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The Greenhouse Effect: How It Can Change Our Lives

The Greenhouse Effect: How It Can Change Our Lives

With the Greenhouse Effect, the human race enters a new phase—dealing with major adjustments in life on the planet because of changes in the environment brought about by human activities. This issue of *EPA Journal* explores the phenomenon known as the Greenhouse Effect and explains its projected impacts.

EPA Administrator Lee Thomas leads the issue with a statement about this planetary problem which we face and what it means to him.

Next is an article by a U.S. scientist who is an expert on the Greenhouse Effect. He defines the phenomenon and explains for the reader what causes it. Then seven articles follow, projecting Greenhouse impacts on U.S. agriculture, forests, sea level, electricity demand, water resources, animal species, and air pollution. The articles on impacts are introduced in a piece jointly authored by two EPA officials who explain how the projections have been made.

Following these articles is a piece by the Electric Power Research Institute describing the challenges and uncertainties the Greenhouse Effect poses to the electric utility industry, one of the industries involved in this environmental concern.

Articles from three foreign countries then describe what the Greenhouse Effect may mean to them and what they are doing to prepare for it. The countries are the Netherlands, Canada, and Japan. A global perspective on changes the Greenhouse Effect may portend is presented by William H. Mansfield III, Deputy Executive Director of the U.N. Environment Programme. The strategic implications inherent in global shifts in farming and other factors in human life are explored by William Nitze, U.S. Deputy Assistant Secretary of State for Environment, Health, and Natural Resources.

An explanation of how the wheels are beginning to turn nationally and internationally to understand and face the Greenhouse Effect is provided by Linda Fisher, EPA Assistant Administrator for Policy, Planning, and Evaluation (OPPE).

Next is an article explaining how the cutting of forests in parts of the world can contribute to the Greenhouse Effect and how forest replanting globally could help alleviate the Greenhouse problem. The piece is adapted from an article by Sandra Postel of the World Watch Institute.

In conclusion, an article by Gus Speth, President of the World Resources Institute in Washington, D.C., addresses a thought-provoking question—Can the human race be saved?

This issue of *EPA Journal* concludes with two regular features—Appointments and Update. □

This corn in Baldwin County, Georgia, grew to normal height last summer, but due to the drought it shriveled and formed very few ears. Scientists agree last summer's drought was not from the Greenhouse Effect, but drought could be experienced in some areas in the future because of the Greenhouse warming.

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EPA is charged by Congress to protect the nation's land, air, and water systems. Under a mandate of national environmental laws, the agency strives to formulate and implement actions which lead to a compatible balance between human activities and the ability of natural systems to support and nurture life.

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Cover: Tumbleweed in a sunset. Symbolic of a warming earth under the Greenhouse Effect. Photo by Larry Lee for Woodfin Camp, Inc.

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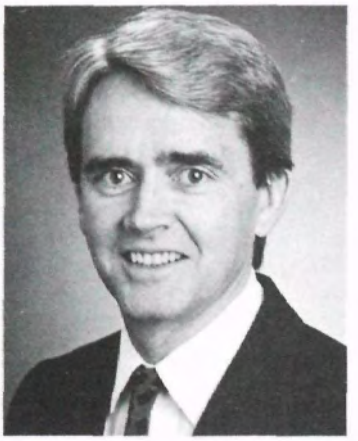

As this issue went to the printer, it was learned that President-elect Bush will nominate William K. Reilly to be the new Administrator of EPA. Reilly is now President of World Wildlife Fund and The Conservation Foundation. Among his previous jobs, Reilly was executive director of the Task Force on Land Use and Urban Growth and was on the senior staff of the President's Council on Environmental Quality.

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How I See It

by Lee M. Thomas

Craig Aurness photo Woodfin Camp

The way we live is profoundly affected by our climate. When and where we farm, how much we heat and cool our homes, how we obtain our water—all depend on the climate we experience. Climate determines whether we have a bumper crop or a shortage. It affects the severity of our pollution problems. It determines where the sea meets the shore and the makeup of our forests and our wetlands.

Mankind's activities are altering the composition of the atmosphere to such an extent that the climate of future generations may be substantially changed. These activities include the use of electricity from fossil fuel-fired power plants, the consumption of gasoline from driving cars, the clearing of forests, the growing of rice—in short, a number of activities that are merely taken for granted in modern societies.

Everyone contributes to greenhouse gas concentrations, and everyone would experience the effects of a global warming. The activities leading to rising concentrations of greenhouse gases occur in every country in the world. In some it may be the burning of wood for heating and cooking. In others, it may be automobile use. But both the source of the problem and its impacts are global in scope. No one country dominates in the emission of greenhouse gases, and any country that takes action to control emissions will achieve only limited success if other countries do not follow suit. It is thus necessary that, if action needs to be taken, it should be taken on a global scale with the participation of as many countries as possible for a sustained period of time.

While we know that much is at stake if the climate changes, there is uncertainty concerning the rate and magnitude of climate change. This poses a major dilemma since the longer we wait before taking action, the larger the amount of warming we will have to live with. Already, we have seen an increase in greenhouse gas concentrations which means that some climate change may be inevitable. Since there is a great deal of year-to-year variation in climate from purely natural causes, it will also be difficult to detect the early signs of a global warming. If we wait until we can actually measure warming before we take action, then we may have to live with warming for many generations, since it takes many years before emission reductions could have an impact on atmospheric concentrations and the climate system.

In short, global climate change is an issue with potentially profound consequences for mankind and nature. Limiting climate change would require sustained concerted action by many nations for a long period of time.

Given these facts, a number of actions must urgently be undertaken. We must continue to build our scientific research capabilities and to develop an international scientific consensus on the nature of the climate change problem—the kind of consensus that can endure changes in governments and incorporate a wide number of nations. This international understanding of the problem is necessary before effective policy responses can be developed.

Yet, we do not have the luxury of sitting on our hands while a scientific consensus emerges. Rather, the United States and other countries should begin to think of ways to reduce greenhouse gas emissions, in the event that it ultimately proves necessary to do so. The source of these reductions would be different for every country. For one, it may be changing land-use patterns to reduce tropical deforestation. For another, it may be improving energy efficiency. In many cases, actions that may be found to be effective in reducing greenhouse gas concentrations may make sense on their own, for totally independent reasons. For example, reducing production of chlorofluorocarbons (CFCs) will slow the depletion of the stratospheric ozone layer and have the ancillary benefit of potentially limiting global warming.

Finally, we must improve our understanding of the effects of warming in case we find that we need to adapt to climate change. Since greenhouse gas emissions have already increased, some amount of adaptation may be necessary even if we limited emissions today. Moreover, if concerted action on an international level is to be undertaken, then a consensus must emerge on the seriousness of the climate change problem. Only through internationally coordinated research on the impacts of climate change can this be accomplished.

Fortunately, several steps are already underway. The major nations of the world have already taken the precedent-setting action of agreeing to reduce CFCs under the Montreal Protocol signed in September of 1987. This treaty will have the positive benefit of slowing the rate of global warming in addition to protecting the ozone layer. The treaty is by far the most significant international environmental agreement ever reached, and it came about as a result of a concerted scientific and diplomatic initiative by the U.S. government. As this issue of the magazine went to press, enough ratifications had been received for the treaty to go into effect on January 1, 1989. Even further reductions are being contemplated by many governments.

In addition, the consensus-building process on the greenhouse issue and what to do about it has begun. In November 1988, the United Nations Environment Programme and the World Meteorological Organization organized the first meeting of the Intergovernmental Panel on Climate Change (IPCC). This was the first meeting of countries from all over the world to discuss global climate change. It was agreed by all in attendance that countries should work together to assess the scientific information concerning greenhouse warming, its potential effects, and options for responding to it. While much work needs to be done, the IPCC provides a process for developing the international consensus that must precede taking action on an issue with the potentially enormous consequences of global climate change.

It is ironic that the very technologies that have raised the standard of living of millions of people over the last hundred years, and which are so sought after by all countries of the world, may also be responsible for global warming in the future. We must begin now to build the international understanding of the greenhouse gas issue, its likelihood, its effects, and its sources, in order to develop an appropriate policy response to it. Only through international cooperation can we ensure that the world of the future will be as conducive to prosperity as the world of the present. □

(Thomas is Administrator of EPA.)

A Character Sketch of Greenhouse

by Dr. David Rind

The Greenhouse Effect has caught the imagination of the general populace in the last decade. What's more, the respected, generally conservative scientific establishment has become associated with relatively dire predictions of future climate changes the Greenhouse Effect may cause.

But how much do we actually know about the Greenhouse Effect? Can we really establish how much the climate will change, and when? Perhaps by separating the "hard" science—that which can be verified and is considered well-understood—from scientific theory or estimates, we can investigate the likelihood of near-term climate changes that have been projected. The series of questions which follow will help us explore what we currently know, or think we know, about the Greenhouse Effect.

Question: Do we really understand the "Greenhouse Effect"?

The "Greenhouse Effect" is the name for the physical process whereby energy from the sun passes through the atmosphere relatively freely, while heat radiating from the earth is partially blocked or absorbed by particular gases in the atmosphere. Because the sun is warmer than the earth, its energy is radiated at a higher frequency which is not absorbed well by gases such as carbon dioxide (CO_2) or water vapor. In contrast, these triatomic gases (gases with three atoms per molecule) are effective absorbers of the lower-frequency energy radiated by the earth. Since the gases responsible for this selective absorption make up only about one percent of the atmosphere, they are known as "trace" gases. In general, we can calculate very accurately the energy absorbed by different gases, although there are some uncertainties, and when the concentration of a gas changes, we know how much more energy is being absorbed. This additional absorption by itself warms the planet: for example, doubling the concentration of CO_2 in the atmosphere would eventually lead to a global air temperature increase of 1.2^0 Centigrade (C)—about 2.2^0 Fahrenheit (F)—if there were no other changes in the climate system.

However, what we do not know is exactly how the rest of the system will react. The current numerical computer models of the earth's climate predict that the warming due to the increase in CO_2 will lead to more evaporation of water vapor from the ocean. Water vapor itself is a "greenhouse" gas, so as its concentration increases in the atmosphere, the planet will warm even further. With rising temperatures there will be less snow and ice to reflect energy from the sun back to space (snow and ice are very good reflectors). This promotes further warming because more of the sun's heat is retained in the earth.

These are examples of "positive feedbacks" in which the system responds to a warming climate with changes which amplify the warming even further. Both of these system responses are very likely to occur, although we cannot be sure of the magnitude of the changes. The models also predict cloud cover changes that will provide even more warming, but clouds are not modeled in a very sophisticated way because they are not well understood. Thus, the likely impact of cloud cover changes is quite uncertain.

The net result of these different processes in the various models is the tripling of the warming caused by the doubled CO_2 levels alone, producing a total warming of about 4^0 C (or 7^0 F) for the global, annual average. Yet it is only the initial Greenhouse Effect due to increased CO_2 or increases in other trace gases, which we know with great confidence.

Question: Can we use the temperatures on other planets to determine what the climate system feedback will be on earth?

The atmospheres of nearby planets validate the general concept of the greenhouse theory, especially in a qualitative sense, but they cannot tell us what the magnitude of the changes on earth will be. Venus, with its massive atmosphere composed essentially of CO_2, has a surface air temperature close to 500^0 warmer than would be expected without a Greenhouse Effect. Mars, with a very thin atmosphere and thus little atmospheric capacity to absorb radiation, has an observed temperature close to the expected. The earth, with intermediate amounts of greenhouse gases in its atmosphere, is about 30^0 C (54^0 F) warmer than it would be otherwise. The differences among the planets are very large, and cannot really be used to estimate sensitivity to relatively small changes in greenhouse gas levels. Furthermore, as noted above, the big uncertainty lies in the magnitude of the climate system response (or feedbacks). The most important feedbacks involve the reaction or processes related to water, and the other planets have no free-standing water.

Are greenhouse gases increasing?

Since the establishment of an atmospheric monitoring system in 1958, we have observed the concentration of CO_2 growing systematically. During the past 28 years, CO_2 values in our atmosphere have increased from 315 parts per million (ppm) to 350 ppm. These values are especially significant since air bubbles trapped within the ice in Greenland and Antarctica have been used to measure what CO_2

concentrations were like over the past several hundred thousand years. During that time, up to just prior to the industrial revolution, CO_2 levels had not exceeded 280 ppm (and thus were well below current values). The rising CO_2 concentrations are believed to be associated with the widespread use of fossil fuels such as gas and oil and by the denuding of the world's tropical and other forests, a process which lowers the earth's ability to use trees as a CO_2 absorbent.

Chlorofluorocarbons (CFCs), better known for their impact on atmospheric ozone levels, are artificially generated gases that also have the capacity to contribute to the Greenhouse Effect, and which are known to be increasing. They have no natural sources and probably did not exist in the atmosphere prior to the last few decades. Recent measurements indicate that other contributing greenhouse gases, such as methane and nitrous oxide, are also increasing; however, since we are not sure of the reason for their increase, we have less confidence in their long-term trends.

Question: Is the temperature record of the past century consistent with the increase of gases which contribute to the Greenhouse Effect?

It is estimated that the average surface air temperature has increased globally by about 0.6^0 C (or 1^0 F) in the past century, but there is some uncertainty as to how accurately the change can be estimated because there were far fewer temperature recording stations 100 years ago. Large portions of the globe were poorly sampled, especially in the Southern Hemisphere. Even today, full global coverage is not available.

The record, such as it is, does not indicate a continuous worldwide

warming. There was apparently a cooling period in the Northern Hemisphere from the 1940s into the early 1970s. This is inconsistent with the concept of greenhouse warming, but it may be due to other climate disturbances such as variations in the solar energy constant, or a change in the amount of volcanic discharge into the atmosphere, or it may simply represent internal variability within the system.

The overall warming for the past century is the right order of magnitude for the expected Greenhouse Effect. However, given the uncertainties about the actual temperature change, the climate feedback factor, the actual amount of CO_2 in the atmosphere in 1880, and the rate at which oceans absorb heat (which slows down the atmospheric warming), we cannot be more precise in determining what the expected warming would have been. Similarly, we cannot use the record to establish what the climate-feedback factor really is.

Despite these qualifications, one aspect of the temperature record clearly stands out: during the past century, the four warmest years, globally, were all during the 1980s; this does not include 1988, which appears as if it will be the warmest year of all. This has occurred despite the eruption of the El Chicon volcano, putting additional dust into the air, and a decrease in the sun's energy output, both of which should have had a cooling effect. While modern temperature records may be contaminated to some extent by heat island effects which create warm areas in cities, the rapid rise of temperature during the 1980s is consistent with computer model projections. This suggests that the anticipated Greenhouse Effect changes may actually be appearing at this time.

Question: Are current computer models adequate to allow us to forecast climate change?

Numerical models (called general circulation models) which simulate the known workings of the earth's climate system are used to calculate its response to increases in trace gases. The four models in current use all estimate that the doubled CO_2 climate will have a global average temperature some 4^0 C (7^0 F) warmer than today. They are thus all calculating similar climate feedback factors. However, even though many climate processes are handled similarly in the different models, their unanimity does not guarantee accuracy. For example, the treatment of cloud cover in all the models represents a major uncertainty. The models also differ to some extent as to the seasonal and latitudinal distributions of the calculated warming. It is thought unlikely that the models could be wrong by more than a factor of two, but this cannot be proven.

In addition, a climate change forecast should indicate when the warming would be expected to be evident, but only one model, the Goddard Institute of Space Studies (GISS) model, has been used to calculate the temperature increase over the next 50 years in response to a gradual change in greenhouse gas concentrations. Its results indicate substantial warming in the next decade. This calculation is affected to some extent by uncertainties in how much heat the oceans will absorb and the true climate feedback factor. Nonetheless, by providing an estimate of how much warming should be observed in the relatively near future, the model does give us a chance to test the accuracy of its projections.

Question: How "dire" is the forecast of coming climate change?

It is estimated that the ice age climate was some 4^0 C colder than today's. At that time (some 18,000 years ago), ice covered the area now occupied by New York City. Considering that the doubled CO_2 climate is estimated to be warmer to the same degree that the ice ages were cooler, large changes in the climate system may well be expected if this comes to pass. The GISS model's forecast for the next 50 years gives changes of 2^0 C (3.6^0 F) by the year 2020, which would make the earth warmer than it is thought to have been at any point in historical time. Estimates for summer temperatures in the doubled CO_2 climate indicate that Washington, DC, which currently experiences 36 days of temperature above 90^0 F would routinely have 87 such days; Dallas would go from 19 days with temperatures above 100^0 F to 78 days.

Sea-level rise due to thermal expansion of the oceans would cause severe problems in many coastal cities, and this effect would be exacerbated if additional glacial melting occurred. Rainfall patterns would likely be substantially altered, posing the threat of large-scale disruptions of agricultural and economic productivity, and water shortages in some areas.

We may start experiencing the effects of a changing climate fairly soon. If we define a "hot" summer as the warmest one-third of the summers during the period 1950-1980, then, if the models are correct, during the 1990s we will experience "hot" summers twice as often, or two-thirds of the time. The summer of 1988 may be an all-too-tangible indication of how dire such changes in summertime climate can be.

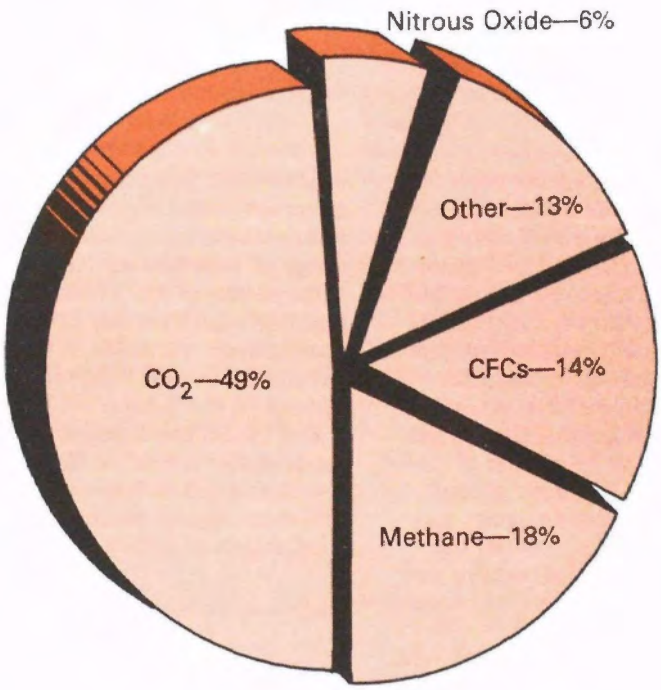
Question: Is there any way to prevent these changes from occurring?

The climate is being altered by the release of greenhouse gases due to fossil fuel consumption and industrial processes, and by deforestation. These factors are inherent in our current civilization. It may be possible to limit specific trace gas increases (such as the CFCs) and slow down rates of increase of CO_2 through increased energy conservation. Our ability to manipulate the climate system deliberately, so as to offset the warming by some other process, is nonexistent. It is likely that the additional greenhouse gases which have been added to the atmosphere during the past 50 years have already built considerable warming into the system, which we have not yet experienced because of the slow warming response of the ocean.

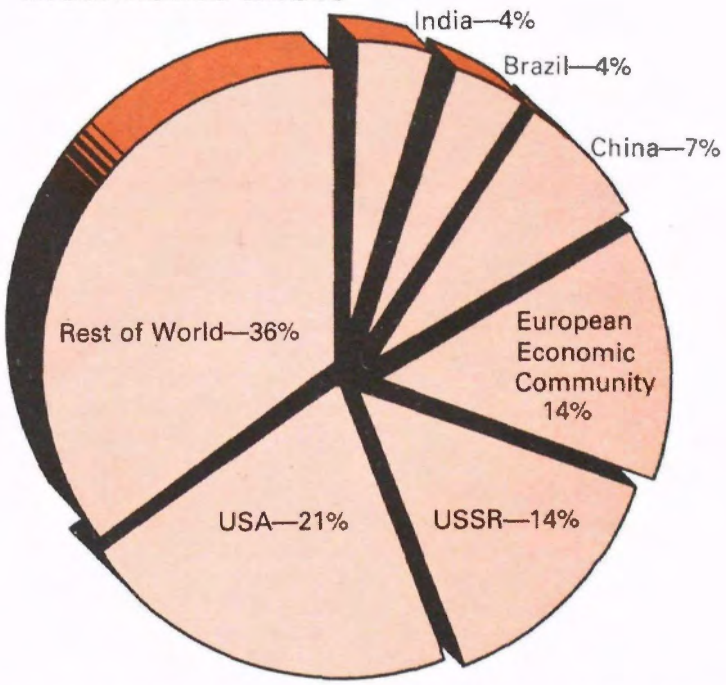
The climate of the next century will very likely be substantially different from that to which we have become accustomed. Uncertainties in our knowledge of the true climate sensitivity prevent us from knowing exactly how different it will be. The consequences of the climate change that is currently being estimated would be enormous. With that in mind, it is worthwhile for us to factor climatic change into decision-making processes related to our future, even though there are many uncertainties that still exist in our understanding of what may actually happen. □

(Dr. Rind is an atmospheric scientist at the Institute for Space Studies, Goddard Space Flight Center, National Aeronautics and Space Administration, and an adjunct associate professor at Columbia University. He is a leading researcher on aspects of the greenhouse theory of atmospheric warming from certain gases.)

Manmade Contributions to the Greenhouse Effect



Regional Contributions to the Greenhouse Effect



(The top chart represents the estimated increase in the Greenhouse Effect due to manmade emissions of Greenhouse gases in the 1980s. The chart is adapted from work by Dr. James Hansen and his associates at the Goddard Institute for Space Studies. The bottom chart is based on EPA estimates of each region's contribution to manmade emissions of Greenhouse gases.)

Projecting the Impacts of Greenhouse Warming

by Richard D. Morgenstern
and Dennis Tirpak

The past several years have seen the emergence of a new interest in the issue of global climate change within the scientific community. Until quite recently, a century-year old theory about man's emission of carbon dioxide into the atmosphere, the role of water vapor, and global warming has remained largely unexplored. With increasing evidence on growth in greenhouse gas emissions, and with the advent of computer models to simulate global climate, the scientific community has been examining in greater detail the complex issues involved. As more and more scientists studied the Greenhouse Effect and became convinced that there was indeed a potential for a significant global warming, Congress requested a report from the Environmental Protection Agency that would:

> ...examine the health and environmental effects of climate change. This study should include, but not be limited to, the potential impacts on agriculture, forest, wetlands, human health, rivers, lakes and estuaries as well as other ecosystems and societal impacts.

EPA's efforts to respond to this request began with workshops composed of atmospheric scientists and specialists in such fields as ecology, hydrology, forestry, and agriculture. With the help of these scientists, EPA began the process of responding to Congress, selecting climate scenarios, and identifying topics for impact analyses.

The first step involved selecting future climate "scenarios." We could have used historical climate patterns, a panel of experts, or other methods. Consistent with the approach adopted by the National Academy of Science and other scientific experts, we chose to use Global Circulation Models (GCMs). These atmospheric models are complex mathematical representations of the ocean-atmospheric relationships that determine our global and regional climate. With hundreds or even thousands of equations, variables like evaporation, precipitation, cloud coverage, wind direction, and temperature are simulated. To get a range of possible scenarios, we used three different models, differing in their detailed assumptions, to see how atmospheric variables such as precipitation and temperature could change in the future.

But for all the sophistication of these models, the scenarios they generate are not consistent in regional detail and therefore cannot be considered predictions of future climate. We simply do not know enough about all the atmospheric and oceanic processes to get a truly accurate scenario of how climate will react on a local and regional scale. GCMs also cannot predict how climate variability will change, so we don't know how the frequency of extreme events will differ. If heat waves, storms, droughts, or hurricanes occur more or less often, the effects of climate change could be worse or better than expected.

Our analyses suggest that climate change could ... result in a world that is significantly different from the one that exists today.

The next step was to see how those scenarios affected various systems (for example, water management systems, ecosystems, etc.), both natural and manmade. To capture the possible wide-ranging implications of climate change for the United States, we divided the impact analyses into regional and national studies. Regional studies were deemed important because they provide insights into the sensitivity of systems in different regions of the country. With this in mind, we selected the regions of California, the Great Plains, the Great Lakes, and the Southeast. Systems chosen for national study were picked because they broadly affect our quality of life. In particular, the potential impacts of climate change on water resources, agriculture, forests, biodiversity, health, air pollution, and electricity demand were analyzed, as were the implications of accelerated sea-level rise.

Like the GCMs, the methods for studying impacts have limitations. We have no experience with the rapid warming of 1.5^0 to 4.5^0 C projected to occur during the next century and cannot simulate in a laboratory what will happen over the entire North American continent. We don't know if a forest will be able to migrate, whether fish will be able to find new habitats, how agricultural pests will spread, or how impacts will combine to create or reduce stress. Nor can we know how changing technology, new scientific advances, urban growth, and changing demographics will affect the world of the next century. These changes and many others may singularly or in combination exacerbate or ameliorate the impacts of global climate change on society. With the large number of unknowns, our analyses of the varieties of impacts can at best provide an indication of the direction of changes, but not the magnitudes.

With these caveats in mind, what follows in the next several articles are summaries based on the current scientific literature and our draft Congressional report. Our analyses suggest that climate change could change the landscape of the globe and result in a world that is significantly different from the one that exists today. The ultimate effects could be felt for centuries, and most will be difficult to reverse. We hope that our analysis challenges other to examine this issue and to amplify and improve our understanding of the potential implications. We view EPA's effort as but a first step to improve the information on climate that will be needed by many decision-makers in the future. □

(Morgenstern is Director of the Office of Policy Analysis in EPA's Office of Policy, Planning and Evaluation (OPPE). Tirpak is Director of the Strategic Studies Branch in OPPE and co-editor of the draft EPA Report to Congress on the Potential Effects of Global Warming on the United States.)

How It Might Be:

Agriculture

by Cynthia Rosenzweig

Climate and agriculture are inextricably linked. Witness the Dust Bowl years of the 1930s, when crop yields declined by up to 50 percent. And just last year, in 1988, drought in the Midwest caused corn yields to drop by almost 40 percent.

Now, with the advent of the Greenhouse Effect, scientists are projecting that temperatures will rise to higher levels in the coming decades than at any time in the last 100,000 years. In addition, certain regions are predicted either to become substantially drier, or to become wetter. Climate changes such as these are likely to have large impacts on U.S. agriculture.

The exact nature of the agricultural consequences of climate change is difficult to predict, however. Scientists are uncertain about the rate and magnitude of the changes in temperature and precipitation. Also there are many potentially mitigating factors in agriculture, such as substitution of better acclimated crop varieties or species, that may counteract the harshest climate effects.

Some agricultural scientists have predicted a boom in agricultural crop yields because of the beneficial effects of increasing levels of carbon dioxide (CO_2) on crop growth. In experimental environments, elevated concentrations of CO_2 increase photosynthesis in crops, resulting in increased size and often in increased yield. Increased CO_2 also improves the efficiency of the water regimes of crop plants in the same settings.

Other scientists have studied the impacts of the predicted climate change, excluding the physiological effects. How these two factors—climate change and the direct effects of CO_2 on crop yields—will combine in the future is a critical research question.

In order to begin to foresee what effects these two factors (and others) may have on U.S. agriculture, EPA sponsored studies in the following areas: crop growth and yield, regional and national agricultural economics, demand for water for irrigation, water quality, pest-plant interactions, direct effects of CO_2 on crop growth and yield, impacts of extreme climatic events, potential farm-level adjustments, livestock diseases, and agricultural policy. It is the most integrated and comprehensive set of studies yet done on the subject.

In sponsoring these studies, EPA was primarily concerned with the future adequacy of food supplies. Results from studies using crop yield and economic models imply that projected declines in crop yields do not threaten domestic food supplies. These results are for a range of climate-change scenarios predicted by atmospheric scientists. In general, consumers may have to pay a small to moderate amount more for their food, while food producers either gain or lose depending on the severity of the climate change scenario. Given the potential for continued improvement in agricultural technology and other beneficial effects, the overall agricultural outlook for climate change is not catastrophic.

However, agriculture as currently practiced in many regions may change. In rural areas, agricultural activity may decline in the South and may grow in

USDA photo

Studies done for EPA suggest that wheat and corn production may shift away from the Great Plains, especially if severe climate change occurs.

the North. In northern states such as Minnesota, where crops are currently limited by cold temperatures, climate change is predicted to create more favorable conditions for agriculture: namely, warmer and longer growing seasons. This will tend to enhance productivity in northern regions relatively more than in the southern parts of the country. At more southerly latitudes, crops are grown closer to their high temperature tolerances and may experience excessively high temperatures with Greenhouse Effect-induced warming.

Farmers will not be the only ones in rural areas to bear the brunt of climate change. Equipment dealers, seed suppliers, and rural credit managers, among others, all participate in the ebb and flow of rural economies. If climate change is severe, people in these businesses will also be vulnerable.

As agricultural regions shift northward, extensions of crop pest ranges are predicted as well. Thus grain and specialty crop farmers may have to deal with increased insect pest survival in the winter, increases in pest species with more than one generation per year, and pest establishment earlier in the growing season.

Livestock producers may also experience changes in pest regimes. Increased temperatures may cause a northern shift in the distribution of some existing livestock diseases and may enable tropical diseases to extend their ranges into the southern regions of the United States. Cold stress on livestock may be mitigated in the winter, but heat stress is likely to increase in summer, possibly decreasing reproductive capabilities.

In the Great Lakes states, agricultural production in the northern part of the region could expand as production declines elsewhere in the country. This might mean an opportunity for growth in related agricultural businesses, such as transportation and marketing networks. However, agricultural expansion might also put pressure on forests and other natural areas to be converted to cropland. Wider cultivation could increase erosion and run-off and degrade surface- and ground-water quality. However, the presence of thin, glaciated soils in the North could limit this expansion.

According to computer model studies, farmers may see yield increases of 50 to 100 percent in Minnesota, while yields may decline in the rest of the region by up to 60 percent. If photosynthesis and crop water use are improved, crop yields may increase even more in the North and in the rest of the region, except in cases where climate change is severe.

One study examined potential actions by Illinois corn producers in the face of climate change. Not surprisingly, the degree of adjustment depends on *how much* the climate changes. For example, farmers could relatively easily plant their crops earlier in the spring to avoid low soil moisture in the summer, switch to long-season corn varieties for longer growing seasons, and use lower planting densities to better conserve soil moisture.

Climate change could exacerbate many of the current trends in environmental pollution and resource use from agriculture—and could initiate new ones.

However, if climate change occurs according to the warmest and driest scenario, corn production might no longer be feasible in Illinois. Consequently, farmers there would be likely to switch to a better-adapted crop such as grain sorghum.

In the southeastern states, soybeans and corn are the crops most widely cultivated. In recent years, summer droughts and heat waves have caused failures of these crops in many parts of the region. On the other hand, several recent freezes in the winter have destroyed a significant portion of the citrus harvest. Thus, predicted warmer temperatures caused by the Greenhouse Effect are likely to be detrimental to grain crop production in the area, while favoring citrus production and expansion of other tropical crops, particularly in Florida.

The Great Plains is one of the most marginal agricultural regions in the United States. Some observers feel that the southern Plains are so sensitive to climatic swings that intensive dryland farming should be abandoned. Yet in a wet year, the Plains produce bumper crops of small grains that add significantly to the nation's export trade balance.

Studies done for the EPA Report to Congress imply that wheat and corn production may indeed shift away from the Great Plains, especially if severe climate change occurs. Yields of these crops may decrease significantly, and the agricultural economy may no longer be able to sustain the rural population. For many communities in the region, this may further weaken an economic base already under pressure from long-term structural changes in U.S. agriculture.

As cropland area decreases in the southern latitudes of the country, demand for irrigation is likely to grow on the remaining acreage, because of improved reliability of irrigated yields and higher crop prices. This could increase the ground-water overdrafts already occurring in the dry regions, such as the area fed by the Ogallala Aquifer in Nebraska, Kansas, Oklahoma, and the High Plains of Texas.

It is important to note that the regional shifts in agriculture described above are potentially harmful to the environment. Expanded irrigation and shifts in regional production patterns could result in competition for water resources, increased potential for ground- and surface-water pollution, loss of wildlife habitat, and increased soil erosion. A northward migration of agriculture would increase the use of irrigation and fertilizers on sandy soils, thus endangering ground-water quality. Farmers may rely on chemical pesticides to deal with changes in both crop and livestock pests. The above examples show that climate change could exacerbate many of the current trends in environmental pollution and resource use from agriculture—and could initiate new ones.

In conclusion, EPA's studies found that climate change could cause significant shifts in regional agriculture, even with the beneficial effects of increasing CO_2. Agricultural researchers and policymakers should begin now to build awareness of these potential changes into their programs, in order to minimize any adverse impacts and facilitate adjustments to those shifts.

Finally, it should not be forgotten that the impact of climate change will reverberate throughout the global food economy, potentially altering the international food trade and the location of food-deficit regions. Changes in U.S. agriculture will thus take place in a global context. □

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How It Might Be:

Forests

by Jack K. Winjum
and Ronald P. Neilson

Maple sugaring in New England: under climate change scenarios, the sugar maple area would shift northward, with die-back along its southern range.

If average annual temperatures in the United States increase, as predicted, from 2.7^0 to 8.1^0 F (1.5^0 to 4.5^0 C) during the next half century, forest effects resulting from such climatic changes could be apparent within the next 30 to 80 years. For example, the ranges of tree species in eastern North America are likely to shift northward, with dieback along their southern boundaries. During this period, and subsequent decades of adjustment, the health and productivity of many U.S. forest areas may be reduced.

Although many factors influence the condition of forests, climate is the dominant one. Mean annual temperature and rainfall strongly influence the distribution and composition of all biological systems of the world, and forests are no exception. Other important influences are sunlight, soil nutrients, atmospheric chemistry, and natural disturbances. Changes in atmospheric chemistry and natural disturbances are part of the scenario projected for the Greenhouse Effect.

Oddly, carbon dioxide (CO_2) and certain other atmospheric chemicals at elevated, human-caused concentrations are not only associated with the Greenhouse Effect, but also have direct effects on plants, including forest trees. For example, CO_2 at higher than present natural concentrations (all else remaining the same) is known to enhance photosynthesis, while elevated levels of other chemicals resulting from air pollution, such as ozone (O_3), are detrimental. The effects of such atmospheric chemicals in combination with climatic change are complex and not fully understood at present.

Vermont Travel Division photo

Forests experience natural disturbances almost continually. Examples are insect infestations and disease outbreaks, plant competition, wildfire, drought, cold extremes, and windstorms. These produce stresses on forests, and in general, forests stressed by one factor (e.g., weather extremes resulting from accelerated climatic change) are more susceptible to natural disturbances (i.e., secondary stresses). Thus more wildfires and insect damage are likely if the nation's forests are stressed by rapid climatic change. This is consistent with the concept of multiple stresses causing reduced forest health, which is becoming more widely recognized by forest scientists.

From studies of fossils, pollen in peat bogs, and tree rings, among other things, it is clear to scientists that vegetation has been constantly adjusting to climate change over past centuries and millennia. For example, in response to the most recent glacial advance (ending about 10,000 years ago), treeless tundra

existed in the Great Lakes states, while "northerly" species of spruce shifted south into Georgia and east Texas. Subsequently, during a warming period (6,000 to 9,000 years ago), which averaged 1.5° C (2.7° F) above present temperatures, many plants in North America were found one to two hundred miles north of today's distributions.

Forests occupy 33 percent of U.S. land area and exist in some areas of all 50 states. In total, they occupy approximately 737 million acres, which constitute 10 percent of the world's forest lands. Eight major forest regions of the conterminous 48 states contain 84 percent of the forested ecosystems of the United States; the forested areas of Alaska and Hawaii represent the remaining 16 percent. U.S. forests are rich in essential resources such as wood, water, and wildlife, and offer many opportunities for outdoor recreation.

Most people in the United States live and work close to or within a forested region. A widespread rural population is dispersed throughout the nation's forest regions, but even many urban centers have a forest backdrop. For instance, the Boston-Washington corridor is located within the eastern hardwood region of maple/beech/birch forests. Atlanta and other Southeast population centers are interspersed among the southern forests of loblolly, shortleaf, and slash pine. Chicago and nearby Great Lakes communities are surrounded by the mixed conifer-hardwood forests of that region, and the Los Angeles to San Francisco populations parallel the forests of the Sierra Nevadas to the east. Forests, in short, are part of the living environment of U.S. citizens, and clearly the continued health and productivity of the nation's forests are of critical importance.

In 1987, EPA commissioned five new studies to enhance the present understanding of the effects of global warming on U.S. forests. These studies used several methods to estimate how forests would respond to the warmer conditions predicted by global climate models for the next century as a result of the Greenhouse Effect. In two studies, fossil records of the pollen of plant species (including trees) deposited during past geologic periods found to have climatic conditions similar to greenhouse conditions were used to estimate forest composition in the future. In two other studies, existing models that simulate forest tree growth and productivity over time were used to predict forest conditions under future climate scenarios. A fifth study correlated present temperature and precipitation patterns with existing tree distributions. Then, looking at predicted temperatures and precipitation (and assuming the correlations would continue to hold), estimates were made on how the tree distributions would look in the future.

Time is short considering the magnitude of forest change possible under predicted global warming.

Results from the five studies vary because different assumptions were used in different studies. In addition, there were a number of uncertainties in all of these studies. For instance, the global climate models may not give precise climate predictions. The rates of predicted climatic change are more rapid than in recent geological history. The influence of all factors influencing forest health cannot be incorporated in estimates (e.g., natural disturbances resulting from weather extremes accompanying rapid climatic change). And possible rates of species migrations to adjust to new climates were coarsely estimated. Collectively, however, the studies have strength in that they suggest roughly the same kinds of forest effects under the climatic scenarios developed, based on a doubling of atmospheric CO_2 over pre-industrial levels.

Several important conclusions from the studies serve to advance knowledge and justify concern regarding the future of U.S. forests. All the studies suggest a northward expansion of most eastern tree species. Potentially, the range of spruce, northern pine, and northern hardwood species could shift northward by about 350 to 450 miles into the Hudson Bay region of the Canadian boreal forest. Actual northern migration may be limited to about 60 miles over the next 100 years. Eventually, however, New England coniferous forests could be replaced by more hardwood forests and especially by the oak species from the eastern mid-United States.

Additionally, southern pine species could shift into the present hardwood forest lands of eastern Pennsylvania and New Jersey.

Ultimately, forest decline and mortality could reduce southern distributions of many northern hardwood tree species by as much as 600 miles latitudinally, or by less than 100 miles for southern pines and hardwoods. Under the driest scenario, projections for the Great Lakes region and New England are that species like eastern hemlock and sugar maple could disappear. Mature natural forests in the region could be reduced from one quarter to one half their present volumes per land unit, with many poor sites for tree growth also giving way to grassland or scrub conditions.

Projections for the West are mixed. Because of the mountainous conditions, upslope shifts are possible for Douglas fir, ponderosa, and western hemlock in the northern Rocky Mountains. In the coastal mountains of California and Oregon, Douglas fir could be replaced by western pine species in the lowlands. Overall, the western forest lands are predicted to favor more drought-tolerant pines, at the expense of fir, hemlock, larch, and spruce species.

Overall, these estimated forest effects have many implications for the nation. Consider the potential ecological and socioeconomic impacts.

Ecologically, in addition to trees, there are other important components of forests to consider, such as other plants, animals, soils, water, and atmosphere. All of these components are affected by interacting processes. For example, for animals such as rodents, birds, or large mammals, a change in the size and relative homogeneity of forests could mean changes in their regions of habitat. In cases where receding forests leave wide stretches of unfavorable habitat, migrations could be hindered and some species may be lost.

Soil development is many times slower than plant migrations, and favorable nutrient conditions for trees in more northerly locations could be delayed by centuries. Warmer climates leading to drier conditions may bring droughts that reduce timber and water yields from present forest areas.

These prospects raise socioeconomic issues. As forests shift to new areas and existing forests lose vigor, there will probably be disruptions and/or reductions in the availability of major forest resources—wood, water, wildlife, recreation opportunities—and in many cases forest aesthetics as well. It is not hard to imagine very significant economic impacts of such developments in terms of unemployment, community instability, industrial dislocation, and international trade impacts. These far-reaching impacts would call for a comprehensive review of U.S. forest policy. Fundamental questions that will surely need review involve the amount of U.S. lands that should be maintained in forests, how they are managed, by whom, and for what priority uses.

In the coastal mountains of California and Oregon, Douglas fir could be replaced by western pine species in the lowlands.

A growing consensus among scientists is that global warming from the Greenhouse Effect is almost inevitable. The timing and magnitude are somewhat uncertain, but stopping or turning back in less than a century or two is likely not possible now. Forestry research could lessen the impact by developing methods, first, to detect the extent and magnitude of forest response, and second, to offset some of the adverse effects through forest technology.

Time is short considering the magnitude of forest change possible under predicted global warming. It is urgent, therefore, to begin the research as well as the national planning and policy review very soon. □

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How It Might Be:

Sea Levels

by James G. Titus

Construction in many coastal cities, like Miami Beach, is already very close to the ocean. If the sea level rises, building foundations could be greatly weakened by wave action.

In the last five years, coastal communities have begun to prepare for the possibility of a rise in sea level due to the Greenhouse Effect. In the United States, Maine has enacted a policy declaring that shorefront buildings will have to be moved as sea level rises to enable beaches and wetlands to migrate inland. Maryland has shifted its shore-protection strategy from a technology that cannot accommodate sea-level rise to one that can. Seven coastal states have held large public meetings on how to prepare for a rising sea. Australia and the Netherlands are beginning to undergo a similar process. The president of the Republic of Maldives has told the U.N. General Assembly that the global warming could completely inundate his island nation.

A global warming could raise worldwide sea level by melting mountain glaciers and causing the ice sheets of Greenland and Antarctica to melt or slide into the oceans. It is generally recognized that a complete disintegration of West Antarctica, which would raise sea level 20 feet, would take 200 to 500 years. However, the other factors could make significant contributions in the next 50 to 100 years.

Effects of Rising Sea Level

A rise in sea level would inundate wetlands and lowlands, accelerate coastal erosion, exacerbate coastal flooding, threaten coastal structures, raise water tables, and increase the salinity of rivers, bays, and aquifers.

Coastal wetlands are generally found between the highest tide of the year and mean sea level. Wetlands have been able to keep pace with the past rate of sea-level rise, because they collect sediment and produce peat upon which they can build. Thus, the area of wetlands today is generally far greater than the area that would be available for new wetlands if sea level rises a few feet. The potential loss would be the greatest in Louisiana, which is already losing 50 square miles of wetlands per year to the Gulf of Mexico. Moreover, in many areas people have built bulkheads just above the marsh; as sea level rises, the wetlands will be squeezed between the estuary and the bulkhead.

In the last five years, coastal communities have begun to prepare for the possibility of a rise in sea level due to the Greenhouse Effect.

EPA estimates that if today's densely developed areas are protected, the United States could lose 30 to 70 percent of its coastal wetland with a one-meter rise in sea level and 33 to 80 percent with a two-meter rise. Ninety percent of those losses would occur in the Southeast. Moreover, if undeveloped areas become developed and if those areas are protected as well, the losses could be increased to 50 to 80 and 66 to 90 percent. Even a 50 cm. rise in sea level could drown about one third of our coastal wetlands.

The dry land within the two meters of high tide includes forests, farms, low parts of some port cities, the bay sides of barrier islands, and cities that sank after they were built and are now protected with levees. The low forests and farms are generally in the mid-Atlantic and Southeast, and would provide potential areas for new wetland formation. Major port cities with low areas include Boston, New York, Charleston, Miami, and New Orleans; the latter is generally 8 feet below sea level. A one-meter rise in sea level would inundate 7,000 to 8,000 square miles of dry land, an area the size of Massachusetts. Most of these losses would also be concentrated in the Southeast, particularly Louisiana and Florida.

Among the lands most vulnerable to inundation are the 100 to 150 square miles of recreational barrier islands of the Atlantic and Gulf Coasts. Coastal barriers are generally long narrow islands and spits (peninsulas) with the ocean on one side and the bay on the other. Typically, the ocean-front block of an island ranges from 5 to 10 feet above high tide, while the bay side is two to three feet above high water. Thus, even a one-meter rise in sea level would threaten much of this valuable land with inundation. With a 50 by 100 foot lot often selling for $50,000 or more even without a waterfront view, the land alone can be worth about $250 million per square mile.

Erosion, moreover, threatens the high part of these islands, and is generally viewed as a more immediate problem than the inundation of the bay sides. A rise in sea level can cause an ocean beach to retreat by considerably more than the retreat due to inundation alone. The shape of a beach profile is determined by the pattern of waves striking the shore; generally, the visible part of the beach is much steeper than the underwater portion which comprises most of the active "surf zone." Coastal geologists estimate that a one-foot rise in sea level would

Stephen P. Leatherman photo

generally erode beaches 50 to 100 feet from the Northeast to Maryland, 200 feet in the Carolinas, 100 to 1000 feet along the Florida coast, 200 to 400 feet in California, and several miles in Louisiana. Because most U.S. recreational beaches are less than 100 feet wide at high tide, even a one-foot rise in sea level would create problems.

Flooding would also increase along the coast if sea level rises. A higher sea level provides a higher base for storm surges to build upon; a one-meter rise in sea level would generally enable a 15-year storm to flood many areas that today are only flooded by a 100-year storm. Moreover, erosion would leave ocean-front properties more vulnerable to storm waves. Higher water levels would increase flooding due to rainstorms by reducing coastal drainage. Flooding from rainfall and storm surges would be further exacerbated if global warming increases the frequency and severity of hurricanes; because these tropical storms require a water temperature of 79^0 F to form, many meteorologists believe that such an increase is likely.

A less obvious impact of sea-level rise would be the inland penetration of saltwater into rivers, bays, wetlands and aquifers, which would be harmful to some aquatic plants and animals, and would also threaten human uses of water. Increased salinity has already been cited as a contributing factor to reduced oyster harvests in Delaware and Chesapeake Bays, and for converting cypress swamps in Louisiana to open lakes. Moreover, New York, Philadelphia, and much of California's Central Valley get their water from areas that are just upstream of the point to which saltwater currently penetrates during droughts. Farmers in central New Jersey as well as the city of Camden rely on the Potomac-Raritan-Magothy aquifer, which could become salty if the sea level rises. The South Florida Water Management District already spends millions of dollars per year to prevent Miami's Biscayne aquifer from being contaminated with seawater. These impacts could be compounded if global warming increases the frequency of droughts.

Adaptive Responses

The possible responses to inundation, erosion, and flooding fall broadly into three categories: erecting walls to hold back the sea, allowing the sea to advance and adapting to it, and raising the land. For over five centuries, the Dutch and others have used dikes and windmills to prevent inundation from the North Sea. By contrast, many cities have been rebuilt landward as structures eroded. For example, the town of Dunwich, England, has had to rebuild its church seven times in the last seven centuries. More recently, fill has been used to counteract beach erosion and raise the surfaces of rapidly subsiding communities such as Galveston, Texas. Venice uses a hybrid of all three responses, allowing the sea to advance into the canals, while raising some low

lands and erecting storm-protection barriers.

EPA estimates that even with a two-meter rise, low-lying coastal cities could be protected with bulkheads, levees, and pumping systems, at a cost of $30 to 100 billion. Although these estimates are probably conservative, they are such a small fraction of the value of the nation's coastal cities that one can reasonably conclude that these cities are clearly worth protecting and hence will not be inundated.

Studies of the possible responses of barrier island and moderately developed mainland communities show less agreement on the likely response, but generally suggest that environmental factors would be as important as economics. Although levees and seawalls would hold back the sea, they would generally result in the loss of the beach as well as waterfront views. Recent EPA studies suggest that the most reasonable approach for many islands would be to hold back the sea by extending the current practice of pumping sand onto beaches to raising entire islands in place. Nevertheless, urbanized islands such as Galveston and Absecon (Atlantic City) may find levees more appropriate. Undeveloped and lightly developed islands may be allowed to erode and retreat naturally.

EPA estimates that the cost of raising the nation's developed barrier islands in place would be $50 to 100 billion for a one-meter rise, and $135 to 215 billion for a two-meter rise. On an annualized basis, barrier island communities would have to approximately double their property taxes. Although property owners are unlikely to welcome this prospect, it would generally be preferable to losing one's property. Hence, it seems reasonable to conclude that sea-level rise will not necessitate the abandonment of the nation's coastal barrier islands.

Although the impacts of sea-level rise on the open coast could be important, environmental policy-makers should probably focus on sheltered waters. Because the beach generally is a barrier island's most important asset, economics would tend to encourage these communities to preserve their natural shorelines. By contrast, along sheltered shorelines, economic self-interest would encourage property owners to erect bulkheads that would prevent new wetland formation from offsetting the loss of inundated wetlands.

Among the lands most vulnerable to inundation are the 100 to 150 square miles of recreational barrier islands of the Atlantic and Gulf Coasts.

State and local governments are beginning to seriously contemplate how to plan an orderly retreat from the shore. Maine's Dune Regulations stipulate that houses along the shore are presumed to be movable in the event that sea level rises. For high-rises, the regulations require that the builder submit an abandonment plan for any building that would block the migration of wetlands or dunes resulting from a rise in sea level up to three feet. Other states, such as South Carolina, have recently moved toward explicitly discouraging the construction of additional bulkheads. In the case of Louisiana, it will be necessary to change the ways by which we manage the flow of water for navigation and flood control.

A number of measures for counteracting saltwater intrusion due to sea-level rise have been employed to address current salinity problems. The Delaware River Basin Commission, for example, protects Philadelphia's freshwater intake on the river—as well as New Jersey aquifers recharged by the river—from excessive salinity by storing water in reservoirs during the wet season and releasing it during droughts, forcing the saltwater back toward the sea. Other communities have protected coastal aquifers by erecting underground barriers and by maintaining freshwater pressure through the use of impoundments and injection wells.

Looking Ahead

A rise in sea level caused by the Greenhouse Effect would have significant economic impacts on the coastal zone of the United States, but the cost of protecting cities and recreational beach resorts from a rising sea would generally be affordable. The environmental problems, however, could be more serious. To maintain our coastal wetlands, we will probably have to gradually remove coastal structures from much of our coastal lowlands. Although this will probably not be necessary for several decades, we need to lay the groundwork today, while the impacts are far enough in the future for people to agree on objectively fair solutions without being compromised by the desire to avoid their share of the eventual costs. □

(Titus, EPA's Project Manager for Sea-Level Rise, works in the Office of Policy Analysis, part of the Office of Policy, Planning, and Evaluation.)

How It Might Be:

Electricity Demand

by Ken Linder

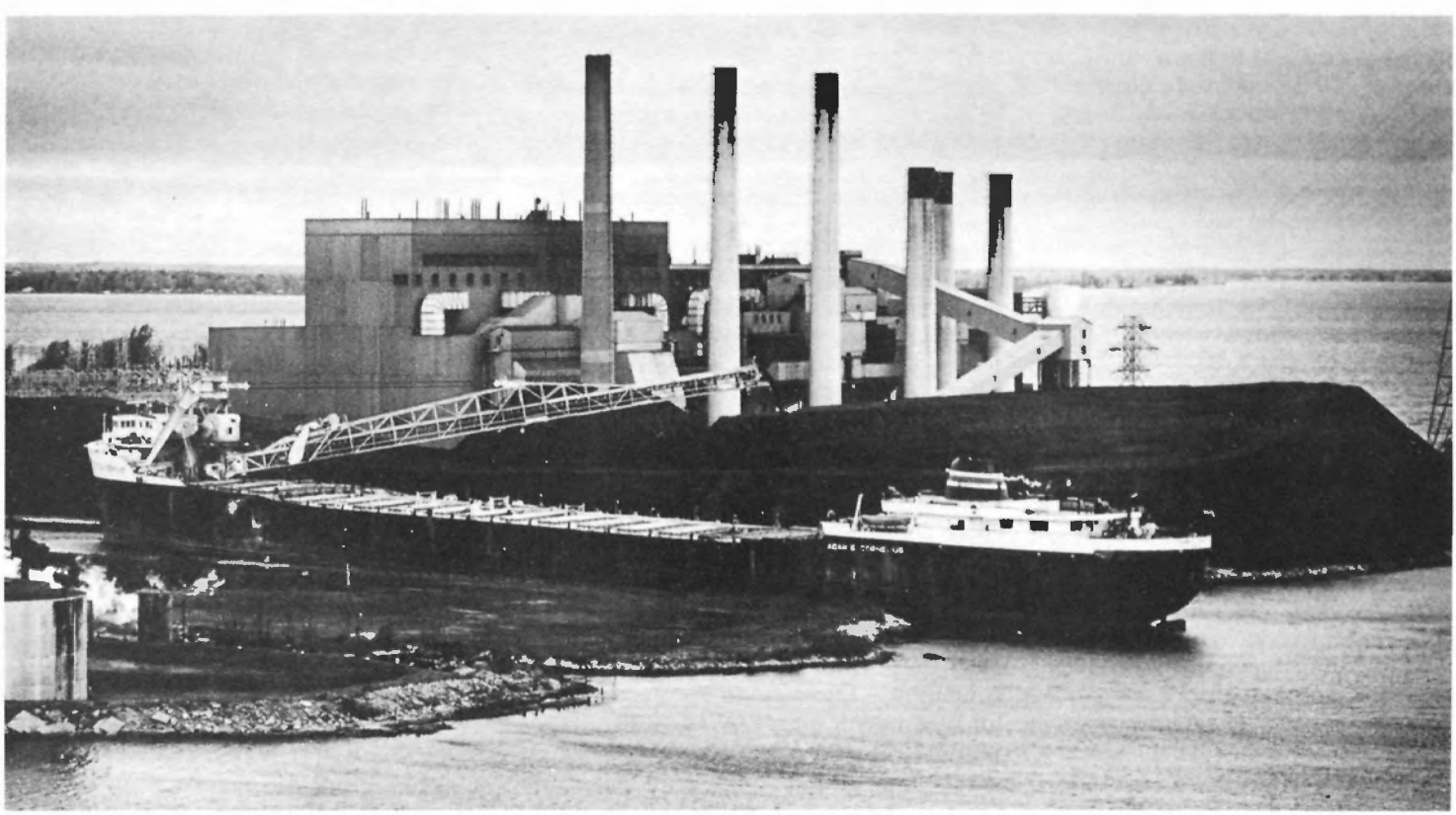
If the world experiences significant temperature increases due to the Greenhouse Effect, both people and nature will have to adapt. One way people will need to adapt is in the way they use energy.

For example, everyone uses energy in ways that are affected directly by weather conditions. Heating, cooking, refrigeration, and water heating are important uses of energy affected directly by temperature, humidity, and other weather conditions. One consequence of higher temperatures caused by global warming would be lowered demand for energy used for heating in the winter and increased demand for energy used for cooling in the summer. Under the Greenhouse Effect, the changing seasonal patterns in energy use—less energy needed in winter and more consumed in summer—and the overall impacts on total energy demand could have important implications for energy planning and ultimately on the cost of energy for individuals and businesses.

Impacts on Electricity Demand

While climate change could affect a wide range of energy sources and uses, the implications for the demand for electricity are particularly significant. This is because the primary weather-sensitive energy uses—space heating and cooling, water heating, and refrigeration—make up a significant portion of total electricity sales for public utilities. These "end-uses" can account for as much as one third of a power company's total sales, and an even higher percentage during daily and seasonal peak-usage periods.

Also, because of the large investments by utilities in long-lived, capital-intensive power plants, the



Changes in electricity demand by 2055 due to the Greenhouse Effect could increase the need for new power plants in the United States by 14 to 23 percent.

Mike Brisson photo.

One consequence of higher temperatures . . . would be lowered demand for energy used for heating in the winter and increased demand for energy used for cooling in the summer.

industry must focus on long-term planning. In other words, utilities must begin planning their investments now to meet their power generation needs into the next century.

To address these issues, EPA and ICF Incorporated, an environmental and energy consulting firm, have assessed the potential impacts of the Greenhouse Effect on the demand for electricity and the consequences of these impacts for utility planning. Based on this study, preliminary regional and natural estimates were developed for a period from the present to the middle of the next century (2055).

Certain key assumptions were factored into the analysis, including estimated temperature changes due to the Greenhouse Effect that would occur over this period. Temperature change estimates for regions across the United States were derived from computer modeling experiments conducted by the Goddard Institute for Space Studies (GISS). In these modeling experiments, alternative emissions rates for "greenhouse" gases and other atmospheric conditions were assumed, so that ranges of estimates were produced.

The GISS estimates of average annual temperature change increase over time, and by the 2050s, the estimates of cumulative temperature increases range from 3.1^0 to 5.3^0 C (5.6^0 to 9.5^0 F). Based on these temperature change estimates, considered together with relationships between temperatures and electricity demand, and a utility planning model, we were able to estimate how the Greenhouse Effect could impact future electricity demands, utility requirements for fuel and power plants to meet the demands, and the costs of producing electricity.

Study Results

By the year 2055, the Greenhouse Effect could measurably change regional demands for electricity in the United States.

A principal factor in utility-generating capacity requirements is the peak (highest hourly) demand the utility must meet. For most utilities in the United States, this occurs on a day during summer hot spells. Peak electricity demands are driven largely by peak use of air conditioning. Because the Greenhouse Effect is expected to have a significant influence on air conditioning and other summertime uses of electricity, higher temperatures in the future could lead to significant increases in the capacity needed to satisfy those uses.

In fact, in several states in the Southwest, Southeast, and Southern Plains regions, requirements for new generating capacity could increase by 20 to 30 percent, as compared with a scenario in which global warming does not occur.

Capacity requirements would not increase in all states, however. Because of greater demands for heating than cooling in colder regions, some utilities experience peak demands in the winter. In these cases, warmer winter temperatures caused by the Greenhouse Effect could reduce the amount of generating capacity required. Such reductions in new capacity requirements induced by the Greenhouse Effect are restricted to a few states in the Northeast (Maine, New Hampshire, and Vermont) and in the Northwest (Washington, Oregon, Montana, and Wyoming).

On a national basis, changes in electricity demand by 2055 due to the Greenhouse Effect could increase needs for new power plants by 14 to 23 percent. Another way to look at this result is that eight to 16 large (500-megawatt) power plants would have to be built on average in each state by 2055 to meet the additional requirements induced by increasing temperatures.

Implications for Utility Planning

The EPA-ICF study estimated that the investment in new power plants necessitated by the Greenhouse Effect could total several hundred billion dollars (not including any increase in costs due to inflation) over the next 70 years. In addition, increased fuel and operating and maintenance costs to generate electricity with these plants could reach several billion dollars per year by 2055. Much of these costs would undoubtedly be reflected in higher electric bills for consumers.

It is, of course, difficult if not impossible to predict the future. The extent and rate of climate change that will occur are very uncertain. Nonetheless, the picture painted by the study results is a very real possibility. The findings suggest that a substantial amount of our resources could be devoted to planning for and adapting to the Greenhouse Effect in this one sector alone. There are a number of other ways the Greenhouse Effect could impact electric utilities (for example, reductions in the availability of water in rivers used to generate hydropower), and there are many other sectors of the world economy and environment that will feel the effects of climate change.

Designing and implementing strategies that will help to mitigate the Greenhouse Effect and to adapt to climate changes in the future that do occur are the challenges facing policy-makers and planners today. □

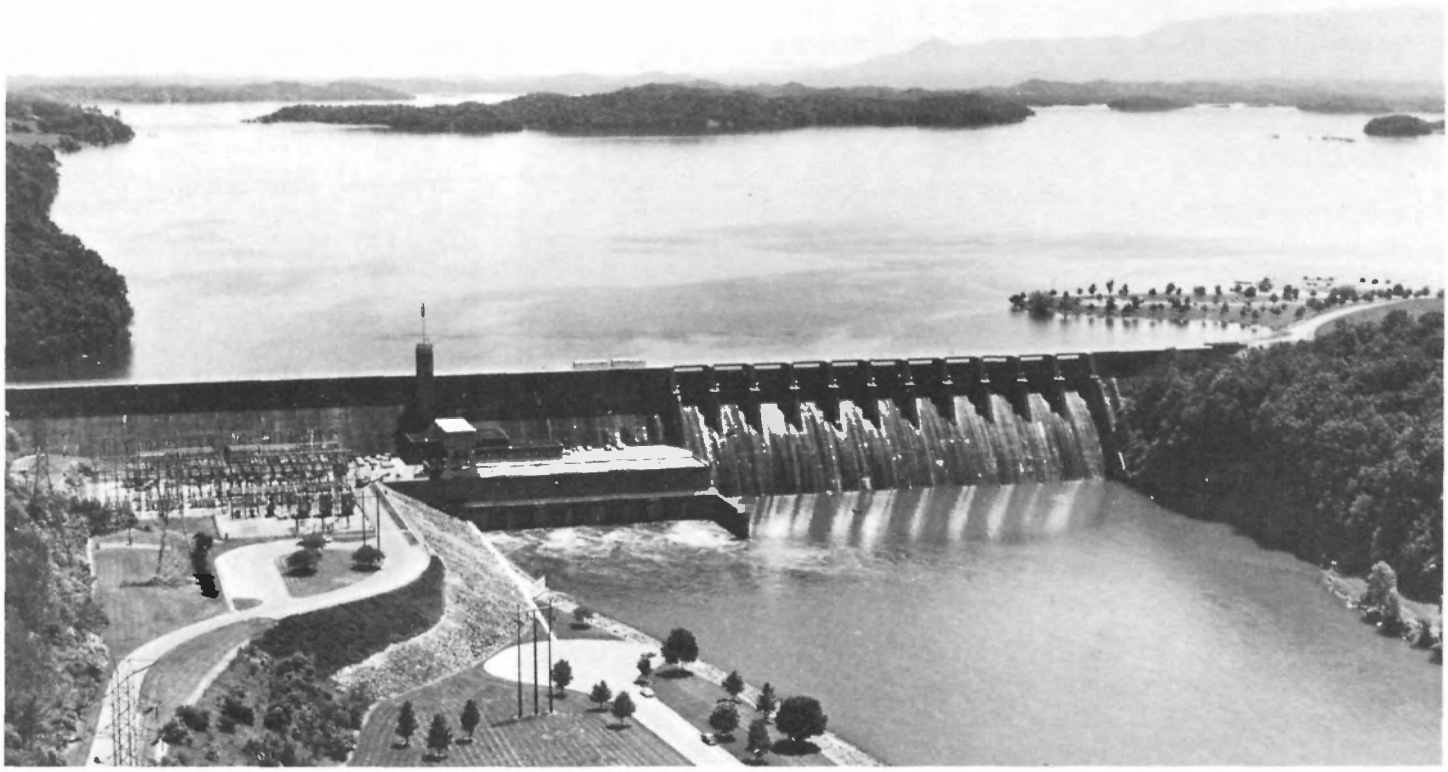
(Linder is a Vice President of ICF Incorporated.)

How It Might Be:

Water Resources

by Joel E. Smith

Water resources in many parts of the country are likely to be affected by climate change. Some reservoirs and dams might not be able to handle the new water flows.



TVA photo

Last summer, widespread drought led to restrictions in water use in many parts of the United States. Low rainfall levels caused the Mississippi River to drop to record lows, tying up barge traffic for miles. The drought also caused a major decline in crop production. Was this just a once in a lifetime event or a warning of future change?

Analysis of the 1988 drought is complicated by a long-term issue now emerging on the horizon; of global climate changes that will raise temperatures around the world and change rainfall patterns. This could cause major changes in the reliability of freshwater supplies and the way we use water.

Congress asked EPA to study the potential impacts of the Greenhouse Effect on natural resources such as freshwater. In responding to that request, EPA examined, among other things, how the availability and use of water may change in the United States, with special focus on California, the Great Lakes, the Southeast, and the Great Plains. The results of this study, released in December 1988, form the basis of the water-resources analysis presented here.

Before proceeding, a short discussion on what is known and not known about the Greenhouse Effect and water resources is in order. The supply of water is influenced by a number of factors, including rainfall and temperature. We know that increased atmospheric concentrations of greenhouse gases such as carbon dioxide will eventually raise global temperatures. We also know there will be more global rainfall, but we are not sure where and when it will fall. Some areas could get more rainfall, others less; some could see changes in when rainfall occurs.

Global warming will likely change the availability and use of fresh water in most regions of the country. California is a good example. The problem there is that rainfall is limited and tends to fall where people do not live and when they do not need it. Two-thirds of the precipitation in California falls in the northern mountains, while 80 percent of the water is used in central and southern California. In addition, much of the precipitation falls as snow in the

winter, while the greatest need for water is in the summer.

To store the water and deliver it to user in the south, the largest reservoir and water distribution system in the world was constructed. The system was designed to capture run-off at a certain time of the year, and it is that very precision that makes the system vulnerable to climate change. Warmer temperatures will melt the snow in the Sierras earlier. Flood control is currently the major wintertime water management problem in northern California, and earlier Greenhouse Effect-induced snowmelt could make the problem worse. To protect areas such as Sacramento from flooding, reservoir levels will have to be kept lower and more winter run-off released. Letting more water go in the winter will result in inadequate supplies for consumption in the summer.

While supplies in California could become less reliable, there may be a need for even more water. The state's farmers, who already use about 85 percent of the state's water supplies for irrigation, may need more water. Higher temperatures will increase electricity demand, which may mean more power plants and greater need for cooling water. Sea-level rise could increase salinity near the freshwater pumping stations in the Sacramento-San Joaquin Delta, requiring the use of more fresh water to repel saline waters. Furthermore, with higher temperatures, residential use of water for drinking and watering lawns could increase. Faced with a system that may not be able to deliver adequate supplies, Californians may have to choose between building more storage capacity or using water more efficiently.

In contrast to California, rainfall in the Southeast is well distributed geographically. In recent years the problem in the Southeast has been drought. In 1986 and 1988, low rainfall reduced crop production. This year low river flow restricted commerce on the Mississippi and led Atlanta to restrict residential water use.

We are not sure whether climate change will raise or lower river flow and lake levels, but a change in either direction could have significant implications for the Southeast. If river flow and lake levels become higher, the likelihood of flooding may rise. If levels drop, the problem becomes one of allocating scarce supplies.

As in California, the need for water will rise in the Southeast. Many farmers in the region may install irrigation in order to increase crop yields. Also, the increase in electricity demand may be greatest in the Southeast, and that could mean greater need for water both for cooling and for hydroelectric power production. The problem that may face water managers in the Southeast, especially if river flows and lake levels decline, is deciding which uses of water to protect. Should water be set aside for irrigation or for municipal and industrial use? Should hydropower be favored? What about recreation and protecting fish and wildlife?

Some areas could get more rainfall, others less; some could see changes in when rainfall occurs.

In the Great Lakes, the concern in recent years has been with changes in lake levels. Three years ago, record high levels caused millions of dollars of damage to shoreline properties, while lower levels this year reduced shipping tonnage and hydroelectric power production. The EPA studies indicate that average lake levels may fall one-half to as much as two and one-half meters, dropping average levels below the lowest levels on record.

Lower levels may create more beaches, but could cause problems for shipping and hydropower. Shipping channels either would have to be dredged or the cargo tonnage on ships reduced. (Warmer temperatures, however, will reduce ice cover, which will allow shipping to continue almost year round.) Lower lake levels will also reduce hydropower production, which currently supplies one-fourth of New York State's electricity.

How people outside of the Great Lakes region respond to climate change could also affect the Lakes. During the drought this summer, there were calls to increase the diversion of water out of the Great Lakes to raise flow in the Mississippi. This could be an indication of things to come. The report concludes that the demand for irrigation will increase in most regions of the country. The demand for water for other uses, such as power plant cooling, may also rise across the country. With the availability of water in areas such as the West possibly becoming less reliable, water users may look outside of their regions for supplies. One possible source may well be the Great Lakes, which, despite lower levels, will still constitute the largest source of surface fresh water in the United States.

Climate change will not only affect the supply of fresh water in many regions, but also the quality. Where river flow and lake levels are lower, there would be less dilution of pollution and water quality could decline. Conversely, where they are higher, there could be more dilution and an improvement in water quality. We found that in lakes such as Lake Erie, higher temperatures would increase the growth of aquatic species such as algae and would change lake circulation patterns. These changes would reduce dissolved oxygen levels in other lakes as well, thereby harming fish and other creatures.

In general, water resources in many parts of the country are likely to be affected by climate change. The availability of water—how much there is and when it is available—will change and the need for water will probably increase. Many reservoir and dam systems may not be able to handle the change. These systems were built based on historic flows and, as is the case in California, a shift in availability could impair the system's ability to provide adequate supplies or flood protection. Thus, some change in the structure of many of these systems or in the use of water may well be necessary.

There are two basic ways to make these changes. One is to wait until climate change occurs before acting. This could lead to expensive engineering solutions and, perhaps, bitter battles over the allocation of water. Another approach is to take steps now that might minimize future impacts and also make sense for other reasons. For example, reducing water use may lessen the impacts of any future reductions in supply. Such steps may also reduce pollution and costs in the near term. Furthermore, deciding on water allocation schemes for droughts before they occur may be much easier than deciding when supplies are short. Incorporating climate change in the management and planning of our water management systems may make it easier for our children to meet future challenges. □

(Smith is a Policy Analyst in EPA's Office of Policy Analysis and co-editor of the draft EPA Report to Congress on the Potential Effects of Global Warming on the United States.)

How It Might Be:

Species

by Sandra Henderson

Wide-range species such as the grizzly bear need vast areas of relatively undisturbed land. If climate change makes their current habitat unsuitable, alternative areas might not be available.

Grizzly bears, elk, peregrine falcons, California condors, rainbow trout, monarch butterflies: the inventory of species that provide beauty and function in our ecosystems seems endless. Yet scientists are warning of a possible loss of 20 percent of the earth's species before the end of the century—a rate of species destruction greater than any since the mass extinctions of the dinosaurs 65 million years ago.

A major factor in this modern species extinction may be our alteration of the earth's climate: global warming due to increased concentrations of greenhouse gases. As a result of the Greenhouse Effect, animal life is likely to be affected by several processes: shifting climatic zones, changes in vegetation zones, rising sea level, and increased frequency of natural catastrophic events.

Plants and animals adapt to particular geographic regions where the climatic conditions favor their continued survival and reproduction. Although animals are generally much more mobile than plants, they are still highly dependent on plants for sources of food, cover, and nesting or den sites. Even predatory species are ultimately dependent on plants to support their prey. Consider the fate of timber wolves if the abundance of deer, rabbits, and rodents changes dramatically. Climate-induced shifts in vegetation will significantly affect future animal distribution and survival.

When climatic zones shift, adaptable species can modify their range and distribution to accommodate shifts in vegetation. Many species have moved hundreds of miles in these historic redistributions. However, those not able to disperse easily, or those whose "escape routes" were blocked by mountains or oceans, suffered reductions in numbers or became extinct. Modern species must also contend with manmade barriers such as roads, cities, and agricultural lands. The rapid change in climate together with a human-altered earth will make it more difficult for species, especially the slow movers, to redistribute their location successfully. It is likely that species currently threatened and endangered will face the greatest risk of extinction due to their already precarious situation.

William S. Keller photo, National Park Service

As we continue to alter the earth, there are fewer suitable places for species to use as refuge. Wide-range species such as the grizzly bear need vast areas of relatively undisturbed land. Yellowstone National Park and adjacent public lands are unique in the lower United States in providing grizzly bear habitat—a vast area protected by public

Migratory birds would be affected by global warming. Increased temperatures and rainfall changes might dry up prairie potholes, and rising sea levels could inundate coastal wetlands that are vital bird habitats.

Vernon Ekedahl photo Fish and Wildlife Service Department of the Interior

ownership. If climate change makes the Yellowstone area unsuitable for grizzlies, alternative habitat may not be available in the conterminous United States, thus reducing this threatened species' chances for survival in our country.

With global warming, migratory waterfowl that breed in the continental interior are likely to experience negative impacts. Over one-half of all waterfowl production in North America occurs in the prairie pothole region, a vast agricultural area riddled with permanent and seasonal wetlands. Increased temperatures and changes in seasonal rainfall are likely to reduce the number of potholes in the area and significantly affect the productivity of breeding waterfowl.

Species associated with coastal wetlands are likely to fare no better. A rise in sea level is an almost certain impact of climatic change. Rising sea level will drown many coastal wetlands, directly impacting inhabitants of these ecosystems such as fish, mollusks, shellfish, waterfowl, and those species that use wetlands as "nurseries." In addition, upland species that depend on wetlands as a source of food and nesting areas will be forced elsewhere, probably to less than ideal areas, for their basic life requirements. Another impact of sea level rise will be the intrusion of saltwater in estuaries. Species that cannot survive in higher saltwater conditions will perish.

Rising sea level, in particular, will further complicate the survival and management needs of the threatened and endangered species of the southeast United States. The Florida panther, Key deer, manatee, Mississippi sandhill crane, and Everglades kite are all species whose future may depend upon the security of their remaining habitat.

Rapid climatic changes are also predicted to bring an increase in catastrophic events such as fires, insect plagues, and floods in some parts of the world and droughts in others. Catastrophic events have always had a major impact on living organisms.

It is likely that species currently threatened and endangered will face the greatest risk of extinction due to their already precarious situation.

Under the conditions of rapid climatic change, however, there will be little time for recovery between such catastrophes. Many species could be lost forever as a result of such events.

The spotted owl is a rare species dependent for its survival upon old-growth Douglas-fir in the Pacific Northwest. Currently, logging is the major threat to this species and its habitat, prompting the U.S. Forest Service to set aside large areas of this forest type. Under a warmer and drier climate, increases in fires, catastrophic windstorms, and shifts to a different type of forest will threaten the permanence of these preserves and thwart attempts to manage this resource.

Climate change will not have the same effect on all species. Some animals will be able to adapt quite readily to changes in temperature and precipitation, and to shifts in climatic zones. Many animals are "generalists": English sparrows, deer, coyotes, raccoons, opossums, and many rodents have characteristics that allow them to do well under a wide range of conditions. They reproduce quickly, are quite mobile, and can exploit a variety of food sources and habitat types. The presence of these species in urban areas is an example of their adaptability.

Other species such as grizzly bears, panthers, and bald eagles have much more specialized habitat requirements. Panthers, for example, need very large areas of wilderness and do not do well in close contact with humans. They are unlikely to find suitable new areas to exploit if their current ranges are significantly altered by changing climate.

Generalist species will likely fill the gaps created by the species lost due to climatic change. The aesthetic and ecological characteristics of the natural world after climatic change will likely differ from the present. The form and magnitude of these differences cannot currently be predicted with confidence. However, EPA is currently developing a research program to improve predictive capability and to identify possible methods to minimize adverse impacts of climatic change on wildlife. □

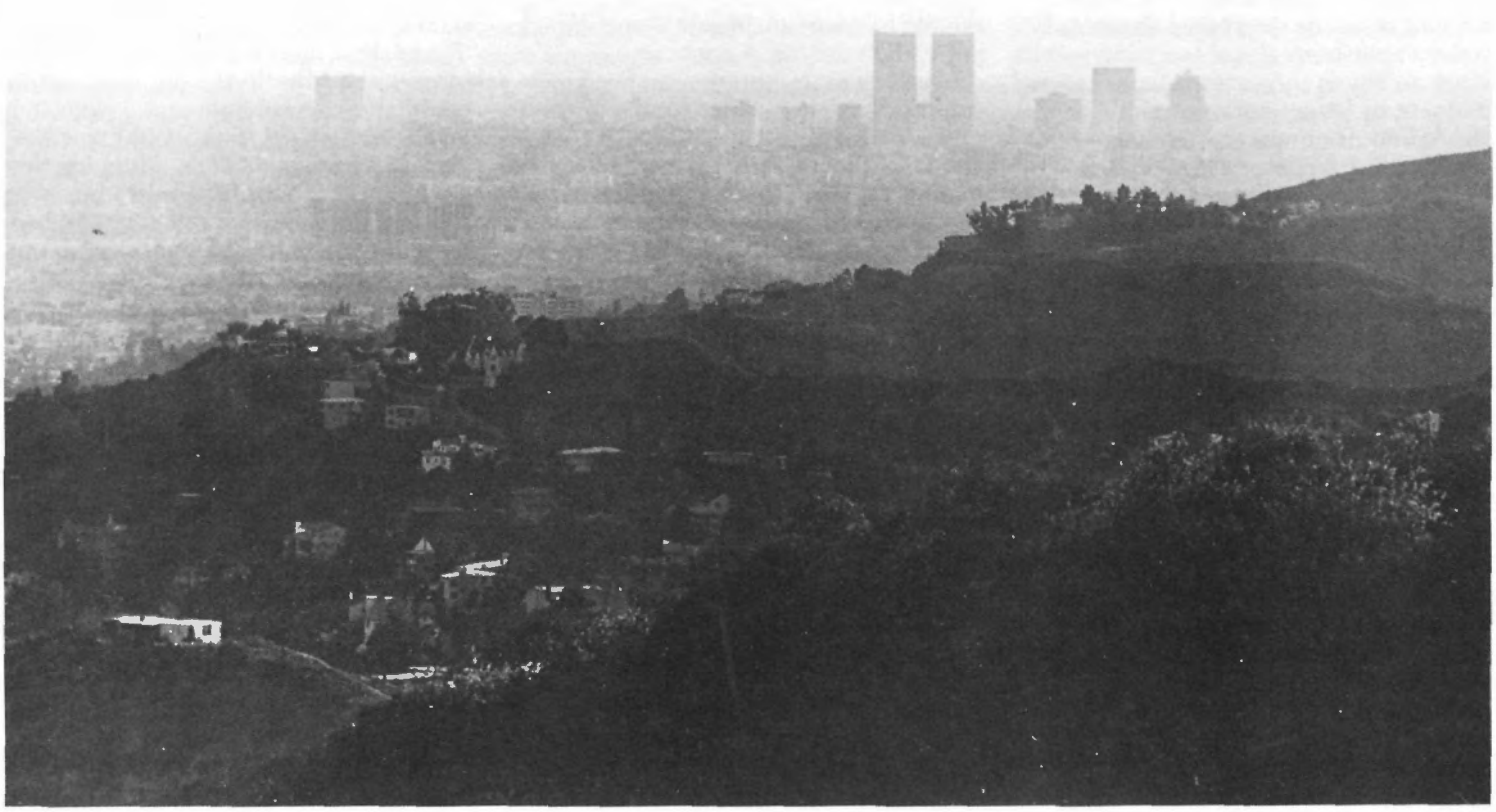
(Henderson is a biogeographer at EPA's Environmental Research Laboratory in Corvallis, Oregon.)

How It Might Be:

Air Pollution

by Eugene C. Durman

Smog in Los Angeles, 1981. Temperature rises under the Greenhouse Effect could present additional problems to areas trying to meet the national clean air standards.



Jim Anderson photo, Woodfin Camp

Global warming caused by the Greenhouse Effect could aggravate our nation's smog and acid rain problems and make Clean Air Act ozone standard attainment even more difficult than it already is for many American cities. This prospect is being raised as environmental scientists begin to realize that the projected time frames for attaining prescribed safe levels of ground-level ozone and reducing the causes of acid rain may overlap with the onset of global atmospheric warming.

The problem of ground-level ozone—better known as urban smog—is *potentially linked to climate change* partly because of the way in which ozone is formed. Ozone, unlike most other air pollutants, is not emitted directly into the air by factories or automobiles. Instead, it is formed by the interaction of volatile organic compounds (VOCs) and nitrogen oxides (NO_x) in the presence of sunlight. The severity of a smog problem in a given locale is directly related to the temperature and ultra-violet radiation intensity in that area.

The "chemical soup" nature of the ozone problem suggests the potential links between two aspects of human-caused global climate change: depletion of the stratospheric ozone layer, and the warming trend due to increased emissions of greenhouse gases. If the upper ozone layer is thinned out by chlorofluorocarbons (CFCs) and halons, more ultraviolet radiation could reach the earth to speed up the mixing of low-level chemicals in the "chemical soup" that produces ozone/smog. Smog chamber studies have shown that a rise in temperature will be matched by a rise in ozone formation; this was confirmed by computer modeling of ozone episodes in New York.

Paradoxically, to the extent that temperature rises lead to increased cloud cover, the lessened sunlight

As for acid rain, there are a number of possible links between this serious air pollution problem and global warming.

reaching the earth might actually slow down ozone formation. However, most of the indirect effects of rising temperature would tend to increase the amount of ozone. Increased amounts of water vapor from global warming would bring an ozone increase, as would more frequent or longer episodes of air stagnation. Higher temperatures would also produce higher rates of VOC and NO_x emissions (for instance, gasoline, a major source of VOC emissions, becomes more volatile as the temperature rises, and NO_x emissions from power plants could rise with increasing demand for energy to run air-conditioning units in a hotter climate.) Computer simulations in California suggested that a 4-percent increase in temperature could produce anywhere from a 2- to 20-percent increase in ozone concentration.

From an economic and policy point of view, these studies are potentially significant because:

- Ozone levels in many areas are just below the present national standard. Any increase in ozone formation could push them into violation. In the period 1983 to 1985, 68 metropolitan areas exceeded the ozone air standards. A 10-percent rise in ozone levels could double the number of nonattainment areas and bring a number of mid-sized and smaller cities in the South, East, and Midwest into non-compliance.

- Many relatively inexpensive controls for ozone are already in place in nonattainment areas. If the ozone levels rose, much more expensive controls would be required. If, for example, higher temperatures resulted in a 10-percent increase in emissions in nonattainment areas, this could increase control costs as much as $3 billion annually.

- Any rise in temperature could present additional problems for areas trying to meet the national standard. Ozone levels and ozone precursors are closely related to economic expansion and population growth. Consumer solvents—paints, sprays, and even deodorants—are a major source of ozone precursors. These are difficult to control and will undoubtedly increase over time in all areas, including many already attaining the standard. If auto emissions also rise, any temperature rise will exacerbate efforts to stay in compliance.

One possible saving grace is that, because the full effect of global warming will not be felt until well into the next century, various national measures to reduce ozone precursors, such as a reduction in the volatility in gasoline or changes in manufacturing processes or transportation patterns, might provide offsetting cushions in marginal areas. But, unfortunately, economic considerations and population growth may make this unlikely.

As for acid rain, there are a number of possible links between this serious air pollution problem and global warming.

- Emissions from fossil fuel power plants contribute to both acid rain and global warming. If more electricity is needed for air conditioners in northern areas, emissions would go up, although there could be offsetting regional shifts in emissions growth.

- As climate change influences atmospheric reaction rates and the quantities and form of acid deposition, areas of high deposit may shift or more acid rain may fall away from the North American continent. In any event, strategies that seek to control power plants in regions near sensitive areas may or may not be as effective if there is global climate change.

- Global climate changes may alter the impact of acid rain on the ecology and other systems. Changes in rainfall amounts could dilute the effect of acid rain on sensitive lakes. Cloud changes could alter fertilization of high-elevation forests. Changes in humidity and rainfall patterns may change degradation rates for organic materials. Increased aridity in the mid-continent could alter the calcium and magnesium levels in dust, thereby neutralizing the acid rain impact on soils. More frostless days would reduce frost-related forest damage, and snowpack changes and rainfall patterns could change acid levels in streams and the timing of major spring run-offs.

With all of the foregoing in mind, air pollution control agencies such as EPA need to review the impact of global climate change on their policies to determine the interrelationships between those policies and global warming. Such impacts as the cost of added controls resulting from climate changes should be considered when regulations are proposed or reevaluated. Future regulatory decisions should take into account their impact on energy use and greenhouse gases, especially since EPA regulations often serve as models for other countries. Also, future reports to Congress and major assessments of ecological effects like the 1990 Acid Deposition Assessment should include sensitivity analyses of alternative climates because these relationships could have an important bearing on the future of air pollution controls. □

(Durman is Chief, Air Economics Branch, in EPA's Office of Policy, Planning, and Evaluation.)

From an Industry View

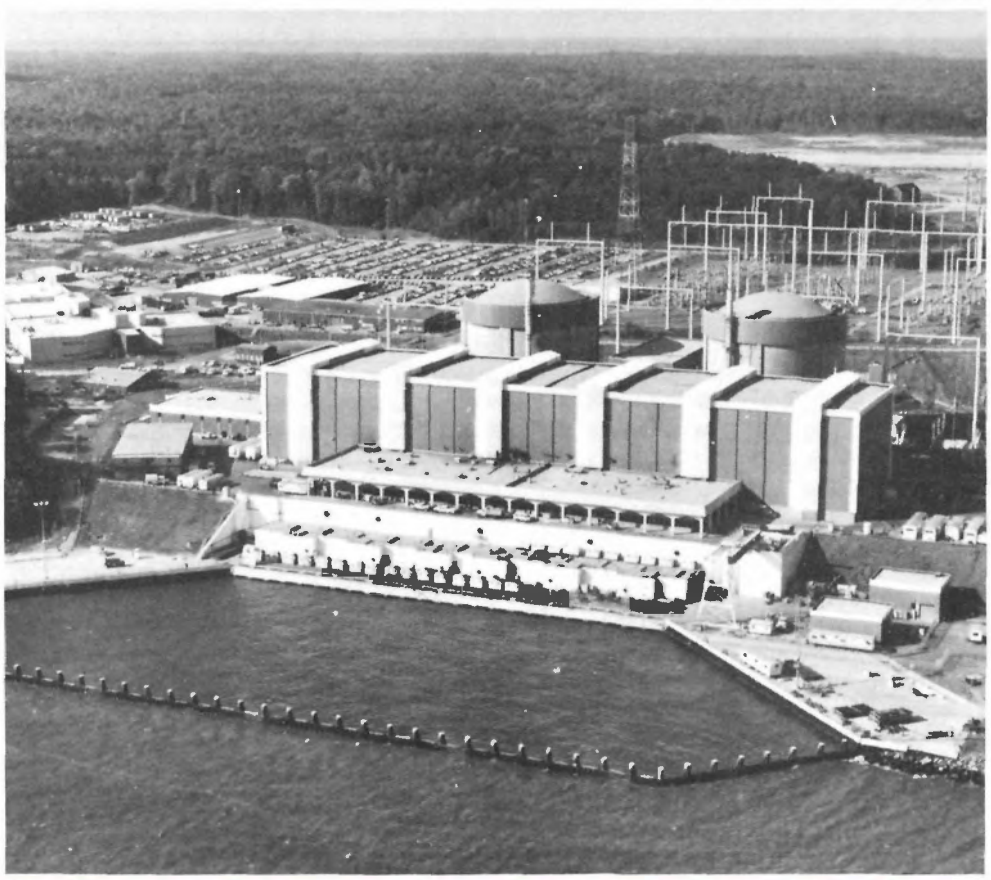
by Stephen C. Peck and Richard G. Richels

The possibility of climate change presents a unique challenge to American electric utilities. If there is indeed a significant warming of the earth's climate due to rising concentrations of greenhouse gases, utilities may be affected at three distinct levels. First, they will inevitably play an important role in any broad societal response to climate change and have an opportunity to forge a new relationship with their customers to achieve common goals. Second, utilities recognize that their industry will be among those whose operations are most deeply affected by a changing climate, perhaps within the time-frame of current planning for construction of new facilities. Finally, electric utilities are concerned that costly and potentially counterproductive regulations may be promulgated before a rational basis for policy-making is achieved.

An overriding consideration in each of these three areas is the number of uncertainties that remain in the scientific understanding of the Greenhouse Effect and in the likely effectiveness of various countermeasures. In particular, the apparent 0.6^0 C (1^0 F) rise in average global temperature over the last century lies within the long-term range of natural variability, although the recent rate of increases seems rapid. Current models suggest that a warming trend of this magnitude could result solely from the increases in atmospheric CO_2 and other greenhouse gases (e.g., nitrous oxide, methane, chlorofluorocarbons, and ozone). However, the observed rise in temperature over the last century has not been steady and has been marked by unexplained periods of cooling. More research is needed before the time-scale of present climate change and the contribution of human activity to this change are well understood.

Even more uncertain are future trends. The earth has numerous, complex feedback mechanisms that could enhance or counteract the Greenhouse Effect in still unpredictable ways. Rising temperatures, for example, could increase evaporation of surface moisture, leading to a greater cloud cover that could influence the warming by both reflecting more sunlight away from the earth and trapping more outgoing radiation. No one knows which of the opposing feedbacks would dominate.

Baltimore Gas and Electric Company photo



One of the issues in the debate about how to deal with the Greenhouse Effect is the role nuclear power should play as an alternative to fossil fuel. Shown is the Baltimore Gas and Electric Company's Calvert Cliffs Nuclear Power Plant on the Chesapeake Bay in Maryland.

Perspective on Regulation

In spite of these uncertainties, legislation has been proposed that would reduce U.S. CO_2 emissions 20 percent from current levels by the year 2000 and 50 percent by 2015. Achieving these goals—which many knowledgeable observers doubt is possible—would involve tremendous costs for electric utility customers and for the economy as a whole. Unfortunately, it is impossible to say, given the current state of knowledge,

The reliability of electricity delivery systems could be affected by weather changes caused by the Greenhouse Effect.

whether such measures would significantly affect any global warming that might occur.

At issue is whether we can afford to wait for greater scientific certainty about the Greenhouse Effect and its likely impacts. The answer requires weighing the possible costs of delay against those of premature action, such as the imposition of tremendous costs on the U.S. economy unnecessarily if the warming trend turns out to be more modest than some current projections.

Calculations by Irving Mintzer at the World Resources Institute indicate that if no action is taken for 30 years to alter current trends, we would probably have to deal with an additional average warming of between .25° to .8° C. Clearly, a significantly higher degree of certainty on a wide range of critical scientific issues could be gained in a far shorter period of time. The first order of business for the research community, therefore, is to develop a better understanding of both the consequences and likelihood of an additional commitment to global warming within the range calculated by Mintzer. Such an understanding would tell us what is at stake by waiting.

Research is not only needed to tell us when to act but also how to act. Although the focus of recent debates has been primarily on strategies to reduce emissions, it is not at all clear that the point of emissions is the best place for intervention. There is, in fact, a wide variety of options potentially available for countering the Greenhouse Effect. The four main options:

- Reducing greenhouse gas production: Examples are reducing energy use, fuel switching from coal to natural gas, increasing the use of nonfossil sources, and reducing the rate of deforestation.
- Removing greenhouse gases from effluents or the atmosphere: Examples are removing CO_2 from power plant emissions as well as starting forestation programs.
- Making countervailing modifications in climate and weather: One example is cloud seeding; another more speculative example is changing the atmosphere's reflectivity by releasing particles in the stratosphere.
- Adapting to changing climate: Examples are heating and cooling of buildings, compensation of disadvantaged regions, and changing of agricultural practices.

Thus, another important research direction is to conduct analyses of the feasibility and cost-effectiveness of such options so that an informed judgment can be made on the appropriate combination of options, when action is required.

Regardless of when action may be taken, however, it is clear that unilateral emissions reductions by the United States or its utilities would do very little to slow global trends. While worldwide emissions of manmade CO_2 more than tripled between 1950 and 1980, the U.S. share of the total steadily decreased, from about 42 percent to a current level of about 22 percent. By contrast, the portion attributable to developing countries grew during the same period 7 percent to more than 20 percent, and these countries may produce two-thirds of CO_2 emissions by the middle of the next century.

There is, in fact, a wide variety of options potentially available for countering the Greenhouse Effect.

American utilities, on the other hand, now produce about 35 percent of U.S. and 8 percent of global emissions—an amount which, even if it were reduced significantly, would delay the date of a doubling of atmospheric CO_2 from pre-industrial levels by a fraction of a decade at most. Paradoxically, premature restrictions on American utilities could actually increase CO_2 emissions by driving up the domestic price of electricity and forcing more industries to move offshore, where the efficiency of energy use is frequently lower. Clearly, any regulatory attempts to counteract global warming must be international in character.

Effects on Utility Operations

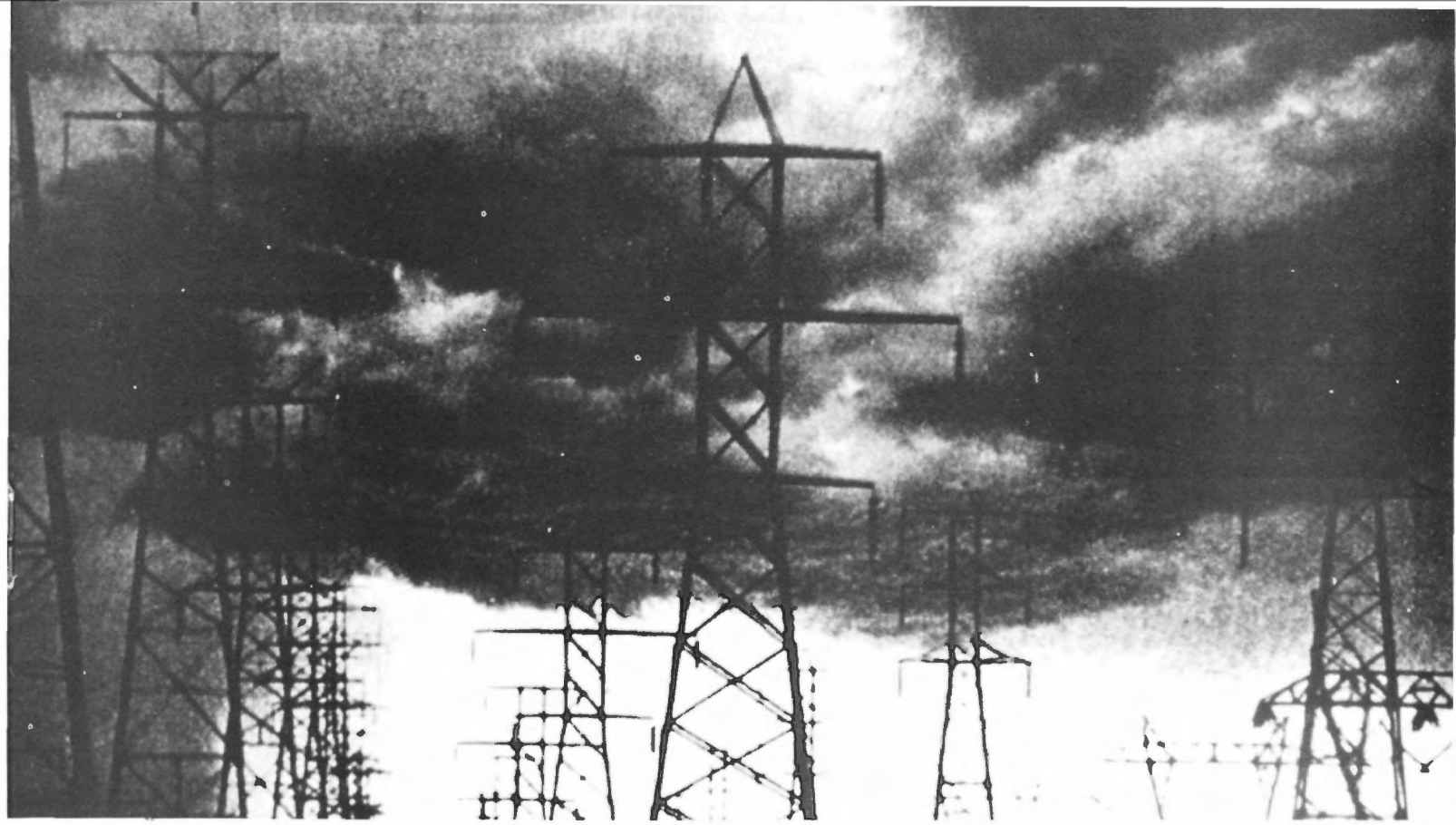
Because of the large amounts of capital and time required to build generation and transmission facilities, electric utilities must plan for decades ahead. Recent studies indicate that if significant climate change occurs, some effects may be felt within the current planning horizon for utilities. The need for more air conditioning during longer, hotter summers, for example, would not only raise the annual demand for electric energy but increase demand peaks as well. Utility planners must therefore consider both the likelihood of having to build new power plants to meet higher peak demand and the probable need to purchase more fuel for increased generation.

Planners will also need to consider potential changes in energy supply resulting from climate change. Stream flows that affect the availability of hydroelectric energy, for example, depend on both the amount and timing of precipitation, which could be altered in some regions by even small changes in the average global temperature. In addition, the reliability of electricity delivery systems could be affected by shifts in the frequency and intensity of weather extremes, such as tornadoes, hurricanes, and severe storms. Power plant operations in some coastal regions could also be hampered by even a moderate rise in the sea level resulting from thermal expansion of the oceans and possibly increased melting of glaciers and Antarctic ice.

To meet these challenges, utilities will need to adopt more sophisticated strategies of risk management. Although many of the effects of climate change remain unpredictable, the cost of adapting will be much less if some prudent contingency plans are made well in advance. Recognizing this need, the utility industry is sponsoring a program of research to provide a better understanding of the linkages between climate change and electric power operations, and to develop strategies for considering climate-related uncertainties in capacity planning, long-term fuel commitments, and transmission investment.

Helping Society Respond to Climate Change

Beyond facing immediate regulatory and operational challenges, electric utilities will play an important role in the broad societal response to any climate change that does occur. Several of these initiatives, which are quite diverse, represent extensions of ongoing



Richard G Richels photo.

cooperative efforts between utilities and their customers and are being taken to use our natural resources more effectively:

- Energy conservation: Many utilities have longstanding, customer-focused conservation programs in place, involving such actions as helping finance home insulation or the purchase of efficient electrical appliances. Such efforts, on a global scale, probably represent the most cost-effective means of slowing the accumulation of greenhouse gases.

- End-use efficiency: The utility industry, largely through the activities of the Electric Power Research Institute (EPRI), is co-sponsoring research on increasing the efficiency of electricity use in the residential, commercial, and industrial sectors. Such efficiency improvements are contributing to a longstanding trend of electrification of the world economy, which will also aid adaptation to climate change.

- Electric vehicles: Electric vehicles, charged overnight using off-peak power from the most efficient baseload power plants, could significantly reduce urban pollution and—depending on the use of nonfossil power plants—could potentially reduce overall emissions of greenhouse gases as well.

- Generation technology: The efficiency of existing plants is being improved, one of the many benefits of the clean coal program. In addition, new technologies are being developed that, over the long term, can help reduce emissions of greenhouse gases from power plant operations. These include more efficient ways of burning coal, development of renewable sources such as wind and solar energy, and design of smaller, advanced nuclear plants with improved safety features.

More research is needed before the time-scale of present climate change and the contribution of human activity to this change are well understood.

- Technology transfer: Since the major contribution of greenhouse gases may eventually come from developing countries, utilities in industrialized nations can play an important role in making advanced technology more widely available for both the generation and use of electric power. Such technologies could help raise the currently low efficiency of power generation and hence reduce CO_2 emissions in the Third World.

- Planning for adaptability: As the effects of climate change become more apparent, utilities will need to work closely with government agencies and the public to make plans for adapting. These plans should include multifaceted responses to population shifts, economic dislocation, increased irrigation needs in major agricultural areas, and possibly the pumping of sea water in extensive coastal dike systems.

U.S. electric utilities represent a relatively minor part of the problem of global warming, but potentially a major part of the solution. They remain an easy target for regulation, but national resources would now be better spent on contributing to the scientific basis for policy-making and providing future options to help the world manage climate change if it occurs. Since both utilities themselves and the communities they serve will inevitably be effected by climate change, now is the time to forge a new partnership for creatively addressing the challenges that lie ahead. □

(Peck is Director of the Environmental Risk and Health Science Department at the Electric Power Research Institute. Richels is Manager of the Environmental Risk Analysis Program at EPRI.)

Three Foreign Perspectives

The United States is not the only country that will have to come to terms with the Greenhouse Effect. This global phenomenon is concerning people the world over. EPA Journal decided it would be valuable to take a closer look at what three other countries are doing right now. The Netherlands, Canada, and Japan—like the United States—have advanced industrial economies, but their own particular circumstances can give them a different view of the Greenhouse Effect.

The Netherlands

by Pier Vellinga

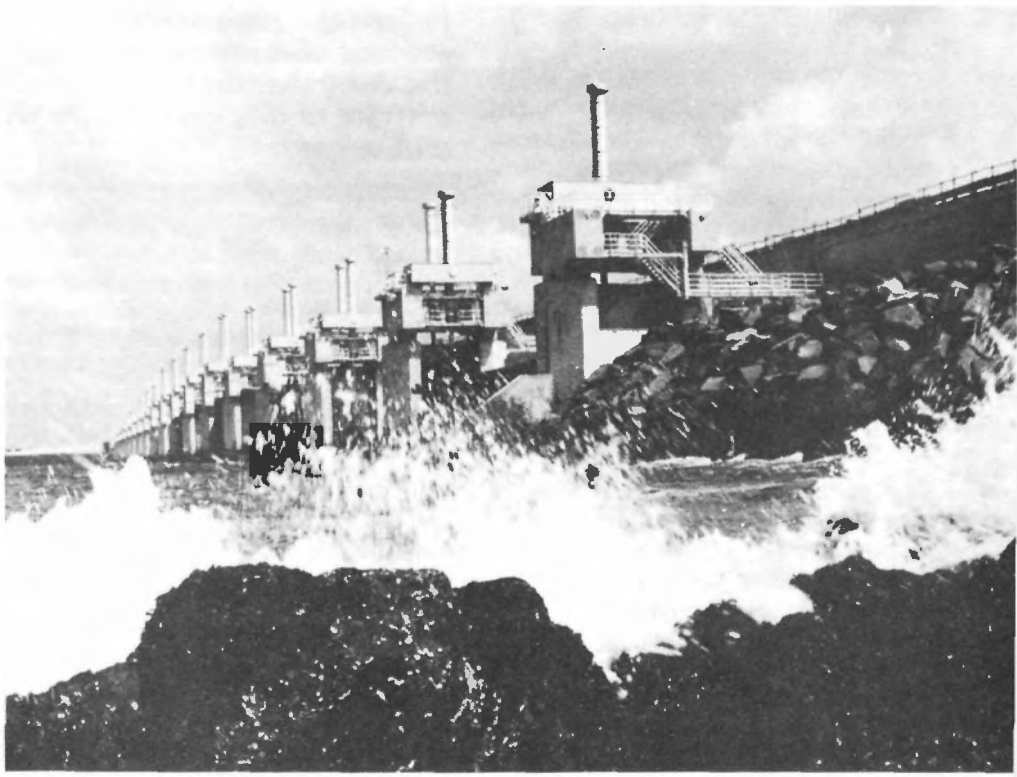
Netherlands Board of Tourism photo.

In the Netherlands, which is particularly vulnerable to any rise in sea level, there is a growing concern about climatic change and its consequences. The Dutch have 1,000 years' experience in fighting the sea and reclaiming their land in the face of a "natural" rise in sea level of about 0.15 meter every 100 years. By comparison, the latest projections of sea-level rise, accelerated by global warming, range from 0.5 meter up to 1.5 meters per 100 years. This yields a totally different picture.

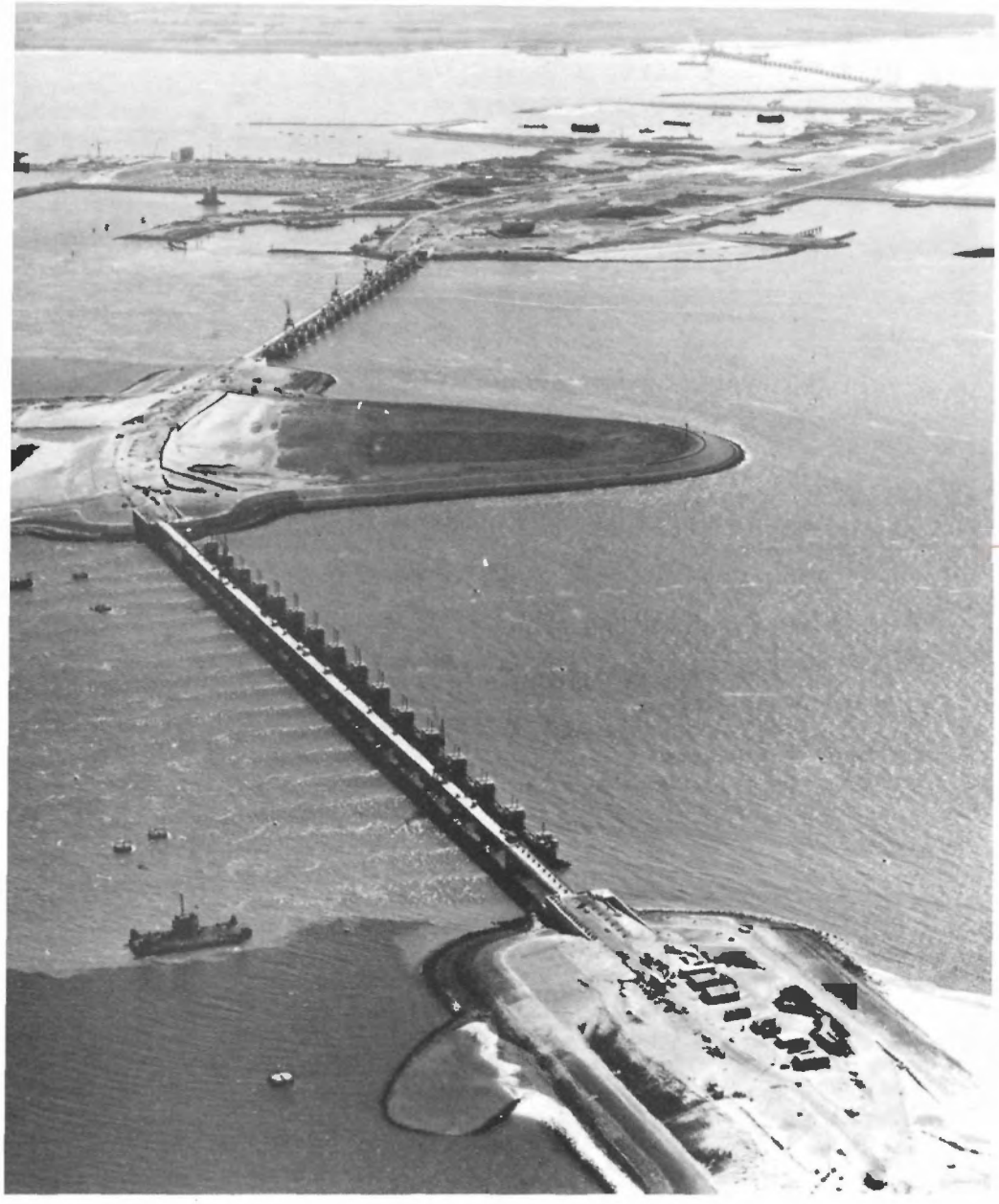
Nowadays about two-thirds of the country is protected from the sea by dikes. In this area, which includes large cities such as Amsterdam and Rotterdam, about 10 million people live below sea level. Preliminary investigations indicate that the Netherlands will be able to survive a rising sea level in the relatively short run. Technically and economically, it will be feasible to protect the country against a one-meter rise in sea level by raising the dikes, strengthening the coastal dunes, and adjusting the inland water management system.

The estimated cost of such an operation will be roughly 5 to 10 billion U.S. dollars. When this amount is spent over a period of 10 years, it will be less than 1 percent of the Gross National Income of the Netherlands. However, if emissions of greenhouse gases continue, the Netherlands will face a losing battle in the long run. If all snow and ice on earth were to melt, sea level would be 85 meters higher than today. In the long run, continued greenhouse gas emissions would cause the Dutch to flee their own country.

Netherlands Board of Tourism photo.



After a storm surge in 1953 that killed 2,000 people, the Netherlands began working on more coastal protection. The Deltaplan's major dikes have been completed and a road built over them. Local communities are paying most of the maintenance costs.



The manmade island at center was the Deltaplan headquarters during the major building phase. In the foreground is a museum that explains the $8 billion coastal defense system.

While the Netherlands may succeed, at least in the short-term future, in protecting the country against the rising sea level, what about other countries with much vaster unprotected coastal areas? A protection strategy will be virtually impossible for many developing countries that do not have the requisite experience, administrative system, and economic means.

The only way to fight the greenhouse gases is to limit their concentration by reducing emissions. Presently the Netherlands is investigating the possibilities of a limitation strategy, focussing on a reduction of energy consumption, more ecologically sound systems of land usage, and a total phasing-out of chlorofluorocarbons. In this way we will not only reduce the emissions of greenhouse gases but also help to solve a number of other environmental problems.

International Initiatives

The Netherlands contributes about 1 or 2 percent of the global emissions of greenhouse gases. This means that a solo action on our part would be like Don Quixote fighting his windmills. Given this situation, the Government of the Netherlands is stressing the need for international action to augment national measures. Two recent international initiatives are:

- The Netherlands' minister responsible for our coastal protection, Mrs. N. Smit-Kroes, has initiated cooperation between our government and the United Nations Environment Programme (UNEP) to increase international awareness of sea-level rise. This cooperation covers a global inventory of vulnerable areas, a framework to describe the Impact of Sea-level rise On Society (ISOS), and a number of site-specific case studies. The aim is to define the social, economic, and environmental impact of sea-level rise on a global scale. The investigations are being carried out by a worldwide network of scientists and policymakers, coordinated by Delft Hydraulics Company. The results of the investigations will be made available to UNEP to serve as a basis for the development of policy responses.

- The second international initiative has come from our ministry with primary responsibility for the environment. Mr. Ed Nijpels, Minister of Housing, Physical Planning, and Environment, has taken the initiative to organize a Ministerial Conference on Atmospheric Pollution and Climatic Change, to be held in the Netherlands in the fall of 1989. He intends to bring the discussion of climatic change to a policy level, with the aim of preparing policy options for the protection of the atmosphere. This conference will be organized in close cooperation with UNEP and the World Meteorological Organization to ensure coordination with their activities and to support world conferences on this issue to be held in 1990 and 1992. It may be of interest to note that Lee Thomas of EPA has pledged to support the initiative of the Netherlands, and EPA is assisting in the preparations.

Actions in the Netherlands Today

The first impact of the rising sea level will be an increased risk of inundation. The present coastal protection works are designed to resist a North Sea storm surge that has a frequency of occurrence of 1 in 10,000 per year. Under such storm conditions, the water of the North Sea would surge against the coast of the Netherlands up to a level of 5 meters above mean sea level. With a rising sea level, the level of the storm surges would also rise. Moreover, the waves reaching the shore would be higher and, last but not least, the frequency, the intensity, and the direction of storms would be affected by climatic change.

The community of Zaanse Schans has houses and windmills that have been built close to the water.

Netherlands Board of Tourism.

As a result, the safety of the population would be uncertain. Climatic change will bring surprises; therefore we are investigating the range of surprises.

The first visible effect of sea-level rise would be an increase in beach erosion. The coastal defense system of the Netherlands consists for the most part of sandy beaches and dunes, which would respond directly to a rising sea-level. So far the effect of sea-level rise on sandy beaches has been described as a two-dimensional process: as the sea level rises, the upper beach will be eroded and the coastal profile will shift in a landward direction. However, in most cases the situation is much more complicated because coastal dynamics is a three-dimensional process. Along the coast there are barrier islands, shore-connected ridges, tidal basins, river outlets, and inner and outer deltas. These systems are continuously changing, even in the present situation. The long-term development of these systems is closely related to the water depth. A change of the mean sea level will directly affect the entire coastal system, and the actual changes in the narrow visible rim of this system (which we call the shoreline) are likely to be completely different from the results of the commonly applied two-dimensional approach.

Our present-day coastal zone management policies anticipate an accelerated rise in sea level. In cases where a coastal stretch is suffering from beach erosion—beyond what is considered acceptable from a safety or land-use point of view—the erosion will not be stopped anymore by the construction of long-term rigid structures like sea walls or groins. Instead, more flexible solutions like short-term beach nourishment (using natural sand to "feed" the beach) are applied.

The first major coastal structure that will be built taking into account a sea-level rise induced by greenhouse gases is the storm surge barrier to be constructed in the Rotterdam Waterway. The structure will have to protect the low-lying areas near Rotterdam against the North Sea storm surges. The cost of constructing the barrier will be almost one billion U.S. dollars. This barrier will be closed when the water level exceeds a critical value. The present inland protection is such that, to reduce the risk of inundation, this new barrier will have to be closed about once or twice a year. The structure has been designed so that it will still function properly given a sea-level rise of 0.35 meter within the next 50 years. Moreover, the structure can be adjusted to deal with a greater sea-level rise.

Administration, Taxation, and Planning

Since the Netherlands has 1,000 years' experience in land reclamation and coastal protection, there is a well-established system of administration, taxation, and coastal zone planning, with local governments fully devoted to water management and coastal protection. After the major storm surge of 1953, with 2,000 people killed and large areas inundated, a new coastal protection plan, the Deltaplan, was commenced. The coastal protection works necessary to implement the Deltaplan were begun in 1960 and will be finished in 1995. The total cost of this plan, paid by the central government, will be about 8 billion U.S. dollars. When the plan is finished, the local governments, and thus the local communities, will have to pay for the major part of the maintenance.

The responsibility for coastal defense and protection measures will be elaborated in a new act that is presently in preparation. With a continuously rising sea level, the coastal protection works will need to be adjusted within a few decades, and the maintenance will probably be much more expensive than originally anticipated. Under the new coastal protection act, the local communities will pay for the major part of maintaining coastal protection works. One reason for this is to create an economic mechanism for planned retreat if it ever becomes too expensive to maintain certain areas against the rising sea.

In Summary

The Netherlands is vulnerable to sea-level rise. Knowing this, however, actually makes us less vulnerable. We want to raise our voice in the international community, not just for ourselves but for all people and countries vulnerable to climatic change. The real challenge to all of us is to tackle the problem of climatic change at the source. □

(Dr. Vellinga is Coordinator of the National Climate Programme for the Netherlands Ministry of Housing, Physical Planning, and Environment.)

Canada

by Tom Agnew

A cursory look at global warming scenarios might seem to suggest that Canada, being a cold northern country, would emerge as a net winner from the Greenhouse Effect. Indeed, in many respects Canada will benefit. However, expected changes in global climate involve more than a simple rise in temperature. Global circulation models indicate that temperature increases will be accompanied by shifts in global wind and rain patterns. These changes could have major detrimental effects on Canadian agriculture and water resources.

In southern Canada, for instance, where most of the nation's fertile soils and population are located, severe droughts may well become more frequent, while increased flooding may occur in the north. And throughout the country, natural vegetation and forest stands are likely to become mismatched with ambient climate, making them ripe for stagnation and/or dieback.

Physical and Biological Impacts

Computer modeling studies of warming due to the Greenhouse Effect suggest that the future distribution of Canada's water resources will be significantly altered. If storm tracks and hence rainfall patterns move northward, as projected, water supplies in southern Canada are expected to decline significantly, due both to increased evaporation caused by warmer temperatures and to a possible decrease in precipitation during the summer months. Water levels in rivers, lakes, and reservoirs would be reduced.

Studies concerning the future Great Lakes water supply suggest that water levels may be considerably lower, with outflow through the St. Lawrence Seaway possibly decreased as much as 21 percent. Shipping on the Great Lakes would be adversely affected. Where water supplies are already contaminated, as in the Great Lakes, lower water levels would concentrate existing pollutants. Moreover, increased dredging of toxic-laden sediments in harbors and navigation channels would pose environmental problems.

Decreased water supplies generally mean increased competition for available water resources. In the populated regions of southern Canada, heavy demands are already placed on our water supply for industrial, agricultural, and domestic needs. These demands are likely to increase substantially. In addition, lower water levels would seriously affect the generation of hydroelectric power. The shortfall would have to be made up through increased use of nuclear or thermal power generation, with its attendant increases in acidifying sulfur emissions.

In southern Canada, where most of the nation's fertile soils and population are located, severe droughts may well become more frequent . . . .

Higher temperatures and longer growing seasons could significantly improve growing conditions for crops. The limits of northern agriculture, especially wheat production, are expected to expand considerably into areas such as the fertile river valleys of the Peace and MacKenzie Rivers in the Northwest Territories. However, in most of the north, soils are unsuitable for cultivation, and expansion of intensive agriculture will be limited for that reason.

Alterations in regional and seasonal rainfall and evaporation are expected to have major effects on agriculture, particularly in the mid-latitudes, where soils may become drier and severe droughts more frequent. The grain-producing areas in the southern prairie provinces are especially vulnerable. The increased severity and frequency of drought, such as the ones experienced during 1986-87 and 1987-88, will pose the largest threat to Canadian agriculture.

Gradual changes in forest cover are also expected as the climate warms. In the Arctic, the tree line is expected to move slowly northward at the rate of approximately 100 kilometers per degree Centigrade of warming. The mixed temperate forests of the east are expected to expand, replacing boreal forests as far north as James Bay.

However, because of the slow process of forest succession, many existing stands of trees, including those now being planted under the reforestation program, will gradually be left outside their optimum temperature range, stunting their growth and inducing major diebacks. This problem may exacerbate the current dieback problems associated with acid rain, ozone, and other manmade pollutants.

Drier climates in southern Canada could also reduce tree growth and significantly increase the risk of forest fires. Warmer winters may seriously affect the stability of winter logging roads.

Greenhouse warming is expected to have a substantial and largely beneficial effect on northern Canada. Higher temperatures would greatly improve shipping conditions in the far north by reducing the amount of floating ice and lengthening the short summer season. Warmer temperatures would also be a boon to tourism and settlement.

Rainfall patterns are expected to shift northward, bringing significantly increased precipitation in some areas. Despite warmer winters, snow depths may be greater—bringing an increased threat of extensive flooding with the

spring run-off. Storms could be more frequent and more severe.

There is also concern that slow but widespread melting of the permafrost will create an unstable foundation for roads, buildings, pipelines, and other structures. In addition, melting of the permafrost is likely to release significant amounts of the greenhouse gases carbon dioxide (CO_2) and methane to the atmosphere. And while snow depths may be greater, snow will cover less area for shorter durations, resulting in increased absorption of incoming solar radiation. Considered together, these two factors constitute a probable "positive feedback" mechanism which would reinforce the warming effect.

The anticipated warming would mean less ice cover on navigable waters, and this would substantially benefit shipping and the offshore resource industry in Arctic and coastal waters. However, there is concern that icebergs could increase as much as 300 percent, posing a major threat to offshore activities in the eastern Arctic and Labrador.

In the Great Lakes, reduced winter ice would extend the shipping season. However, this advantage is expected to be outweighed by the previously noted problems associated with lower water levels.

The Canadian Climate Program

Recognizing the potential impacts of climatic fluctuations and climate change on Canadian Society, Canada established, over a decade ago, the Canadian Climate Program (CCP) to integrate the efforts of various federal and provincial agencies as well as universities and the private sector in the field of climatology. The program is steered by a Climate Program Board, which provides guidance and coordination on a wide spectrum of international and national climate-related activities. The lead agency for this national program is the Atmospheric Environment Service (AES) of Environment Canada.

CCP climate impacts studies are being carried out to assess the potential social and economic repercussions of climate warming expected under a scenario in which atmospheric CO_2 levels are doubled over pre-industrial levels. Thirteen major studies have now been completed, and others are in progress. This work has identified specific areas of sensitivity in agriculture, forestry, navigation, power generation, fisheries, recreation, and tourism.

In the Arctic, the tree line is expected to move slowly northward at the rate of approximately 100 kilometers per degree Centigrade of warming.

One noteworthy study examined the impact of climate change on agriculture in Saskatchewan. This work was done as part of a joint project with IIASA/UNEP (International Institute for Applied Systems Analysis/United Nations Environment Programme). The study found that Saskatchewan could expect occasional drought years like that of 1961, with losses to the agricultural economy exceeding $1.8 billion and 8,000 person years. A shift to a warmer long-term climate would cause reduced spring wheat yields with losses of $160 million and 700 person years.

As a possible premonition to the most recent 1988 severe drought, the same study also indicated that there would be a major increase in the frequency and severity of droughts. Warmer climates would conceivably allow northward expansion of prairie agriculture. However, soils in this northern area are suitable only for marginal crops such as forage, and the potential economic benefits of such expansion are questionable.

Results of these studies are now being disseminated to the Canadian public through the *Climate Change Digest*, a new publication series initiated in 1987. Press releases announcing each issue have attracted considerable media attention.

The CCP also provides support for impacts workshops such as the joint U.S.-Canada Symposium on the Impacts of Climate Change in the Great Lakes Basin, held in Chicago in September 1988.

Canadian Research Activities

Numerous research projects are being pursued at Canadian universities and government agencies with resources provided by funds from various federal departments, from the Natural Sciences and Engineering Research Council of Canada (NSERC), which gives grants to universities, and from the CCP for research directed at improved climate monitoring and prediction. Recently, a climate research chair at McGill University has been funded jointly by the NSERC and the AES, and a chair will also be funded at Dalhousie.

Some of the more notable research activities are:

- Canada operates continuous air sampling stations at Sable Island (Nova Scotia), Cape St. James (British Columbia), and Alert (Northwest Territories) as part of the global monitoring of background atmospheric CO_2 concentrations being coordinated by the World Meteorological Organization (WMO). Samples are also collected at Mould Bay, Northwest Territories, for analysis by the National Oceanic and Atmospheric

U.S. Coast Guard photo

Although the anticipated warming would mean less ice cover on navigable waters, there is concern that the number of icebergs could increase as a result of melting polar ice caps. This could pose a major threat to offshore activities in the eastern Arctic and Labrador.

Administration (NOAA) as part of its program for Geophysical Monitoring of Climate Change. The CO_2 concentration measurements obtained from the analysis of the air samples are quality-controlled and added to the existing station data bases, with copies forwarded to WMO. These data bases are used for trend analysis and studies into regional and long-range sources of CO_2.

- Central to Canadian research into climate change is the ongoing development of an atmospheric general circulation model (GCM) at AES's Canadian Climate Centre. By early 1989, the first enhanced Greenhouse Effect experiment with this model should be complete.

- Scientists in Canada's Department of Fisheries and Oceans (DFO) are working with Swedish scientists to study the uptake of atmospheric CO_2 in Arctic waters and the uptake of freon gases in the Labrador Sea. DFO is actively involved in investigations of air-sea climate interactions in cooperation with various international programs.

- Research into past changes in the earth's climate is diverse and widely distributed among universities and government agencies across the country. The National Museum of Sciences has brought some of these study results together in joint publications on climate change in Canada since the last glaciation.

International Activities

Canada has long been an active participant in international activities related to climate change, both through its WMO and United Nations Environment Programme memberships and through major contributions to international meetings. Perhaps Canada's most notable role was hosting and organizing the International Conference on "The Changing Atmosphere: Implications for Global Security," held in Toronto June 27-30, 1988. This meeting attracted more than 340 participants from 46 countries, United Nations organizations, other international bodies, and non-government groups representing diverse sectors of society.

The conference called on the United Nations and its special agencies, governments, industry, educational institutions, non-government organizations, and individuals to take action to reduce the impending crisis caused by pollution of the atmosphere. It recommended an Action Plan for the Protection of the Atmosphere, which would be financed by a World Atmosphere Fund generated in part by taxes on fossil fuel consumption in industrial countries. Specific recommendations of the plan included:

- Ratifying of the Montreal Protocol on substances that deplete the ozone layer.

- Developing energy policies which will reduce emissions of CO_2 and other greenhouse gases.

- Collectively reducing CO_2 emissions by 20 percent of 1988 levels by 2005, through energy-efficiency and conservation measures and through use of cleaner energy sources.

- Increasing research funding directed to low-CO_2 and non-CO_2 emitting energy options including advanced biomass conversion technologies and revisiting the nuclear power option.

- Vigorously applying existing technologies to reduce emissions of acidifying substances, of substances which are precursors to tropospheric ozone, and of other non-CO_2 greenhouse gases.

- Introducing product labelling that will allow consumers to judge the contamination of the atmosphere resulting from the manufacture and use of specific commodities.

Conclusion

Predicted changes to Canada's climate due to global warming involve changes in wind and precipitation patterns as well as temperature. This complicates any attempt to assess impacts and reinforces existing doubts that Canada would be a winner from such warming. Although the exact details of these climate changes are not fully known, studies to date suggest that there will be major impacts on Canada's natural, economic, and social systems. In anticipation of these impacts, Canada has instituted a broad climate program to evaluate potential impacts and promote public awareness and discussion in Canada and internationally. □

(Agnew is Acting Head, Canadian Climate Program Office.)

Japan

by Roy Popkin

(This article by Roy Popkin of EPA Journal is based on a report by a special panel established by the Japanese Environment Agency.)

Japan Information and Culture Center photo

The government of Japan, a highly industrialized and intensely farmed island nation, is deeply concerned about the potential impact of global warming and rising seas resulting from the Greenhouse Effect. This concern is reflected in a report published early last November by a scientific Panel on Global Warning established by the Japanese Environment Agency.

The report documents the Panel's belief that the Greenhouse Effect is already with us, saying: "Over the last hundred years, atmospheric concentrations of carbon dioxide have been steadily increasing as a result of rapidly expanded industrialization and other human activities." It notes that during that period, the trapping of these gases in the earth's atmosphere has raised global temperatures an average of 0.6^0; that worldwide concentrations of carbon dioxide (CO_2) in the atmosphere have been steadily increasing; that the sea level has already risen from 100 to 200 millimeters (4 to 8 inches) during the century because of what is believed to be thermal expansion of sea water or the melting of polar ice.

Further, as it points the way for government action, international efforts, and additional research activities, the Panel report says, "The global warming problem is one of the most important problems facing the international community."

As in the United States, the Greenhouse Effect could alter Japan's fishing patterns. At present, tons of fish pour into Tokyo's fish market every morning. Before noon, the stands are empty.

The report then goes on to say, "Global warming seriously affects the whole world and is a complicated process continuing gradually over time. Once the impact of global warming occurs, it will be extremely difficult to reverse the trend and to take remedial measures . . . it may be too late to tackle the problem if we wait until actual damages are shown to be caused by global warming. It is now necessary both to actively promote studies on the topic and to take feasible actions as soon as possible, based on scientific and technological information already available. Global warming is closely related to other global environmental problems such as desertification, deforestation, and marine pollution. New approaches should be developed to deal with all of these problems within one comprehensive system."

The report documents the Panel's belief that the Greenhouse Effect is already with us . . . .

Predict the Japanese, "If no measures are taken to curtail present energy usage, the combined concentration of atmospheric greenhouse gases would by 2030 be double what it was in pre-industrial times, and the doubling of CO_2 levels alone would cause a sea-level rise of 26 to 165 centimeters (10 to 65 inches) because of the thermal expansion of seawater and the melting of small glaciers." The scientific panel also sees the potential for increased winter precipitation in high latitudes and in the tropics, and a summertime decrease in precipitation and an increase in evaporation in the middle latitudes. The Panel foresees wide-ranging changes in agricultural productivity as a result of a northward movement of farming areas, serious crop damages and a drop in land productivity—no small matter for a nation where every inch of productive farmland is of vital importance. In addition, it projects extensive social changes and economic impacts.

The Japanese government Environment Agency first expressed its concern over the problem of global warming in a 1981 environmental quality report, and initiated intensive examination of the problem by its National Institute for Environmental Studies in 1984. This effort, abetted by the country's Ad Hoc Group on Global Environmental Problems, began formulating recommendations for Japan's approach to global warming in the spring of 1988. These recommendations ultimately became part of the Panel report issued in November, in time for submission to the United Nations/World Meteorological Intergovernmental Panel on Climate Change meetings which began that month.

The Japanese urge the international community and their own government to develop policies to cope with global warming that involve the concepts of prevention, elimination, and adaptation, giving preventive technology the highest priority. This includes energy conservation through improving the efficiency of energy systems and changing life-styles, along with the use of solar energy and other alternative energy sources. The report emphasizes that much of this effort needs to be initiated and completed quickly, in one to 10 years, to forestall global warming impacts later in the early or mid-twentieth century.

Noting that annual worldwide CO_2 emissions from human activities total 18 billion tons—far more than emissions of

Japan's peaceful Byodoin Temple provides a respite from busy streets. The main hall, built in 1053, was built to represent the mythological bird, the phoenix.

Japan Information and Culture Center photo

other air pollutants—the report calls creation of technology to eliminate CO_2 from large-scale boilers and to strengthen emission controls on emissions of chlorofluorocarbons and other artificial greenhouse gases. Prevention of deforestation is also cited as important to environmental conservation, with reforestation on a continental scale needed for effective absorption of atmospheric CO_2. The report also calls for development of adaptive technologies, such as growing crops that are resistant to changes in climate, water supply, and irrigation, and for the modification of social systems if necessary to accommodate changes work habits, farming methods and areas, transportation patterns, and perhaps, relocation of populations because of such factors and the rising seas.

The Japanese urge the international community and their own government to develop policies to cope with global warming that involve the concepts of prevention, elimination, and adaptation . . . .

These efforts, plus a substantial research program, should be conducted on international and national levels, with international groups establishing guidelines for action based on currently available and new-found scientific knowledge. Each nation would be responsible for taking appropriate actions in line with the guidelines, which should include policy and technical measures related to emission control of CO_2, such as energy conservation, fuel conversion, energy substitution, improvement of energy systems, removal of CO_2 from emissions, resource conservation, development of new forests and other global biomass, recycling, and other measures to reduce the effect of other greenhouse gases.

The report also calls for creation of a permanent international mechanism to develop guidelines for worldwide actions and to continuously monitor and evaluate their implementation. Because greenhouse gas emissions are expected to increase dramatically in developing countries, where they are expected to be especially damaging because of such countries' lack of resources, developed countries are urged to share the responsibility for offering technical and financial assistance to developing countries to help them implement appropriate global warming countermeasures.

At the national level, the report calls for the Japanese government to draft national guidelines, participate actively in international efforts to achieve an international consensus on global warming, to promote research projects, to promote public awareness, and to coordinate the nation's administrative and scientific efforts to reduce their nation's contribution to the atmospheric pollution creating global warming, and to prepare the nation for the impact of global warming if and when it worsens.

This includes, says the report, developing social and economic measures against global warming, and studying their cost and feasibility. It also entails the development of national and international energy scenarios that go to the mid-21st Century, and the development of risk management methods that will help select the most effective policy options. To this end, the panel will continue its work to develop further recommendations on specific actions for the Japanese government and various international bodies to take. □

(Popkin is a writer-editor in the EPA Office of Public Affairs.)

With a Global Focus

by William H. Mansfield III

"Global warming may be the greatest challenge facing humankind," according to Dr. Mostafa K. Tolba, Executive Director of the United Nations Environmental Programme (UNEP) and Under Secretary General of the United Nations. Indeed, the mounting concern about climate change impacts has sent storm warning flags aloft in the United Nations, where the President of the Maldives, Maumoon Abdul Gayoom, gave a dramatic, impassioned address to the 1987 U.N. General Assembly on the severe consequences of sea-level rise on his low-lying island country. Malta put a resolution on the same issue poignantly before the 1988 General Assembly. The resolution was adopted, and a meeting of heads of U.N. organizations on environmental matters in Paris in July 1988 featured climate change as a major discussion item. It was also a major topic at the Economic Summit in Toronto last June.

Sea-level rise as a consequence of global warming would immediately threaten that large fraction of the globe living at sea level. Nearly one-third of all human beings live within 36 miles of a coastline. Most of the world's great seaport cities would be endangered: New Orleans, Amsterdam, Shanghai, Cairo. Some countries—the Maldives Islands in the Indian Ocean, islands in the Pacific—would be inundated. Heavily populated coastal areas such as in Bangladesh and Egypt, where large populations occupy low-lying areas, would suffer extreme dislocation.

Warmer oceans would spawn stronger hurricanes and typhoons, resulting in coastal flooding, possibly swamping valuable agricultural lands around the world. Reduced water quality may result as coastal flooding forces salt water into coastal irrigation and drinking water supplies, and irreplaceable, natural wetlands could be flooded with ocean water, destroying forever many of the unique plant and animal species living there.

Food supplies and forests would be adversely affected. Changes in rainfall patterns would disrupt agriculture. Warmer temperatures would shift grain-growing regions polewards. The warming would also increase and change the pest plants, such as weeds, and the insects attacking the crops.

The precedent established in tackling the stratospheric ozone issue may well be a useful model for dealing with climate change. But climate change is an infinitely more complex issue to deal with.

The effects on oceanic fisheries are not known now, but warming could result in changing ocean currents and upwelling and thus fewer nutrients. It could alter salinity, acidity, and turbulence, bringing certain harm to the existing food chain.

These potential disruptions in human food supplies must be placed against another stark backdrop: namely the increase of the human population from just over 5 billion today to an expected 8 billion in another 40 years, an increase that will inevitably require more food.

Human health would be affected. Warming could enlarge tropical climate bringing with it yellow fever, malaria, and other diseases. Heat stress and heat mortality could rise. The harmful effects of localized urban air pollution would very likely be more serious in warmer conditions. There will be some benefits from the warming. New sea lanes will open in the Arctic, longer growing seasons further north or south will create new agricultural lands, and warmer temperatures will make some of today's colder regions more habitable. But these benefits will be in individual areas. The natural systems—both plant and animal—will be less able than man to cope and adapt. Any change of temperature, rainfall, and sea level of the magnitude now anticipated will be destructive to natural systems and living things and hence to man as well.

The list of possible consequences of global warming suggests very clearly that we must do everything we can now to understand its causes and effects and to take all measures possible to prevent and adapt to potential and inevitable disruptions triggered by global warming.

This will not be an easy matter for two reasons. First we must take such measures before we have convincing evidence that warming will have harmful impacts. Second, the human activities that are causing the temperature rise—such as burning of coal, oil, and wood and the release of other trace gases—are fundamental to the world economy. So as with the 1987 Montreal Protocol to protect the ozone layer, we will have to make a "leap of faith" to save ourselves and future generations.

As with the ozone layer, dealing with climatic change will require the cooperation of all nations. Almost all are contributing to the problem; almost all will suffer its impacts.

The United Nations is Acting: The first steps of the great international collaboration are being taken now within the U.N. system. To assess the scientific aspects of the problem, consider the potential effects of climate

Warmer oceans could spawn stronger hurricanes and typhoons. This infrared nighttime picture shows Typhoon Kit in the Pacific. It was taken by Nimbus II, one of NASA's weather satellites, from an altitude of 700 miles.

change, and identify policy options available to deal with those effects, the World Meteorological Organization (WMO), UNEP, and the International Council of Scientific Unions (ICSU) are conducting a number of studies and assessments under the umbrella of the World Climate Programme. The International Geosphere/Biosphere Programme is studying the interactions among land, the atmosphere, and the oceans. A number of national programs are being launched that will supplement this work.

The mounting concern about climate change impacts has sent storm warning flags aloft in the United Nations . . . .

The World Climate Programme is coordinated by WMO, which handles the data and applications of climate knowledge components. ICSU, WMO, and UNESCO focus on research; UNEP coordinates climatic impact studies, including the examination of food production vulnerability in climate-sensitive regions. This information will help us cope with climatic change.

We are collaborating with other international organizations, governments, and non-governmental organizations to bring together in a series of conferences and meetings the world's most distinguished experts and leading policy-makers to address the global warming issue. In 1985 the WMO-UNEP-ICSU Conference in Villach, Austria, developed—for the first time—a broad scientific consensus about anticipated global warming.

The Villach conference established the primary direction and guidelines for UNEP's efforts. It identified issues and provided recommendations for research needed to quantify the unknowns.

Science and Policy are Early Steps: The 1985 Villach conference recommended early dialogue between scientific and political communities on climate change. UNEP organized a policy-response study on regional vulnerabilities with the Beijer Institute of Sweden at a second conference held in Villach in 1987. Study results were presented to policy-makers at a meeting at Bellagio, Italy, later that year. These findings and options were fed into the June 1988 Canadian conference on "The Changing Atmosphere: Implications for Global Security." This conference was supported by UNEP and WMO and set forth findings and made proposals for certain lines of policy response to climate change.

The results of these meetings will provide important inputs to the Second World Climate Conference to be held at Geneva in June 1990 under WMO auspices, supported by other U.N. agencies. The 1990 conference will assess progress and outline further actions needed.

The Villach conference pointed out the need for greater understanding of regional climate change and policy considerations. UNEP is encouraging regional studies around the world. Some of these are being conducted by governments, including Canada's Great Lakes Study, a U.S. study, and a Dutch study of sea-level rise impact on society. UNEP supported the Netherlands European Workshop on interrelated bioclimatic and land-use changes in October 1987, which considered possible climate change impacts in Europe.

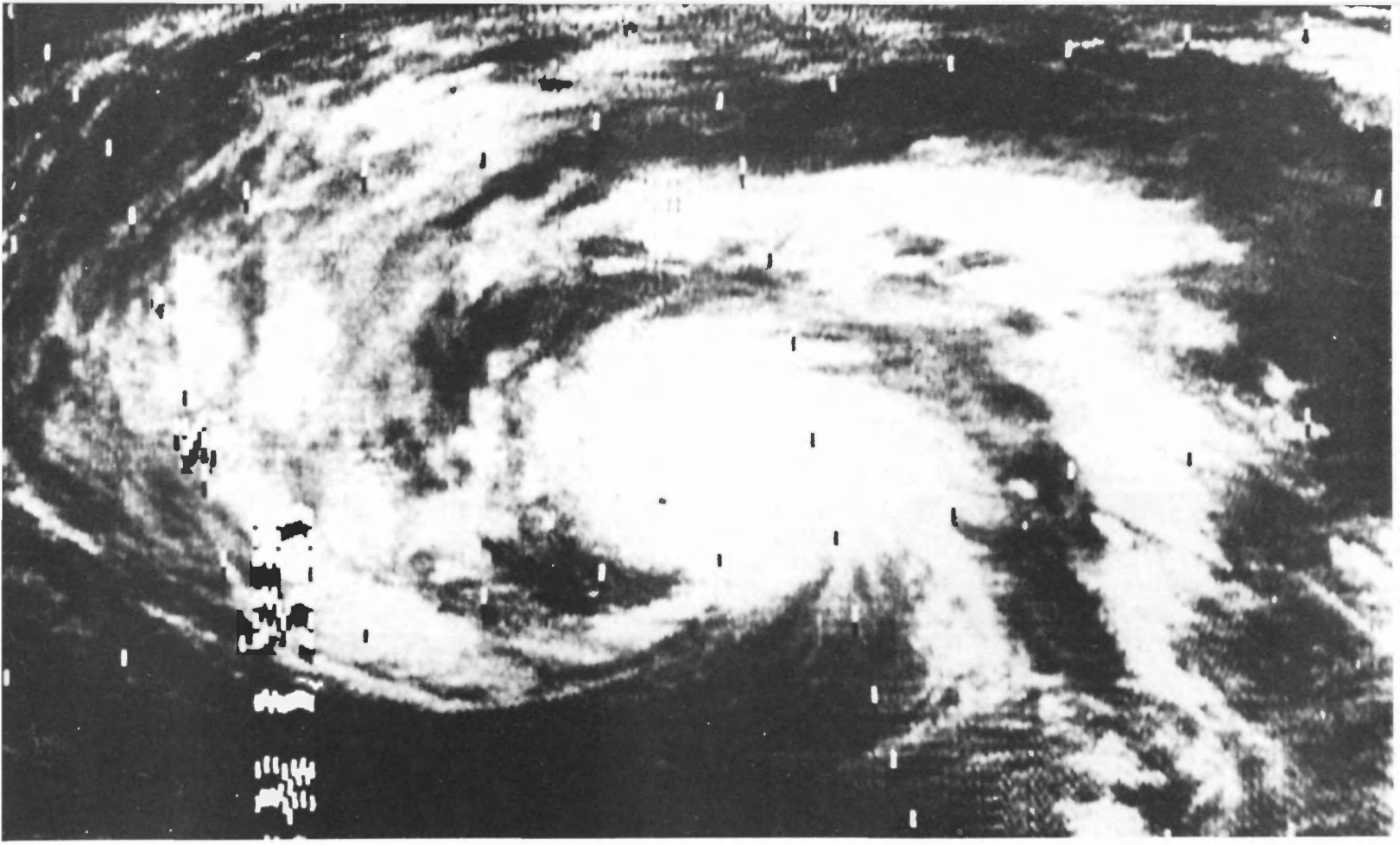
In the developing world, we have initiated regional studies in Southeast Asia, Latin America, and Africa. Using a variety of analytical methods, we are seeking to identify the environmental sectors susceptible to climate change, then to quantify possible impacts and develop an array of possible response options.

Likewise, we have commissioned studies on the climatic impacts associated with the Eastern Pacific Ocean's El Niño phenomenon and have published a study by the International Institute for Applied Systems Analysis (IIASA) in Vienna on research needs in agriculture, water resources, marine fisheries, and forest management; we have also commissioned studies on food production in cool, temperate, cold, and semi-arid zones.

Sea-Level Rise is Critical: Villach put the finger on the problem of sea-level rise. UNEP has commissioned a vulnerability analysis of global, coastal, delta, and estuarine regions susceptible to sea-level rise. Our Ocean and Coastal Areas Programme is conducting a climate change and sea-level impact study for each major global region. Programme leaders convened a conference at Split, Yugoslavia, from October 3 to 8, 1988, and issued a report on implications of climate changes in the Mediterranean, the Caribbean, the South-East Pacific, the South Pacific, the East Asian, and the South Asian Seas.

Under UNEP's international coordination role for information and research, we are establishing a network of the more active climate impact programs and facilitating communication and cooperation among them. As more countries conduct impact studies, the value of the network will increase.

To disseminate knowledge on climate change, we have published books and pamphlets, prepared audio-visual material and TV films, and sponsored training courses.



NASA photo

Putting International Institutions in Place: Beyond gathering and disseminating scientific information, it is also imperative to organize the institutions that can direct and coordinate international efforts to deal with climate change. In addition to the World Climate Programme's scientific work, the WMO-UNEP-ICSU Advisory Group on Greenhouse Gases has been set up to advise their executive heads on global warming issues. And because ozone-depleting trace gases affect global warming, the Coordinating Committee on the Ozone Layer, set up to provide scientific assessment on the ozone layer problem, also provides assessments related to warming—including the climatic consequences of changing quantities of CFCs and tropospheric ozone.

The next major organizational step (which parallels earlier action under the ozone convention) is to bring together, within a permanent framework, the appropriate governmental experts to consider climate change. In response to decisions of their governing bodies, UNEP and WMO have formed the Intergovernmental Panel on Climate Change (IPCC), which held its first meeting in Geneva November 9-11, 1988. The IPCC will be the major intergovernmental body addressing climate change. It is comprised of governmental experts on climate change, environment, and development planning from all regions of the world. It will regularly review scientific evidence, assess social and economic impacts, and evaluate national and international policy options to address the problem.

Together, we must prepare for anticipated change, be ready to take adaptive and limitation measures . . . and capitalize on whatever benefits are possible.

At the same time, U.N. agency heads are considering possible steps that would strengthen their own cooperation on measures to address global warming.

Continuing Action Needed: These actions represent only a modest, indeed humble, start in our effort to address the world's largest and most far-reaching environmental concern. Many additional steps will be needed. The precedent established in tackling the stratospheric ozone issue may well be a useful model for dealing with climate change. But climate change is an infinitely more complex issue to deal with.

These early actions can help the community of nations enter the 21st century less a victim of disturbed nature and more in a position to exert some control over the climatic change problem. Together, we must prepare for anticipated change, be ready to take adaptive and limitation measures such as reforestation and coastal defense construction, and capitalize on whatever benefits are possible.

The task ahead will be long and hard. It will involve each of us individually and our entire society, and we have barely begun. Nonetheless, the warming is a warning. And if we are to leave future generations a liveable world, we have little choice but to address climate change with all the energy, determination, and wisdom we have. UNEP and the U.N. system will be active partners in facing that challenge. □

(Mansfield is Deputy Executive Director of the United Nations Environment Programme. He was previously at EPA as Deputy Associate Administrator for International Activities (1983-86) and Director of Bilateral International Programs (1971-74).)

Strategic Implications

by William Nitze

AP/Wide World photo

Low-lying countries like Bangladesh already have flood problems. In September 1988, monsoon flooding caused rivers to overflow; about three-quarters of the country was inundated.

It is already fashionable to predict winners and losers from global climate change with statements such as "the grain belt will move north" or "the tropics will get more rain."

Global climate change may present mankind with its greatest environmental challenge to date. It appears more and more likely that increasing concentrations of carbon dioxide and other greenhouse gases in the atmosphere will cause average global temperatures to rise by 1.5^0 to 4.5^0 Centigrade within the next half century or so.

Existing global circulation models are not capable of predicting the magnitude and timing of this global warming with any degree of precision. They are even less capable of predicting the regional distribution of temperature change and its associated effects. The models appear to agree, however, that temperature changes will be greater in northern latitudes than at the equator, that sea levels will rise, and that some areas will receive significantly less rainfall than they do today—and some significantly more.

If global warming occurs within the time frame and temperature range roughly predicted and if these general predictions about its distribution and effects hold true, there will be strategic impacts on all nations and on every sector of human activity.

To assess these strategic impacts, one must look at the capacity of individual societies and the international system as a whole for "anticipatory response." By capacity for anticipatory response I mean a nation's ability to defer current consumption in order to strengthen its ability to minimize future adverse impacts, even when the nature and timing of those impacts is uncertain. This capacity depends more on the political, economic, and social characteristics of a nation than on its physical characteristics.

It is already fashionable to predict winners and losers from global climate change with statements such as "the grain belt will move north" or "the tropics will get more rain." Not only are these statements difficult to prove, given the current state of scientific knowledge, but they disregard relative capacities for anticipatory response. For example, the Netherlands and Bangladesh each face a similar problem with sea-level rise, yet there is little doubt that the former has a far greater capacity for anticipatory response than the latter.

From a purely physical perspective, a small island nation such as Japan has far less room to maneuver in responding to global warming than a huge continental nation such as the Soviet Union. But Japan would appear to have the greater capacity for anticipatory response if one takes other factors into account. In general, one can say that low population density, high per-capita income, and technological sophistication contribute to a nation's capacity for early, preventive response and that their opposites detract from it.

Another factor I see contributing to a nation's capacity for anticipatory response is the openness of its political system. At first blush it might appear that authoritarian states with command-and-control economies would have an easier time imposing changes in energy use, agricultural practices, and other resource uses to minimize and adapt to climate change. Experience indicates, however, that effective responses to long-term changes of this kind require a combination of market signals, development of new technologies, grass-root political support, and participation by non-governmental groups which is only possible in democratic societies.

The United States is an interesting case in point. As de Tocqueville pointed out more than 150 years ago, American democracy seems to have a short time horizon and has not always been successful in developing and carrying out long-term policies. At times of crisis, however, the American people have been able to marshal their creativity and other resources with great success. One can only hope that a growing public understanding of global climate change, combined with strong leadership at the national level, will enable us to make political decisions in the short term that will preserve our options in the long term.

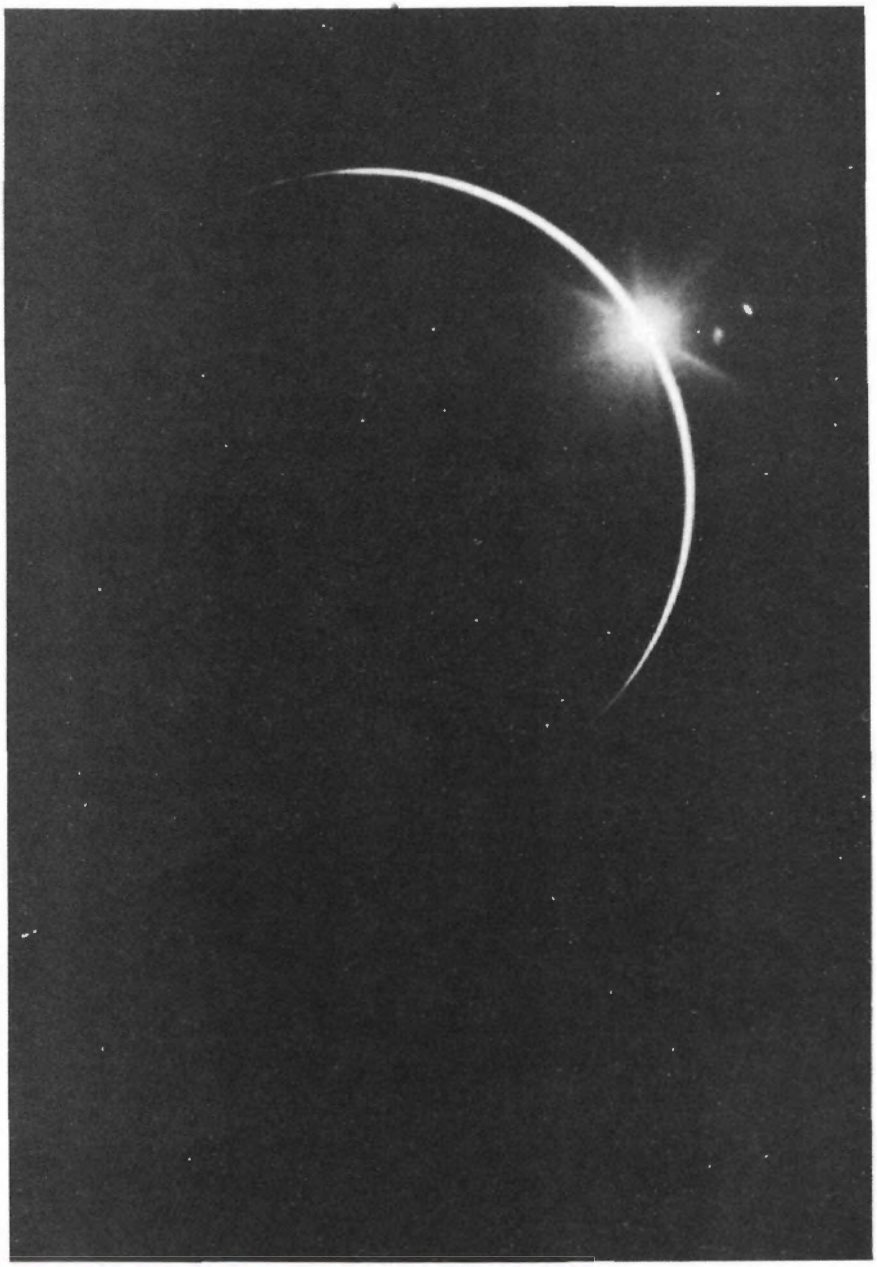
To assess the capacity for anticipatory response of any one nation, however, is to miss the crucial point. The cumulative impacts of manmade greenhouse gas emissions cannot be restricted to any one nation or region, but affect the atmosphere over the whole globe. No matter how well any one country does in minimizing greenhouse gas emissions or adapting to climate changes, it is at the mercy of its neighbors. Therefore, we must look to the international system as a whole and in particular to organizations such as the United Nations Environment Programme to develop international strategies to deal with climate change.

It is in the interest of all of us that our joint capacity for participatory response be developed and strengthened. In the end, one of the greatest benefits that may emerge from meeting the challenge of global climate change is international cooperation on an unprecedented scale. □

(Nitze is Deputy Assistant Secretary of State for Environment, Health, and Natural Resources.)

The Wheels Are Beginning to Turn

by Linda Fisher



A global perspective: the sun fades in eclipse behind the black disc of Earth as the Apollo 12 astronauts head for the second lunar landing mission. Global warming is a worldwide problem that will require unprecedented cooperation among all countries.

NASA photo

Global warming is an international problem that will require extensive and unprecedented cooperation among both developed and lesser developed countries. No single country, acting alone, will be able decisively to affect the global warming problem.

Moreover, within any one country, no single sector is entirely responsible for the problem. The transportation, industrial, commercial, and residential sectors all contribute to greenhouse gas emissions—just as many sectors of the economy may be affected by global warming. Thus no single policy initiative can effectively mitigate manmade climate change.

EPA is actively involved in both domestic and international activities related to global climate change. The Global Climate Protection Act of 1987 requires that the U.S. President, through EPA, "shall be responsible for developing and proposing to Congress a coordinated national policy on global climate change." The Act also requires the Secretary of State to pursue international cooperation on limiting global climate change. It requires the Secretary of State and the EPA Administrator jointly to submit, by the end of 1989, a report that will:

- Analyze current international scientific understanding of the Greenhouse Effect.
- Assess U.S. efforts to gain international cooperation in limiting global climate change.
- Describe a U.S. strategy for seeking further international cooperation to limit global climate change.

This is a very broad mandate that will require close cooperation with other federal agencies (including the Departments of Energy, Agriculture, and Interior, NASA, the Army Corps of Engineers, the National Climate Program Office, and the Domestic Policy Council. The Act encourages coordination of domestic and international climate activities with research and impact analyses that are consistent with policy goals.

EPA and other federal agencies are attempting to develop a process for designing a national policy that will respond to the global warming problem. Such a national policy must include options for adapting to climate change, and options for stabilizing the atmosphere and limiting emissions of greenhouse gases. It must reflect assessments of the feasibility of alternative technologies for stabilization and mitigation, and assessments of the costs of these technologies. EPA has already identified, for example, improvements in "end-use" efficiencies—cost-effective ways of reducing emissions of greenhouse gases. Such end-use efficiency options include making appliances, buildings, and transportation more energy-efficient, enhancing industrial competitiveness with energy-efficiency research, promoting least-cost utility services, and promoting international cooperation to encourage energy efficiency on a global basis. All of these considerations should be included in a national policy framework.

At the international level, several organizations have recognized the need for multilateral cooperation and have become involved with the global climate change issue. The United Nations Environment Programme (UNEP) is responsible for conducting climate impact assessments. The World Meteorological Organization (WMO) is supporting research and monitoring of atmospheric and physical sciences. The International Council of Scientific Unions (ICSU) is developing an international geosphere-biosphere program.

EPA is actively involved in many of these efforts. On the multilateral level, the Agency is working with the Department of State and other federal agencies to support UNEP and WMO in establishing an Intergovernmental Panel on Climate Change (IPCC). The panel is developing a vigorous international process to address global climate change issues. It is channeling efforts into three tracks: first, to assess the state of scientific knowledge on climate change; second, to assess the potential social and economic effects from a warming, and third, to assess potential response strategies.

Such a national policy must include options for adapting to climate change, and options for stabilizing the atmosphere and limiting emissions of greenhouse gases.

The first meeting of the IPCC was held in Geneva in November 1988. At this initial meeting, the IPCC established three working groups. The first work group, chaired by the United Kingdom, is responsible for the timely production of reports on the assessment of available scientific knowledge on climate change. Brazil and Senegal are vice chairs of this group. The second group, chaired by the U.S.S.R., will assess the environmental and socio-economic impacts of climate change. Australia and Japan are vice chairs of this second group. The third working group will formulate response strategies. This group is chaired by the United States, with Canada, China, Malta, the Netherlands, and Zimbabwe serving as vice chairs. Each working group is expected to deliver its final report to the IPCC by late 1990.

EPA also has bilateral relationships with the Soviet Union and China. Since 1972 the United States and the U.S.S.R. have been actively cooperating in the field of environmental protection and have conducted joint research on a wide variety of environmental issues. In 1987, EPA also signed a bilateral agreement with the Peoples' Republic of China, which included specific provisions on climate change. In general, these bilateral agreements provide an excellent opportunity to facilitate international cooperation and mutual understanding of the climate change issue.

The Agency has studied the effects of global warming for several years, and by Congressional request is currently producing two reports. The first report examines the policy options that, if implemented, would stabilize current levels of atmospheric greenhouse gas concentrations. The second report studies the health and environmental effects of climate change in the United States, including such issues as agriculture, forests, water resources, as well as other ecosystems and societal impacts.

EPA, along with other federal agencies, will continue to be an active participant in the formulation of a policy-oriented federal research agenda and in future debates over strategies to adapt to climate change or to limit emissions. The evolution of national policy in this area will be complex, and the formulation of a coordinated international response may take many years. Much work remains to be done by the research community to understand emissions, the interactions of emissions with the biosphere, and the ultimate effect on man and the environment of increasing greenhouse gas emission into the atmosphere. □

(Fisher is Assistant Administrator for EPA's Office of Policy, Planning, and Evaluation.)

Part of the Problem and Part of the Answer

by Sandra Postel

Over the last century—a mere instant of geologic time—the activities of the human species have caused unprecedented changes in the atmosphere. A continuing buildup of certain chemical compounds—most importantly, carbon dioxide (CO_2)—is propelling the environment towards [a] potentially catastrophic shift .... Fossil fuel combustion has spewed 150 to 190 billion tons of carbon into the air, and forest clearing for cropland and fuelwood has contributed an additional 90 to 180 billion tons ....

While some climatic change is inevitable, societies can gain precious time to adapt if action is taken now to dampen its ultimate magnitude and slow its pace. The first step requires curbing the use of fossil fuels, now the leading cause of the CO_2 buildup.

But there is another step crucial to restoring atmospheric balance: protecting our remaining forests and planting more trees. Forests and woodlands are vast storehouses of carbon, so clearing and burning them—as is now happening on a large scale in the tropics—contributes to CO_2-induced climate change. Because trees remove CO_2 from the air through photosynthesis, planting more of them can be part of the remedy. Therein lies an opportunity to capitalize on the enduring link between earthly life and the atmosphere—by reforesting the earth ....

The earth's trees, shrubs, and soils hold about two trillion tons of carbon, roughly triple the amount stored in the atmosphere. When vegetation is cleared and burned, or just left to decay, the carbon it contains, along with some of that in the underlying soil, is oxidized and released to join the atmospheric pool of CO_2.

Today the bulk of the CO_2 emitted from the land in this way comes from developing countries in the tropics. Each year, 28 million acres of tropical forest are destroyed through the combined action of land clearing for crop production, fuelwood gathering, and cattle ranching. Commercial timber harvesting degrades an additional 11 million acres. All told, an area of trees slightly larger than New York and Vermont combined is lost or logged each year.

There is another step crucial to restoring atmospheric balance: protecting our remaining forests and planting more trees.

Scientists have spent many years trying to pinpoint how much carbon is added to the atmosphere through forest clearing .... In a January 1988 *Science* magazine article, R. P. Detweiler and Charles Hall placed the amount of carbon released by tropical deforestation in 1980 somewhere between 0.4 and 1.6 billion tons. Another authoritative study, led by Richard Houghton, associate scientist at the Woods Hole Research Institute in Massachusetts, figured it to be between 0.9 and 2.5 billion tons. Since about 5 billion tons are emitted each year by fossil fuel burning, the midpoint of Houghton's estimate would attribute one-quarter of the total annual carbon buildup to deforestation.

Houghton and his colleagues ... estimate 40 percent [of these emissions] comes from tropical America, 37 percent from tropical Asia, and 23 percent from tropical Africa. Just five countries account for half of all carbon emissions: Brazil, Colombia, Indonesia, the Ivory Coast, and Thailand.

Brazil alone already contributes a fifth of the total, a figure likely to rise if deforestation in the Amazon continues. A recent study of satellite data by Brazil's Institute of Space Research suggests that 20 million acres of forest were cleared and burned in the Brazilian Amazon in 1987, some three times the annual rate of clearing that had been estimated for the early 1980s.

A worrisome twist to the forest/climate change link is how the world's remaining forests will behave in a warmer climate and an atmosphere richer in CO_2 ....

Higher CO_2 levels usually have a fertilizing effect on plants, spurring them to grow faster .... If trees did indeed grow faster as atmospheric CO_2 levels increased, they would remove carbon from the atmosphere more rapidly. This "negative feedback" would help slow the global warming. So far, unfortunately, no convincing evidence suggests that trees in their natural environments would respond this way ....

Another possibility results in positive feedback, a worsening of the warming trend. George Woodwell, director of the Woods Hole Research Institute, points out that as temperatures rise, trees and microorganisms in the soil substantially increase their rates of respiration .... The danger is that an increase in respiration because of rising temperatures could release more CO_2 to the atmosphere, reinforcing the very buildup that initiated the warming.

If respiration exceeded photosynthesis for an extended period of time, trees would stop growing altogether and

Forests and woodlands are vast storehouses of carbon; thus, the practice of clearing and burning them contributes to carbon dioxide-induced climate change. Here, a Panamanian forest has been cleared in preparation for crop planting. Photo is from the exhibit, "Tropical Rainforests: A Disappearing Treasure," organized and circulated by the Smithsonian Institution's Traveling Exhibition Service in cooperation with the World Wildlife Fund. The exhibit will travel to 14 U.S. cities through 1994.

ultimately die .... Woodwell maintains that a widespread forest die-off could release enormous amounts of carbon to the atmosphere—perhaps hundreds of billions of tons—depending on the speed of the warming. He warns that "the sudden destruction of forests by air pollution, now being experienced in northern and central Europe . . . is but a sample of the destruction that appears to be in store."

Woodwell's scenario might never come to pass. Ecologists do not yet agree on how forests will respond to a warmer climate, or even on whether that response will add CO_2 to the atmosphere or remove it. Some point out, for example, that higher temperatures would increase rates of organic decomposition, which in turn would release nutrients to the soil and thus potentially boost the productivity of trees. This could cause a helpful negative feedback: since trees would be growing faster, they would remove more CO_2 from the atmosphere, helping slow the warming.

How forests will actually respond looms large in the climate change picture, since the potential for a strong feedback—positive or negative—clearly exists.

Protecting forests and planting trees need to be high on the international agenda for several compelling reasons other than stabilizing the global carbon cycle. The growing wave of deforestation has left in its wake a severe energy crisis in the Third World (wood provides the primary source of energy for more than two-thirds of the people in developing countries), an accelerating loss of the earth's biological diversity, and large areas of degraded land ....

Countries are unlikely to invest substantial resources in tree planting solely to ward off global warming. But, in much of the Third World, satisfying fuelwood needs and restoring productivity to degraded ecosystems provide a sound—even urgent—rationale. Expanding forest cover for these purposes would yield the added bonus of slowing the buildup of CO_2, which gives industrial countries ample reason to step up support for tree planting in the Third World.

An analysis by the Worldwatch Institute suggests than an additional 320 million acres of trees—an area nearly twice the size of Texas—will be needed by the year 2000 to meet developing countries' growing demands for fuel and industrial wood products and to rehabilitate deteriorating ecosystems. What contribution could that much tree planting make to slowing the CO_2 buildup? Too many uncertainties exist to answer this question precisely, but some back-of-the-envelope calculations suggest . . . that [an effort of this sort] would cut net carbon releases from tropical forests by nearly half.

Carl Hansen photo Smithsonian Institution

A worrisome twist to the forest/climate change link is how the world's remaining forests will behave in a warmer climate and an atmosphere richer in CO_2 ....

Of course, slowing the destruction of existing forests is also crucial. Halving the CO_2 contribution from deforestation in Brazil, Indonesia, Colombia, and the Ivory Coast would reduce net carbon emissions from tropical forests by more than 20 percent. Together, that achievement and the carbon-storage benefits of 300 million acres of trees would cut releases from tropical forests by two-thirds. The total amount of carbon added to the atmosphere from all human activities—deforestation and fossil fuel combustion—would be cut by 17 percent.

According to Houghton and his colleagues, natural systems in Europe and possibly Japan and South Korea are already accumulating more carbon than they are releasing. Many European countries have in recent decades abandoned substantial areas of cropland and allowed forests to regrow .... Japan and South Korea have purposely planted large areas in trees. Japan now has the fourth largest area of commercial tree plantations in the world, nearly 24 million acres .... [South] Koreans planted an area in pines roughly equivalent to two-thirds of the area cultivated in rice, their staple food.

As a result of the Food Security Act of 1985, the United States could also turn some of its land into a carbon bank. The Act created the Conservation Reserve, under which farmers will take at least 40 million acres of highly erodible cropland out of production by 1990 and plant it in trees or grass. Each acre of recovered grassland or woodland will store roughly 16 more tons of carbon than when it was cultivated. Assuming the carbon accumulates at an average yearly rate of half a ton per acre as the land undergoes conversion, the reserve would absorb a total of 20 million tons of carbon annually for the next three decades, assuming the land remains in the reserve ....

Ken Andrasko photo.

This village girl in Nepal is tending seedlings. These tiny trees include 20 species to replant in deforested areas in the Himalaya Mountains. Tests are being conducted to see which types grow best in Nepal's high altitudes.

Can the community of nations plant trees on the scale required to improve prospects in the Third World and simultaneously help balance the global carbon cycle? There are reasons for optimism.

International development agencies now recognize that rural people form the only labor force large enough to plant trees on the vast scale that is needed. More than ever before, this labor force is being mobilized into action ....

International relief agencies, such as CARE in the United States and Oxfam in the United Kingdom, have orchestrated some of the most successful reforestation projects to date.

Worldwide, thousands of women's groups, peasant collectives, churches and other small, local organizations have taken up the cause of tree planting .... Kenya's Greenbelt Movement ... has enlisted ... more than 15,000 farmers and a half-million schoolchildren in setting up 670 community nurseries and planting more than two million trees ....

Chinese officials have set a goal of getting 20 percent of their country's territory in trees by the year 2000 .... Indian Prime Minister Rajiv Ghandi tripled funding for forestry in his development agenda for 1985-90, gave forestry new prominence within his ministries, and created a National Wastelands Development Board to spearhead a "people's movement" for reforestation ....

Reforestation's potential to help avert climate change barely gets mentioned in reports or plans that sketch out forestry's future. But as the consequences of global warming becoming clearer, and their magnitude and cost hit home, tree planting solely for the purpose of stabilizing climate could appear on the international agenda.

Environmental philosopher René Dubos pleaded for people to "think globally, act locally." Perhaps no activity harmonizes global interests and local needs better than does reforestation. Reforesting an area equal to twice the size of Texas by the year 2000 entails successfully establishing some 18.4 billion trees annually. That target sounds staggering, but it would only require each person now living in the Third World to plant and care for five seedlings a year.

A strategy of forest protection and tree planting cannot by itself ward off climatic change .... But curbing deforestation and planting trees will help our generation ensure that succeeding ones inherit a habitable earth. □

(Postel is vice president for research at Worldwatch Institute. This article is an excerpt adapted from her article entitled "A Green Fix to the Global Warm-up," published in World Watch *magazine (Vol. 1, No. 5; September-October 1988).)*

Can the Human Race Be Saved?

by Gus Speth

Today, in the last years of the 20th Century, pollution is occurring on a vast and unprecedented scale around the globe.

Rudi Frey photo Time *magazine*

Facing nature: dozens of giant gates, shaped like empty steel boxes, will be installed in the three shipping canals that connect the Venice Lagoon with the Adriatic Sea. When no storms threaten, the boxes will be filled with water and hinged to a concrete foundation buried in the lagoon bed so shipping can proceed. Here, the first gate of the "Moses Project" is towed out to sea.

In an amusing scene in a recent popular movie, the intrepid Captain Kirk awakes from the sleep of the time traveller and, gazing out, sees that his starship is, as hoped, orbiting Earth. "Earth!" he says, "but when?" To which the genetically unflappable Spock, checking his instrument panel, replies, "Judging from the pollution content of the atmosphere, I believe we have arrived at the latter half of the 20th Century." And indeed they had. And so have we. And there is plenty of pollution here to measure.

Today, in the last years of the 20th Century, pollution is occurring on a vast and unprecedented scale around the globe. Trends since World War II have been in two directions: first, toward large releases of certain chemicals, principally from using fossil fuels that are now significantly altering natural systems on a global scale and, second, toward steady increases in the release of innumerable biocidal products and toxic substances. These shifts from the "sewage and soot" concerns of the pre-war period to vastly more serious concerns pose formidable challenges for societies—challenges that today's pollution control laws just begin to address.

The dramatic changes in pollution in this century are best described in terms of four long-term trends.

First is the trend from modest quantities to huge quantities. The 20th Century has witnessed unprecedented growth in human population and economic activity. World population has increased more than threefold; gross world product by perhaps twentyfold; and fossil fuel use by more than tenfold.

Second is the trend from gross insults to microtoxicity, from natural products to synthetic ones. Paralleling the dramatic growth in the volume of older pollutants, such as sulfur dioxide, has been the introduction in the post-World War II period of new synthetic chemicals and radioactive substances, many of which are highly toxic even in minute quantities and some of which persist and accumulate in biological systems or in the atmosphere.

Third is the trend from First World to Third World. A myth easily exploded by a visit to many developing countries is that pollution is predominantly a problem of the highly industrialized countries. While it is true that the industrial countries account for the bulk of the pollutants produced today, pollution is a grave problem in developing countries, and many of the most alarming examples of its consequences can be found there.

These first three trends combine, with others, to produce the fourth, the trend from local effects to global effects. When the volumes of pollution were much smaller and the pollutants similar to natural substances, impacts tended to be confined to limited geographic areas near sources. Today, the scale and intensity of pollution make its consequences truly global.

Nothing better illustrates this broadening of the concern about pollution from a local affair to a global one than air pollution. Local air pollution is improving in some cities in industrial countries, but it is worsening in others, principally in developing countries, and is hardly solved anywhere. Meanwhile, global use of fossil fuels, and emissions of traditional pollutants such as sulfur and nitrogen oxides that result from it, continue to climb. Acid rain, ozone, and other consequences of these pollutants are affecting plant and animal life—killing forests and fish, damaging crops, changing the species composition of ecosystems—over vast areas of the globe. Depletion of the stratosphere's ozone layer is a matter of such concern that an international treaty has been negotiated to reduce emissions of chlorofluorocarbons (CFCs), but the latest measurements indicate the current protocol is already inadequate. And, probably most serious of all, the buildup of infra-red trapping greenhouse gases in the atmosphere

continues. This buildup is largely a consequence of the use of fossil fuels and CFCs, deforestation, and various agricultural activities, and it now threatens societies with far-reaching climate change.

These interrelated atmospheric issues probably constitute the most serious pollution threat in history. I say "interrelated" because these atmospheric issues are linked in ways that scientists are still discovering, and the scientists are far ahead of our policymakers. First, they are linked in time. The view is still common today that, initially, we should address local air pollution, then we should turn attention to regional issues like acid rain, and then, at some point in the future, we should address the global issue of greenhouse gases. But the failures of our clean air efforts make urban air quality an issue for today, forcing a 1970s issue from the past into the present. Simultaneously, the realizations that greenhouse gases other than carbon dioxide (CO_2) double the urgency of the problem, and that societies may have *already* committed the planet to a 1^0 to 2.5^0 C global average warming—these realizations are forcing what was thought to be a "21st-Century issue" into the present.

When we take all these challenges together, we see that we are witnessing nothing less than the emergence of a new environmental agenda.

These atmospheric issues are also linked in the vast chemical reactor that is the atmosphere, where pollutants react with each other, other substances, and solar energy in a fiendishly complex set of circular interactions. Touch one problem, you may touch them all.

Third, they are linked in their effects on people and on the biota. What are the consequences of multiple stresses—a variety of pollutants, heat waves and climate changes, increased ultraviolet radiation—when realized together? Who knows? We are still learning.

And these atmospheric issues are linked through the sources of the pollutants involved. CFCs, for example, contribute both to greenhouse warming and ozone layer destruction, but the dominant source of these problems is the use of fossil fuels.

In short, the *time* to address all these atmosphere problems—local, regional, global—is *now*. *The way* to address all these problems is *together*. And, in the long run, the *key* to these problems is *energy*.

What can we say about the U.S. role in causing these atmospheric problems? We should take pride in what has been accomplished to date under the Clean Air Act and various U.S. energy laws. But let's not overdo it. The United States still produces about 15 percent of the world's sulfur dioxide emissions, about 25 percent of NO_x, 25 percent of the CO_2, and we manufacture about 30 percent of the CFCs. While emissions of criteria air pollutants other than NO_x have fallen over the last 15 years, a period during which real GNP grew about 50 percent, emissions today still exceed two-thirds of 1970 amounts, particulates excepted. In other words, the bulk of the pollution that gave rise to the Clean Air Act in 1970 continues. Similarly, real strides have been made in increasing U.S. energy efficiency: between 1973 and 1985, per capita energy use in the United States fell 12 percent while per capita gross domestic product rose 17 percent. Still, the United States today remains a gas guzzler of a nation, consuming a fourth of the world's energy annually and producing only half the GNP per unit of energy input as countries such as West Germany, Brazil, France, Japan, and Sweden.

Beyond these atmospheric issues are other pollution concerns, and beyond them the challenge of the planet's biological degradation—deforestation, desertification, the loss of biodiversity—in short, the steady process of biological impoverishment. When we take all these challenges together, we see that we are witnessing nothing less than the emergence of a new environmental agenda. This new agenda encompasses the great life-support systems of the planet's biosphere. It is global in scope and international in implication. It is rapidly forcing itself on the attention of policymakers and the public at large.

In the early 1970s the CBS Evening News with Walter Cronkite ran a series of environmental stories entitled "Can The World Be Saved?" I remember the globe behind this title was firmly grasped by a hand which seemed to come from nowhere. I was never sure whether this hand was crushing our small planet or saving it, but I was sure at least that Cronkite was out to save it. He dramatically presented the much simpler environmental problems of that period to a huge audience, and helped build the powerful environmental consciousness of the day. Today, the question "Can The World Be Saved?" is a much more serious and legitimate question than it was then.

People everywhere are offended by pollution. They sense intuitively that we have pressed beyond limits we should not have exceeded.

Societies near and far have set two long-term goals for themselves: improving environmental quality, in part by reducing current pollution levels, and achieving a virtual order of magnitude increase in economic activity. Let us not deceive ourselves, or accept blithely the assurances of political leaders who say casually that we can have both. We know from sad experience that we can have economic growth without having environmental protection. But the stakes on the environmental side are much higher now, and they will be one of the dominant challenges facing leaders on all continents in the 1990s and beyond.

AP/Wide World photo

Santa Barbara's 1969 oil spill helped raise the public's consciousness about pollution problems. Concern for a safe, decent environment is now global.

It will need constant attention at the highest levels of government. It will require strong, effective, smart government.

Environmentalism began on the outside, on the periphery of the economy, saving a bit of landscape here, bottling up some pollution there. It will inevitably spread as creed and code to permeate to the core of the economies of the world. We will all be environmentalists soon.

If these are the challenges before us, what should be done? Let's rephrase Cronkite's question into a somewhat more answerable one: *how* can the world be saved? Certainly, we must strengthen the efforts already begun. The regulatory programs of the industrial countries have yielded definite results over the last two decades, and continuing challenges will require that these programs be enhanced. Monitoring and enforcement capabilities must be strengthened; new types and sources of pollution must be tackled; inter-media effects must be attended to; regional and global approaches to pollution control must become increasingly common; and the overall regulatory process must become more cost-effective, efficient, and streamlined. And much, much more attention needs to be paid to the pollution problems of the developing countries. They can learn from our successes and failures, and pioneer new development paths rather than repeat old ones.

One might say that only technology can save us. That is a hard thing for a congenital Luddite like myself to say. In a small victory of nurture over nature, I do now believe it. I do not diminish the importance of life-style changes—some go hand-in-hand with technological change—and I await the spread of more voluntary simplicity in our rich society.

But growth has its imperatives; for much of the world it is the imperative of meeting basic human needs. And, we must not forget it is sustainable economic development—growth that takes the pressure of mass poverty off an eroding resource base—that is an essential component of environmental progress worldwide.

To guide and speed the application of solution-oriented technologies will require policy action in the form of both economic incentives and direct regulation. It will require institutional innovation and concerted action at the national and international level. Today, the problems are coming faster than the solutions. We will need a new international law to reflect the environmental concerns in our trade and other international economic relations.

If we and other countries are to meet our economic and environmental challenges, what energy paths should we take? The coming energy transformation, I would argue, must have rapid energy efficiency improvements as its dominant feature, supplemented by increased reliance on renewable energy sources. The potential for energy efficiency gains through technological change is simply enormous. If the efficiency in energy use current in Japan today could be matched in the United States and around the world, total economic output could be doubled globally, and virtually doubled in the United States, without increasing energy use.

Politicians around the globe are increasingly hearing the demand that things be set right. And that is very good news indeed.

Auto efficiency provides a good example of what is possible. Miles per gallon achieved by new cars sold in the United States doubled from 13 mpg to 25 mpg between 1973 and 1985. Ford, Honda, and Suzuki all have cars in production that could double this again to 50 mpg, and Toyota has a prototype family car that could double efficiency again to almost 100 mpg. I am reminded here that there is a huge role for the private sector in the coming technological transformation. Those companies that see the future can profit from it.

In such a low-energy, high-efficiency future, the great energy supply debates, such as coal vs. nuclear, which preoccupy us so, lose much of their significance, and pollution problems are knocked down to more manageable proportions.

Large energy efficiency gains, and the consequent reductions in CO_2 emissions, will be essential in addressing what is probably the most serious environmental challenge of all: the global warming, which seems already to have begun. I recognize the uncertainties remaining in characterizing the Greenhouse Effect, but given the risks, I would advocate consideration now of a series of international conventions responsive to the various aspects of the problem.

First, we need to secure swift international approval for the ozone layer protection protocol signed in Montreal last year. We need this for its own sake and to continue the momentum that can get the nations of the world back to the table so that a complete, swift phase-out of CFCs can be negotiated. The phase-out is fully justified on ozone layer grounds alone, but the fact is that a CFC phase-out is the fastest and cheapest way societies can do something major to contain the Greenhouse Effect.

Second, we need an overall global climate protection convention, the prime goal of which should be to stabilize atmospheric concentrations of greenhouse gases at safe levels. This convention should focus particularly on steps needed to secure reductions in CO_2 emissions from fossil fuel use. Two facts stand out in this regard: the United States and the Soviet Union together account for almost half of global CO_2 emissions today, and the United States, the Soviet Union, and China together account for about 90 percent of the estimated coal reserves.

Third, the time is ripe for an international agreement to protect the world's tropical forests and to reforest the spreading wasteland areas in many developing countries. The industrial nations have a double stake in halting the now rapid clearing of the tropical forests. Not only are these forests repositories for about half of the wildlife and genetic wealth of the planet, but CO_2 emissions from biotic sources such as deforestation are estimated to be about a fifth of CO_2 emissions from fossil fuels. Our stake in the salvation of these forests is sufficiently large that we should be more than willing to help provide financial incentives—incentives that will be necessary if countries of the tropics are to turn their attention to what often appears to be a low priority or even a threat to development and sovereignty. I suggest that we go far beyond the debt-for-nature swaps under way today and consider a global bargain as part of this international convention. This bargain would involve the easing and forgiving of international debts in exchange for forest conservation. Of the top 17 most heavily indebted countries, 12 are destroying their tropical forests at extraordinarily rapid rates, contributing to the world's annual loss of 27 million acres.

To guide and speed the application of solution-oriented technologies will require policy action in the form of both economic incentives and direct regulation.

And fourth, we need international agreement on the protocol now being developed to limit NO_x emissions. Unless capped, increasing NO_x emissions will lead to increasing ozone concentrations, and ozone is a greenhouse gas as well as a source of urban and rural air pollution.

My concern about nuclear power, as things stand today, is that it probably will not, in the end, provide a major part of the answer to global warming. Its public acceptability is too low and its price is too high. If we try to solve the greenhouse problem by cramming nuclear power down the throats of an unwilling public and unwilling investors, we will be setting the stage for prolonged confrontation and stalemate. Moreover, I believe there are safer and cheaper alternatives for the short run, including the vast potential for efficiency gains in how we generate and use electricity.

In all these areas, in seeking these treaties and in setting an international example by acting on our own, U.S. leadership and EPA leadership could not be more important. The world is not exactly waiting on our leadership, but neither will it get very far without us.

Let me conclude with a word about why I am optimistic that the world can indeed be saved. This address, you have doubtless noted, reflects a deep appreciation of the importance of economic and technological forces in the modern world. One reason for optimism is that science and technology are presenting us with answers. We are in the midst of a revolution in earth science and a revolution in industrial and agricultural technology, both with huge potentials in the areas we have been reviewing.

But if solutions are found, they will come from another realm as well, from the hopes and fears of people, from their aspirations for their children and their wonder at the natural world, from their own self-respect and their dogged insistence that some things that seem very wrong are just that. People everywhere are offended by pollution. They sense intuitively that we have pressed beyond limits we should not have exceeded. They want to clean up the world, make it a better place, be good trustees of the Earth for future generations. With Thoreau, they know that heaven is under our feet as well as over our heads. Politicians around the globe are increasingly hearing the demand that things be set right. And that is very good news indeed. □

(Speth is President of the World Resources Institute. This article is an excerpt from a speech Speth gave at EPA in June 1988.)

Appointments

Erich W. Bretthauer

Louise P. Wise

Glenn L. Unterberger

Craig B. Annear

Michael M. Stahl

Erich W. Bretthauer has been appointed Acting Assistant Administrator for Research and Development, succeeding Vaun A. Newill. Bretthauer had been Acting Deputy Assistant Administrator since September 1987.

A commissioned officer in the U.S. Public Health Service, Bretthauer began his government career in the Southwestern Radiological Health Service Laboratory, then a U.S. Public Health Service laboratory in Las Vegas, Nevada, in 1962, after obtaining his Master of Science degree in Chemistry from the University of Nevada-Reno.

He held progressively senior positions at the Laboratory, primarily in the areas of analytical chemistry and environmental monitoring. In 1979, he directed the EPA's emergency radiological monitoring program after the accident at Three Mile Island. After completing a Congressional Fellowship to the U.S. Senate Committee on Environment and Public Works in 1982, he was named Director of the Office of Environmental Processes and Effects Research in Washington. In 1985, he returned to Las Vegas as Director of the Environmental Monitoring Systems Laboratory.

Louise P. Wise has been appointed Deputy Director in the Office of Marine and Estuarine Protection. Prior to joining the Office of Water in October 1988, she was a special assistant to the Administrator for RCRA and Superfund issues.

Wise joined the EPA in 1984. Before coming to the Agency she was a law clerk in the office of Federal District Court Judge John H. Pratt and practiced law for several years with the law firm of McKenna, Conner and Cuneo.

At EPA, Wise has been RCRA attorney advisor in the Office of General Counsel, a program analyst in the Office of the Assistant Administrator for Solid Waste and Emergency Response, Director of the Policy and Standards Division in the Office of Underground Storage Tanks, as well as holding her most recent post in the Administrator's office.

She is the author of numerous environmental publications and a frequent lecturer, and has earned two EPA Gold Medals for Exceptional Service. She earned her Doctor of Jurisprudence from the Georgetown University Law Center and a bachelor's degree from Vanderbilt University.

Glenn L. Unterberger is the new Associate Enforcement Counsel for Waste in the Office of Enforcement and Compliance Monitoring. The 11-year EPA veteran joined the Agency as a law clerk for the Assistant Administrator for Enforcement after earning his Doctorate in Jurisprudence at the Georgetown University Law Center in 1977.

Unterberger advanced to general attorney the following year. Subsequently, he held supervisory attorney and advisory attorney positions in the Office of the AA for Enforcement, the Mobile Source Enforcement Division, and as branch chief and then director of the Office of Legal Enforcement Policy before becoming Associate Enforcement Counsel in November 1984. In the fall of 1988 he advanced to his present position.

He earned his Bachelor of Arts degree at the University of Pennsylvania and is the recipient of EPA Gold and Bronze Medals for Exceptional Service.

Craig B. Annear has been named Associate General Counsel for Grants, Contracts, and General Law in the Office of General Counsel (OGC).

A veteran federal attorney, Annear joined the government in 1973 as a lawyer with the Federal Trade Commission. In mid-1975 he became an Attorney-Advisor in the Department of Housing and Urban Development. He moved to the Federal Emergency Management Agency four years later as an Associate General Counsel serving there until October 1983. For two months in 1983 he was detailed to EPA as a Special Assistant to the Acting Deputy Administrator and the Acting Assistant Administrator for Solid Waste and Emergency Response.

Upon joining EPA permanently later that year, Annear became Associate General Counsel in the Inspector General Division of OGC. He graduated from Cornell University with a bachelor's degree in Government, and earned his law degree from the University of Michigan Law School.

Michael M. Stahl has been named Director of the TSCA Assistance Office (TAO) in the Office of Toxic Substances (OTS). He had been Acting Director since February 1988. TAO is responsible for public liaison and technical assistance efforts for EPA's toxic substances programs.

Stahl joined the federal government in mid-1980 as a Presidential Management Intern, after serving as a Research Assistant in the Office of the Missouri State Senate Majority Floor Leader. He began his federal career at the Consumer Product Safety Commission, where he served as a Special Assistant to the Executive Director. In 1983 he moved to EPA's Office of Administration and then to EPA's Office of Human Resources Management.

Stahl has worked in EPA's Asbestos in Schools program since 1984. He was responsible for implementation of the Asbestos School Hazard Abatement Act of 1984 and the Asbestos Hazard Emergency Response Act of 1986. He was appointed Acting Director of the Asbestos Action Program in November 1986, and was named Chief of the Hazard Abatement Assistance Branch when the asbestos program was moved to OTS in May of 1987. He has received EPA Bronze and Gold Medals for his work in the asbestos program.

Stahl is a graduate of the University of Missouri where he earned a Master of Public Administration degree in May 1980. □

Update

A review of recent major EPA activities and developments in the pollution control program areas

AIR

EPA, CSPC Publish Indoor Air Quality Guide

EPA, in conjunction with the Consumer Product Safety Commission, has issued *The Inside Story, a Guide to Indoor Air Quality*. Intended for homeowners and renters, the guide is filled with the latest scientific information about sources of indoor air pollution, the health risks it poses, and what steps the homeowner or apartment dweller can take to minimize or eliminate pollution sources.

The Agency has also published a *Directory of State Indoor Air Contacts*. Copies of the publications are available from EPA Regional Offices or the Public Information Center, EPA, Washington, DC 20460.

New CFC, Halon Production Limits

New EPA Clean Air Act regulations limiting domestic production and use of ozone-depleting chlorofluorocarbons (CFCs) and halons fulfill the U.S. commitment under the Montreal Protocol which went into effect January 1, 1989. The rule allocates quotas to firms that produced or consumed CFCs and halons in 1986, freezing manufacturing and consumption at 1986 levels, with further reductions to come in 1993 and 1998. Halon levels are also limited.

U.S. Agrees To International Nitrogen Oxide Protocol

EPA Administrator Lee M. Thomas, representing the United States, signed the Nitrogen Oxides Protocol in Sophia, Bulgaria. The Protocol provides for a freeze on NO emissions, technology-based standards for new sources, and research on a long-term strategy that may establish future control levels.

National Radon Advisory

U.S. Public Health Service Assistant Surgeon General Vernon J. Houk and EPA Administrator Lee M. Thomas have issued a national advisory urging the testing of most American homes for the presence of radon. EPA estimates that over 3 million houses in 17 states tested so far have radon levels above Agency guidance levels, and recommends that families living in detached houses, mobile homes with permanent foundations, or in basement or first-floor apartments or townhouses or row houses should have the radon testing done.

EMERGENCY RESPONSE

National Incident Coordination Team

The Office of Solid Waste has established a high-level intra-Agency National Incident Coordination Team (NICT) to coordinate Agency-wide involvement in major environmental disaster situations. The team is composed of representatives of all Assistant, Associate, and Regional Administrators.

Its primary goal is to enhance EPA's capability to deal with issues and situations which historically go beyond existing emergency response mechanisms. Incidents which would activate the team will require the awareness and cooperation of Agency staff at all levels. Anyone with needed expertise can be called upon to support the activities involved, with NICT providing coordination and support and assisting the Agency as it works with other federal and state agencies to deal with extraordinary situations.

WATER

Underground Storage Tanks

EPA has issued comprehensive and stringent requirements for nearly two million underground storage tanks, half of which are used for gasoline at service stations. The new rules require owners and operators of such tanks containing petroleum products or certain hazardous chemicals to notify authorities when a leak occurs and to clean up the contamination. Financial standards will be announced requiring maintenance of an ability to handle a cleanup and compensate third parties for damages. Proper installation certification is also required.

RECENT FEDERAL LEGISLATION

Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) Amendments of 1988 strengthen EPA's authority in several major areas. The amendments require a substantial acceleration of the pesticide reregistration process and authorize collection of fees to support reregistration activities. They also change EPA's responsibilities and funding requirements for the storage and disposal of suspended and cancelled pesticides and the indemnification of holders of remaining stocks of such pesticides. Criminal penalties are increased for registrants, applicants for registration, or other pesticide producers who knowingly violate the pesticide law; submission of false test data, violating suspension or cancellation orders, and failure to submit required records or allow inspection are unlawful.

Lead Contamination Control Act of 1988 amends the Safe Drinking Water Act to deal with the recall of lead-lined drinking water coolers. EPA is required to publish a list of all brands and models which are not lead-free or which have lead-lined tanks. Manufacture and sale of such products in interstate commerce is forbidden, and the Consumer Product Safety Commission is required to order manufacturers and importers of such coolers to repair, replace, or recall them and to provide a refund for the coolers within one year after enactment.

Asbestos Information Act of 1988 requires asbestos product manufacturers to submit to EPA information on the types or classes of products, the years of manufacture, and other information identifying the characteristics of their asbestos-containing products. EPA must publish the information. The law is intended to facilitate early identification of manufacturers or processors of particular types of asbestos or asbestos-containing products to help reduce the time and costs involved in naming parties as defendants in asbestos-related litigation.

Ocean Dumping Ban Act of 1988 prohibits all municipal sewage sludge and industrial waste dumping into the ocean after December 31, 1991. The law also requires permits for dumping and a plan for terminating dumping, beginning 270 days after enactment. Other provisions include a ban on disposal of potentially infectious medical waste into ocean waters by a "public vessel"; listing of Massachusetts Bay, Barataria-Terrebone Estuary Complex, Louisiana, Indian River Lagoon, Florida, and Peconic Bay, New York, for priority consideration for inclusion in the National Estuary Program; and, under the Shore Protection Act of 1988, a prohibition against transportation of municipal or commercial waste within coastal waters by a vessel without a permit and adequate identification.□

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