more we focus our inquiry on details, the less we really seem to know. In the light of such scientific uncertainty, it is difficult to know what policy prescriptions make sense. We can speculate about the future but, in this case at least, it is difficult to know how to modulate our behavior in the light of our speculations.

This essay consists mainly of ruminations on these themes. I begin with a brief description of the environmental problem to which I have referred: global warming brought about by the injection of "greenhouse" gasses into the atmosphere. I then sketch one plausible picture of how we might think about managing this problem. On this view information flows like a wild river, and the relations between science and policy are linear and well-kept. I show that however beautiful this picture may be, it is more like a surrealist painting than a photographic snapshot. I go on to identify some important issues that I believe are involved in global warming, and sketch some guidelines for policy-making.

In what follows there are few, if any, deductive arguments.

Instead I try to conceptualize an important issue in a way that is illuminating, highlighting some important features and drawing some significant morals. Alot of analytic work remains to be undone.

1. The Greenhouse Effect

Carbon dioxide was first identified as a constituent of the atmosphere by Joseph Black in 1754.[1] Early in the nineteenth century the French mathematician Fourier speculated that certain atmospheric gases might inhibit heat from escaping, thereby warming the Earth's surface. In 1861 John Tyndall measured the absorption of infrared radiation by carbon dioxide and water vapor, and showed that slight changes in atmospheric composition could significantly raise the Earth's surface temperature. By 1870 scientists were able to make measurements of atmospheric carbon dioxide comparable in precision to those made today. In 1899 T. C. Chamberlin theorized that changes in the Earth's climate could be explained by changing carbon dioxide concentrations.

In 1896 the Swedish Nobel Prize-winning physicist, Svante Arrhenius, speculated about the possibility of anthropogenic atmospheric change. He thought that the release of fossil fuels might increase atmospheric carbon dioxide, thereby affecting both climate and terrestrial biological processes. He estimated that a doubling of atmospheric carbon dioxide would increase the Earth's mean surface temperature by about 4-6 degrees centigrade. Arrhenius's ideas were rejected, however, when it was discovered that water vapor also absorbs long-wave (infrared) radiation. Since it absorbs so strongly in the same general spectral regions as carbon dioxide, it was thought that carbon dioxide could have little influence on infrared radiation.

Arrhenius's ideas were revived in 1938 by the British engineer, Callendar, who suggested that a high proportion of the carbon dioxide released by industrial activity remained in the atmosphere, and that there might already be observational evidence of global warming. However Callendar thought that such a warming should be welcomed. He wrote:

> In conclusion it may be said that the combustion of fossil fuel, whether it be peat from the surface or oil from 10,000 feet below, is likely to prove beneficial to mankind in several ways, besides the provision of heat and power. For instance the above mentioned small increases of mean temperature would be important at the northern margin of cultivation, and the growth of favorably situated plants is directly proportional to the carbon dioxide pressure . . . In any case the return of the deadly glaciers should be delayed indefinitely (Callendar 1938, p. 236).

Callendar's views were rejected because observations did not seem to bear out his predictions, and because there was skepticism about whether increases in atmospheric carbon dioxide really would result in increasing the Earth's surface temperature.

During the mid-1950s the work of Gilbert Plass, and Roger Revelle and Hans Suess, brought the speculations of Arrenius and

Callendar into the scientific mainstream. It was Revelle and Suess who pointed out that an experiment was now in progress that "could not have happened in the past nor be reproduced in the future" (Revelle and Suess 1957, 19). They proposed that measurements relating to changes in atmospheric carbon dioxide and its effects on climate be made a priority during the International Geophysical Year of 1957. In 1958 Charles Keeling, a colleague of Revelle and Suess at Scripps Institute of Oceanography, began measuring atmospheric carbon dioxide in Hawaii and Antarctica. By 1963 the evidence for increasing atmospheric concentrations of carbon dioxide was strong enough for the Conservation Foundation to convene a meeting to discuss its implications. This meeting came to the conclusion that a doubling of atmospheric carbon dioxide would result in a temperature rise of about 3.8 degrees centigrade. In 1965 the President's Science Advisory Committee published a report warning of this possibility. This document was the first public acknowledgement by a government body of the possibility of anthropogenic climate change. The issue was now on the table.

Although there are some dissenters, there is widespread agreement in the scientific community that atmospheric concentrations of carbon dioxide and other "greenhouse" gases are increasing, and that as a result we are already committed to a 1.5 to 4 degree centigrade increase in the mean temperature of the Earth's surface (United Nations Environment Programme, 1987).

The evidence for the increase in atmospheric carbon dioxide rests mainly on the obeservations of Keeling's observations. They show a 9.5% increase in atmospheric carbon dioxide since 1958 (see Figure 1). This increase correlates with increases in fossil fuel consumption. Although it is more difficult to determine earlier concentrations of atmospheric carbon dioxide, there is evidence of a 19% increase over the last century (MacDonald 1988, p. 433).

Other "greenhouse" gasses include methane, nitrous oxides, ozone, and chlorofluorocarbons (CFCs). Although the behavior of these gases is not as well understood as that of carbon dioxide, their concentrations are increasing much more rapidly, and on a molecule for molecule basis they absorb infrared radiation much more strongly than carbon dioxide. It is widely believed that in the next century they will be as significant for climate change as carbon dioxide (Ramanathan et al. 1985).

While the overall results of a 1.5 to 4 degree increase in the Earth's mean surface temperature are not well-understood, there is a great deal of agreement that the expected warming will have a dramatic effect on rainfall patterns and climate variability. There will also be significant effects on sea levels, and biological and ecological systems. These changes could greatly affect human societies. For example, it has been estimated that 12-15% of Egypt's arable land could be flooded by a "greenhouse-induced" sea level rise. This area is home to about 48 million people, and contributes 15% of Egypt's GNP (Mintzer 1988a).

The injection of "greenhouse" gasses into the atmosphere appears to be a problem. For this reason this behavior and our responses to its effects appear to be good candidates for management. In the next section I will discuss one approach to management, and exhibit a picture of how some may think science and policy are related.

2. One Picture of the Relation Between Science and Policy

Consider the following picture. We begin with a problem (see figure 2). In this case the problem is increasing concentrations of "greenhouse" gases in the atmosphere. These increasing concentrations of "greenhouse" gases cause various physical effects, which in turn cause various societal effects. Many of these effects are regarded as undesirable. The goal of management is to prevent, mitigate, or adapt to these undesirable effects.

In order to manage successfully we need information (see figure 3). The role of physical science is to produce information regarding the physical effects of increasing concentrations of "greenhouse" gasses. Physical effects include climatological effects, hydrological effects, and biological and ecological effects. With respect to global warming, such effects are likely to include increasing global mean temperature and precipitation, rising sea levels, drier soils, species extinctions, and shifting patterns of biological activity. Once information about physical effects is developed, it is transferred to social scientists who evaluate the effects of these physical changes on individual and social behavior, and economic and political systems. These effects may involve impacts on individual life-styles, the availability and price of food, migration patterns, economic development, the stability of national governments, and patterns of international relations.

Information from both physical and social scientists is then transferred to policy-makers and their advisors (philosopher-kings). One response would be to welcome or ignore the anticipated changes. But if the effects of such changes are regarded as undesireable (and this is presupposed by calling something a "problem"), then some policy interventions would seem to be called for. These interventions may aim at preventing or mitigating the predicted physical or societal effects, or individual or collective adaptation. Policy interventions may be implemented by designing new institutions or institutional processes, or by redirecting existing ones.

This picture of the relation between science and policy consorts with what may be regarded as a (broadly) "positivist" view of science and value. This view is deeply entrenched in American science and public life. According to this view, there is a radical distinction between facts and values. Determining the physical and societal effects of increasing concentrations of greenhouse gases is, on this view, a factual matter to be resolved empirically by value-free science. This stage of the inquiry is purely descriptive; normative considerations do not enter at all. The next stage involves assessing and selecting management strategies. This is the normative, value-laden, stage. Here notions like equity, fairness, and efficiency come into play. The difference between these two stages is this. Management and policy-making are matters of decison while scientific inquiry is a matter of discovery. Since scientific inquiry involves the determination of the way things are, it is the proper domain of experts. Since management involves resolving conflicts of values, interests, and preferences, it is the proper domain of democratic participation. Management and policy are matters of politics rather than expertise. Preferences are created equal, but judgments about what is the case are not.

This picture (or some of its variations) underpins the way we think about many important public issues. The Environmental Protection Agency has instituted a version of this approach in its regulatory procedures.

During the Reagen years, the federal government turned away from prohibitive regulatory policies towards policies that permit some environmental degradation as a consequence of economically worthwhile activities. Instead of the absolute standards envisioned in the legislation of the early 1970s, notions of "acceptable risk" and "optimal pollution" gained currency.

When William Ruckelshaus began his second tenure as EPA Administrator, he instituted an analytic approach to the development of new regulations. On this approach, when potential risks are being investigated, the inquiry is to be divided into two stages. The first stage is the risk assessment stage. This involves the identification of a hazard, the establishment of a dose-response curve, the construction of an exposure model, and finally the characterization of the risk. These activities are regarded as purely scientific; values are not supposed to enter at this stage. The second stage is the risk-management stage. On the basis of the results of the risk assessment, policies are established and regulations are written. Since risk management decisions involve matters of value, public participation is appropriate. These decisions need not be left to the experts. Many factors affect people's tolerance for particular risks: whether it involves communities or scattered individuals, whether it is familiar or unfamiliar, whether individual intervention is efficacious or not, and so on. Knowledge of these attitudes and opinions are important when making management decisions.

In the philosophical community there is growing dissatisfaction with models of decision-making that are rooted in positivist conceptions.[2] Recent work in philosophy of science has convincingly demonstrated that facts and values are tightly interwoven in actual scientific practice. Skepticism about science as an objective, value-free, inquiry has become so great that it has become difficult to keep the public out of what once were regarded as strictly scientific matters. We see this in the controversies over scientific uses of animals and embryos, over recombinant DNA research, over the determination of carcinogenic substances, and over the appropriate level of AIDS funding. Activists for various causes increasingly see scientific rhetoric as a mask for substantive value commitments. They seek to expose value dimensions, and make policy debates more open and participatory. On the other side many scientists are frustrated by what they regard as incompetent management decisions. They decry what they see as the scientific illiteracy of policy-makers and the general public. While some members of the public and various organized interest groups want the domain of values to swallow that of facts, many scientists seem to want the converse. They seem to think that if we knew the facts, then the correct policy responses would fall out, without detouring through messy discussions of values and interests.

Despite growing dissatisfaction with the positivist picture, it remains influential. Whatever we may think about its ultimate tenability in other spheres, it is useful to see why the picture I have painted of the relation between science and policy is not a good model for us to adopt in our attempts to manage global warming.

3. SOME FLAWS IN THE ARTWORK

There is, as I have said, an emerging consensus that we are already committed to a 1.5 to 4 degree centrigrade warming of the Earth's mean surface temperature. In looking for support for this view, there are two main sources to which one may turn. The first source is actual climate observations, and the second source is model-based projections. Both sources face difficulties and have limitations. We will consider the first source first.

The Summer of 1988 has been noteworthy for how quickly the problem of global warming has moved from being a matter of professional attention to a major public concern. During this summer the "greenhouse effect" made the cover of Newsweek magazine, the front page of the New York Times, and even the Democratic party platform. In addition, Senator Tim Wirth of Colorado introduced a multi-billion dollar spending bill to combat the "greenhouse effect." Wirth's bill had fifteen co-sponsors from both political parties.

It is clear that what brought the "greenhouse effect" to center stage. Much of the United States spent the summer in the grip of extreme heat and serious drought. As a result, agricultural production declined dramatically.[3] In addition water levels in the Mississippi River system continued their decline, resulting in channel closings and ship groundings (Koellner 1988). On the Eastern seaboard, demand for electricity to run fans and air conditioners hit an all-time high. Air conditioners were even in short supply.

Many people have felt for some time that climate is changing. Their suspicion seemed to be confirmed by the headline in the New York Times for Friday, June 24: "Global Warming Has Begun, Expert Tells Senate." This headline was misleading, however. The heat and dryness of the Summer of 1988 is consistent with the hypothesis of global warming, but by no means does it establish it as a fact, nor does it even provide very strong evidence for it. There are well-known problems with inferring climate change from observations of present climatic conditions (Katz 1988). I will discuss two.

One problem is that annual mean mean temperatures can vary greatly within a stable climate regime. Climate change that involves a two-degree centigrade change in mean temperature is very small be comparison. For this reason it is difficult to distinguish the "signal" from the "noise."

The second difficulty is the "multiplicity" problem (also called "data snooping" (Freedman et al. 1978, p. 494)). In order to identify a statistically significant shift in temperature, it is necessary to examine each year in the light of preceeding and succeeding years. But this means that each examination will fail to be independent of previous ones. Subjecting overlapping sets of observations to statistical analyses makes it difficult to be sure that an apparently significant change is really statistically significant. If we make one set of observations, the probability of not reaching statistical significance at 5% is 95%. With two sets of observations taken together, the probability of not reaching statistical significance is 95% squared or 90.2% With three sets of observations taken together, the probability is 95% cubed or 85.7%, and so on. By taking different looks at the same data, we increase the chances of finding an apparently significant deviation that is really just due to chance (Tukey 1977). In the case of climate change, we have no choice but to look at overlapping data sets. For this reason it will always be problematical to determine on the basis of observation whether a climatically deviant year marks a climate change or is due to chance.

The evidence for global warming that many in the scientific community find convincing does not come from observation but from projections based on general circulation models (GCMs). These models are enormously complex. Each model run requires solving about 200,000 equations, and solving each equation requires many calculations. The projections of a 1.5 to 4 degree centigrade warming come from calculating the consequences of a doubling of atmospheric carbon dioxide. More than one hundred independent studies have indicated that such a doubling will increase global mean temperature within this range (MacDonald 1988).[4] Despite their complexity and sophistication, there are problems with and limitations on these models. I will mention two areas of difficulty.

First, there are enormously complicated feedback relations in the global system. Some of these have been taken into account, but it is not clear whether they have been adequately represented. Consider the case of clouds. If the Earth's surface warms as predicted, then more clouds will be formed. Additional cloud cover will contribute to warming by trapping more heat, but it will also contribute to cooling by reflecting more of the sun's energy. A warmer surface would also mean less snow and ice cover, which would mean less reflectivity (albedo) from the Earth's surface. This would contribute to a warmer surface which would contribute to more cloud formation, and so on back through the cycle. While the effect of cloud cover has been modeled, no one can be sure that it has been modeled correctly.

There are also problems in assessing the roles of the oceans and biomass. While it is clear that the oceans are a sink for both heat and carbon dioxide, it is not clear how much of a sink they are or how they might behave as the atmosphere changes. Similarly it is clear that biomass, especially the huge forests such as those of Amazonia, is an important carbon sink. But it is unclear exactly how important, and how biomass productivity might be affected by global warming. In theory, at least, biological productivity should be greater in a carbon-dioxide rich world.

In general, the overall carbon budget is not well-understood. Of the carbon dioxide released by human activity over the last century, probably less than half is in the atmosphere. It is not entirely clear where the rest is, nor what the principles are that govern its storage. It is sobering to remember that none of the atmospheric models predicted the antarctic ozone hole. There could be other surprises in store for us.

A second problem area for the models concerns their lack of resolution. Modeling efforts divide the Earth's surface into thousands of grid points, and treat the areas between grid points as undifferentiated. They assume, for example, that climate, clouds, and topographical features are uniform throughout areas of about 500 square kilometers. This lack of resolution is problematical because many of the forces that profoundly influence climate are much smaller in scale.[5]

Thus far we have discussed the uncertainties involved in our knowledge of the physical effects of increasing atmospheric concentrations of "greenhouse" gases. It is now time to turn our attention to the difficulties involved in assessing the societal effects.

On the picture of the relation between science and policy that we are considering, information about physical effects is transferred to social scientists so that this information can be used in assessing societal effects. Due to this transfer of information, uncertainties about the physical effects ramify. Any doubt that attaches to the reliability of model-based projections, for example, also attaches to projections about the societal effects of global warming.

In addition to this transfer of uncertainty, the kind of information developed on the basis of model-based projections is often not the most useful information for assessing the societal impacts of atmospheric changes. This is not a defect of the models. GCMs were developed in order to assist with basic research in atmospheric science. In recent years they have been put to new uses. It is not surprising that they are not altogether suited for purposes for which they were not designed (Katz 1988).

GCM output tends to focus on means and averages rather than extremes. It is also more accurate with respect to temperature than precipitation, and provides more insight into global than regional climate patterns. These are all problems from the point of view of assessing the societal impacts of climate change.

Consider the importance of understanding climate variability versus knowledge of means and averages. Earlier in this section we saw how difficult it is to distinguish the "signal" of climate change from the "noise" of variability. Suppose that we want to know, for example, whether citrus groves will be an economically viable investment in Central Florida in the twenty-first century. Predictions about mean or average temperatures over the next century would not be very useful. We need to be able to assess the probability of extremely cold winters, and have some idea of how extreme these winters might be. This information is not revealed by focusing on mean temperatures.

This case also suggests that societal impacts are essentially diverse and local. The social, economic, and political impacts of global warming matter greatly on how the physical effects are distributed and on what form they take. If the American high plains heats up and dries out, the impacts of this will be very different than if the deserts of the Southwest become even hotter. Unfortunately, while there is a great deal of agreement about a future rise in global mean temperature, there is much less agreement about regional impacts.

The final problem with assessing societal impacts that I shall mention is conceptually the most interesting. The global warming that we may already be experiencing is anthropogenic in origin. It is not something that is happening to people, but it is something that people are doing. Interaction between the physical effects of climate and societal responses is continuous and ongoing. Physical effects cause societal effects which cause physical effects and so on. These modulations do not occur sequentially, but often simultaneously. It is not like a chess game: first the physical side makes a move, then the societal side, then the physical side, and so on. The feedback between climate and human behavior is both constant and continuous.

The final stage of the model which we sketched in Section 2 involves transferring information from physical and social scientists to policy-makers and their advisors. We have already seen that there are severe problems with the quality of the available information. It is not clear how reliable the models are, our knowledge of regional impacts is sketchy, and there is constant, continuous, feedback between physical effects and societal responses. There are two other difficulties that appear in this stage of the model that should be mentioned.

First, there is a problem with the communicability of the information that is produced by physical and social scientists. It is well-known that ordinary people and even scientists have difficulty reasoning about probabilistic events. The same is true of policy-makers. Moreover, GCM output and statistical profiles of anticipated behavior are not the currency of policy-making. Scientific vocabularies, though perhaps precise both in conveying what is and what is not known, are often regarded as arcane and obfuscatory by policy-makers. They are often much more responsive to stories, metaphors, analogies, adages, homilies, and so on (Jamieson 1988a). This is not surprising, and perhaps not even deplorable. Policy-makers have different backgrounds and education than scientists, and their political survival depends on judgments whose grounds are very difficult to quantify and rationalize.

The final problem that I wish to focus on concerns the time constraints within which policy-makers must operate. For the purposes of scientific inquiry it might make sense to have very strong standards of proof, and to pursue a research project in orderly stages. But if there is anything to the "greenhouse effect," we will be experiencing its consequences long before rigorous science has been able to prove its existence. And even if this were not the case, we would still be committing future generations to dramatic climate changes while waiting for definitive scientific results.

There are many things wrong with the attractive model sketched in Section 2, but for present purposes the major problems are these. First. information about the extent and physical effects of global warming is uncertain and incomplete. Second, information about the societal effects is even less certain and complete because it depends on information from the physical sciences, because it involves difficult problems of its own, and because there is continuous feedback between societal and physical effects. Third, the information-transfer process cannot be as linear and sequential as the modle specifies. If we face a serious problem, and if policy is to be effectual, then we must make policy while we continue to investigate the physical and societal effects of global warming. But this means that policy will also enter the feedback loop, influencing societal responses and physical effects. Instead of a pyramid with the physical sciences forming the foundation for social knowledge and policy interventions, we have something much more like the hermeneutic circle.[6]

It is beyond the scope of this paper to sketch an alternative way of thinking about the relation between science and policy. Instead what I shall try to do in the next two sections is to identify some salient considerations that should be taken into account when making policy relating to the "greenhouse" effect, and then to suggest some policy prescriptions.

4. SOME IMPORTANT CONSIDERATIONS

As I have tried to show, there are many uncertainties surrounding the "greenhouse effect." Yet some things are clear, and need to be taken into account in formulating policy. I will discuss five such considerations.

First, there will continue to be substantial increases in atmospheric carbon dioxide. North America and Europe are responsible for most of the anthropogenic increases thus far. China, the Soviet Union, and the developing countries will be responsible for a much greater proportion of the future increase. Already this shift is occuring. During 1960 the United States was responsible for more than 36% of carbon dioxide emissions from fossil fuels. By 1985 the American share had dropped to little more than 26%. Over this twenty-five year period, emissions by the United States increased by slightly more than

400 million tons. During the same period emissions from China, the Soviet Union, and the developing countries, all taken together, went from about the same to nearly twice the American share. Their absolute increase was nearly 1500 tons. During this period the developing countries increased their emissions by about 450% (Mintzer 1988).

Second, increases in "greenhouse" gases will probably cause climate change. There will be longer, more frequent, spells of extreme heat and drought, and perhaps more episodes of extreme wintertime cold. There will be more monsoons, typhoons, hurricanes, and other extreme events.

Third, there will be important biological and ecological impacts. These will be especially severe with respect to "unmanaged" ecosystems, causing increases and decreases in various populations of plants and animals, as well as some extinctions. There may be some tendency towards biotic simplification.

Fourth, economically there will be "winners" and "losers" both within and among nations (Glantz 1988a). Although it is difficult to tell which countries or regions or segments of societies will benefit and which will not, we can say with confidence that sea level rises and shifting patterns of agriculture and other economic activities will be felt differentially.

Finally, although we are not in a position to predict what they may be, there will be effects on the political stability of some countries and on the pattern of international political and economic relations.

This much seems clear and important. The "greenhouse effect" threatens to be not just an issue of concern for "environmentalists," but one that has implications for economic policy and national security as well. In June 1988 an international conference, attended by delegates from 46 countries and 15 international organizations, was held in Toronto, Canada. The theme of the conference was "The Changing Atmosphere: Implications for Global Security." In its final statement the delegates declared that anthropogenic atmospheric change constitutes a threat to the planet that is second only to global nuclear war (New Scientist 1988, p. 24). Despite the uncertainties that I have identified, the "greenhouse effect" is a serious threat. The question is what should we do about it.

5. ADVICE FOR POLICY-MAKERS

The first thing that we should do is to give up the idea that all problems can be "managed." We are at the beginning of a new era in our relation to the environment. Fundamental global systems are being modified by human activity. The impacts will be felt for decades or even centuries. The effects are potentially devastating. Unsurprisingly, we are woefully ignorant of the consequences of what we have done. The usual techniques of policy analysis are not adequate to "managing" problems of this scale and magnitude. The beginning of wisdom is the acknowledgement of our limits.[7]

Second, it is very important to be clear about what problem global warming is supposed to pose. Two different conceptions have been articulated though they have not been distinguished. On one conception the problem is the fact of the warmer world; what we should fear is the warmer world itself. On the other conception the problem is not the fact of the warmer world, but the transition to it. It is important to clarify the nature of the problem, since what interventions would count as successful depends on what the problem is supposed to be. Delaying the warming so that it occurs over a long period of time would be a solution to the second problem but not to the first.

Third, for the purposes of societal assessment we should disaggregate the effects of global warming. We are not in a position to assess many very different impacts on a global scale. We are in a position to assess the impacts of rising sea levels on Boston Harbor, drought in Northeastern Brazil, or floods in Bangladesh. Indeed, we have a great deal of experience in assessing these kinds of impacts. Our best chance of understanding what a warmer world would be like is from the "bottom up" rather than from the "top down"(Glantz 1988b).

Fourth, since so little is known about the societal effects of global warming, and even less about what policies might be successful in responding to it, we should act conservatively. This has two dimensions.

~~First,~~ When we seek policies to mitigate or adapt to global warming we should focus on incremental changes, and select the ones we do for multiple reasons. For example, the Wirth bill calls for requiring the American auto fleet to reach 55 miles per gallon fuel efficiency by 2010. Such a policy makes sense environmentally, economically, and from the point of view of national security (Chandler et al, 1988). In addition, it seems to have a great deal of public support.[8] Similarly, there are multiple reasons to be concerned about deforestation. Deforestation contributes to global warming both because it removes a carbon sink, and because it releases stored carbon. There is also reason for concern on grounds of cultural preservation, species preservation, land degradation, and long-term economic sustainability. Polices that swap rainforest preservation for debt, for example, can be recommended on all these grounds (Whelan 1988). Even if the "greenhouse effect" turns out to be a chimera, we will not regret having preserved the rainforests and stimulated the production of more fuel-efficient cars.

Acting conservatively also means incorporating a concern for global systems into environmental impact assessments. Coal-mining (for example) does not just scar landscapes, it also contributes to global warming. If we were to take the full effects of our projects into account, we would tend to favor those that are small-scale and decentralized over those that are large and glitzy. We might, for example, focus on the development and marketing of energy efficient lightbulbs and refrigerators rather than on building new power plants or developing new energy sources. Conservative policies may not permit us to win big, but they would minimize our chances of suffering devastating losses.

Fifth, in pursuing our policies we should act through coooperation and consensus to the greatest extent possible. This cooperation must be local, national and global in scope. Any effective long-term policy will need to enlist those who stand to win from global warming (or think they do) as well as those who stand to lose. As we have seen, the excess carbon dioxide that is now in the atmosphere was injected mainly by Europeans and North Americans. Although these people continue to inject "greenhouse" gases into the atmosphere, the developing countries are becoming equally important sources.

Some regional scenarios suggest that the anticipated warming will result in more precipitation in the African Sahel and less in the American and Soviet grain belts (Kellogg 1983). This could benefit some poor African nations at the expense of the industrialized nations. Bandyopadhyaya 1983 has argued that rich nations enjoy many natural advantages over developing nations, and that trying to preserve the global climate status quo is an attempt to preserve their advantage. If there is to be progress on this issue, the rich nations must avoid pressuring the poor nations to remain poor so that the rich nations do not suffer. Real progress must be international and inclusive.

Finally, scientific research should be continued and accelerated. The reasons for this are obvious, but two cautionary notes are also worth sounding. First, we should not think that additional scientific research will necessarily resolve our current uncertainties. Indeed, it may increase them. Just as a little light may only make one more confused when stumbling around in the dark, so more science may only increase our perplexities. We are dealing with enormously complicated issues that we are nowhere near understanding fully. Second, since there is such uncertainty, a number of different methods and approaches should be supported. When ignorance is as great as ours, especially about the societal effects of global warming, the best strategy is to encourage diverse and various lines of research.[9]

6. CONCLUSION

In this essay I have provided an overview of what may be an important environmental problem: the increasing concentrations of carbon dioxide and other gases in the atmosphere that result from human activities. I then applied an influential model of the relation between science and policy to this problem, and tried to show that it provides a distorted picture. I went on to identify some salient facts about the "greenhouse effect" and to suggest some policy prescriptions.

Many aspects of this problem have not been explored. Some of these, no doubt, are of more philosophical interest than the ones that I have discussed. Still, by my lights, the issues are more important than the disciplines that are supposed to encompass them; and if applied philosophy is to be worth doing, it must take "real world" issues on their own terms rather than using them as props for philosophical discussion.[10]

NOTES

[1]For historical background I have relied on Ausubel 1983 and Kellogg 1987, as well as on original sources.

[2]It should be noted that Ruckelshaus himself was acutely aware of the difficulties involved in keeping risk assessment and risk management distinct. He once wrote, ". . . risk assessment data can be like the captured spy: if you torture it long enough, it will tell you anything you want to know" (Ruckelshaus 1984, pp. 157-158).

[3]This is documented in various reports issued by the United States Department of Agriculture, and in the Weekly Weather and Crop Report issued jointly by the National Weather Service, and the National Agricultural Statistics Service and World Agricultural Outlook Board.

[4]It is not clear, however, that these studies really are independent. Only a few different models are employed in these studies, and it is common to discard model runs whose results fall outside the range of expected values.

[5]For discussion of these and other limitations of atmospheric models, see Dickenson 1986.

[6]For a clear account of the hermeneutic circle, see Hoy 1978.

[7]Peter Brown 1988, p. 475 argues that microeconomic tools are useful for certain purposes, but "they are of little or no value in helping to decide what kind of world we should try to create."

Thomas Schelling 1983, pp. 453-4 reminds us of how difficult it would have been for people of a century agc to even imagine a world like ours.

> Electronics was not dreamed of. Electric light would have been new in our lifetime and unknown to most of our countrymen. there was telephone but no radio. . . Anesthesia was by ether, there were no antibiotics, bedbugs were a scourge . . . Electric street railways were transforming our cities . . . Only a third of the U.S. population lived in places with more than 5,000 inhabitants.

[8]According to a survey by the Analysis Group of New Haven, Connecticut 77% of a randomly selected group of registered voters favor requiring automobiles to average 45 miles per gallon by the year 2000, even if such a requirement increases the price of a car by $500 (Rocky Mountain News, October 4, 1988, p. 7-B).

[9]I sketch an alternative approach to thinking about the societal impacts of global warming in Jamieson 1988a. The volume in which it appears is devoted to exploring the possiblities of this approach.

[10]For more on this last point see Jamieson 1988b.

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