Resources

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CONTENTS

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Threats from above

SOME RECENTLY PERCEIVED threats to environmental quality and human health and safety seem almost the stuff of science fiction: inexorably rising global temperatures, poison rain, and increasing incidence of skin cancer caused by ultraviolet light all have an other-worldly aspect to them, a quality that sometimes strains the credulity of a public increasingly skeptical about unseen risks of disaster.

Yet global warming caused by the accumulation of carbon dioxide in the atmosphere, acid rain, and depletion of the protective stratospheric ozone shield are real problems, despite significant uncertainties about each of them, and they deserve serious study and evaluation. Perhaps what is most important, they require sustained international cooperation for their amelioration, and it is not at all clear that U.S. or other national leaders are prepared to deal with these issues either soon or effectively.

Taking advantage of the presence at Resources for the Future of visiting scholar John W. Firor, RFF produced a radio program on atmospheric problems for the FOCUS public affairs series featuring Firor and Paul R. Portney and moderated by Harry B. Ellis. FOCUS is the product of a consortium of seven Washington nonprofit organizations and is headquartered at RFF. "Focus on Threats from Above" was aired during June on some two hundred public radio stations throughout the United States.

John Firor, a physicist, is director of the Advanced Study Program of the National Center for Atmospheric Research in Boulder, Colorado, and formerly was NCAR's executive director. Economist Paul Portney, a senior fellow in RFF's Quality of the Environment Division, spent two years as senior economist at the President's Council on Environmental Quality during the Carter administration. Harry Ellis is deputy chief of the Washington bureau of the *Christian Science Monitor* and frequent panelist on the PBS television show, "Washington Week in Review."

The following article is an edited transcript of the radio discussion.

ELLIS: Gentlemen, to a certain extent human beings can change their environments: they can move from, say, a cold climate, and often are concerned if they think that their immediate environment is being damaged by deforestation, strip-mining, or the like. But perhaps relatively few of us look beyond our immediate environment to the atmospheric envelope that encases our earth and is the heritage of all living creatures.

I'd like to discuss with you three atmospheric problems which may portend changes that fundamentally would affect all of us. We'll concentrate on climate change through the increase of carbon dioxide in the atmosphere, caused partly by the burning of fossil fuels; ozone depletion, which may add to the damage caused by carbon dioxide increase; and the emergent problem, at least to laymen, of acid rain. To begin, how conclusive is the evidence for changes in the atmosphere?

FIROR: It's variable over the three problems you mentioned. I think the consensus among experts is that acid rain is indeed happening—there's no doubt that the origin is anthropogenic, that the sulfur dioxide and nitrogen oxides we people put in the atmosphere end up as the acid-forming component.

Hence, the details that need to be worked out are not what is occurring, but exactly how, and how much, and what steps we might take to ameliorate it.

The ozone problem is perhaps one step less certain. I think the theoreticians believe they have a perfectly credible story about how fluorocarbons damage ozone.

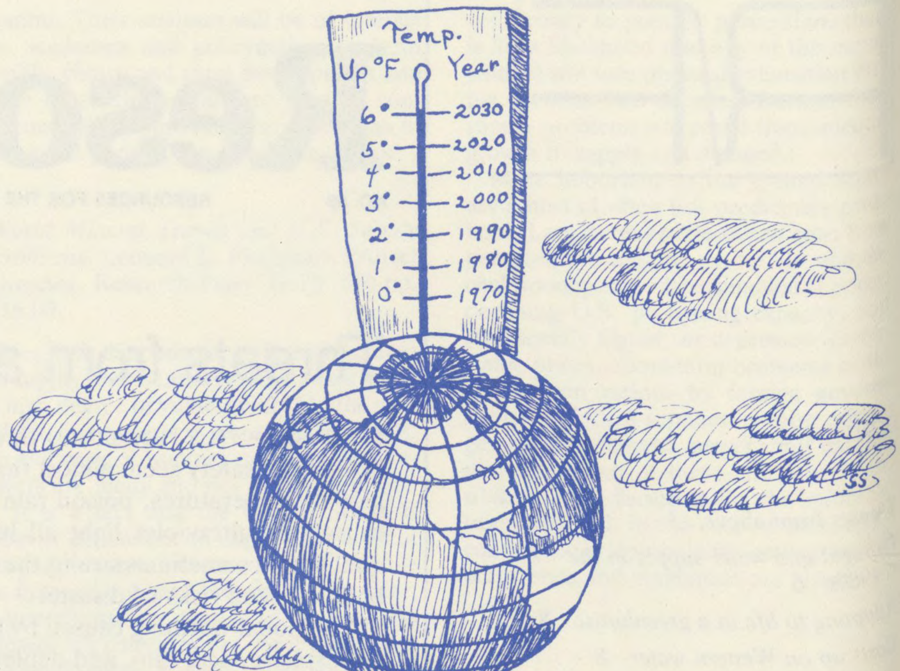
ELLIS: Can you define fluorocarbons for us?

FIROR: Well, there is a sequence of compounds with a carbon atom, surrounded either by several chlorine or fluorine atoms. These compounds are very stable, and very useful: they used to be found in all our spray cans, and they still are used in all our refrigerators, but when they get to the stratosphere they are broken down by sunlight and free chlorine then enters a complicated reaction that destroys ozone. And that has led to some worries about more ultraviolet light coming in through the stratosphere—entering through the ozone screen that used to keep it out—and doing damage on the surface of the earth, in particular through increased incidence of skin cancer and, hypothetically, through damage to plants. We do not know exactly how it might hurt plant life, but it's hard to imagine that plants would not be sensitive to more ultraviolet light.

ELLIS: And climate change through the increase of carbon dioxide in the atmosphere? Would you define the problem for us and then give us an idea of how urgent it is?

FIROR: The greenhouse effect. That, of course, is the biggest one of all, and on a scale of certainty, perhaps the least certain of the three. It's fairly simple in concept. Each year we put more carbon dioxide into the atmosphere, mostly by burning fossil fuels, as you said. This carbon dioxide stays in the atmosphere for a very long time—maybe a thousand years, because the ways it's removed from the atmosphere are slow. While it is in the atmosphere it traps heat—the so-called greenhouse effect. The sunlight coming in warms the surface, the heat trying to get out is blocked by carbon dioxide, and hence the earth warms up. So the forecast is that, as we continue year by year to increase the total carbon dioxide burden of the atmosphere, the earth will, in time, respond by getting warmer and warmer.

There's no measurement right now that speaks directly to the problem except the fact that carbon dioxide is increasing in the atmosphere every year. But the projected impact of that change in carbon dioxide is global, it's slow—it occurs in the next decade, or the next three decades—and there are no measurements now that say, yes, it's happening. So the problem as such still has to be considered in the realm of a calculation: there is lots of evidence to suggest that yes, it's real, but you cannot promise it's going to happen.



ELLIS: Dr. Portney, would you tip the scale of risk a bit differently than Dr. Firor does?

PORTNEY: I don't think so, but I might add that, in the case of carbon dioxide, one of the reasons that there is so much uncertainty about whether the buildup of carbon dioxide in the atmosphere is affecting temperature is that there are long swings in temperature that occur independently of carbon dioxide concentration and, in fact, shorter swings that still may take ten or twenty years to work themselves out. So that the world could be on a downward, twenty-year swing, during which time an increase in carbon dioxide might raise temperatures above the level they would be normally, but it would not be noticed because temperatures would be colder than twenty years ago.

The problem is that if you disregard upward tendencies during downward swings, when there is an upward swing—and, in fact, the atmosphere has been warmed because of the presence of carbon dioxide—temperatures may climb far above the highest point that the globe has seen for awhile. That is why this is such a dangerous problem: It's hard to detect, it gets mixed up with shorter and longer swings, and it may be happening even during a period when general temperature conditions appear to be getting colder.

Irreversibility

ELLIS: Is a part of the danger the fact that these changes, indeed if they are occurring, are irreversible?

FIROR: Eventually carbon dioxide would disperse if we quit pumping more into the atmosphere, but that "eventually" is a thousand years, so that as far as any planning horizon that we use in this life is concerned, it's permanent, it's irreversible.

The other two problems—ozone depletion and acid rain—I think are reversible on a decadal scale: if you quit putting something into the atmosphere now, it will clear itself up in a decade or two. But carbon dioxide mixes with the ocean; the oceans are very slow to change, and it's going to take a long time to change the amount of carbon dioxide in the atmosphere.

ELLIS: Dr. Firor, how much evidence is there of actual warming of the atmosphere due to carbon dioxide and, second, are there benign causes of an increase—benign in the sense that they are wholly natural increases, and how much of it is due to the fact that, all in a rush, so far as history is concerned, humans are burning fossil fuels?

FIROR: How much evidence is there that we have actually warmed? The forecast of warming—the theoretical forecast—is that evidence of warming should become visible perhaps a decade from now. So there is no present measurement that contradicts the theory, but there is none that supports it either. It's supposed to be a slowly changing event.

On "benign" causes: people digging down into glaciers have found ice that occurred at a datable time, say, in the last Ice Age, and have analyzed that ice for dissolved carbon dioxide. And sure enough, there was a lot less carbon dioxide during the Ice Age than there is now. Some ice has been found from a period of time called the altithermal, back in the Bronze Age, when it was somewhat warmer than it is today, and that seems to show a little more carbon dioxide. So there is circumstantial evidence that ties carbon dioxide to climate. But we do not know whether that is cause or effect; it could be either. So we are still putting together as much evidence as we can to try to make a coherent story.

Policy complications

ELLIS: Dr. Portney, the layperson might ask, What are the consequences of warming? Why should we be concerned with it?

PORTNEY: That's a very good question, because it points to the reason why making policy—even if the scientific uncertainties could be eliminated—is going to be very difficult. One does not have to be a meteorologist to know that in certain areas a little warming would be seen as a good thing.

One of the economic consequences of climatological change would be shifts in cropping patterns; for example, some areas would experience a lengthening of the growing season; this would be partially offset by desertification in other areas. Places that were favorable to crop growing might find that it's either too hot or the pattern of precipitation has been changed in such a way that, at the very least, more irrigation would be needed.

And one of the most worrisome aspects of potential climate change—though one of the most speculative—has to do with the possible melting of the polar ice caps. If—and I want to emphasize *if*—the period of warming were sustained enough and if the polar ice caps began to melt, it might significantly affect sea level and, consequently, coastal areas. Some predictions have had sea level rising by as much as 5 meters if warming were sustained over a long time. Well, this obviously has severe implications for those who live close to the sea. Since people tend to cluster near coasts, it would mean the inundation of heavily populated areas in large parts of the United States and in other maritime nations.

FIROR: To a degree, we can look historically at these problems that Paul's talking about. There was a period during the twelfth century when it was a bit warmer than it is now. That was the period of the great Viking exploration of the North Atlantic, characterized by colonization and the creation of communities in Greenland, for example. That was brought to a rather abrupt end by the onset of a slightly cooler period, known to climatologists as the Little Ice Age, when you couldn't sail the North Atlantic in primitive craft, and trade routes were disrupted.

To some extent we can use as a model of what might happen the smaller climate changes of the past. So our laboratory at the National Center for Atmospheric Research is working very hard to reconstruct the period of four to six thousand years ago, when it was somewhat warmer than now—warmer even than it was in the twelfth-century period—to see what we can tell about how it will be when carbon dioxide warms us up.

ELLIS: It seems to me that here we are entering a problem area. On the one hand, we know that the increased burning of fossil fuels contributes to the problem, but under President Reagan's administration, there is a thrust toward producing more fossil fuels—natural gas, coal, and oil—and a lessening of the budgets for solar and renewable resources. This would seem a risky proposition, and yet if there is no conclusive evidence, how does one persuade policymakers of it?

PORTNEY: You have touched on an interesting point. On the positive side, one has to remember that a keystone of the administration's energy proposals has been the complete decontrol of crude oil prices, and this has had the commendable effect of discouraging profligate energy use: fossil fuel combustion is discouraged as the price goes up. So while it's true that the budget shift away from such sources as solar energy, windpower, and geothermal may push us in the direction of more fossil fuel use, with the possible outcome that we may be exacerbating the buildup of carbon dioxide in the atmosphere, I think we do have to keep in mind that the decontrol of crude oil, and the possible decontrol of natural gas, may act to dampen overall energy demand. What will be the net effect of deemphasizing solar and renewable energy sources, coupled with decontrol of crude oil and natural gas prices, I can't say, but it's not as if all of the signs point in the direction of more fossil fuel combustion.

Fossil fuel differences

FIROR: There is another aspect, and that is that all fossil fuels are not the same in their capability of producing heat and carbon dioxide in a fixed ratio. Natural gas, for example, produces a relatively large amount of heat for each ton of carbon dioxide put into the atmosphere, because by and large the heat comes from the hydrogen rather than the carbon in the molecule. The other end of the spectrum is held down by the so-called synfuels, which produce a good deal of carbon dioxide merely in their creation, in their processing, and then even more when they are burned. So natural gas is a much more favorable fuel than synthetic fuels if you are trying to decrease the amount of carbon dioxide you are putting in the atmosphere. Coal is intermediate. Coal is pure carbon, so it's straightforward in that every time you burn it you produce carbon dioxide.

It seems to me that the strategy we have to engage in—in the light of the uncertainty we have emphasized—is a many-part strategy. There is no way that we scientists can come to the decision makers of the world and say, "We think there's going to be a carbon dioxide problem, so quit burning fossil fuels." Everybody would laugh. Correctly. Because fossil fuels are too fundamental to everything that we do.

Therefore, if you cannot find a complete solution to a problem, you have to find ten 10-percent solutions, or partial solutions. And it seems to me what we need to do first is to slow down the use of fossil fuels wherever we can, by replacing them with renewable sources, or non-carbon-dioxide-producing sources. This will give us more time to work. And second, we should learn how to live with a warmer climate, so that we can move more gracefully into such a period when and if it comes. This strategy involves doing lots of different things. Afforestation makes sense, for example, because forests eat up carbon dioxide and that helps lengthen the time before we get into trouble.

Spray cans and ozone depletion

ELLIS: Gentlemen, I would like to shift our focus just a bit. Another problem on which scientists have approached policymakers is ozone depletion. To the layperson, it seemed mostly an argument that one should no longer use a spray can for shaving cream or deodorant. Now fluorocarbon sprays are banned, and yet the problem still exists. Dr. Portney, how do you define the importance of this problem and its effects?

PORTNEY: Let me try to indicate some of the policy responses to the ozone-depletion threat and suggest how it's regarded both in the United States and in the rest of the world.

The United States did ban all aerosol uses of chlorofluorocarbons—as you have indicated, uses in spray cans of deodorants, hair sprays, and the like—because of their potential ozone-depleting nature.

One of the discouraging things about the United States' having taken that step is that chlorofluorocarbons released anywhere in the world have the same effect; it all goes into one big mixing layer in the stratosphere. So that if every country in the world but one cut out chlorofluorocarbons, and one country continued to pump them out, everybody would still suffer from the same problem. The point is that when the United States banned all aerosol use of chlorofluorocarbons, I believe only two or three other countries followed suit, and that's still true to this day.

Now the United States finds itself in the position of considering not bans on nonaerosol uses, but a limit on chlorofluorocarbon production. One of the plans that the Environmental Protection Agency is considering is the limitation of all CFC production (CFCs being chlorofluorocarbons) to either 1979 or 1980 levels. Again, however, while this would reduce the U.S. contribution to CFC production each year, and we are a major contributor, I do not believe we represent even as much as 30 percent of worldwide production. One of the discouraging things is that, if we take this step by ourselves and impose additional costs on this country by denying the use of chlorofluorocarbons in flexible foams, in rigid polyurethane foams, in coolants in refrigators, and other uses, it will not have the impact that it would have if other countries in the world joined us and took similar steps. The Carter administration did try to initiate cooperative worldwide efforts on chlorofluoride control, but it remains to be seen whether the United States will pursue its own effort, and if we do, how successful we will be in enlisting the cooperation of the other CFC producers in the world.

ELLIS: Dr. Firor, I realize that ozone depletion is a separate problem from the increase of carbon dioxide in the atmosphere, but does the type of damage done to the atmosphere by ozone depletion link up and make worse the total damage to the atmosphere caused by these two problems?

FIROR: The problems link up in many ways. Incidentally, I'm calling them fluorocarbons, and Paul's calling them chlorofluorocarbons, but we are talking about the same subject.

It turns out that both carbon dioxide and fluorocarbons are exceedingly powerful absorbers of infrared radiation. Indeed, this absorption is what makes carbon dioxide troublesome, in heating up the environment. Fluorocarbons also will heat up the environment, and because they are so much more powerful per molecule it takes a lot fewer of them to do the job, so that some projections show fluorocarbons, by the middle of the next century,

being perhaps half as important as carbon dioxide, and therefore pushing climate change more rapidly.

This warming effect has nothing to do with ozone, but the two problems link up, from a policy point of view, in that they are global, many countries contribute to them, there is no international mechanism for agreeing to do anything about them (no standing mechanism—we will have to create one) and there are scientific uncertainties about the timing and amount and size of the changes that will occur and their regional distribution. That's an important issue; none of these effects will be evenly spread over the earth.

Regional conflict threatens cooperation

PORTNEY: Let me elaborate a bit on John's last point. One of the really vexing difficulties of climate warming caused by carbon dioxide is that, as John has identified, it will have unequal regional effects. While the climate changes in one country may be negative—perhaps desertification or shortened growing seasons—other countries in northern climes, for instance, Canada and the Soviet Union, countries that now have shorter growing seasons and more difficult winters, may find that some global warming, from carbon dioxide or anything else, may benefit them. Of course, that makes it a lot more difficult to take the necessary and, in some cases, very difficult steps, to prevent carbon dioxide buildup by imposing taxes on fossil fuels, or some kind of limit on the combustion of fossil fuels. Some countries can ask quite legitimately, Why should we penalize ourselves and cut down on our use of fossil fuels to prevent something that would be good for us in the first place?

So it's not just a matter of trying to secure international cooperation in the case where everybody is made a little worse off, but it may be in no one country's interest to penalize itself. That is difficult enough, but this is a case where some are going to be made better off, others are going to be made worse off, and there is even less incentive for international cooperation in this kind of instance.

Acid rain

ELLIS: Isn't this question of international cooperation and divergent interests, Dr. Firor, equally evident in the emerging problem of acid rain? I think of the fact that Canada complains that its lakelife is being killed by acid rain which emanates from the United States, that the Swedes say the same about Western Europe, and so on. As we look at this problem of acid rain, are we talking about something entirely different in a policy sense than the carbon dioxide and ozone depletion problem?

FIROR: I think it's different in that it is not quite global. The other two are distinctly and absolutely global, and we have to think of them as global problems because the substances are mixed clear around the earth. Acid rain, which results from sulfates and nitrates in the atmosphere, may move 100 miles or 1,000 miles, but it's not a global problem in the same sense.

We and the Canadians are going to have to get together. We both produce lots of sulfates and nitrates. The winds blow sometimes one way, and sometimes the other, so that at times we are producing their acid rain, and they are producing our acid rain a week later. So we need to get together and talk about it.

ELLIS: What types of manufacturing or other processing produce acid rain?

FIROR: That is a technical question, and it's a difficult one. We know that basic substances ending up as acids are sulfur oxides and nitrogen oxides. Sulfur oxides come largely from coal burning in factories and electric-power-generation-plants, with a little bit from oil burning. The nitrogen oxides come from a broader range of activities, including automobiles and other mobile sources. These substances in the atmosphere can oxidize to the next state of oxidation and form nitrates and sulfates, which are acidic, and which then dissolve in water and fall as rain or other precipitation.

Self-defeating policies?

ELLIS: It seems to me that, in the struggle of the United States and other industrial countries to reduce their dependence on OPEC oil, we are adopting policies which run counter to the risk that you gentlemen are pointing out. For example, at the 1980 Venice Economic Summit, I remember very well how each of the participants said, "We must all produce and use much more coal." Indeed, the United States committed itself to producing a great deal more coal and exporting it. If what you are saying is correct, not only about the problem of acid *rain, but also about the increase of carbon dioxide, this is, in the very long run at least, a kind of self-defeating policy.*

PORTNEY: As a practical matter that may be correct. I should point out, however, that if we were willing to commit large amounts of resources to removal of sulfur dioxide and nitrogen oxides from the flue gases of electric power plants and other kinds of coal-fired boilers, then we could, in fact, burn more coal and not necessarily exacerbate the acid rain problem. It does mean, however, that at a time when economic problems have become particularly vexing, we would be increasing our commitment to stack scrubbing or fluidized-bed combustion, new and expensive technological means of removing pollutants before they get into the atmosphere.

And I believe it is also the case with respect to carbon dioxide that there are at least imaginable technological solutions to the problem. We could continue to burn fossil fuels, for instance, and, in what may sound like a Jules Vernian solution, pump carbon dioxide into the oceans before it comes out of the stack. Now whether that would be an ultimate solution to the problem, I don't know, but it almost certainly would be extraordinarily expensive. I should stress that I am not advocating a technological solution in general, let alone pushing a particular technology. My only point is that it's not necessarily the case that more use of domestic coal inevitably would now and forever exacerbate carbon dioxide buildup or the acid rain problem. It would mean we would be spending more, and that is something that we have to think seriously about as well.

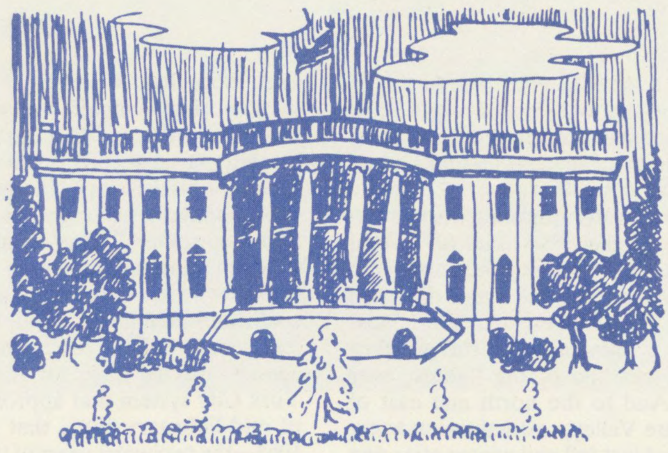
FIROR: Paul's right in saying that there are varying degrees of technological solutions to these problems. Acid rain may be the easiest one, for the reasons he mentions, and getting rid of the sulfur from coal at least sounds feasible. And getting rid of the nitrogen oxides from automobile exhaust is something that's scheduled to occur if we don't back away from our clean air standards.

ELLIS: If a lake or other body of water has "died" because of acid rain—that is, it now supports neither plant nor fish life—can it be brought back?

FIROR: Only with difficulty. You can dump a lot of, say, lime into the lake and neutralize the acid, but it would take quite a while for the lake's living systems to recur.

Part of the trouble with acid in the lakes is that it mobilizes substances that are usually not dynamic. Rocks at the bottom of the lake have heavy metals in them which usually stay in the rock. Acid dissolves them and produces then, in solution, some cadmium, arsenic, mercury, or other toxic substances that the lake ordinarily would not have.

So a lake can be pretty thoroughly poisoned by the secondary effects of acid rain, and cleaning it up is a big task. The effect is reversible in the sense that, if by magic we quit putting all those acid-producing substances in the atmosphere, the atmosphere would cleanse itself in a matter of weeks. These things just do not stay there that long. Then there would be a very long recovery period of the ecosystem, which works much more slowly. Some lakes probably would take a century to come back to their preindustrial state.



International leadership needed

ELLIS: Clearly, from all you have said, if we simply consider the United States in isolation, there are myriad problems—economic and political, scientific and technical. But it is not, of course, the United States in isolation, as you both have brought out.

PORTNEY: That's an excellent point, one that brings up a recent event that is troubling in its portents for international cooperation in this area. We have identified that certainly acid rain has international ramifications, as do chlorofluorocarbon emissions and the concomitant depletion of ozone, as well as carbon dioxide buildup in the atmosphere resulting from fossil fuel combustion. It's clear that we need more international cooperation to deal with these international problems, and I wonder what role the United States is prepared to play. I bring that up because the United States recently reversed its position on the Law of the Sea Treaty, which had been negotiated over a seven-year period, and had the near-unanimous consent of the nations involved; at the last minute the United States decided not to sign the treaty. I think that raises the question of whether other nations are going to want to follow the United States in other kinds of international environmental cooperative ventures, if they fear that the United States may pull out.

ELLIS: Does that lead to the conclusion that the scientific community has to find a way to impress upon the Reagan administration the enormity of the dangers involved, and the probability, if not the certainty, of the risks?

FIROR: We have our work cut out for us, because, at least in their *public* statements, the people in the administration have downgraded these problems. And, to be fair, people speaking for the environment side sometimes have exaggerated certain problems and have strained their credibility.

But certainly we have to give it a try. The scientific world must do its homework very well; it must be skeptical of its own work; it must make sure that its predictions are credible, and that they are soundly based. And then there is the selling job, and that will be very difficult.

Drought and water supply in the 1980s

One would be cloistered indeed not to have noticed that over the past year or so less than normal precipitation has characterized much of the continental United States.

Crops and water supplies are threatened. For example, 1980 yields for several crops (including corn and peanuts) were reduced by the heat wave and dry spell that baked the Midwest and South, and last winter's snowpack in the western mountains was one of the lightest ever recorded. And to the north and east of the Delaware Valley, restrictions on water use, imposed last fall and winter after one of the driest summers on record, remained in effect well into 1981.

These events so moved the editors of *Newsweek* that their February 23 cover depicted an outline of the forty-eight contiguous states filled in their entirety with drought-parched earth. And inside, the feature story reflected the cover art. *U.S. News and World Report* devoted its June 29 cover story to water scarcity, and many other publications, from the revivified *Life* to *Organic Gardening,* also have given cover treatment to the issue. Thus, the "drought" of 1980–81 afforded the media promising material for analysis, as well as a basis for gloomy predictions.

Nowhere has this theme been more enthusiastically pursued than in the Northeast, particularly in New York, where the national newspapers and television networks have made much of regional and nationwide droughts. This could be considered harmless, except that under the dual stresses of actual precipitation shortfalls and hectoring newspaper and TV stories, water system managers and municipal and federal agency officials may commit themselves to unwise projects or policies.

To better understand the potential for distortion, it is useful to review what is known about the 1980 drought in the urbanized Northeast; how it was analyzed in the press, especially by *The New York Times;* and how that analysis reinforces traditional approaches that are biased toward expensive increments to water-system capacity.

The 1980 drought. Precipitation shortfalls, even when regionwide, vary in intensity so that no single set of measurements captures *the* regional experience. But some easily available measures show that the 1980–81 water shortage really was severe in the Northeast. For example, New York City's total precipitation for the three summer months of 1980 was 3.42 inches, the lowest ever recorded and, as significant, more than 20 percent lower than the second driest summer, that of 1916.

The summer of 1980 also was one of the hottest on record, increasing the demand for water for pools, commercial air conditioning, lawn irrigation, and fire hydrant sprinklers. The combination resulted in more rapid than normal reservoir drawdown (see figure 1). And as the dry spell continued into the fall, the reservoir levels kept falling, producing a percentage-of-capacity trace for the giant New York City system that approximated, until mid-February 1981, that of 1964 and 1965—the two worst years of the mid-1960s drought.

As reservoir levels fell in the fall and winter, one water system after another announced drought alerts, warnings, and emergency situations, and imposed restrictions on car washing; hosing down streets, driveways, and sidewalks; and operating ornamental fountains. To publicize restrictions, restaurants were asked to serve water only on request; and a great deal of advice was offered about showering, shaving, flushing, and dishwashing.

In some parts of northern New Jersey and southwestern Connecticut an attempt was made to enforce real rationing by limiting household connections to 50 gallons per capita per day, by increasing meter reading frequency, and by applying either criminal penalties or water surcharges to those who appeared to be in violation.

These measures gave one a sense of *déjà vu,* since they were the same as those imposed during the several drought years of the 1960s. Granted, some lessons had been learned from the California experience of the late 1970s about how far authorities could push people to change their habits in such sensitive areas as toilet-flushing, but no water systems had installed remotely read meters or other technological innovations that would increase the feasibility of a truly effective rationing scheme.

"Drought" perspective. The drought of the 1960s, a much more severe event overall than the 1980–81 dry spell, came almost immediately after New York City's water system had completed its three Delaware watershed reservoirs. The system's "safe yield"—that quantity of water deliverable every day in all but 5 percent of years (based on what then was the worst drought on record)—was then about 1.55 billion gallons per day. With consumption averaging about 1.2 gallons per day, then-Commissioner D'Angelo might be forgiven his impetuous statement, made in January 1961, that the city would never again experience a water shortage. As the drought years followed each other, however, the existence of new reservoirs discouraged the media from blaming inadequate planning and insufficient investment for the shortage of water. It seemed clear, even to the *Times,* that this was a natural event so severe that it overwhelmed the most ambitious of plans and the most generous of investment programs.

In 1980–81 the city's physical capacity is the same as in the 1960s, but water withdrawals from it on an average day now are about 1.5 billion gallons, close to safe yield. Other systems in the region are in similar shape, whether because of en-

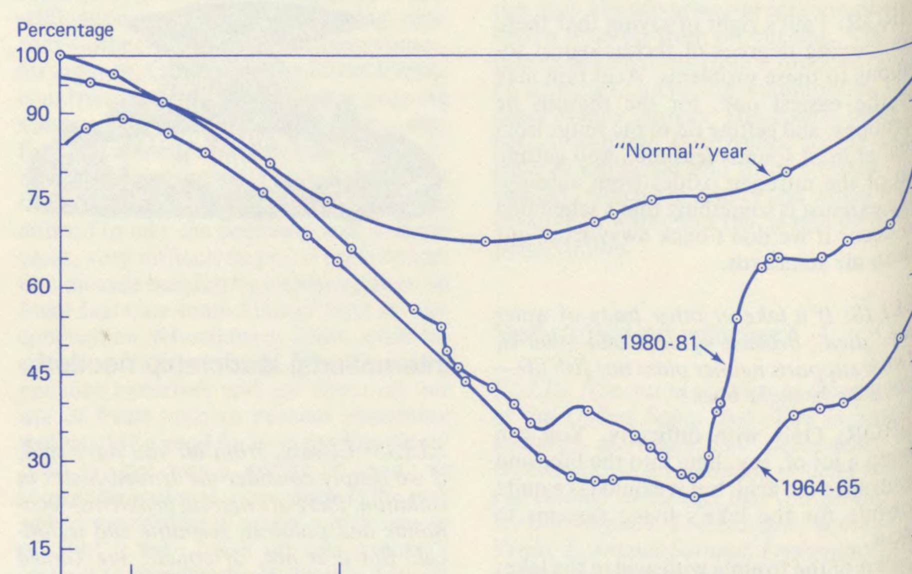


Figure 1. Percentage of capacity held in New York City reservoirs.

vironmental objections to the construction of new reservoirs or because investments in new sources were postponed as a result of budget constraints. (In northern New Jersey two reservoirs had been built by the state after the 1960s drought, but they are not connected to the water systems that had problems in 1980–81.)

This left an irresistible opening for the media analysts. In February 1981 the *Times* stated that the need for water use restrictions "has raised the question why something was not done to prevent the shortages, especially when water resource experts were saying that even in times of drought there was plenty of water in the region for all essential uses." There followed some agitation for measures to "prevent" shortages, but media skeptics were not sanguine that citizen concern would survive the end of the drought, whenever that came.

Some observations about droughts, shortages, and expansion of water system capacity. The quotation from the *Times* captures the essence of a polar view of municipal water system planning: shortages are unacceptable, and capacity should always be large enough, relative to demand, to prevent them. This view is based on comprehensive misunderstanding, and attempts even to approximate its implications for investment are bound to be enormously expensive—perhaps even infeasible in the heavily populated Northeast.

Fundamentally, it is impossible to prevent shortages because, short of zero, there is no lower limit to possible precipitation over any given period. No matter how much storage capacity is provided, a natural event can make it impossible to meet all demands at whatever price normally is charged.

Second, shortages do not fit the characteristics implicit in the no-shortage position. Except in the kind of extreme situation that is experienced only very rarely and usually by systems without any significant storage, shortages do not arise from an actual lack of water. Shortages are "created" by system managers who impose water-use restrictions long before their reservoirs go dry, precisely in order to prevent that from happening. This is done because their own intuition and the best available evidence say that damages are a steeply nonlinear function of shortage size. Thus, if there is overperiod storage in the system, and if it seems likely that in one period the available supply might be as much as 30 percent below demand, it often seems prudent to "save" 10 percent over each of three periods, rather than 30 percent in one period.

Given almost complete uncertainty about weather conditions for more than five days ahead, no one knows when it will be necessary to reduce withdrawals by 30 percent. In retrospect, it often proves unnecessary to have imposed restrictions on use: it usually rains enough to have supported normal use. But not always—and in a multiyear drought the system could court trouble by forecasting such a happy ending. Hence risk-averse managers create shortages, even though enough water may be physically available.

Also, while shortages may be annoying and even psychologically disturbing to some people, they have quite modest economic effects until they become very large indeed. Pseudo shortages almost always begin by involving restrictions on such uses as car washing and pavement cleaning, surely nonessential tasks by any reasonable view. Even restrictions on watering lawns and shrubs cost consumers little unless the precipitation shortfall is severe enough to kill valuable trees or shrubs. Restrictions on commercial activity usually involve only nonrecycling systems and can easily be avoided by modest investments (some of which should perhaps have been made in any event).

Some data on drought losses from an RFF-funded study of the 1960s drought in Massachusetts, and a U.S. Corps of Engineers' study of the same event in York, Pennsylvania, produced estimates of losses as connected to reductions in water use (percentage "shortages"). See table 1.

Table 1. Some Annual Drought Damage Estimates

Damages in 1978 dollars	Percentage of shortage: 10	14	22	50
Worst assumptions[a]	$11.20	$22.90	$9.40	$10
Best assumptions[a]	10.60	3.10	7.10	21

Sources: Data for the 10, 14, and 22 percent shortages reflect the experience of three Massachusetts cities and are taken from Clifford S. Russell, David G. Arey, and Robert Kates, *Drought and Water Supply: Implications of the Massachusetts Experience for Municipal Planning* (Baltimore, Md., Johns Hopkins University Press for Resources for the Future, 1970); data for the 50 percent shortage are from G. K. Young, R. S. Taylor, and J. J. Hanks, *A Methodology for Assessing Economic Risk of Water Supply Shortages* (Institute for Water Resources, Department of the Army, Corps of Engineers, 1972).

[a] The assumptions involve such things as applicable interest rates, the extent to which "lost" production or sales are made up later, and the appropriate accounting stance, whether local or national. The estimates of both studies have been inflated to 1978 dollars using the Consumer Price Index.

In short, the appropriate response to pervasive uncertainty about future precipitation levels is planning to have shortages and *not* planning to prevent them. That is, municipal water systems should be designed so that, at the margin, the cost of increasing capacity is equal to the expected damages avoided by that addition. Because total expected damages usually can be reduced by intelligent and foresighted application of restrictions before there is a physical need for them, the expected damage estimates should be developed by costing the effects of programs of staged drought response, which include gradually tightened restrictions.

This is, in fact, the approach that has been taken by the Washington (D.C.) Suburban Sanitary Commission in deciding on its latest increment to capacity. For the sake of New York and New Jersey residents, one can hope that this is the lesson drawn from the 1980 drought, and not the one that has been portrayed by the news media.

The above article was written by Clifford S. Russell, director of RFF's Quality of the Environment Division.

Adapting to life in a greenhouse

DESPITE A GOOD DEAL of uncertainty about the subject, there is the growing consensus among scientists that the atmospheric accumulation of carbon dioxide, through the so-called greenhouse effect, eventually will lead to a significantly warmer planet.

The principal risks of warmer global temperatures are distorted agricultural patterns and flooded coastal cities (by rising sea levels caused by melted polar ice), and the principal villains are the combustion of fossil fuels, like coal, and of less importance, the destruction of forests throughout the world, whether for timber, or agricultural land clearing, or firewood. Combustion releases carbon dioxide, and trees and other vegetation store it. The growing pace of both fuel combustion and deforestation thus combine to deliver a double dose of carbon dioxide to the atmosphere. A doubling of the atmospheric load and a consequent average temperature rise of perhaps 2 to 3 degrees Celsius is possible within the next fifty years, with the mid and high latitudes affected much more than the Equator.

What is to be done about this very uncertain but potentially grave threat? Not much, suggest many who are studying the problem. Indeed, most articles conclude that learning to live with a warmed-up earth may prove the most realistic option. Charles F. Cooper's 1978 *Foreign Affairs* article offers a good illustration: ". . . If the geophysical assumptions are correct, the process of climatic change due to industrialization is probably almost irreversible; the only practical strategy is adjustment."

It may be, however, that adjusting incrementally to the slow changes in temperature, as they come along, is the worst thing that we can do. Adaptability normally is a distinctive human strength, but in this case it may be self-destructive.

Humankind at times has demonstrated foresight and ability to make rational decisions in the face of uncertainty. But people also are prone to discount the future—to give more weight to current than to future consequences—and this tendency is greater as the uncertainty about future events increases. In everyday commercial and economic life such discounting is built into the structure of interest and profit rates: a dollar delivered today is always worth more than a dollar promised for delivery in the future. If people believed that there was, say, a 20 percent chance

Costs up on Western water

In July Kenneth D. Frederick, director of RFF's Renewable Resources Division, testified before the House Agriculture Committee's Subcommittee on Department Operations, Research, and Foreign Agriculture. The following brief article is excerpted from his more extensive testimony, entitled "Water Supplies and Agricultural Exports."

IN THE PAST, the availability of relatively cheap water spurred the expansion of irrigated agriculture in the western United States. In the future, rising water costs and scarcity will constrain irrigation's growth and, in some places, may eliminate irrigation altogether.

In many of the West's prime agricultural areas, total water requirements exceed average year streamflows. Thus, the importance of water beneath the surface—groundwater—has grown to the point where it now accounts for 39 percent of all western irrigation.

The combination of rising energy costs and declining groundwater tables brought large increases in groundwater costs during the 1970s. This situation is deteriorating daily: current groundwater withdrawals result in the mining (withdrawals in excess of recharge) of more than 22 million acre-feet per year. Within the High Plains area alone, annual groundwater mining is roughly equivalent to the annual flow of the Colorado River. Water scarcity now retards further development in much of the West, and the subsidies and laws insulating many water users from the increasing value of the resource deter rather than stimulate development. Federal and state laws and policies not only allow an inefficient use of western water, they almost guarantee it by reducing or eliminating the incentives and opportunities for transferring water to higher-value uses.

Improving the efficiency of western water use does not require forcing the owners of water rights to pay for what has been legally given to them. Indeed, any attempt to abrogate these rights would be futile and damaging to the region, since it would threaten the entire legal and institutional structure that has brought order to the allocation of western water. Rather, the need is for laws and institutions that allow and facilitate the sale and transfer of water.

Since irrigation is a relatively low-value user, a more market-oriented allocation system is likely to transfer water from irrigation to other uses. And in some areas, the inevitable adjustments to declining groundwater supplies will not be pleasant. Nevertheless, the socially most expensive response would be to provide subsidies that either enable farmers to pump to greater depths or to import water.

We have begun to recognize that water is becoming increasingly valuable; now we need to provide the incentives to assure that we treat it as such. The worst social costs associated with the changing water situation will arise if we attempt to keep water cheap when it is not.

that the human race would become extinct in 200 to 300 years unless certain changes were made, no doubt they would be willing to make substantial sacrifices today to avoid it. That is, they would use a lower discount rate than in ordinary life.

But on this issue they are not convinced; there is an insufficient basis for convincing them; and all the pressures—from budgetary limitations to conventional thought processes—are in the opposite direction. Given the nature of the carbon dioxide problem—in particular, the long time period involved and the immense degree of uncertainty—these pressures will dominate and could lead to behavioral responses that not only are inappropriate but also potentially disastrous.

There are three broad categories of possible responses: one is to restrict fossil fuel combustion; another is to reverse the destruction of forests; and the third is to allow carbon dioxide to continue to accumulate and to adjust as the effects are felt.

Restricting combustion

The only pervasive tool to restrict combustion worldwide is the price mechanism. All other mechanisms—taxes, import regulations, and so on—can be applied on a country-by-country basis but require cooperation between countries to accomplish much. Since important nations are likely to see their self-interest in quite different ways, there is little basis for agreement. On the other hand, what if the price of energy continues to rise?

On the demand side, there is no doubt that the long-run effects would be beneficial as far as carbon dioxide is concerned. But the supply responses are likely, on net, to be negative. Importantly, the increased price will stimulate the search for and use of other sources of fossil fuels (new sources of oil, shale, tar sands, coal, and others), all of which will generate additional carbon dioxide emissions. Moreover, particularly in developing countries, an increase in the price of commercial fuels will induce greater cutting of forests.

There are a number of things government programs could accomplish, especially on the supply side. Greater efforts could be put into the development of nuclear fusion, for example, and massive hydroelectric projects could be set along, say, the Amazon and Brahmaputra rivers, with the excess power used to produce hydrogen for export. And energy could be beamed to earth by solar-powered satellites.

But all such projects have serious difficulties. Some, like fusion, have technological problems; others, like the damming of the Amazon, raise ecological unknowns; yet others, like building hydroplants along the Brahmaputra, which flows through three countries, present political problems. And most require massive amounts of capital and have very long gestation periods and unfavorable benefit–cost ratios. Apart from fusion research, which is reasonably well funded in only a few countries, no serious work is going ahead on any of these projects. Nor will there be any until energy becomes vastly more expensive or the carbon dioxide problem far more immediate.

Forest conservation

Global, cooperative efforts to halt deforestation, or better, to reverse the process are thwarted by the desperate need for additional agricultural land, a need that clearly is going to take precedence, and by the increasing need for cheap fuel, particularly in poor countries. Governments could combine to mount a massive global program of reforestation. But the trees would have to be left standing, not grown for timber or fuel, if the program were to have much effect. And that is not a bankable proposition.

Adjustments

Thus, given the slowness and the uncertainties of the postulated effects, the most likely social response is to allow carbon dioxide to build up and to adjust only as the effects are felt. Where does this lead us? Given the two most probable principal effects—climatic changes affecting agriculture and the eventual melting of the polar ice caps—what kinds of responses might be expected?

The most likely response in areas that slowly become more arid is to resist the change, to keep out foreign competition, to call for subsidies, and to build irrigation systems. Unless the change is relatively sudden and dramatic, such responses will appear to be more cost-effective and less risky to the current generation of farmers than abandoning the land and opening up new lands in the north. Once an irrigation system is built, it will continue to appear more cost-effective to marginally expand it to offset further changes in climate. Given this tendency, plus the high cost of investing in the whole package of factors involved in developing farming on new lands, the movement of agriculture from areas hurt by climate change to areas benefited by that change could take a long time. Thus, the cost of food and the risks of crop failure will rise, at least during the transition period, if not permanently.

A more clear-cut example of myopic adjustment can be seen by considering how coastal populations are likely to adjust to a slow but inevitable rise in sea level. Such a rise may proceed by only 10 feet or less each century, but once begun, it is likely to continue long after all the fossil fuels have been burned. If all the water now trapped as ice in Greenland and Antarctica were added to the oceans, the sea level eventually could rise by a very significant amount, perhaps as much as 100 feet.

Only two responses to this situation appear possible: low-lying lands can be evacuated, or seawalls and dikes can be built. Given the slowness of the change in sea level and the use of anything other than a zero rate of discount in deciding such matters, seawalls and dikes are all but certain. And once built, it will appear cheaper to make them a bit thicker and higher than to evacuate the area. Eventually, much of the human race could find itself living below sea level, with the probability of a catastrophic breach in the dikes growing over the centuries. Under such conditions a repetition of the legendary sinking of Atlantis is highly probable. Only the date of the event is uncertain.

This is perhaps the clearest possible example of a situation in which the normal human processes of adapting to changing circumstances eventually can become self-destructive. But other, less dramatic, examples exist, such as the excessive use of pesticides that induce the evolution of more resistant strains or the diking of rivers to avoid flooding of adjacent lands, when silt continually raises the level of the riverbed.

Compared with other living things, humankind is very adaptable. But people also are stubborn and unlikely to alter their behavior until faced with what is perceived to be a necessity. Even then, there is a tendency to take the line of least resistance, which ultimately may be self-defeating.

Human adaptation patterns put a heavy burden on scientists studying the carbon dioxide problem, for they suggest that only by sharply reducing the range of uncertainty surrounding this problem is there any hope of escaping the trap laid for us by our normal responses to change. Granted that the hazards posed by the greenhouse effect now seem remote and many even question their existence, will we ever be certain enough to abandon our attempts at incremental adjustments? Learning to live with a warmed-up earth ultimately may be more risky than other more radical options.

This article is based on material from Ronald G. Ridker, formerly a senior fellow in RFF's Renewable Resources Division, and now on the staff of the World Bank.

On assessing risk

RFF Senior Fellow William Ramsay this summer testified on societal risks of energy systems before the House Committee on Science and Technology. The following article is adapted from his testimony.

RISK ANALYSIS IS a formal extension of the almost automatic calculation of risks that everyone performs when preparing, say, to cross a busy street. Assessing the risks of one action and comparing the risks of several make sense for the individual, and risk analysis makes sense for governments and private firms.

Indeed, the need to analyze and compare the risks of proposed policies and actions makes such good sense that too much faith now may be invested in risk analysis. It is a valuable analytical tool in making sensible policy decisions, but it is by no means infallible, nor even very precise.

Both analysts and policymakers need to recognize that a great many uncertainties plague the application of risk analysis. These uncertainties generally fall into three groups—incomplete or inaccurate raw data; ignorance about cause and effect; and value judgments, with value questions probably the most serious and least tractable.

Uncertain data

The simple-sounding task of determining the level of carcinogens produced by a new coal synfuels plant, for example, is not easy at all. For one thing, while it is difficult enough to measure certain pollutants at their source, it may be exceedingly tricky to do so at some later point in time and space. And even if it is known what combination of pollutant compounds are released at a power plant smokestack, for example, the mixture of compounds may turn out to be quite different after being carried long distances through the atmosphere. Finally, whatever is known about present pollution patterns offers no guarantees about what will happen in the future.

Consider Three Mile Island and the question of nuclear reactor accidents: we now realize we know much less about the probability of nuclear accidents than some had thought. And this brings up a point that needs emphasis—the "uninformed" public may not always be wrong. In some nuclear circles, the feeling long had been that the public is unaware of comparative risks and unable to think rationally about tradeoffs between energy technologies. There undoubtedly is some truth to this proposition, but one might also bear in mind that the public may have a healthy skepticism about the general state of scientific knowledge on the risks of energy technologies, and of nuclear power in particular.

Causes and effects

A pollutant released into the environment may be identified, and a general process such as strip mining observed, but linking both discrete and general probable causes with specific impacts on health and environment still can be more speculation than science. The problem in assessing the damage from Love Canal—if any—is a typical example.

Or, growing more grain to produce fuel alcohol probably would increase water pollution. This can be estimated and perhaps even measured for a particular piece of cropland, but what is the net impact on the downstream environment?

And what about low-level radiation from nuclear power, or extra low frequency radiation from microwave ovens and other devices? Controversies over these questions have to do not so much with the amounts of radiation emitted, but with what that radiation actually does to the human body. We are still a long way from understanding all of these phenomena.

Questions of value

Knowledge grows. More raw data on health and environmental risks will be gathered and connected with definite effects on the human body or on the ecosystem. Some emissions from coal may be shown to actually cause cancer in human beings; certain amounts of strip mining demonstrably may lead to a loss of species variety in a particular environment. However, even if this kind of knowledge increases, the third and probably worst uncertainty remains—the question of differences in values.

Suppose there are two different effects, one on health, and one on the nonhuman environment: which effect is more important? Or, confining the dilemma to human health alone, are fatal falls from roofs while installing solar collectors—surprisingly, a considerable health risk, as these things go—more important than chronic lung disease that may (or may not) be caused or aggravated by emissions from coal-fired power plants? Are chronic diseases like asthma less serious than acute diseases like pneumonia? They probably are, but, if so, how many asthma attacks are equivalent to one case of pneumonia?

Why is clean air important? Does the answer lie in better visibility or in better health? If the answer is health, then why do the Clean Air Act Amendments of 1977 tend to put more pollution where pollution exists now, rather than spreading it around more evenly?

The difficulties in deciding such questions are no secret; probably everyone working in the field has been guilty of giving them short shrift. Nevertheless, most analysts have given most importance to death rather than illness, even though one can note that death is inevitable but illness not always so. One can go even further, and worry about at what *time* the death or illnesses are caused.*

These questions involve important human values about which most people probably possess a greater depth of understanding than some analysts give them credit for. For example, there is the key comparison of catastrophes with routine events. How do 200 coal miner deaths, say, *every* year compare, with 200,000 *possible* deaths from some sort of nuclear power impact spread out over 1,000 years? Is there any difference between having a small chance of a large disaster or a large chance of a small disaster? How does the real acid rain problem, which though

* The time dimension is addressed in William Ramsay's and Milton Russell's "Time-Adjusted Impacts from Energy Generation," *Public Policy* vol. 26, no. 3 (Summer 1978). For an in-depth discussion of value uncertainties, also see Ramsay's *Unpaid Costs of Electrical Energy: Health and Environmental Impacts from Coal and Nuclear Power* (Baltimore, Md., The Johns Hopkins University Press for Resources for the Future, 1979).

important, probably can be lived through, compare with the more hypothetical carbon dioxide accumulation, which could lead to serious worldwide environmental catastrophes?

Finally, there is the question of equity—or whose ox is gored. Does it make any difference if an energy technology visits most of its harm on workers, as opposed to members of the general public? This is possibly the case for the synfuels industry, where there may be some dangers to workers of developing cancer from compounds produced in the process of turning coal to fluids, but relatively little danger to the general public. Is this type of arrangement "fair?" Similarly, city residents are more exposed to air pollution than people in the country. In either case, of course, one can say that there is some freedom to choose: presumably one does not have to take a dangerous job, and one does not have to live in a city if one fears the effects of bad air. On the other hand, freedom of job and location choice, while great in America, certainly is not perfect.

Equity includes fairness to future generations. Not all scientists are persuaded that the nuclear waste problem is very difficult, let alone insolvable. Nevertheless, to the extent that nuclear wastes are hazardous, their impacts will fall not on us, but on future generations. One may ask, of course, What have future generations ever done for us?—a question not quite as cynical as it may seem. Regardless, there seems to be within the human animal some feeling of responsibility for transmitting an environment as relatively clean as possible to those who follow us.

Common sense

Risk analysis is a useful tool, but the role of key uncertainties—in data, cause and effect, and in human value judgments—must be recognized if it is to gain respect as a serious element in making policy decisions. In particular, analysts should take into account that some attitudes of the public, such as preferring small routine risks to catastrophic nonroutine risks, may not be "irrational" but rather provide clues about how policy risk analysis should seek to incorporate human value preferences. In other words, much wisdom already resident in "common sense"—that uncommon quantity—must be combined with scientific advances in the field of quantitative evaluation of risks if risk analysis is to become a widely accepted and truly useful device for developing future policy.

RFF fellowship and grant programs

Gilbert F. White Fellowships

Christopher K. Leman and John A. Miranowski have been awarded Gilbert F. White Fellowships for the 1981–82 academic year. The fellowships were established in 1980 in honor of Dr. White, distinguished geographer and former chairman of RFF's Board of Directors.

The fellowships, awarded annually, are intended for young professionals who wish to devote a year to scholarly work at RFF on social or policy problems in the areas of natural resources, energy, or the environment. The program is directed by Herbert C. Morton.

Leman, an assistant professor of politics at Brandeis University, will use his fellowship to study resource assessment and management, and policy economics.

Miranowski, who is assistant professor of agricultural economics at Iowa State University of Science and Technology, will devote his time at RFF to work on soil erosion and conservation.

Small Grants Program

RFF's Small Grants Program is designed to support the individual scholar with an innovative idea in a relatively ignored area of research, or the researcher who needs help in bringing a significant research undertaking to fruition. Paul R. Portney, director of the program, recently announced the recipients of the 1981 grant awards.

The recipients, their affiliations, and topics are:

- Martin L. Cody, University of California, Los Angeles, "The Influence of Habitat Dissection and Patchiness on Biotic Diversity"
- Thomas G. Cowing, State University of New York, Binghamton, "Cost–Benefit Analysis and the Evaluation of Alternative Electricity Rate Structures"
- David L. Kaserman, University of Tennessee, Knoxville, "The Automatic Fuel Adjustment Clause and Fuel Purchasing Practices in the U.S. Electric Utility Industry"
- Jon C. Sonstelie and Robert T. Deacon, University of California–Santa Barbara, "The Value of Time and the Cost of Non-Price Rationing: The Case of Gasoline Pricing"
- Richard A. Winnet, Virginia Polytechnic Institute and State University, "Psychological Field Experiments in Resource Management: Relevance to Economic Theory and Policy"
- Charles W. Howe, University of Colorado, "Innovations in Water Management: An Ex-Post Analysis of the Northern Colorado Water Conservancy District—Colorado–Big Thompson Project."

Forest Economics and Policy Program

Roger A. Sedjo, director of RFF's Forest Economics and Policy Program, announced the following dissertation fellowship grants for 1981: Richard L. Barber, Department of Forest Management, Oregon State University; Theodore D. Graham-Tomasi, Department of Natural Resource Economics, University of Michigan; and Wendy Barbara Max, Department of Economics, University of Colorado. The dissertation fellowship program was established in 1981 for the support of doctoral dissertations in forest economics and policy.

Climate change and economic impact analysis

It was just ten years ago that the Study of Man's Impact on Climate conference held near Stockholm first focused world attention on the possibility of global climate change. Today, national and international scientific groups and policymakers uniformly acknowledge that average global temperatures by the close of this century may be warmer than those of any period in the past 1,000 years. Moreover, the factors behind this trend are persistent and could lead to even more pronounced temperature increases in the next century.

Unfortunately, scientific consensus and legislative mandates, such as that of the 1978 National Climate Program Act, do not necessarily imply a wealth of technical information necessary for intelligent policymaking. Indeed, neither causal factors associated with climate change nor the mechanisms by which changes take place are known with much confidence. Figure 1, from a recent paper by William W. Kellogg, shows the constituent elements of the climate system, all of which interact to determine the patterns of climate.

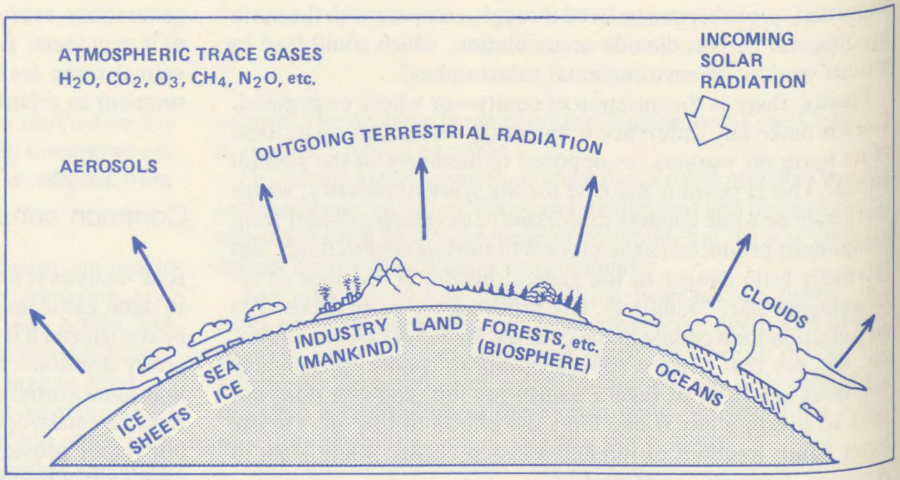


Figure 1. Components of the climate system. (Based on a figure in William W. Kellogg, "Modeling the Prospects for Climatic Change: Current State of the Art and Implications." Paper presented at the RFF/NCPO Workshop on Economic Methodologies for Climate Change, Fort Lauderdale, Florida, April 24–25, 1980.)

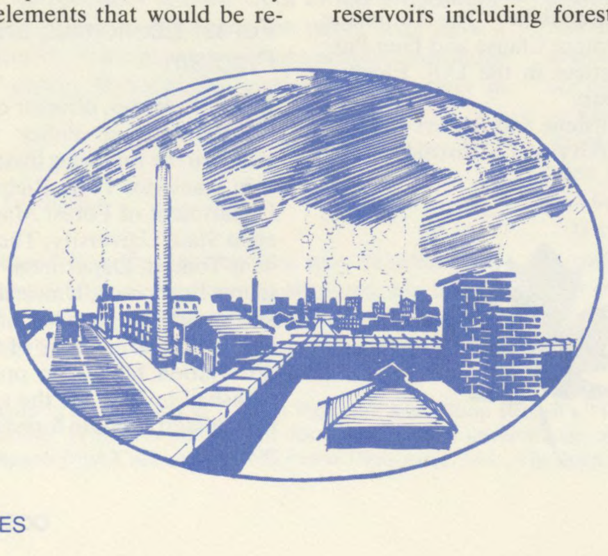
Climate change is one of a class of environmental concerns that share three attributes which confound the design of appropriate policies: (1) significant uncertainties exist with respect to the technical, economic, and often the temporal dimensions of effects; (2) some effects extend over a long time and may transcend national boundaries; and (3) a sequence of physical changes to the natural environment is involved that, for practical purposes, is irreversible. Thus, while there may be some twenty to thirty years before the impacts of change in climate would be felt, the information necessary to design programs to avoid them is simply not now available.

To appreciate some of the difficulties posed by these problems, we need only consider the elements that would be required for a policy analysis of the prospects for a change in world climate induced by carbon dioxide.

Carbon dioxide (CO_2) is thought to be a principal cause of possible climate change. It is a persistent, chemically stable gas that absorbs infrared radiation, so increases in its atmospheric concentration can lead to an increase in surface temperatures. There are at least three components of a policy analysis of such a change.

First, one must understand the carbon cycle and the relationship between changes in the atmospheric concentration of CO_2 and climate change. For example, primarily as a result of CO_2 released by fossil fuel combustion, it is estimated that atmospheric CO_2 has increased by about 15 percent since the middle of the nineteenth century (from 290 parts per million to 334 ppm in 1979).

Of course, not all carbon emitted in combustion adds directly to the atmospheric concentration of CO_2. A significant fraction remains in natural carbon reservoirs including forests, the surface and intermediate waters of the ocean, and the deep sea. Just how great a proportion remains is one of the most perplexing technical uncertainties. Customarily, scientists have assumed 50 percent will be absorbed by these natural "sinks." However, the fraction could be as high as 70 percent.



Based on the interannual variability of temperature at a particular latitude (60°N), together with the predictions of three-dimensional, general-circulation climate models, Roland A. Madden and V. Ramanathan conclude that surface warming due to the increase already made in the atmospheric stock of CO_2 should be detectable today. However, their empirical analysis of recent temperature readings does not confirm the predicted warming. They conclude that one important reason for this discrepancy is the inability to fully account for the role of oceans in current atmospheric models of climate.

The second step in evaluating the impacts of CO_2 involves an analysis of the economic and social effects of predicted climate changes. Information in this case is even more limited than in modeling the climate system itself. We cannot judge, for example, whether the temperature increase usually estimated to be associated with a doubling in CO_2 concentrations would have a favorable or an unfavorable effect on the world economy. Indeed, it is not clear that existing economic methodologies are fully adequate for the task of gauging the net economic impacts of such changes.

More specifically, since a climate change would affect all industrial sectors and households in a given region, partial equilibrium analysis, which tends to localize attention to a single market, firm, or household and is also the economic basis for most cost–benefit methodologies, may not be appropriate for these problems. It is difficult to judge the errors in estimates based on conventional methods. Nonetheless, the most recent economic evidence suggests that, using extreme outcome climate scenarios, the losses to some segments of the global economy may outweigh the gains to any others.

In short, there is only a limited body of social science research on the economic and social consequences of climate change and, given the current state of institutional support for this area, there is not likely to be much progress made soon.

The final step in the evaluation process requires analysis of the cost of CO_2 abatement and a mechanism for incorporating the information on the costs and benefits of CO_2-induced climate change into a policymaking process that recognizes the international dimensions of the problem. Surely, a task of staggering proportions!

The CO_2 example illustrates the difficulties of formulating public policy for possible influences on the earth's climate. It also highlights the research needed to expand understanding of accumulating stocks of residual byproducts of production and consumption.

None of this will be easy. But with significant, irreversible change in the earth's climate possible, the task must be addressed, and the sooner this is done the better.

Author V. Kerry Smith, professor of economics at the University of North Carolina, Chapel Hill, formerly was associated with RFF's Quality of the Environment Division.

RFF's Food and Agricultural Policy Program

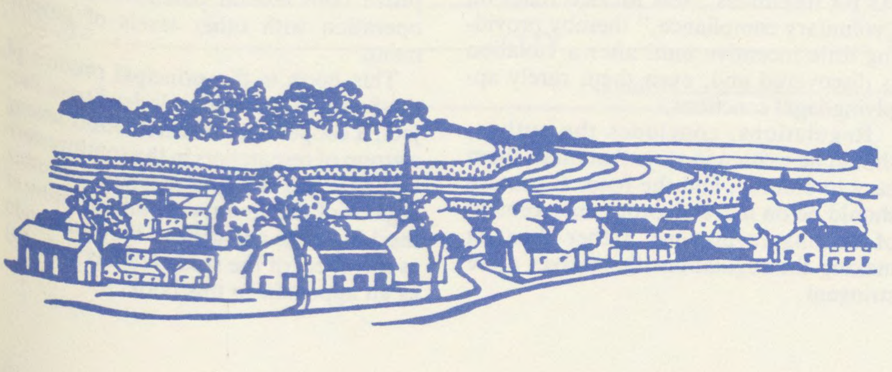
KENNETH R. FARRELL, for the last four years administrator of the Economics and Statistics Service of the U.S. Department of Agriculture, has been named first director of a new food and agricultural policy program at Resources for the Future.

Established with the help of a grant from the Ford Foundation, the program will aim at a comprehensive analysis of agricultural policy that will include not only supply and demand of agricultural commodities, but also such topics as energy impacts on agricultural productivity; the contribution agriculture might make to easing the demand on domestic fuel supplies; the implications for food and fiber production of changes in water availability and price; and the role of agriculture in relation to overall natural resource use and adequacy. The emphasis will be on policy application and design, and special efforts will be made to bridge gaps between academics, business people, and government officials.

In announcing the program, RFF President Emery N. Castle said, "It is most appropriate that RFF have a program on food and agricultural policy. Many people are quite conscious of the world food situation, but few are aware that agriculture employs more people than any other industry. Nor is it widely recognized that agriculture is the world's largest user of natural resources. Although RFF has for some time sponsored a great deal of research on agriculture, the new program will permit us to examine food, agricultural and resource use in a systematic way. We are very fortunate in obtaining a person of Dr. Farrell's stature and experience to head the program."

Farrell, 54, joined the USDA in 1971 as deputy administrator of its Economic Research Service. Much of his earlier career was spent at the Berkeley and Davis campuses of the University of California, where he specialized in agricultural marketing, policy, and international trade. He was involved in the full spectrum of University service—teaching, research, extension and administration. He also was a Fulbright lecturer at the University of Naples.

A native of Ontario and a graduate of the University of Toronto, Farrell earned his graduate degrees in agricultural economics from Iowa State University. He is a member and former director and president of the American Agricultural Economics Association, and in 1980 was named AAEA fellow, the organization's highest honor.



New RFF books

Energy Demand Behavior: A Study of Energy Elasticities. Douglas R. Bohi. 191 pp. $19.50.

Econometric methods are widely used to estimate demands, particularly the response to a price change. This study shows how the information supplied by econometrics may be colored by a number of factors, among them choice of model, type of data, and the estimation method. Differences among these features can and do produce substantial disparities in results.

While the conditions under which estimation errors may arise are known in theory, the importance and often the direction of the errors can be determined only by empirical verification. This work attempts to shed light on how these errors arise and their significance for those who use the estimates.

The large number of energy demand studies carried out in recent years provide an unusually good source for comparisons and verification. They also reveal a startling lack of consensus in results. Bohi uses these differences to examine the importance of the empirical procedure, to explore the differences among estimates and their causes, and to elevate the effectiveness of econometric methods in dealing with them. Some of the differences in results reflect economic and institutional conditions contained in the sample; others follow from the choice of procedure.

Although it is apparent that price indeed matters, our knowledge of the specific relationship between price and consumption remains in doubt for several major energy products, consuming groups, and end uses.

On a broader level, the study looks at the policy implications for using demand estimates. Finally, this work provides a convenient reference source for econometric methods, estimation problems, and statistical estimates about energy demand.

High Energy Costs—Uneven, Unfair, Unavoidable? Hans H. Landsberg and Joseph M. Dukert. 118 pp. Hardcover, $12.50. Paper, $4.95.

Do the poor suffer more? As energy prices advance along a broad front, do they affect some groups of American consumers more severely than others and, if so, what should be done about it?

These concerns, alive since the first jump in oil prices in 1974, acquired even greater urgency following the 1979–80 price shock and the Reagan administration's decontrol of oil prices. High energy costs may be unavoidable, but do their burdens fall unevenly? Are they "unfair"?

The authors cut through the confusion arising from various definitions of poverty. By most measures, they report, the poor indeed are in worse shape; energy expenditures represent a relatively large part of their budget and—especially since mid-1979—energy prices have outpaced general inflation. But assistance programs—apart from energy—soften the impact. This book attempts to penetrate the thicket of figures and assess by how much.

Generally, the authors favor establishing need as the criterion for assistance: if someone falls below an acceptable level—because of rising energy costs or any other reason—then the problem is poverty, not energy. When political sensitivities about aid measures distort energy goals, the authors do not rule out compromise, but they think we should admit what is happening.

Public Lands Politics: Interest Group Influence on the Forest Service and the Bureau of Land Management. Paul J. Culhane. 376 pp. Hardcover, $29.50. Paper, $11.95.

One-third of all the land in the United States is owned by the federal government, including huge chunks of most of the Western states. This fact alone almost guaranteed the Sagebrush Rebellion.

If the federal government is the landlord of the public lands, their "building managers"—those who deal on the spot with a variety of problems and constituents—are two agencies little known to the public, the Interior Department's Bureau of Land Management and the Agriculture Department's Forest Service. How do these agencies perform as land managers, and how do they respond to the pressures of the sagebrush rebels, conservationists, and others with vested interests in the federal lands?

Paul Culhane examines the relationships between the two agencies and their interest group constituents and finds that the agencies often balance the conflicting pressures focused on them by such traditional users as stockmen and the forest product industry against those brought to bear by environmentalists and recreationists.

Culhane's conclusions are based on extensive interviews with local agency officials and key interest-group leaders in the West, and on the use of a formal model of interest group influence. The combination enables him to come as close as possible to measuring the extent to which groups really affect such key public lands policies as the level of timber sales and wilderness recommendations.

The Regulatory Approach to Air Quality Management: A Case Study of New Mexico. Winston Harrington. Research Paper. 142 pp. $7.50.

Regulating stationary sources of air pollution can be a troublesome task for state agencies charged with enforcement. Even very basic questions, such as how the agency identifies what sources are discharging and what incentives are to be used to encourage continuous compliance, remain largely unanswered in many states.

Emphasizing not the regulations themselves, but how establishments comply with them, Harrington uses the experience in New Mexico as a case in point and establishes that source surveillance is expensive and, therefore, infrequent, and that sources probably violate regulations frequently. As for incentives, New Mexico relies on "voluntary compliance," thereby providing little incentive until after a violation is discovered and, even then, rarely applying legal sanctions.

Regulations, concludes the author, should be written in ways that make them easy to enforce, and the focus for future should be on more vigorous enforcement of existing regulations, rather than on making the regulations themselves more stringent.

The Southwest Under Stress: National Resource Development Issues in a Regional Setting. Allen V. Kneese and F. Lee Brown. 288 pp. Hardcover, $30.00. Paper, $9.50.

The 1970s, billed as the environmental decade, may be remembered as much for the beginning of the energy "crisis" as for the raising of environmental consciousness. And energy—its extraction, processing, use, and effluents—is the single biggest threat to environmental quality.

The same ten years has seen a surge in the incessant westering of the American people. More people moving West means more houses, more shopping centers, more development of every kind in an area that in many places is ecologically and culturally fragile.

Energy versus environment. Resource exploitation versus scenic beauty. Regional wishes versus national requirements. These and other aspects of the conflict between development and the quality of the environment are nowhere more sharply drawn than in the Southwest.

This book examines the development-environment conflict in the four contiguous states of Arizona, Utah, Colorado, and New Mexico. It emphasizes three issues with implications that extend far beyond the Southwest: water—its quantity, quality, and allocation; environment—how and to what extent it should be preserved; and the future of Indian and other poverty-stricken peoples. Energy comes in for special attention because the Southwest is a principal repository of fossil and nuclear fuels.

There is a wealth of information in the book that may be used to guide public policy in the region, and many of the policy alternatives set out are aimed at state and local governments. The authors are convinced that far too little attention is given to the local functioning of national policy-making and implementation. Alleviating poverty, improving the lot of the Indians, and formulating workable water, environmental, and natural resources development policies are all of special concern to the region, but the federal government has asserted a dominant role in many of these areas. The book discusses ways in which the federal role may change to improve both federal policy itself and cooperation with other levels of government.

This book is the principal product of the Southwest Region Under Stress Project, a cooperative research effort among a group of researchers in the southwestern United States as well as scholars from other regions of the country. A bibliography of the 145 books and articles they published as members of the study team is included as an appendix to this book.

RFF reprint series

The following reprints of staff material have been added to the RFF Reprint Series. Single copes are available free on request to Resources for the Future.

185. *Measuring Factor Substitution with Neoclassical Models: An Experimental Evaluation*, by Raymond J. Kopp and V. Kerry Smith. 1980. This technical paper evaulates the performance of neoclassical cost functions in estimating input substitution.

186. *Housing Prices, Health Effects, and Valuing Reductions in Risk of Death*, by Paul R. Portney. 1981. This technical paper considers the possibility of drawing inferences about individuals' valuations of risk by combining estimates of the effect of air pollution on both property values and human health risks.

187. *Profit Maximizing Communities and the Theory of Local Public Expenditure* and *Gross Rents and Market Values*, by Jon C. Sonstelie and Paul R. Portney. 1981. The first of these two technical articles examines profit maximization as a normative criterion for communities in a large metropolitan area. The authors develop a Tiebout-like model of residential location, define the profits of a community, and show that profit maximization leads to the efficient provision of public services and optimal community size. In the second paper, the authors propose a new empirical test of the implications of the Tiebout hypothesis, and offer as an example a case study of San Mateo, California.

188. *Risk in Benefit-Cost Analysis*, by William D. Schulze and Allen V. Kneese. 1981. This technical paper examines the philosphical underpinnings of benefit-cost analysis which is a special case of utilitarianism, and compares implications of the technique to those arising from alternative ethical systems in analyzing questions of public safety.

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