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The Greenhouse Effect: What Can We Do About It?

The Greenhouse Effect: What Can We Do About It?

What can we do about the Greenhouse Effect? What *should* we do about it? This issue of *EPA Journal* explores these questions and in doing so covers major aspects of the subject and touches on a diversity of viewpoints.

After an introductory piece, an article explains the science of the Greenhouse Effect and discusses what we know and what we don't yet understand about it. Then a piece explains the Greenhouse gases—what they are, where they come from, trends in their output, and their impact.

The next section focuses on ways in which the United States might try to curb its output of the Greenhouse gases and thus limit climate warming. Included are pieces on energy conservation, reforestation, renewable energy, methane reduction, and increased efficiency in transportation. Another policy option—nuclear power—is presented in a forum that airs differing opinions.

Next is an article on another possible approach: adapting our economies and living styles to global warming as it may occur.

Then William K. Reilly, EPA's Administrator, presents what he believes would be a constructive course of action regarding the climate-warming issue.

An international forum follows, with commentaries by representatives of six nations on how they feel about the Greenhouse issue and what should be done about it. The countries represented are Poland, Brazil, West Germany, the Netherlands, Japan, and India.

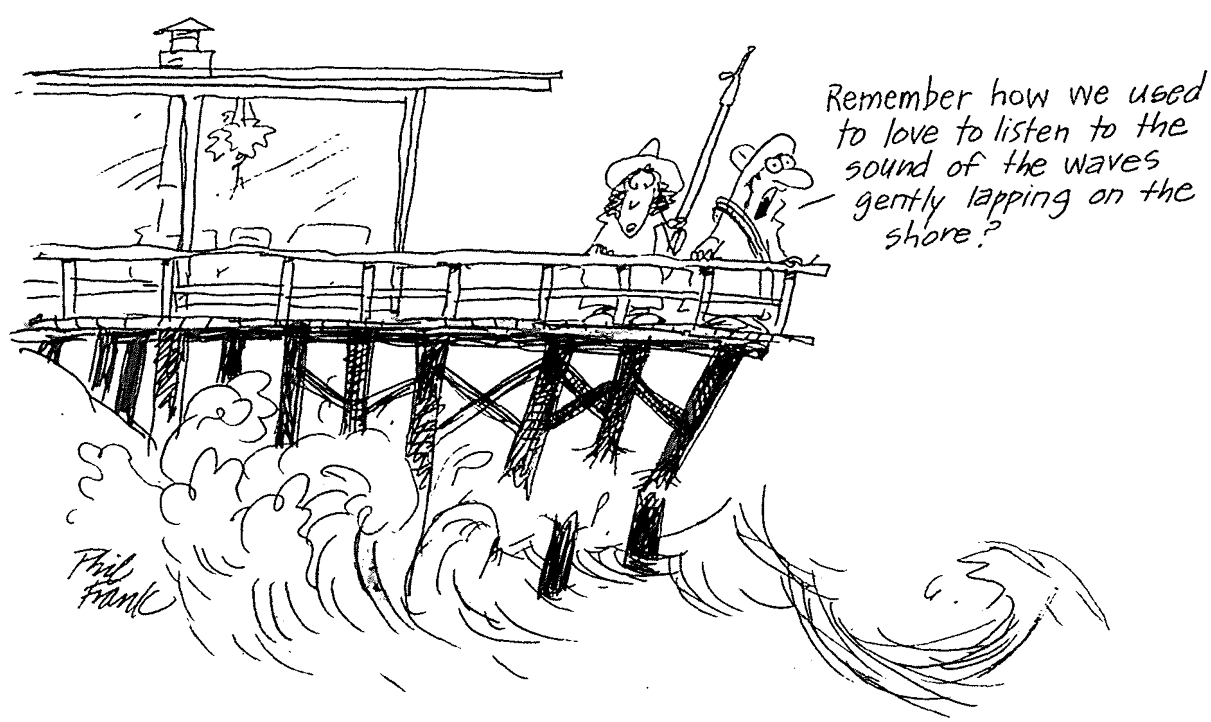
Then a feature explores the lessons the world community has learned in dealing with its problems with stratospheric ozone—"the ozone hole"—that could apply as nations address the issue of climate warming. Another article discusses the concern about global warming from a cost-and-benefit point of view, weighing the potential gain to society from certain levels of effort to control Greenhouse gases.

The skeptical viewpoint—doubting the likelihood of climate warming—is presented by a scientist from the Massachusetts Institute of Technology. And two industry viewpoints are included, one by a large oil firm expressing its concerns about the potential costs and unresolved scientific questions involved in the climate-warming issue and one by a multinational electronics company which is drastically cutting its use of chlorofluorocarbons (CFCs), a Greenhouse gas and a major factor in the depletion of upper-level ozone.

Two complementary articles discuss the particular problems and needs of the developing world in regard to the Greenhouse Effect. The first addresses the realities of developing countries' economies and the nature of these nations' environmental problems. The second explains how Western know-how can help these countries achieve their aspirations for a good living standard while minimizing environmental impacts.

This portion of the issue concludes with excerpts from a speech by British Prime Minister Margaret Thatcher to the U.N. General Assembly on the challenge to humanity of the Greenhouse Effect and other environmental problems.

The magazine concludes with a regular feature, Appointments, and a recent letter to the editor. □



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Front cover: A renewable, non-polluting source of energy, these wind turbines in California's Altamont Pass generate power for the Pacific Gas and Electric Company. See article on page 20. Photo by U.S. Wind Power, Inc.

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An Introduction

by Terry Davies

Mike Brisson photo

Since the beginning of the industrial revolution some 200 years ago, machinery and fossil fuels have saved inestimable amounts of time and labor while substantially raising the standard of living around the world. It is perhaps ironic that the same technology that has raised our standard of living could change the planet's climate and threaten its future.

Global warming must be considered on an entirely different scale from that of most other environmental issues.

The threat of global warming now forces us to evaluate carefully how important our environment is to us. It forces us to consider what sacrifices we are willing to make to ensure an acceptable quality of environment for the future.

As an environmental problem, global warming must be considered on an entirely different scale from that of most other environmental issues: The effects of climate change are long-term, global in magnitude, and largely irreversible. Because of the enormity of the problem and the uncertainties involved—it may take decades to determine with absolute certainty that global warming is under way—we face difficult questions today about how and when we should react.

(Davies is EPA's Assistant Administrator for Policy, Planning, and Evaluation.)

Before the turn of the century, scientists began worrying that fossil-fuel emissions were changing the composition of the atmosphere. In 1896, the Swedish chemist Svante Arrhennius, using a simple model, estimated that if the atmospheric concentration of carbon dioxide (CO_2) doubled, the Earth's surface would warm by approximately 5 °Celsius. Today, we realize that his estimate and concern for the environment may not have been very far off the mark.

A consensus has emerged in the scientific community that a global warming will occur. Scientists are certain that the concentrations of CO_2 and other Greenhouse gases in the atmosphere are increasing, and they generally agree that these gases will warm the Earth. Two questions remain to be answered: *how much* the temperature will rise, and *when.*

Recent estimates indicate that if the concentrations of these gases in the atmosphere continue to increase (see article on p. 8), the Earth's average temperature could rise by as much as 1.5 to 4.5 °C in the next century. While this may not sound like a tremendous increase, keep in mind that during the last ice age 18,000 years ago, when glaciers covered much of North America, the Earth's average temperature was only 5 °C cooler than today.

Fossil-fuel burning and forestry and agricultural practices are responsible for most of the man-made contributions to the gases in the atmosphere that act like a greenhouse to raise the Earth's temperature: hence the term Greenhouse Effect. Most of the processes that produce Greenhouse gases are common everyday activities such as driving cars, generating electricity from fossil fuels, using fertilizers, and using wood-burning stoves. Because so many of these activities are so ingrained in our society, reducing emissions could be a difficult task.

Environmentally, the potential effects of climate change are extensive. The Earth's ecosystems, water resources, and air quality could all experience profound impacts; agriculture and forestry could be seriously affected. Politically, global climate change has the potential to become a very sensitive issue among countries if nations cannot agree on a comprehensive solution—and if climate change shifts the relative advantages among them.

And now that the search for solutions has begun, there is a growing concern that the costs of reducing emissions may be too high. But to put cost concerns in proper perspective, we must ask ourselves what kind of future we want on this planet and how much we value our environment and cultural heritage.

The climate and the human race: A relationship of growing concern.

In light of the prospect of global warming, we must begin considering how important certain parts of the environment are: How important are wetlands? forest lands? an endangered species of fish? Global warming is not an issue of human survival; people will likely be able to survive and adapt to any near-term climate change. Rather, it is an issue that raises basic questions concerning the environment of the future: What steps are we willing to take to protect environmental quality, and at what price? No generation before us has been required to anticipate and react to a problem that reaches so far into the future. The questions we face are difficult, but we must find ways to respond to them.

Research is an important component of our response. The U.S. government has allocated $500 million in this fiscal year for scientific research into climate change, and more than $1 billion is proposed in next year's budget. This research will help us better understand the scientific underpinnings of climate change (see article on p. 4), especially some of the major uncertainties such as the roles of clouds and oceans in relation to the Greenhouse Effect.

In the international arena, the United States is an active participant on the Intergovernmental Panel on Climate Change (IPCC). The IPCC was first convened in 1988 by the United Nations Environment Programme and the World Meteorological Organization to foster international cooperation, improve the science on climate change, assess the potential effects of global climate change, and explore options for responding to it.

Certainly global cooperation is an important consideration when addressing global warming issues. No single country contributes more than a fraction of Greenhouse gases, and only a concerted effort can reduce emissions. In the future, as developing nations grow and consume more energy, their share of Greenhouse-gas emissions will steadily increase. It is important for other nations to offer technological assistance so that these nations can grow in an energy-efficient manner.

This issue of *EPA Journal* attempts to grapple with many of the national and international policy questions surrounding global warming—a tall order. The potential effects of global warming on society are immense, but with sound policy decisions and global cooperation, I believe we can ensure economic growth and at the same time protect the quality of our environment. □

Editor's note: 1 °Celsius is equivalent to 1.8 °Fahrenheit.

What We Know; What We Don't Know

by Daniel L. Albritton

What will the Earth's climate system do in the 21st century? The answer is, It will vary.

This answer is perfectly correct but deceptively glib in that it glosses over the full import of the point. The Earth is fundamentally a planet of change: That fact lies at the heart of the emerging dialogue between science and public policy regarding environmental issues related to global change.

Given the fact of variation in the Earth's climate system, however, it is important to draw a distinction between *natural variation* and *human-induced climate change*. Based on this distinction, it makes sense, in terms of both science and public policy, to break our initial question down into two questions: First, can we predict the naturally varying climate of the next century (particularly the extreme swings)? And second, can we predict how human activities could alter the average climate?

Although these questions are seldom posed as two distinct issues, it is clear that decision-makers need scientific answers to both questions for the following reasons:

• *Natural Variation*. Record-breaking heat waves or unusually frigid winters of recent memory demonstrate that climate variability occurs even on human time scales. Historical and geological records amply document longer-term variations of substantial magnitude: the Little Ice Age of the 15th and 16th centuries; the onset of the current aridity in the southwestern United States somewhat earlier than that; and the great ice sheets of more distant times.

No human causes have been implicated with these changes; they reflect the fluctuations of an inherently variable global system. Yet these natural changes have had great impacts on our species: extensive migrations, economic losses, and personal hardships. The human misery recently wrought by the Sahelian drought in Africa is beyond quantification. The hot, dry summer of 1989 in the midwestern United States shows the vulnerability of even a modern industrial society.

Clearly, to be able to predict such natural variations—and hence to be better able to prepare for them—would be a boon to life on this planet. This is particularly true as population growth increasingly stresses our institutions and societies.

• *Human-induced Change*. Recently, an additional factor has entered the global climate scene. Over the past 100 years, humans have demonstrated the dubious achievement of being able to alter the atmosphere on a global scale. The atmospheric concentration of carbon dioxide (CO_2) has increased substantially since pre-industrial times. Chlorofluorocarbons (CFCs), once nonexistent, are now present throughout the atmosphere. Indeed, CFCs are a semi-permanent feature of our atmosphere because of their century-long "residence" times.

The consequences of these perturbations are very clear in some cases, but not fully clear in others. While the CFCs have valuable industrial uses, they have also given us a new long-term, continental-sized global feature: the Antarctic ozone "hole." Increasing CO_2 concentrations have raised the prospect of an enhanced Greenhouse Effect (see *EPA Journal*, Vol. 15 (Jan/Feb 1989), pp. 4-7). In short, CO_2 absorbs—and reflects back toward the surface—part of the outgoing thermal radiation of the planet, thereby potentially warming the lower atmosphere and the Earth's surface.

Just as decision-makers previously asked science what are the consequences of increasing CFCs on the ozone layer, they are now rightly asking the same bottom-line question regarding increasing CO_2 and climate change.

The Challenge to Science

Science knows the scope of the problem that it faces. As sketched in the drawing on p. 7, a variety of natural and human-induced "forcings" nudges the global system into responding with physical changes. In turn, these changes affect the planet's biological systems, including humans. The challenge to science is to understand the processes that link the so-called forcings, responses, and impacts. That understanding comes from long-term observations, field experiments, laboratory studies, and theory.

• *"Modelsmithing."* As a tool for understanding the dynamics of the Earth's climate system, scientists use computer "models" of the global system. These models, in which mathematical expressions describe the linkages among climate factors, are used to explore "what-if" scenarios—for example, what if CO_2 were to double? The ideal model would be a representative replica of the planet, with adequate formulations of all major pertinent processes. Thus it could identify natural climate changes before they actually occur. In addition, it could identify changes that we ourselves are about to cause.

There are obvious public-policy implications here—first in terms of learning how better to live with what we cannot avoid, and second in terms of making appropriate changes in the way we live. But how good are we at model-building?

• *Feedbacks*. The global system is not as "linear" as our illustration might suggest. In many ways, system components are remarkably intertwined. Certain "feedbacks" can either amplify or counteract the effect of a forcing, such as CO_2 increases. In computer modeling, these positive and negative feedbacks must be represented adequately if the simulated response to a forcing is to be useful.

(Dr. Albritton is Director of the National Oceanic and Atmospheric Administration's Aeronomy Laboratory in Boulder, Colorado.)

Some things are known with high certainty; others remain very poorly understood.

Within the physical system, for example, clouds can introduce both types of feedback. On the one hand, an increasingly cloud-shrouded planet would reflect more of the incoming solar energy back to space, which tends to produce a cooler planet. On the other hand, a cloudier planet also traps more outgoing surface radiation, and this tends to produce a warmer planet. In this particular example, the net effect is a near-cancellation of two effects that are difficult to characterize, posing quite a challenge in modeling.

Another feedback pattern involves emissions of methane, which, like CO_2, is a Greenhouse gas. Changing surface temperatures may alter the amount of methane emitted from high-latitude tundra, for example. These emissions, in turn, can affect the forcing that originally caused the temperature change.

• *Time Lag.* In addition to feedback mechanisms, the simple sketch cannot show the time dimension of Greenhouse-forced climate change. While reflected radiation will increase in step with the increase of trace gases, the response of the planet will not. One key factor is the time lag due to the huge thermal inertia of the world's oceans. Such a large volume of water takes decades to warm, given the slow overturning of the warm surface waters with the colder deep-ocean water.

Predicting the response of the planet to increasing Greenhouse gases necessarily includes predicting the arrival time of the response. This adds a challenging dimension. A key implication of the time lag and the long atmospheric lifetimes of the Greenhouse gases is that it is hard to "quit the game." In other words, we are committed to whatever future planetary responses may be in store due to the long-lived Greenhouse gases that we have placed—and continue to place—in the atmosphere.

• *Impacts: Good and Bad News.* As the sketch indicates, physical changes can cause biological responses that may be either beneficial or detrimental to mankind. Increased CO_2 does stimulate plant growth. Furthermore, a warming of marginally productive high-latitude regions could enhance their habitation and other use.

However, the impacts of past natural variations of rainfall and temperature have demonstrated what the human costs of a Greenhouse-enhanced warming could be. Therefore, with both gains and losses potentially in store, policy decisions become more acutely sensitive to details of the predictions. Current science is hard-pressed to provide accurate details.

How Much Do We Know?

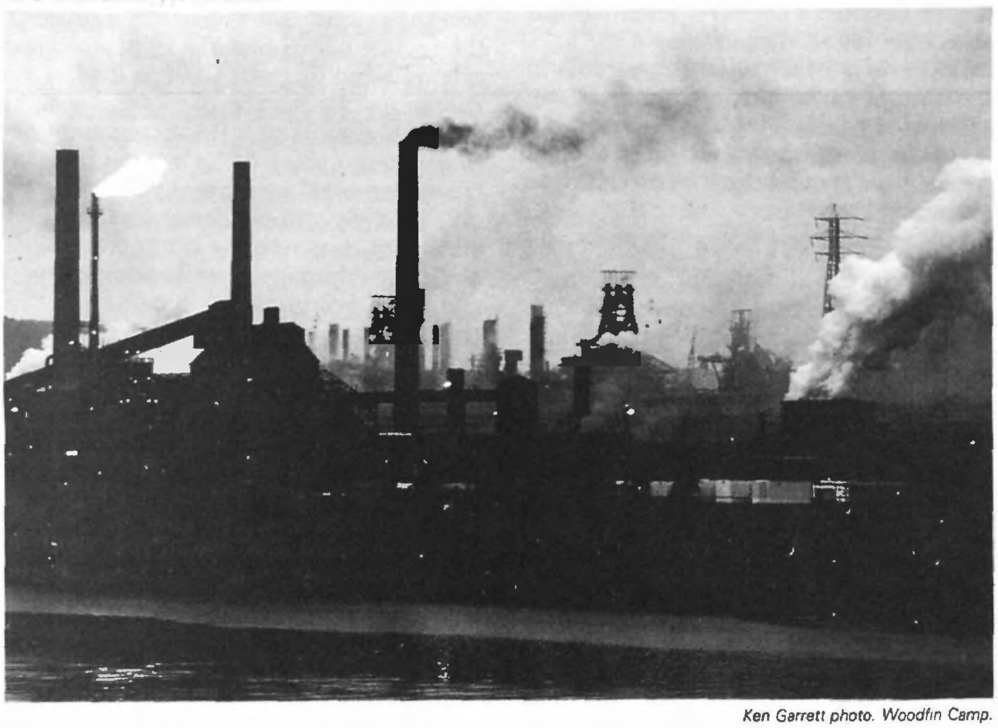
Despite the scope and complexity noted, research to date has provided an understanding of several, but not all, aspects of the Greenhouse Effect. Some things are known with high certainty; others remain very poorly understood. The following status report proceeds through the spectrum from "knowns" to "unknowns."

• *A Greenhouse Effect is essential to life.* If the three major radiation-trapping trace gases—water vapor, CO_2, and ozone—were not present in the atmosphere, our solar-powered planet would be ice-covered. Thus, a Greenhouse Effect is a major feature of the atmosphere, and its general properties are understood: Computer models yield very reasonable simulations of the average temperature of the Earth, the pattern of the seasons, the latitudinal changes in temperatures, and the vertical temperature structure of the atmosphere.

Why, then, is the Greenhouse Effect labeled as an environmental problem? The answer is simple: We have begun to enhance it.

• *In the next century, a doubling of CO_2 over pre-industrial levels is virtually certain.* Atmospheric CO_2 is increasing, due largely to the combustion of fossil fuels by humans. All scientists are convinced of this. However, the *rate* of increase in the concentration of this Greenhouse gas

Ever-increasing human activity could contribute to a warmer planet. This steel mill in the Ohio River valley symbolizes the growing impact of mankind since the beginning of the Industrial Revolution.



Ken Garrett photo. Woodfin Camp.

Scientists disagree whether a Greenhouse "signal" has already been seen.

will depend on technical developments, economic factors, and policy decisions which cannot be predicted entirely in advance; it will also depend on the net uptake of CO_2 by vegetation and the oceans, which is rather uncertain.

- *Not only CO_2, but methane, CFCs, ozone in the lower atmosphere, and nitrous oxide act as Greenhouse gases.* The concentrations of gases other than CO_2 are also increasing in the atmosphere. The reasons for the increases are not fully understood.

The CFCs, of course, are industrially produced. However, the sources of the other gases are not as clear, since the biological mechanisms for their emissions are still ill-defined. Hence, the future atmospheric abundances of all the Greenhouse gases cannot yet be predicted reliably.

All of the Greenhouse gases just mentioned act to reduce the loss of outgoing thermal radiation to space. The basic radiation physics of these trace gases is well understood. The relative "efficiency," molecule by molecule, of each chemical species as a Greenhouse gas can be calculated with a fair amount of certainty; however, the residence time of each in the atmosphere is less well known.

- *The eventual response of the climate system to increased Greenhouse "forcing" is likely to be, on the average, a global warming.* Most (but not all) climate scientists now believe this. Current science can accurately calculate the thermal forcing of the atmosphere due to increases in the Greenhouse gases. However, predicting the subsequent response of the climate system to that forcing is a much more difficult task.

Based on current model simulations, many scientists believe that an eventual global average warming in the range of 1 to 5 degrees Celsius is likely. However, some scientists have cautioned that we may not have identified and characterized all the key atmospheric, terrestrial, and oceanic processes that determine climate responses. If a warming in the range of 0.5 to 1 °C does occur, this would be comparable to or larger than known temperature changes that have happened naturally in the past.

- *Scientists disagree whether a Greenhouse "signal" has already been seen.* Current models indicate that, due to the Greenhouse gases already in the atmosphere, the global average surface warming should be in the range of 0.5 to 1 °C. Has that warming been seen in the temperature record? The answer is not clear, but most scientists currently think not.

While the average surface temperature record shows an increase of that magnitude over the past several decades, the pattern has been one of relatively rapid increase in the 1920s and another in the 1980s. This does not match the pattern predicted for the Greenhouse Effect, namely, a gradual increase in temperature. It follows that there must be other, presumably natural, processes at work that can influence temperature changes of a fraction of a degree Celsius. Therefore, scientists are searching for a "signal" whose magnitude is likely to be comparable to the natural variations of the climate system—a challenging task indeed! As an added complication, the reliability of some of the temperature record has been questioned recently.

- *Current models cannot predict with confidence the climate of a particular region or the climate of a given year.* People who construct climate models point out that today's models of the global system cannot yield reliable predictions of climate features on regional scales. Nor can they predict the climate of a particular year.

This means that scientists do not know for sure whether the U.S. midwestern drought of 1988 was due to the Greenhouse Effect, nor can they foretell year by year the climate features of the near future. However, many scientists agree that, using models, it is possible to predict that episodes like the 1988 drought will become more common in coming decades, due to an enhanced Greenhouse Effect.

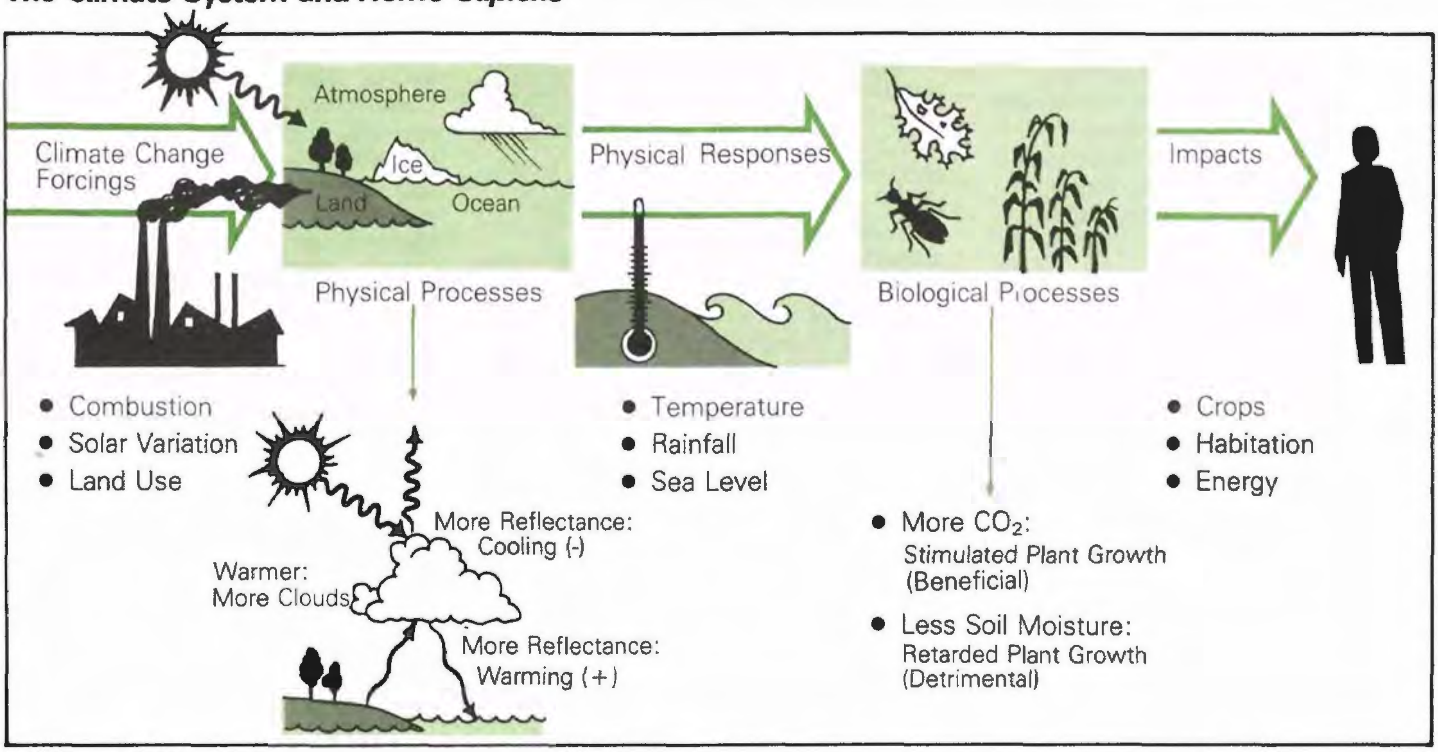
Toward Better Answers

The above summary is my own interpretation concerning the state of the science on the Greenhouse Effect. What are the prospects for improved answers?

A worldwide statement of the knowns, unknowns, and implications of an enhanced Greenhouse Effect is due out soon. The Intergovernmental Panel on Climate Change (IPCC) of the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) are jointly sponsoring an international state-of-knowledge review of climate change. Their report will cover three areas: science, socio-economic impacts, and policy options. The science review will be a peer-reviewed scientific assessment of the whole climate-change phenomenon done by the best scientists available worldwide. It will be accompanied by a summary directed to government officials, the private sector, and the public. The timetable is brisk: the review began in early 1989 and is scheduled to be completed in the summer of 1990.

Of what value will this assessment be to decision-makers? The answer is "considerable," for several reasons. It will provide a single consensus statement in which the international scientific community will speak with one voice regarding the knowns and unknowns of global warming. The scientific scope will be comprehensive, so that decision-makers will have a single homogeneous summary of the current scientific understanding of the whole climate-change phenomenon. This can serve as a common reference point for decision-makers—clearly an advantage over sporadic and separate statements reflecting the opinions of individuals and separate nations.

The Climate System and *Homo Sapiens*



Both natural and human-induced climate change will be considered in the forthcoming report. This means that predicted human-induced climate change will be placed in the context of observed and predicted changes that are a natural part of the climate system. The comparison of the two will afford insight into the significance of the predicted human impacts on the planet.

At the same time, it is clear that key problems related to global warming need further elucidation. Some of the gaps in our understanding have been identified, pointing to research priorities:

- Building a better observational system that could not only provide additional input to computer models, but also signal the real-world arrival of a Greenhouse warming.
- Improving our knowledge of cloud feedback mechanisms.
- Developing the capability to predict increases in the biologically related Greenhouse gases, such as methane. At present, we can make only rough extrapolations concerning increasing concentrations of these gases in the atmosphere.
- Characterizing the processes that determine the thermal inertia of the oceans, such as large-scale vertical motions.
- Improving the quality of our weather records and learning to better interpret the long-term record of past climate change. These are important for further development and testing of our century-scale models, since we clearly cannot wait for future centuries of data to accomplish this.

In the United States, these questions are being addressed by the Global Change Research Program, which is being administered by the Committee on Earth Sciences, a consortium of federal science agencies. Research efforts in these areas have also been mounted by other countries, such as the United Kingdom and Australia.

Improved answers require a better understanding of the basic workings of the ocean/atmosphere climate system, which is a formidable task. Such answers do not come cheap, nor do they all come fast. Nevertheless, the fundamental understanding of natural processes that relate to the well-being of mankind are almost always cost-effective. Consider, for example, the cost of a Salk/Sabin vaccine for polio in comparison to the economic and human costs of a life in an iron lung. Regarding our health and the environment, it is the price of ignorance that we cannot afford. □

The Greenhouse Gases

by Richard D. Morgenstern
and Dennis Tirpak

Since human activities first began significantly influencing the atmosphere during the industrial revolution 200 years ago, sources and emissions of Greenhouse gases have steadily increased. Today, scientists are especially concerned that recent increases in the amount of Greenhouse gases in the atmosphere may cause global warming in the future, altering the Earth's climate.

Some gases remain in the atmosphere for short periods of time, but other gases, such as CFCs, may remain there for several hundred years.

These sources of Greenhouse gases are so numerous and diverse that no single source contributes more than a tiny fraction of total emissions. Similarly, no single country contributes more than a fraction of emissions.

Unlike other environmental problems that EPA could address with the stroke of a regulation, potential climate change is a problem that needs innovative global solutions. Future trends of emissions will depend on a wide range of factors, from population and economic growth to technological development and policies to reduce emissions. Past trends and projected future trends show that all countries have been producing Greenhouse gases at a growing rate, and many countries will continue to do so for years to come. Based on careful study of the sources and trends of Greenhouse emissions around the globe, countries can begin implementing prudent measures for slowing down emissions while increasing economic development.

(Morgenstern is Director of the Office of Policy Analysis in EPA's Office of Policy, Planning, and Evaluation (OPPE). Tirpak is Director of the Climate Change Division in the Office of Policy Analysis.)

Sources

Recent increases in these Greenhouse gases result mainly from expanded energy use, agricultural practices, and population growth. The most important Greenhouse gases are carbon dioxide (CO_2), methane (CH_4), chlorofluorocarbons (CFCs), and nitrous oxide (N_2O). In assessing the importance of these gases, scientists look at three characteristics: the concentration of the gas in the atmosphere, the ability of the gas to block infra-red radiation and thus trap heat in the manner of a greenhouse, and the lifetime of the gas in the atmosphere.

Some gases remain in the atmosphere for short periods of time, but other gases, such as CFCs, may remain there for several hundred years. Some gases are much better at blocking radiation than others. For example, molecule by molecule, CFCs are 10,000 times better at blocking radiation than CO_2, but there are 35,000 times more CO_2 than CFCs in the atmosphere. By weighing these factors, scientists can determine how much each of these gases contributes to the Greenhouse Effect.

CO_2, the most abundant Greenhouse gas, is responsible for approximately half of man-made contributions to the Greenhouse Effect. Since the industrial revolution, the concentration of CO_2 in the atmosphere has increased 25 percent and continues to increase at a rate of 0.4 percent per year. Fossil-fuel combustion and deforestation are the primary sources of this increase in atmospheric CO_2.

Methane in the atmosphere has more than doubled in the past 300 years and is currently responsible for about 18 percent of man-made contributions to the Greenhouse Effect. Agricultural sources, particularly rice cultivation and animal husbandry, have probably been the most significant contributors to recent increases in methane concentrations. Methane emissions from landfills, coal seams, melting permafrost, natural gas exploration and pipeline leakage, and biomass burning associated with deforestation are also

Thomas Sennett photo. World Bank.

important sources. Total methane emissions are increasing at a rate of 1 percent per year.

CFCs contribute about 14 percent of man-made contributions to the Greenhouse Effect. Unlike other Greenhouse gases that have always been in the atmosphere, CFCs only recently appeared in the Earth's atmosphere when scientists began manufacturing these compounds in the 1930s. They are used for a variety of industrial purposes—as propellants in aerosol cans, refrigerants in air conditioners and refrigerators, and cleaning solvents, for example. CFCs are not nearly as abundant as CO_2, but these compounds are much more powerful as a Greenhouse gas, molecule by molecule, than CO_2, and their concentrations are increasing rapidly: more than 4 percent since 1978.

N_2O has increased in concentration by 5 to 10 percent in the past 200 years and is currently increasing at a rate of 0.25 percent per year. The cause of this increase is uncertain, but nitrogen-based fertilizers, land clearing, biomass burning, and fossil-fuel combustion have all contributed. N_2O is over 200 times more powerful than CO_2 as a Greenhouse gas and contributes about 6 percent of man-made contributions to the Greenhouse Effect.

Historical Concentrations of Greenhouse Gases: How Scientists Know

During the yearly thawing and refreezing in Greenland and the Antarctic, small pockets of air are trapped in the ice. Scientists drill into the Antarctic ice cap and extract air that was trapped in these pockets. Back in the laboratory, they analyze this air and determine what portions of the air are carbon dioxide, methane, nitrous oxide, etc.

To determine the age of an air sample, scientists count the number of layers of ice to the depth they took the sample. Like tree rings, these yearly layers from the thawing and refreezing provide a good estimate of age. Scientists have drilled as deep as 2,000 meters and extracted air that was trapped as long as 163,000 years ago. With this information, scientists can compare pre-industrial concentrations of Greenhouse gases with today's concentrations.

Future Trends

The United States is responsible for the largest portion of man-made contributions to the Greenhouse Effect (21 percent), followed by the USSR (14 percent), European countries (14 percent), China (7 percent), Brazil (4 percent), India (4 percent), and the rest of the world (36 percent). The rate of Greenhouse-gas buildup during the next century will depend heavily on future patterns of population and economic growth and technological development; these, in turn, are influenced by the policies of local, state, national, and international private and public institutions.

To assemble a better picture of how emissions may change in the future, EPA, in conjunction with other countries and the International Panel on Climate Change, is assessing future energy plans of different countries and their implications for emissions of Greenhouse gases. The approach relies on information from individual countries evaluated in comparison to results obtained from large global economic models such as used in preparing EPA's recent draft report to Congress titled *Policy Options for Stabilizing Global Climate*. (See table for emissions projections for the year 2025.)

As with all attempts to forecast into the future, the results become less reliable the further they extend into the future; however, from the projections summarized in the table, a certain picture of the future emerges. The analysis suggests that global CO_2 emissions will more than double by the year 2025 (5.24 to 12.18 billion tons per year) in the absence of specific government policies to reduce emissions. This estimate is higher than indicated in EPA's draft report to Congress; most individual countries tend to be optimistic about their future use of energy and do not consider global constraints.

The developed countries, currently the largest CO_2 emitters, will grow in

Projected Global CO_2 Emissions

	Billion Tons Carbon 1985	Billion Tons Carbon 2025	Percentage Annual Growth	Per-Capita CO_2 Emissions * (metric tons/year) 2025
Developed	**3.95**	**6.71**	**1.31**	**4.24**
North America	1.46	2.37	1.23	6.50
Western Europe	0.77	1.11	0.91	2.63
Japan & Australia	0.34	0.63	1.53	2.65
Eastern Europe	1.38	2.60	1.60	5.02
Developing	**1.29**	**5.47**	**3.91**	**0.80**
Centrally Planned Asia	0.55	1.80	3.00	0.98
South & East Asia	0.28	1.55	4.41	0.50
Latin America	0.21	0.65	2.91	1.68
Africa	0.14	0.80	4.53	0.48
Middle East	0.11	0.67	4.72	1.91
Global	**5.24**	**12.18**	**2.61**	**1.41**

*Per-capita CO_2 emissions are calculated for each region based on projected CO_2 emissions and population.

Note: these projections assume no specific international agreements to reduce emissions.

The cultivation of rice, one of the world's most popular staple foods, produces methane, a potent Greenhouse gas. These Bangladesh farmers are transplanting rice shoots.

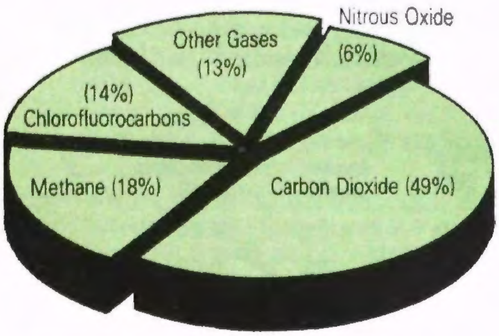
Automobiles are a major source of CO_2, a Greenhouse gas.

California DOT photo.

population at approximately 1.0 to 1.5 percent per year and are projected to emit 6.7 billion tons of carbon by the year 2025. Developed countries are likely to continue to emit more CO_2 per person than developing countries. For example, the average citizen living in the United States produces six times more CO_2 each year than the average citizen in a developing country. In developing countries, population and economic growth will lead to a substantial increase in CO_2 emissions to over 5 billion tons per year, despite anticipated improvements in efficiency of energy use.

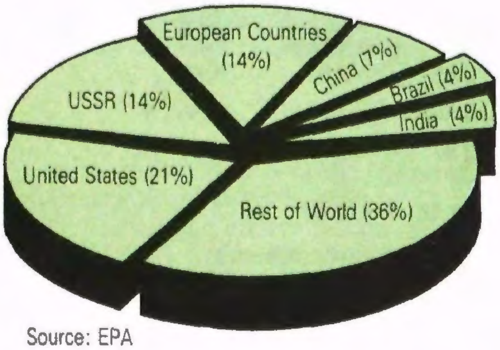
Developing countries now contribute only a small fraction of Greenhouse gases, but their share of emissions is expected to increase significantly in the next 35 years. The table shows the share of CO_2 emissions from Asia (including China), Africa, Latin America, and the Middle East increasing from slightly over one-fourth of the global total in 1985 to nearly one-half the total by 2025. Technologies developed in more industrialized nations to use energy efficiently could help developing nations reduce emissions as they continue to develop, but channels to transfer this technology must be developed.

Greenhouse Gas Contributions to Global Warming (1980s)



Source: J. Hansen et al.

Regional Contributions to Global Warming



Source: EPA

On a regional basis, energy use in Western European countries is projected to grow at a relatively slow rate because of low population growth and anticipated policies to be implemented over the next decade. Several countries, such as Norway, Sweden, and The Netherlands, have already adopted policies specifically to slow the growth rate of Greenhouse-gas emissions. These measures include special taxes, energy-efficiency programs, and promotion of nuclear energy, natural gas, and renewable energy sources.

The case in Eastern Europe is quite different, largely because many of these countries are among the most energy intensive and most energy inefficient in the world. In Eastern Europe and the USSR, energy use and CO_2 emissions are projected to grow considerably over the next 35 years, but policies of *perestroika* aimed at restructuring the economy and improving energy efficiency in the USSR could have a significant impact. If the economies of the USSR and Eastern Europe become more energy-efficient and move from heavy industrial production to production of less energy-intensive consumer goods, they may be able to increase economic growth and enjoy the added benefit of reduced Greenhouse-gas emissions.

In response to these projected increases in emissions, many countries are seeking ways to limit the buildup of Greenhouse gases in a manner consistent with economic development and other environmental and social goals. The most common options for reducing Greenhouse-gas emissions involve reducing fossil-fuel consumption, researching alternative energy sources, switching to fuels that release less CO_2, improving energy efficiency, and starting programs for reforestation. Countries are also looking at a broad range of possible policies including energy taxes, fuel-switching, information programs, economic incentives, and energy-efficiency standards and regulations that could result in low or declining emissions in the next 20 years.

Many available technologies could substantially improve the energy efficiency of automobiles, buildings, and homes, but often require innovative programs to encourage their adoption. Renewable energy sources are also being researched, improved, and demonstrated as viable alternatives to fossil fuels. These include solar energy, wind power, hydroelectric energy, wave energy, and biomass energy. Other important options include reducing methane emissions from landfills, coal mines, and gas and oil facilities. The costs and benefits of implementing such programs are now the subject of extensive analysis by many governments.

In the coming years, we must re-evaluate how emissions are likely to change. But given this preliminary picture of the future, it is important to take the next step of assessing the specific technologies and policy measures that can reduce emissions now at low costs. Each country will have to examine its unique situation and determine appropriate responses. However, only by acting together will the global community slow the trend toward high emissions in the next century. □

Policy Options

Energy Conservation

by Claudine Schneider

"How many light bulbs does it take to change the weather?" The question sounds like a joke in search of a punchline. However, lighting has become a lively topic of discussion at the many conferences discussing the looming threat of global climate change. In fact, highly efficient lighting devices present a premier opportunity to cut energy costs and environmental pollutants simultaneously.

Lighting, considered together with the associated air conditioning required to offset the heat generated from inefficient lights, consumes one-fourth of U.S. electricity. This is equivalent to nearly half of all coal burned by the nation's electric utilities.

The market now offers several dozen highly efficient lighting products which can provide similar quantity and quality of lighting while consuming just 25 percent of the electricity. These products include compact fluorescent lamps, solid-state electronic ballasts that also eliminate hum and flicker from fluorescent lamps, sensors that turn off lights in unoccupied rooms, photosensors that dim lights whenever sunlight is available, mirror-like reflectors that provide the same quality of light with half as many fluorescent lamps as would otherwise be required, polarizing lenses that reduce glare from fluorescent fixtures, and others. When fully used, these products will save consumers over $25 billion per year and prevent the annual generation of hundreds of millions of tons of carbon dioxide (CO_2) in addition to substantial reductions of sulfur dioxide (SO_2) and nitrous oxide (N_2O) pollutants.

(Claudine Schneider (R-RI) is the co-chair of the Congressional Competitiveness Caucus and ranking minority member of the House Subcommittee on Natural Resources, Agriculture Research, and Environment.)

The market now offers several dozen highly efficient lighting products . . . .

Take the compact fluorescent lamp, made with solid-state electronic chips and space-age materials. A "compact" delivers the same light as an incandescent bulb consuming four or more times as much electricity. The compact also lasts 10 times as long and over its lifetime will net a consumer more than $30 in savings. An 18-watt compact, replacing a 75-watt bulb, will also prevent the generation of one ton of CO_2 and 25 pounds of SO_2.

This is not only a bright idea; it's a win-win opportunity. Every major lighting company in the world is now marketing compacts, locked in a competitive drive to capture as many as possible of the 3 billion light sockets in U.S. buildings. A factory producing compacts is even more impressive. A mid-sized facility producing 2 million compacts per year costs $7 million to set up and over its lifetime will displace the need for a 350-megawatt coal plant with a capital cost in excess of $300 million.

Windows offer another premier opportunity to cut costs and pollutants. Windows in U.S. buildings leak roughly the equivalent of an Alaskan pipeline (1.8 million barrels of oil per day). However, as a result of a highly successful research and development (R&D) effort begun in the 1970s by Lawrence Berkeley National Laboratory working jointly with private industry, the market now offers highly efficient windows that approach the heat-retaining ability of well-insulated walls.

These low-emissive windows are constructed with materials that let the

Energy-saving light bulbs are now available for home, industrial, and commercial use. For example, the industrial-type compact metal halide bulb (left) uses 31 percent less power and produces 192 percent more light than the commonly used incandescent type (right). The halide light also lasts much longer—about 7,000 hours.

Lawrence Berkeley Laboratory photo.

The low-emissive windows are expected to penetrate half the new window market within the next several years . . . .

light shine through, but block some of the infrared heat. The low-emissive windows are expected to penetrate half the new window market within the next several years, and full use of the current generation would save the equivalent of half an Alaskan pipeline.

The next generation of more sophisticated windows now emerging from ongoing R&D at Lawrence Berkeley Laboratory is projected to save, eventually, the output of an entire Alaskan pipeline. Again, the factory level offers impressive capital savings. A facility that manufactures low-emissive windows requires a capitalization cost of $7 million; this investment enables window production that results in the equivalent of 10,000 barrels of oil per day in energy savings. In sharp contrast, an offshore oil platform requires a $300-million capitalization to deliver 10,000 barrels per day.

Not only windows, but virtually every energy-consuming device used in buildings offers similarly attractive potential economic savings—and the means for achieving cost-free and tax-free reductions in a range of environmental pollutants. Energy services can be obtained with half or less energy inputs (and waste outputs) by investing in the most efficient furnaces, boilers, pumps, fans, refrigerators, air conditioners and natural cooling designs, motors and drive equipment, computers and peripherals, building design and materials, etc. Testimony presented at Congressional hearings estimates a current, cost-effective potential for saving more than half of the $170 billion per year expended for gas and electricity in U.S. buildings.

Equally large savings are available in the industrial and transportation sectors (e.g., see articles on pp. 26 and 28). Steady advances in microprocessing circuitry, power electronics, and advanced materials are revolutionizing manufacturing processes. A recent state-of-the-art review, conducted by the Rocky Mountain Institute, of efficiency opportunities in electric motors and industrial drivepower devices that run pumps, compressors, fans, etc., found available electricity savings ranging between $30 billion and $60 billion per year. The improvements would result from the widespread use of permanent magnet motors, power-factor controllers, variable frequency drives, fast-speed controllers for turbomachinery, and proper sizing and design of equipment. This would not only reduce the cost of producing goods and services, but eliminate the need for between 90 and 180 large-sized powerplants.

Clearly these changes are not going to occur overnight. Rather, the efficiency gains can be achieved at a relatively modest pace by simply installing the best available devices wherever cost-effective or when worn-out devices need replacement.

The United States accrued substantial savings between the mid-1970s and the mid-1980s with just this approach. Energy-conservation investments in buildings, appliances, factories, and the transportation sector during that time increased the economy's energy efficiency by 2.5 percent per year. These gains in efficiency have achieved energy savings of more than $150 billion per year, displaced the need for 14 million barrels of oil equivalent per day, and reduced CO_2, SO_2, and N_2O emissions 40 percent below what they otherwise would have been. These savings were spurred by a combination of high oil prices, federal vehicle fuel-economy standards, and various state building and appliance efficiency standards.

The stream of scientific advances and technological innovations shows no signs of abating. Additional domestic savings of $200 billion per year remain to be tapped, and energy savings several times that sum loom on the global horizon. Unfortunately, the success of energy efficiency in lowering energy prices has also undermined the incentive to pursue these additional savings.

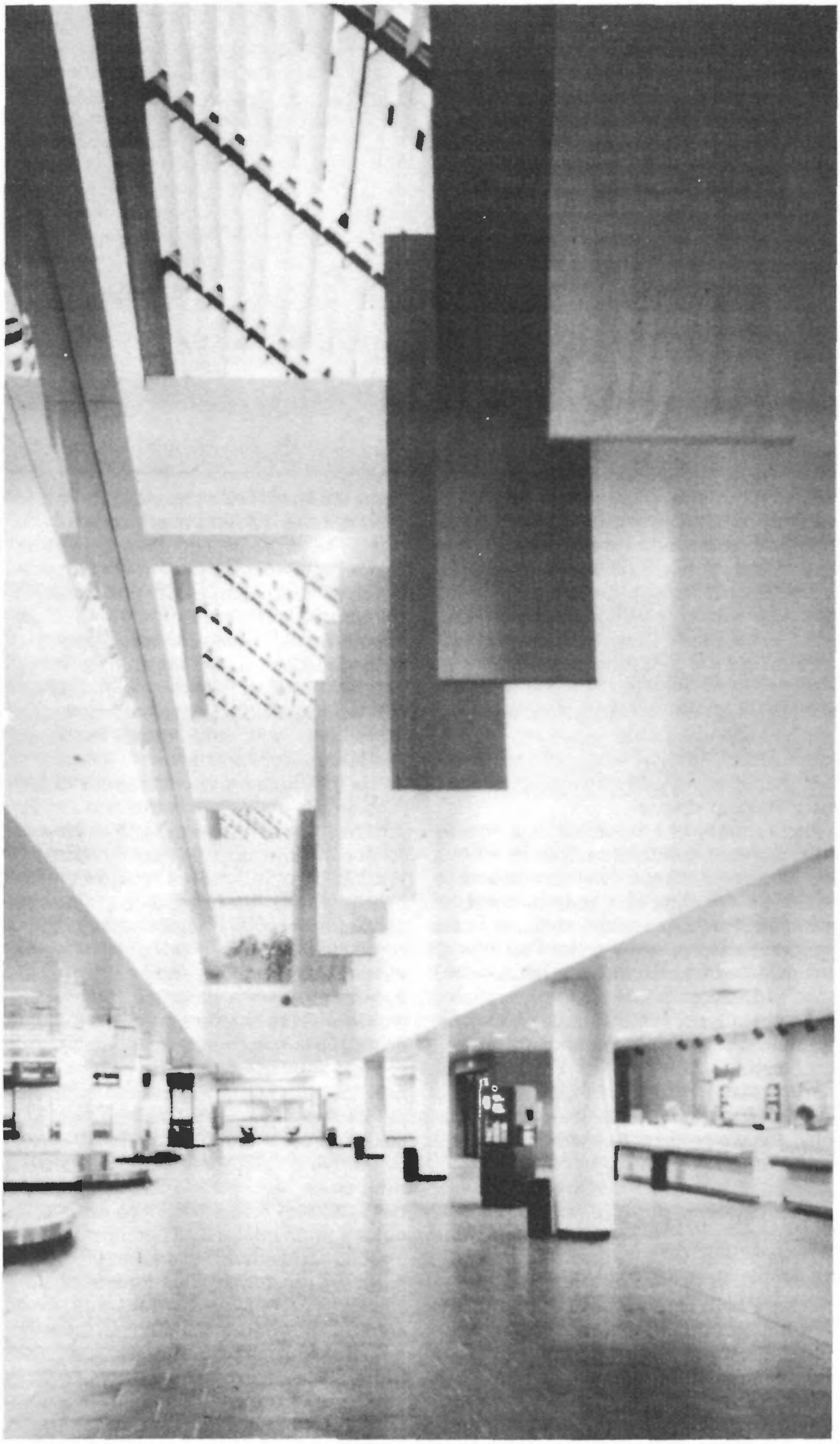
Moreover, energy-efficiency investments are seriously inhibited by a formidable number of institutional barriers and market imperfections. Markets are distorted by subsidies to both energy producers and consumers. For example, U.S. federal energy subsidies amounted to $45 billion per year in the mid-1980s, with over 90 percent going to promote expensive fossil and nuclear resources. Less than $1 billion went to encourage greater reliance on low-cost conservation options. In many developing countries, the government subsidizes 50 percent or more of the price of electricity, dramatically reducing the incentive to use energy more efficiently.

In addition, developers routinely construct inefficient buildings and stock them with inefficient appliances to keep first-purchase costs down. Perversely enough, this can result in utilities' investing as much as half the original cost of the home to install additional capacity to accommodate such fuel-guzzling appliances. Likewise, owners who pass on utility costs to renters have no incentive to improve their buildings, and renters are reluctant to make major capital investments to upgrade their landlords' rental units.

Even in the absence of such a chain of "split incentives," both an "efficiency gap" and a "payback gap" limit energy conservation. The efficiency gap is due to a lack of information: Inadequate information about the availability and reliability of cost-effective efficiency measures keeps consumers and energy producers from investing in these options.

Even where information is available, however, the payback gap short-circuits sound investments. Consumers tend to ignore any efficiency investment which fails to pay for itself within six months to two years. In sharp contrast, utilities routinely build power plants based on 15- to 30-year paybacks. As a result of this enormous payback gap, society is losing investment opportunities that could accrue tens of billions of dollars per year in energy savings and avoid the unnecessary generation of millions of tons of environmental pollutants.

The respected American Council for an Energy-Efficient Economy has identified several dozen policy changes that could overcome these barriers and help spur a 3-percent per year rate of efficiency improvement in the U.S. economy. The recommendations range from restoring this past decade's 70-percent reduction in conservation R&D funding to implementing an energy-efficiency protocol for climate-change control. Pioneering



With its skylit solar court, this airport in Albany County, New York, is a good example of energy-saving design. A microcomputer assists in selecting the most energy-efficient position for the louvers. In daylight, photoelectric controls dim the artificial lights.

states like California have implemented building and appliance efficiency standards that are spurring significant energy and financial savings while overcoming many of the divided incentives noted above. Other states could implement similar standards.

Moreover, a decade of vigorous efforts and collaborative brainstorming among state public utility regulatory commissioners, environmental and consumer advocates, research scientists, and utility executives has resulted in an array of innovative policies and regulatory incentives designed to overcome barriers in the utility sector. One highly successful practice is "least-cost utility planning," pioneered in the Pacific Northwest over the past decade.

Least-cost planning involves ranking all supply- and demand-side options in order of their cost-effectiveness. When Congress mandated least-cost planning in the Northwest region in 1980, 16 coal and nuclear plants were proposed. Instead, the new planning process identified an abundance of available efficiency investments at far below the cost of the power plants. As a result, the 16 plants have been indefinitely deferred.

The least-cost planning process is now being used or examined by 35 state regulatory commissions. A technology-transfer initiative which I succeeded in getting Congress to fund beginning in 1986 is also helping other states carry out this cost- and risk-minimizing process. Identifying the lowest cost options is a key first step. The second crucial step is to get the right incentives in place so that these options are used.

Traditionally, utilities make money by building power plants and selling more kilowatt-hours. Under the current regulatory regime, they suffer serious erosion of cash earnings when they help customers reduce their energy consumption through conservation investments.

The "New England Collaborative" recently initiated by the Conservation Law Foundation appears to lead the nation in correcting this problem. A new regulatory incentive has been structured that rewards utilities for saving electricity whenever this is cheaper than building new powerplants. The utilities provide surveys to customers detailing energy-saving options, then finance part or all of the investment. The innovation looks extremely promising, with potential application in utilities across the nation and around the world. Other refinements are sure to follow, but it is clear that energy efficiency is fast becoming the nation's most abundant low-cost, low-risk energy option. □

Reforestation

by Robert J. Moulton and Kenneth Andrasko

In his State of the Union address to Congress last January, President Bush proposed a new executive initiative to plant a billion trees a year for several years "to help keep this country clean, from our forestland to the inner cities." Significantly, in this age of budget deficits and intense competition for federal dollars, the President went on to announce an unusual item in his proposed federal budget: "the money to plant a billion trees per year."

The new money—$175 million proposed for Fiscal Year 1991—is intended to support a new national tree planting and forestland improvement program to be administered by the U.S. Department of Agriculture (USDA) Forest Service. The program, which remains to be formally approved by Congress, is part of the President's "America the Beautiful" conservation initiative: a three-pronged effort designed to repair and upgrade facilities on our public lands, to purchase critical additions to wildlife refuges and parks, and to plant a billion trees per year.

The goal of the proposed tree-planting program—cooperatively developed in concept by the Forest Service and EPA—is to plant and maintain one billion trees each year on rural lands (970 million trees) and in communities (30 million trees) across the nation. The U.S. Forest Service administers our national forests, conducts forest research, and works in cooperation with state foresters and others to provide private landowner forestry assistance in rural areas and urban communities. EPA is the lead federal agency charged with developing domestic policies and programs to respond to scientific predictions of climate change.

(Moulton is a Forest Economist with the Forest Service, U. S. Department of Agriculture. Andrasko is Senior Forestry Analyst in the Climate Change Division of EPA's Office of Policy Analysis.)

Why spend federal funds on the planting of trees? After all, as the President mentioned during a visit to Sioux Falls, South Dakota, last September, trees are "the oldest, cheapest, and most efficient air purifier on Earth." In fact, trees provide a wide range of environmental benefits and resources: They shade and cool houses, provide timber for construction, offer habitat for wildlife, and slow nonpoint-source pollution from erosion and agricultural-chemical run-off into our lakes and streams.

Trees also have a tremendous capability to assimilate carbon dioxide (CO_2) by converting it to stable carbon "sinks" in the form of woody biomass stored in trunks, branches, roots, and organic matter in forest soils: This is particularly important given the current trend of increasing CO_2 in the atmosphere from fossil-fuel use and tropical deforestation ("sources" of carbon in the global cycle). Forest ecosystems—the trees, soil, surface litter, and understory plants—have no equal in this respect. Forest ecosystems store about two to seven more tons of carbon per acre per year than if the same land were in corn production, for example.

Trees take in CO_2, separate and return the oxygen to the air, and keep the carbon, which is stored as wood, in the growth process. They eventually reach a steady state, well into maturity, in which annual growth roughly equals loss and decay of branches and leaves: Thus, fully mature trees neither store nor emit carbon.

Harvesting forests to produce wood products for construction and other purposes affects the carbon cycle not only by removing CO_2-assimilating trees, but also releases carbon as a result of soil disturbance and increased sunlight—slowly releasing CO_2 over many years. If harvested tracts are rapidly replanted, however, healthy regrowth provides a new, expanding biomass sink to store much of the carbon released by harvest. U.S. forests as a whole are almost in net balance in terms of the carbon cycle, thanks to current replanting and forest management practices. The President's proposed tree-planting initiative is expected to shift the balance so that U.S. forests would become a true sink for CO_2, helping to reduce carbon levels in the atmosphere.

For the urban land component of the President's plan, the goal is to plant 30 million new trees annually. Funding of $65 million is proposed for the first year; $35 million of this would be one-time, start-up funding to create a private, nonprofit foundation to help coordinate a massive volunteer effort in virtually every community in America. A community tree program of this scale would reverse the current trend of declining urban forests, in which roughly four trees are removed for every new tree planted in metropolitan areas.

Tree per tree, urban trees are considerably more effective in countervailing CO_2 emissions than are rural trees. Moreover, well-placed yard trees—which shade buildings and reduce their indoor and surface temperatures—help save energy by reducing residential heating and cooling needs. Urban yard trees can be 15 times more effective than rural trees in reducing emissions and capturing carbon. Trees along city streets and in urban parks typically have large, full crowns which shade pavement and park grounds and thus help temper the urban "heat-island" effect by lessening heat storage during the day and slowing the release of stored heat at night.

Rural lands offer the biggest planting opportunity, however. Planting 970 million trees yearly in rural areas would involve about 1.5 million acres each year. A program on this scale would, in a few short years, become the largest

These children were among 70 students at La Plata Montessori School in Durango, Colorado, who planted honey locust seeds in a "Trees for Life" project in January 1990.

Valerie Brunell photo Durango Herald, Colorado.

tree-planting program in U.S. history. It would exceed the combined planting accomplishments of the Civilian Conservation Corps in the 1930s and 1940s, the Soil Bank from 1956 to 1962, and the current Conservation Reserve Program, which has planted 2.2 million acres since it began in 1986. As proposed by the President, the rural program would be on a 50/50 cost-sharing basis: The federal government would pay for one-half of tree-planting costs, and individual landowners would pay the other half.

Recent statistics on tree-planting in the United States provide another measure of the President's tree-planting proposal. In 1988—the most recent year for which data are available—some 2.3 billion seedlings were planted on 3.4 million acres. Ninety percent of these acres were in private ownership, with the balance in the national forests and on other public lands. Forest-products companies have been the leading tree planters since the mid-1960s, except in 1987 and 1988, when tree planting by private owners not part of the forest industry was boosted by the incentive of the Conservation Reserve.

Since the President's tree-planting program is slated to involve only private, non-industry lands, successful implementation of the program would require private landowners to increase their annual rate of tree planting by about two and one-half times. Is this feasible? What lands would be involved?

A large portion of the program, perhaps as many as two-thirds of the acres, would likely involve planting trees on existing forestlands. USDA field surveys indicate that up to 80 million acres of private non-industrial woodlands are in poor condition due to unsustainable management practices—overharvesting and grazing—and natural events such as severe storms, fires, and outbreaks of insects and diseases. Tree planting and silvicultural practices that promote the natural regeneration of forests can bring such nonstocked and understocked stands back into healthy condition: This is why an emphasis on existing forestlands makes sense and should help encourage voluntary participation in the proposed tree-planting program.

In addition to forestlands, the second major category of land targeted for tree planting is environmentally sensitive and economically marginal croplands and pasturelands. Farming and grazing livestock on these suboptimal lands promote soil erosion and pose a serious threat of nonpoint pollution to ground and surface waters. Large-scale tree planting on these lands would complement the major resource-conservation programs created in the 1985 Farm Bill, including not only the Conservation Reserve, but also the Swampbuster and Sodbuster provisions, intended to discourage such lands from being converted to crop production in the first place.

In concept, the President's Tree initiative is similar to the Conservation Reserve, which encouraged farmers to retire highly erodible and other sensitive lands from annual crop production and establish permanent covers (grasses, trees, legumes, windbreaks, or wildlife plantings). And like the Conservation Reserve, the new program could be administered so as to help farmers implement soil-conservation practices.

Landowner objectives would be the key factor in how trees planted under the President's initiative are used. The program is expected to stress flexibility, providing expanded opportunities for planting hardwood species and stands grown for purposes not limited to timber production. In general, it will encourage tree planting in places where maximum environmental benefits can be attained at relatively minimal costs.

But what about the big picture—the prospect of global climate change? Is it really possible to plant and manage trees in the United States on a scale sufficient to store enough excess CO_2 to help slow climate change? How much can the presently proposed program—or any tree-planting program—accomplish?

Federal analysts recently estimated that an all-out tree program—planting roughly 20 billion trees per year—could capture up to 67 percent of the nation's annual emissions of CO_2, assuming such a program were targeted to environmentally sensitive and economically marginal croplands and pasturelands and existing, privately owned woodlands. Obviously, this would be the upper-limit scenario for using trees as a means to mitigate climate change. Among other things, this scenario would entail major

One of the U.S. Forest Service's current projects is to regenerate existing forestland. At right, a contract hand-planting crew at DeSoto National Forest in Southeastern Mississippi is at work. About 1.4 million slash, loblolly, and long-leaf pines will be planted yearly on 3,000 acres of this national forest. Forest Service efforts will get a boost from the President's proposed tree-planting program.

Forest Service photo.

tradeoffs among competing land uses and would affect food and timber prices.

The direct cost to society for such an all-out program has been estimated at about $19 billion dollars per year (discounted rate), or $24 per ton of carbon per year—a cost considered very competitive with other, non-forestry options to curb CO_2 buildup. This cost estimate includes the full cost of establishing trees, regardless of whether the cost is borne by the public or private owners, plus the annual rental rate of the land involved, a measure of land value in a market economy.

The cheapest, currently least-productive land generally would be tapped first in such a mammoth carbon-capturing program. In general, tree-planting program costs vary greatly depending on the type of land involved, the species of trees planted, and the geographical region. For instance, although it seems counterintuitive, planting trees on agricultural land is usually less expensive than replanting forestland, due to an absence of stumps and logging debris. Even the most severe agricultural sites are less likely to be as rocky and steep as many forest sites. Hardwood trees are generally more expensive to plant than conifers because they require relatively intensive site preparation prior to planting and intensive care following planting. Hardwood tree seedlings typically cost three to five times as much to establish as do conifer seedlings. The species of tree selected depends, of course, on the site and region to be planted.

Admittedly, a tree-planting program to achieve a 67-percent offset of total U.S. emissions of CO_2 is an ambitious scenario. Alternatively, a 10-percent offset program appears to be both eminently feasible and cost-effective. Food or timber prices would be affected only slightly under such a program, according to USDA analyses of land availability, for such a major contribution to storing atmospheric carbon. Planting a billion trees per year, as proposed in the President's program, would achieve roughly a five-percent offset of CO_2 emissions.

Of course, the President's tree-planting program cannot in itself solve the problem of CO_2 buildup in the atmosphere. The same holds true for even the most ambitious tree-planting scenario it is possible to envision. There are no silver bullets waiting to be loaded into some cosmic policy gun to be fired at global change as a quick fix.

But the proposed tree-planting program does offer a low-cost approach for achieving a five-percent offset of U.S. CO_2 emissions over the next 20 years. Combining this program with emissions-reduction initiatives under consideration for other sectors like transportation and energy could achieve the major reductions necessary to slow the U.S. contribution to Greenhouse-gas buildup. And besides, planting a billion trees per year will definitely make America a more beautiful—and cooler—place to live. □

Estimated Costs for U.S. Forestation/Carbon Storage Scenarios

Percent Offset of U.S. CO_2 Emissions	Total Annual Cost of Program*	Annual Cost Per Ton of Carbon Removed
5	$ 545 million	$9.11
10	$ 1.4 billion	$11.39
20	$ 3.7 billion	$14.94
40	$ 9.7 billion	$18.42
67 (maximum)	$19.5 billion	$24.23

*Based on amortized costs over 40 years (discounted 10 percent).

Source: Moulton and Richards, "Costs of Sequestering Carbon Through Tree Planting and Forest Management in the U.S.," U.S. Forest Service (in preparation).

Nuclear Power: A Forum

One much-discussed option to help curb global warming is the use of nuclear power to produce electricity because Greenhouse gases are not emitted in the process. There are strongly differing viewpoints, however, about nuclear power's viability and safety and about the wisdom of relying on it to help limit planet warming. To gain perspective on the points at issue, EPA Journal asked five experienced observers of this energy source the question, Is nuclear power a viable option to help control Greenhouse warming? Their opinions follow:

D. L. Peoples

Nuclear power is already helping to reduce man's contribution of Greenhouse gases to the atmosphere. However, it is only one of a diverse set of technologies required to address global warming.

Providing adequate, economical, reliable, secure, and environmentally acceptable electric energy will require both demand- and supply-side management. Conservation and load management will continue to help reduce the demand for electricity. Nevertheless, to supply the electrical energy required to meet the needs of growing populations and to improve the standard of living in countries throughout the world, electricity-producing technologies that do not emit Greenhouse gases, such as renewables and nuclear power, must be considered. The limited capability of renewable power supplies suggests the need for a new evaluation of nuclear power options.

In 1989, 112 commercial nuclear power plants provided 18 percent of U.S. electricity. To produce this amount of electricity by other means would have required burning approximately 250 million short tons of coal, or 790 million barrels of oil, or 4.5 trillion cubic feet of natural gas; all of these alternatives would have contributed significant amounts of carbon dioxide (CO_2) to the atmosphere.

Nuclear power has minimal environmental impact. Nuclear power production emits no Greenhouse gases. Furthermore, relatively small amounts of waste are produced. For example, the low-level radioactive waste generated in one year by a one-million kilowatt nuclear power plant would fit in a volume of space smaller than a three-car garage. The high-level nuclear waste generated in one year by the same one-million kilowatt nuclear reactor would fit in a volume smaller than that of a typical half-bathroom. Over 4,400 reactor years' commercial experience operating facilities in non-Communist countries (1,300 reactor years in the United States) has demonstrated the minimal environmental impact and public safety of commercial nuclear power.

Future nuclear power plants will be constructed economically by utilizing precertified standard designs incorporating advanced technology for simpler, passively safe, light-water reactors. These units will be easier and cheaper to build and operate.

Nuclear power will be needed in the next decade and beyond. Other nations of the world (Japan, France, Canada, Taiwan, South Korea, etc.) continue to recognize the economic and environmental value of nuclear-generated energy. These countries plan to construct more plants in the 1990s. The United States should also take advantage of our "home grown" nuclear technology. Nuclear power is one of the technology arrows in our quiver of viable options to help control Greenhouse warming, and we should use it in an effective manner.

(Peoples is Vice President of Bechtel Power Corporation.)

Ken Bossong

The nuclear industry's history of cost overruns, accidents, and continued accumulation of radioactive waste discredits its argument that a "new generation" of nuclear reactors is a viable option for solving global warming.

The economic cost to design, build, and operate new "advanced" reactors would be at least as high as that for present-day reactors. Serious safety shortcomings characterize each of the "new generation" reactor concepts—even the so-called "passively safe" designs. In addition, new plants would continue to produce long-lived, highly radioactive waste for which there is still no proven method or sites for its long-term, safe storage.

Most advanced reactor concepts exist only on paper. Constructing demonstration models and building a significant number of commercial units could take 20 years or more—a time frame that is unrealistic if nuclear power is to make a significant contribution to solving the global warming problem.

Further, even if nuclear reactors could displace every fossil-fuel plant, they would address only about 17 percent of the U.S. Greenhouse emissions. Unlike improved efficiency or renewable-energy technologies, nuclear power is not well suited to reduce the emissions from fossil fuels used in transportation, industrial processes, and space heating.

Moreover, the construction, maintenance, and fueling of nuclear reactors are energy-intensive tasks that rely heavily on fossil fuels that add to the Greenhouse Effect. For example, a recent study by the U.S. Department of Energy reveals that when the total fuel cycle is included, nuclear power plants produce more carbon dioxide than do most energy conservation and renewable energy options.

More than half the nation's electricity now provided by fossil-fuel plants could be economically displaced through improved energy efficiency. For example, such improvements during the past decade have already reduced U.S. energy consumption by 37 quadrillion Btu's from projected 1989 levels—an amount seven times greater than nuclear-power output during the past year. These improvements have cost one to four cents per kilowatt-hour; by comparison, new nuclear plants cost approximately 12 to 14 cents per kilowatt-hour to build and operate.

In addition, many renewable energy technologies—including wind, hydroelectric, geothermal, biomass, and direct solar—can provide electricity at a lower cost than new nuclear facilities. These technologies, which have experienced rapid price drops during the past decade, already account for almost nine percent of the nation's domestic energy supply compared to eight percent from nuclear power.

Aside from their lower economic costs, renewable energy and energy-efficiency options are safer, environmentally cleaner, and more socially acceptable. And they can be implemented much faster than nuclear plants can be built.

Given the limited funds available to pursue any energy strategy, investing in nuclear power could actually make a solution to global warming *less* likely by diverting funds from more promising options.

(Bossong is the Director of Public Citizen's Critical Mass Energy Project.)

Commonwealth Edison Company photo

Nuclear facilities are producing electricity in many parts of the United States. Zion, above, is one of six nuclear plants producing 82 percent of the electricity for northern Illinois.

Chauncey Starr

At present, 75 percent of the world's annual energy production is used by industrially developed nations. The United States consumes roughly one-third of that, or about 25 percent of the world's energy. A conservative projection suggests that by the middle of the next century, developing countries will be using about 50 percent of the world's energy, while the U.S. proportion of world energy use would fall to about 18 percent.

Although U.S. energy use may have a relatively small influence on global warming, U.S. policy will nevertheless be an important guide for these developing nations. The future role of U.S. energy options—and of nuclear power in particular—must be viewed in the context of the future global energy mix.

Nuclear power, as well as solar and biomass energy and conservation practices, must inevitably be included in strategies for reducing carbon emissions. The role each of these options plays will depend on future global electricity demand and the various electricity supply alternatives available over the next half century. The options will be sorted out in terms of their comparative emissions and feasibility considerations.

Global demand will be driven by both population growth and the economic growth sought by people everywhere, particularly in underdeveloped countries. Using modest population and economic growth projections, a recent study projected that annual global electricity demand for the year 2060 could be seven times the present demand, if current trends continue. If full use is made of the most efficient technologies and conservation possibilities, 2060 demand might be held to 4.7 times present demand without seriously impairing economic growth.

Of this lesser estimate, energy derived from solar and biomass sources might hypothetically provide about one-third *if* their use, globally, were pushed to practical limits. The remaining two-thirds—from fossil-fuel and hydroelectric sources and nuclear plants—represent about three times the world's present electricity production. Even if fossil-fuel and hydroelectric sources were to double present production levels by 2060, global nuclear-power production would still need to increase by 1,000 percent to supply the world's needs.

A comparable study focusing just on mainland China projects a 1,600 percent increase in electricity demand there by the year 2050. This amounts to roughly 80 percent of the world's present-day output. Indeed, developing countries will dominate the future levels of global carbon emissions.

To date, viability of nuclear power has varied considerably from nation to nation. In many industrial countries, nuclear power has demonstrated its technological capability to compete economically with coal. For example, the cost of a nuclear-kilowatt hour is 60 percent the cost of a coal-kilowatt hour in France, where nuclear power plants supply 70 percent of the electricity. Ontario Hydro of Canada, after a lengthy study of alternatives, has recently proposed adding 10 nuclear plants to the province. Improved, second-generation plant designs now available will further stimulate nuclear growth.

In the United States, costs required to meet U.S.-mandated regulations and procedures have seriously impaired nuclear competitiveness. Eventually this will be remedied, but the present prospects for nuclear expansion in the United States are very dim. However, global growth of nuclear power is inevitable because it will be an essential component of the future mix of non-carbon sources for electricity production.

(Starr is President Emeritus of the Electric Power Research Institute.)

Robert H. Williams

If nuclear power were to play a major role in coping with Greenhouse warming, thousands of nuclear power plants would be needed worldwide. With so many plants, the nuclear power/nuclear weapons link would be a major concern.

Inherent in nuclear technology is the fact that the chain-reacting materials that produce energy inside a reactor can also be used for making nuclear explosives.

Plutonium, a by-product of energy production in nuclear reactors, is especially troublesome. Less than 10 kilograms are required to make a nuclear explosive. One of today's large nuclear plants discharges about 200 kilograms of plutonium per year in its spent fuel.

With large-scale nuclear power, concerns about uranium scarcity would impel a shift to uranium-conserving plutonium breeder reactors. A large breeder reactor would discharge in spent fuel each year about 1,600 kilograms of plutonium, which would subsequently be separated from the spent fuel and recycled in fresh fuel. With thousands of nuclear power plants worldwide, millions of kilograms of separated plutonium would be circulating in nuclear commerce each year, transported in trucks, trains, ships, and planes—often across national boundaries.

The current system of international safeguards is unlikely to be effective enough to prevent some of this plutonium from being diverted to nuclear weapons purposes—either by nations or by terrorist or criminal groups intent on acquiring nuclear weaponry. Would occasional diversions be a necessary consequence of a large-scale commitment to nuclear power? While there is no way to sever the nuclear-weapons connection to nuclear power, the system could be more diversion-resistant.

To improve diversion-resistance, new nuclear power-plant designs would be needed. In such designs, there should be no weapons-usable materials outside of spent fuel, and the reactor inventories should contain such small quantities of weapons-usable materials that it would not be worthwhile to "mine" the inventories to recover these materials. While there are various possibilities for meeting these criteria, the designs being considered for a "born-again" nuclear industry are generally inadequate in this regard. The major unanswered technological question is whether designs can be identified that are simultaneously diversion-resistant and safe, and also sufficiently low in cost that nuclear power could compete over the long term with alternative low-CO_2-emitting energy technologies.

What would be required institutionally would be to bring under secure international control especially sensitive nuclear system components, including spent-fuel storage centers and isotopic enrichment facilities. This would not be easy. For example, creating international spent-fuel storage centers would require persuading the local citizenry to accept foreign-produced as well as domestically produced spent fuel. More generally, nations wishing to pursue the nuclear option would have to relinquish some sovereignty.

Making nuclear power acceptably diversion-resistant would be a daunting challenge, especially politically. Yet unless this is accomplished, nuclear power is doomed as a major long-term energy option. While nuclear power might get a second chance, in light of Greenhouse warming concerns, it would not likely get a third chance if there were a major diversion incident somewhere in the world that could be plausibly linked to nuclear power. The nuclear industry must come to recognize that its long-term viability depends on being able to convince the public that it can offer a peaceful atom that is unambiguously distinct from the military atom.

(Williams is a Senior Research Scientist at Princeton University's Center for Energy and Environmental Studies.)

John C. Sawhill

Given the limits of other options for addressing Greenhouse warming, it is essential that nuclear power play an important role. However, the nuclear industry will have to make significant changes.

Use of alternative energy options to reduce Greenhouse warming are not likely to be enough. Renewable technologies are attractive from an environmental standpoint but have not successfully penetrated the market due to comparatively higher costs. Reductions in projected energy demand are essential but also likely to be insufficient. Worldwide energy use is growing about 3.5 percent annually. Nationally, even sound policies—such as increases in the U.S. gasoline tax—will not result in anything approaching the decreases required to reverse the buildup in carbon dioxide. The most rapid growth in energy use is in developing countries, where economic activity is not likely to be significantly scaled back for environmental reasons. And no reputable forecast projects a drop in energy use.

It is unlikely that nuclear power can close the gap between what is necessary to prevent Greenhouse warming and what can be achieved through other measures. However, given the seriousness of the problem and limited understanding of the thresholds at which dangerous changes in the global climate begin, new nuclear powerplants must be built to meet electricity demand without increasing Greenhouse warming. At a minimum, existing plants should continue operating.

The burden of reestablishing nuclear power as a viable option falls primarily on industry. The halt in new orders in the United States was primarily driven by an increase in capital and operating costs and evidence of lax safety standards in some utilities. Capital costs were often multiples of original estimates, which contributed to regulatory disallowances (refusals to allow utilities to charge rates that will enable them to recoup their full investment). These disallowances have averaged almost 20 percent of original construction costs for utilities completing plants in the 1980s. And operating costs, once a real selling point for nuclear plants, are now higher than those for coal plants.

Economic and safe nuclear plants are not impossible to imagine. Reactors built in Japan have had less than half the construction time of those built in the United States. Utilization rates of plants in many European countries are 20 to 25 percent higher than the U.S. average (although the best U.S. plants have operating costs and utilization rates competitive with European plants). The safety record of some U.S. operators is flawless.

Certainly, some changes in the regulatory environment may be appropriate. Government officials must have the political courage to reconsider nuclear power if the industry strengthens its commitment and comes up with sound new plant designs. But if nuclear power is to make the contribution needed to reduce Greenhouse warming, the industry must generate a more consistent record of performance. □

(Sawhill, formerly the Director of McKinsey and Company's Worldwide Energy Practice, is now President of The Nature Conservancy.)

Renewable Energy

by Michael Brower

"Our civilization," wrote George Orwell in his 1937 essay *The Road to Wigan Pier*, "is founded on coal." Updated to reflect the advent of petroleum and natural gas, Orwell's observation still applies. Fossil fuels heat our homes, generate our electricity, run our cars, and power our industries. Without them, it is safe to say, the United States would not have achieved the great prosperity and power it now enjoys—and to which less-developed countries aspire.

But the world cannot continue to rely so heavily on fossil fuels without placing the global environment at risk.

Power plants have been built in Southern California which run on 75 percent solar energy and 25 percent natural gas . . . .

Acid rain and air pollution are two familiar consequences of fossil-fuel use. Even more serious is the threat of global warming. Whether or not one believes the most dire predictions by scientists of the magnitude and effects of global warming, the risks cannot be reduced without the development of substitutes for fossil fuels.

So far, most public and government attention has been focused on nuclear power as an alternative energy choice. But I believe the more likely long-term replacement for fossil fuels is renewable energy, drawn from vast and inexhaustible resources of sunlight, wind, rivers, oceans, and plants.

Once considered exotic and impractical, the technologies for exploiting renewable resources are becoming increasingly reliable and cost-effective in comparison to conventional energy technologies. Some are already successful enough to supply 7.6 percent of current U.S. energy demand. Others—particularly wind and solar technologies, and processes that convert biomass (plant matter) to liquid and gaseous fuels—are now or soon could be competitive with fossil fuels in a broad range of applications. Although some technical issues remain to be solved, there appear to be no insurmountable barriers to prevent renewable energy sources from eventually meeting most, if not all, of U.S. and world energy needs.

But the promise of renewable energy sources will not be realized without strong government leadership. Amidst the oil "crises" of the 1970s, considerable effort was devoted to developing renewable energy sources as a way to reduce oil imports. However, interest has waned since then as oil prices have fallen and supplies have become more plentiful.

The Reagan Administration and the Congress shortsightedly cut funding for renewable energy research and development by almost 90 percent, in real terms, from 1980 to 1989, and eliminated tax credits for most renewable energy investments. As a result, industry growth has slowed and in many cases reversed, and U.S. manufacturers have been losing ground to foreign competitors—many of whom enjoy better support from their governments—in a pattern reminiscent of the decline of the domestic consumer-electronics industry in the 1970s.

The trend of declining federal funding for renewable energy research and development was finally halted last year, and the proposed 1991 budget released last January contains a 20-percent increase. But it will take much more than a modest funding increase to make a dent in the United States' contribution to global warming and other environmental problems.

Advantages of Renewable Energy

Despite the lack of attention paid to renewable energy sources in recent years, their advantages over fossil fuels and nuclear power are more compelling than ever before. The technologies that have been developed, ranging from wind turbines and solar cells to liquid and gaseous fuels derived from biomass, are of startling versatility. Most of these energy technologies result in little or no pollution or hazardous waste. Drawing entirely on domestic resources, they are immune to foreign disruptions like the 1973 Arab oil embargo, and they provide a hedge against inflation caused by the depletion of fossil-fuel reserves. Their development would almost certainly result in a net *increase* in employment, as renewable energy industries typically require more labor, per unit of energy produced, than coal, oil, and natural-gas industries.

Most important, resources of renewable energy are enormous. Sunlight falling on the U.S. landmass carries about 500 times as much energy as the United States consumes in a year. Wind and biomass resources, though more modest, are also substantial. In practice, only a small fraction of these resources could be exploited because of constraints on available land, the efficiencies of energy conversion, and other factors. Nevertheless, estimates indicate that more than enough renewable energy could be collected to meet current and foreseeable energy demand.

Solar energy has the greatest potential: Solar collectors covering less than 1 percent of U.S. territory—one-tenth the area devoted to agriculture—could make more energy available than the United States consumes in a year. Hydroelectric power has the least room for expansion, since about half of the river resources in the United States have already been developed, with much of the rest barred from development by federal environmental legislation. (See table.)

Is Renewable Energy Practical?

Despite the impressive potential of renewable energy sources, they have been virtually ignored by most mainstream energy analysts, many of whom regard them as expensive and impractical. But if this opinion was valid in the 1970s, it has become less so with each passing year.

The costs of renewable energy technologies have declined dramatically in the 1980s, and their reliability has been proven in government/industry demonstration projects and actual commercial operation. For some emerging technologies, all that is

(Brower is a physicist and energy analyst for the Union of Concerned Scientists, based in Cambridge, Massachusetts. This article is adapted from his recent study, Cool Energy: The Renewable Solution to Global Warming (Cambridge, Massachusetts: Union of Concerned Scientists, 1989).)

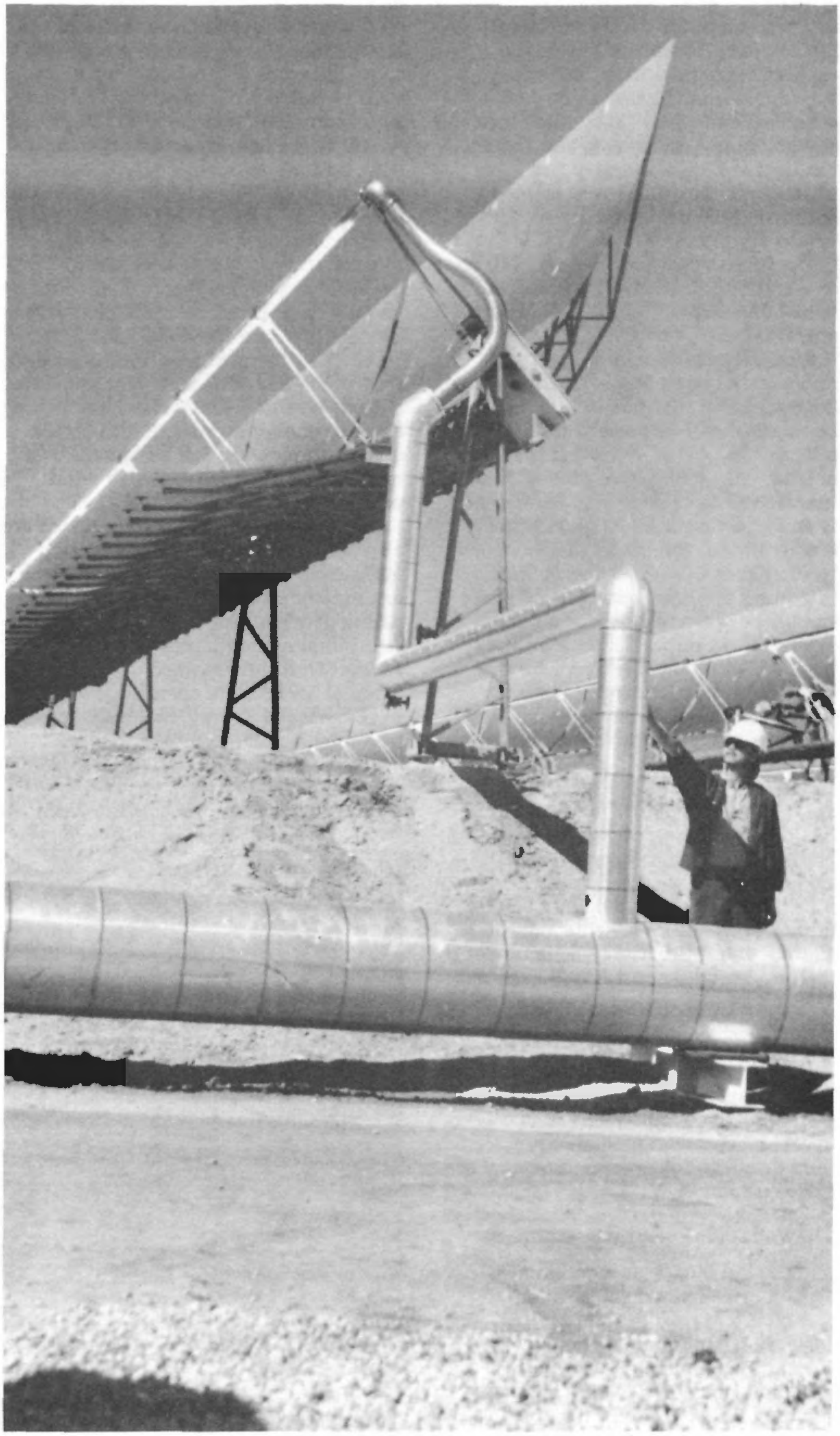
needed to become fully competitive is a market demand large enough to justify economies of scale. For others, further research and development are required, but their long-term prospects are bright.

Wind turbines are a good example of the growing competitiveness of renewable energy technologies. The cost of electricity produced by modern wind turbines has declined from over 25 cents per kilowatt hour in 1981 to 7 to 9 cents per kilowatt hour today, and industry estimates suggest it could fall as low as 4 to 6 cents per kilowatt hour in 5 years. At the current price, wind power is competitive, or nearly so, with electricity generated by new fossil-fired power plants, and in the 1990s it should be one of the least expensive sources of electricity, fossil or renewable.

Reliability problems affecting early wind-turbine designs have been largely resolved, and mature and well-maintained systems are available 95 to 98 percent of the time. Other renewable sources of electricity, such as solar-thermal electric-power plants and photovoltaic cells, also promise to become competitive within a decade, particularly if market demand grows to allow greater production of systems (see graph on p. 22).

For applications requiring direct heat—over half of the end-use energy consumed in the United States—solar-thermal systems are becoming more attractive. Systems now on the market designed for commercial and industrial use generate hot water or steam in sunny climates at about 1.5 to 3 times the current cost of production with natural gas. If the market for solar-thermal systems were larger, the cost of energy would fall sharply. Passive solar-building designs, which use a building's structure to capture and store solar energy, can reduce energy use for space heating by 40 percent or more at little extra cost when incorporated in new construction.

Developing renewable substitutes for gasoline and other transportation fuels is perhaps the most difficult challenge, but even here there is promise of a near-term solution. Ethanol can now be produced from wood and other plants at about twice the pre-distribution and pre-tax cost of conventional gasoline. With continued improvements in conversion processes and the cultivation



Reflector assemblies for the LUZ solar electric generating system are shaped like parabolas. This section of the system is in Kramer Junction in the Mojave Desert. Electricity from LUZ solar plants is sold to Southern California Edison.

of biomass feedstocks, the fuels could become competitive around the turn of the century. According to various estimates, biomass fuels, including ethanol, methanol, and plant oils (a substitute for diesel fuel), could power at least 30 percent of cars and trucks in the United States. Forestry and agricultural wastes, as well as plants and trees grown specifically for energy, would supply the raw materials. Further in the future, cars powered by hydrogen or electricity (provided by low-cost renewable sources, perhaps solar cells) are a realistic possibility.

What happens when the sun goes down or the wind stops? Conventional wisdom holds that energy storage will be needed to keep power flowing reliably, substantially raising the costs of solar and wind power. But although the variability of solar and wind power is an important issue, it should not greatly hinder the use of these technologies in the near term. In some important applications, considerable storage or back-up capacity already exists. For example, electric utilities have a reserve capacity (typically 20 percent of peak demand) in case of unexpected plant breakdowns. This reserve should suffice to maintain reliability until solar and wind energy constitute at least a few percent, and possibly more than 20 percent, of the total electricity supply—a level of market penetration that will not be achieved for at least a decade.

Furthermore, hybrid energy systems drawing on both renewable and fossil sources could provide reliable power in the interim while cost-effective storage systems are developed. Power plants have been built in Southern California which run on 75 percent solar energy and 25 percent natural gas and supply reliable peak power year-round. Natural gas could also supplement solar energy in residential, commercial, and industrial heating applications for little extra cost.

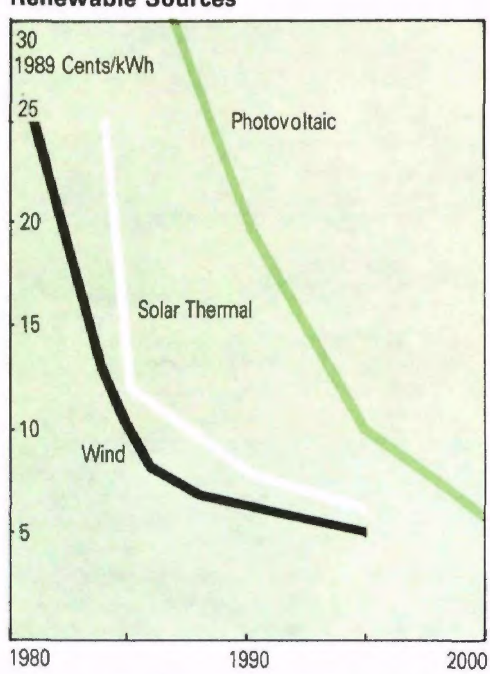
The Path to a Renewable Future

Although wind, solar, and biomass technologies have made striking technical progress in the past decade, they are having more difficulty penetrating commercial markets than at any time since the 1970s. The market picture is likely to improve toward the end of the 1990s as fossil-fuel prices rise. Nevertheless, a Department of Energy forecast suggests that renewable energy sources will account for no more than 12 percent of projected U.S. energy supply in 2010, compared to 7.6 percent today. That is hardly an impressive leap, and not enough to affect fossil-fuel use and global warming in a significant way.

Understanding the barriers to renewable energy use is crucial to developing policies that will encourage its growth. One of the main barriers is the fact that current energy markets ignore, for the most part, the social and environmental costs and risks associated with fossil-fuel use. In effect, relatively harmful energy sources, like coal, are given an unfair market advantage over relatively benign sources, like wind power.

Some conventional energy sources are also heavily subsidized, directly or indirectly, by the government. (One example of an indirect subsidy is the maintenance of large naval fleets and rapid-deployment forces to protect Persian Gulf oil supplies.) If these external, or hidden, costs were reflected in the price of energy, renewable energy technologies would be in a far better position to compete with fossil fuels.

Trends in the Cost of Electricity From Renewable Sources



Source: Union of Concerned Scientists

According to a recent West German study, the hidden costs (not including global warming) of electricity from fossil-fueled plants are in the range of 2.4 to 5.5 cents per kilowatt hour.

If the current market gives insufficient weight to the environmental and social costs of energy technologies, then federal, state, and local governments must step in. Governments can have a decisive influence on energy choices, and the budget burden need not be very great. For renewable energy technologies, many of which are on the edge of commercialization, government actions can be especially cost-effective. The key is to find the policy levers which have the greatest influence on the development of renewable energy sources, and pull them.

As an initial step, the federal government should adopt the following five policies: Reinstitute renewable energy tax credits; increase funding for renewable energy research and development; modify electric-utility regulations to give greater preference to environmentally benign technologies; buy renewable energy technologies for government facilities; and increase support for renewable energy exports. These steps, described more fully in a recent study published by the Union of Concerned Scientists (*Cool Energy: The Renewable Solution to Global Warming*), would cost the government less than $10 billion a year by 2000. The cost would mainly take the form of reduced tax revenues and could be paid for by a modest increase in taxes on fossil fuels. (A 10-cents-per-gallon gasoline tax would suffice.)

I estimate that by the year 2000, these steps could result in a near doubling of the amount of energy derived from renewable sources: from 7.6 percent to 15 percent of U.S. energy supply. This would also mean a corresponding 5- to 10-percent decrease in fossil-fuel use and carbon-dioxide emissions. (These estimates assume that overall energy demand will be constrained to current levels through energy conservation.)

With further technical progress and policy changes in decades to follow, the renewable fraction could rise as high as 50 percent by 2020, putting the United States—and the world—well on the path to a renewable future. □

Policy Options: Methane

by Michael J. Gibbs and Kathleen Hogan

What do cows, coal mines, and landfills have in common? They are all major sources of methane, a Greenhouse gas. That's the bad news. The good news is that they also represent prime opportunities to reduce methane emissions into the atmosphere.

Recent work has identified some promising approaches for reducing methane emissions, and one of the interesting aspects of some of these emissions-reduction techniques is that they are *profitable in their own right*. Although much remains to be done, studies indicate that halting the increase in methane concentrations by the end of the century is a realistic goal.

Much work has focused on methane because this gas is second only to carbon dioxide (CO_2) in its expected contribution to the Greenhouse Effect. And like CO_2, methane's concentration is increasing rapidly in the Earth's atmosphere. Having more than doubled since the mid-1800s, it is currently increasing at a rate of nearly one percent per year.

Methane is very effective in absorbing thermal radiation that radiates away from the Earth's surface. One gram of methane in the atmosphere absorbs infrared radiation about 70 times more effectively than one gram of CO_2. However, unlike CO_2, methane has a relatively short-lived impact because its atmospheric lifetime is only about 10 years. Other Greenhouse gases have atmospheric lifetimes of 100 years or more.

This relatively short atmospheric lifetime makes methane an excellent candidate for control for two reasons. First, to halt the yearly increase in methane concentrations, total global emissions must be reduced by only about 10 percent. In contrast, emissions reductions of 50 to 100 percent would be required to stop the increasing concentrations of the other major Greenhouse gases.

Second, reducing methane emissions provides more "bang-for-the-buck" than is the case with other Greenhouse gases. That is, the full value of reducing methane's contribution to the Greenhouse Effect will be experienced in the near term, whereas it will take centuries for the value of emissions reductions of the other Greenhouse gases to be felt.

For example, about 85 percent of the value of preventing a gram of methane emissions is experienced over a 50-year period while only about 15 percent of the value of preventing a gram of CO_2 emissions is felt during the same 50-year period. In fact, it would take on the order of 1,000 years or longer to experience about 85 percent of the value of preventing CO_2 emissions. This implies that over the next 50 years, a 10-percent reduction in methane emissions is equivalent to a 10-percent reduction in CO_2 emissions, even though CO_2 vastly exceeds methane in the atmosphere.

Livestock emit about 70 million metric tons of methane annually as "methane burps" as they process food.

The increase in atmospheric concentrations of methane has many origins. These include animal husbandry, coal mining, waste management, rice cultivation, and oil and gas recovery and use. And since no single source dominates global methane emissions, it is important to pursue all possible avenues for reducing methane emissions.

A recent EPA report, *Reducing Methane Emissions from Livestock: Opportunities and Issues* (August 1989), provides new perspective on methane emissions from livestock. According to the report, more than 3 billion animals—cattle, sheep, goats, buffalo, and camels—currently account for 15 to

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USDA photo

20 percent of annual methane emissions worldwide. And the numbers of livestock continue to increase.

Livestock emit about 70 million metric tons of methane annually as "methane burps" as they process food. Most of these emissions are associated with the world's 1.3 billion cattle (about 55 million metric tons). In addition, animal wastes that are managed in lagoons and in other ways produce another 15 million metric tons or so of methane per year.

Scientists have identified several techniques for reducing methane emissions from cattle. Significantly, these same techniques will also increase animal productivity—resulting, for example, in more milk from dairy cattle and more meat from beef cattle. Specific measures include improving their diets (both feed and grazing) and managing their waste.

Anywhere from one-third to two-thirds of the cattle in the world, including most of the cattle in Asia and Africa, subsist on poor-quality forages and agricultural by-products during some portion of the year. Poor-quality diets lead to inefficient digestion by the cattle. Inefficient digestion leads to increased methane production and lowered animal productivity.

In India, for example, as part of a development project, the poor-quality diets of cattle were supplemented with locally produced nutrients. Digestion improved, and so did animal productivity. Significant reductions in methane emissions—from 25 to 75 percent—are expected. The cost of the program is being justified chiefly by the increase in animal productivity. Implementing this kind of program in other parts of the world is currently being considered.

In the United States, cattle are much more intensively cared for than in many poorer countries. Most eat prepared feed, and this calls for a different approach to reducing methane emissions than that used in India or other developing countries. Specific kinds of feed (e.g., whole cotton seeds) appear to reduce methane emissions levels. Studies are ongoing to identify the populations of animals that would be candidates for diet modifications; to estimate the costs and benefits of these modifications (including boosted animal productivity); and to estimate emissions reductions that can be achieved.

Other ways to increase cattle's yield while reducing or maintaining methane emissions levels are also being studied. These include feed additives, hormone implants, and a synthesized growth regulator called bovine somatotropin, which can increase milk production.

Better management of animal waste is expected to result in substantial reductions of methane gas emissions. Methane emissions from animal manure create problems wherever large concentrations of animals are kept. In addition to controlling odor or run-off, better practices will help reduce methane emissions significantly. Furthermore, under certain conditions, the methane can be recovered profitably for resale by using devices called biogas digesters, for example. (A biogas digester converts the manure to methane, which can be contained and used as fuel.) Techniques for capturing methane profitably from waste lagoons—areas in which manure is collected—are also under development.

Coal mining is another promising area for methane-emissions control. Currently, an estimated 45 million metric tons of methane are released annually during global coal mining operations.

Traditionally, mine-ventilation systems have been used to dilute the methane that is released during mining operations and remove it from the mine workings, resulting in methane releases into the atmosphere. Now, however, it is technically feasible to recover more than 50 percent of the methane released during underground mining, to be used as an energy source. Furthermore, it has been estimated that at current U.S. natural gas prices, recovery of this methane would be a profitable

Beef cattle and other livestock are important sources of methane emissions. Because the atmospheric lifetime of this Greenhouse gas is only about 10 years, it is an excellent candidate for emissions control. Improving animal feed is one strategy being tested.

enterprise. In fact, methane recovery is already underway at a number of mining locations in Alabama.

In the United States, however, certain obstacles remain to be overcome before methane recovery from coal mines can proceed on a broad scale. These are primarily institutional issues associated with who legally owns the methane. In many cases, the coal-mining companies own the coal, but not the gas. Once these issues are resolved, several million metric tons of methane could be recovered profitably from coal mines. Reduced methane releases to the atmosphere would be a significant side benefit.

Other major coal-producing nations, in addition to the United States, could benefit from methane recovery from their coal-mining operations. One example is China, the world's largest coal producer, which takes nearly all of its coal from underground formations that release methane. An estimated 16 million metric tons of methane are released annually from China's coal mines. With technical and financial assistance, China might be able to recover a large portion of these emissions. From the standpoint of global warming, the benefits of this achievement would be twofold: First, China could achieve a significant reduction in its methane emissions. Second, the Chinese could use recovered methane to meet a portion of their future energy needs; methane, when burned, produces much less CO_2 than does coal.

Methane can also be profitably recovered from landfills and used as an energy source. In the United States and other countries, methane recovery from landfills is already being performed. These activities may be expanded as waste-management practices are modified to enhance methane generation in order to increase profitability.

There are still other opportunities to achieve reductions in methane emissions. For example, a panel of rice experts recently concluded that improved irrigation and fertilizer practices, combined with better rice selection, could reduce methane emissions from rice cultivation by 10 to 30 percent.

Since many methane emissions-reduction techniques are profitable in themselves, cost is not a major obstacle to their widespread adoption. However, this does not mean that these techniques will automatically "catch on" around the world. Further efforts are needed to overcome barriers to change. One approach might be to define a set of internationally preferred practices in key methane-emissions areas. National bodies such as the National Academy of Sciences in the United States as well as international bodies could play a role in defining and describing these practices. The preferred practices could then be adopted as part of international agreements and assistance programs, for example. Parties to the agreements would be responsible for promoting the applicable set of practices in their own countries.

Clearly, much work remains to be done. The cost and effectiveness of the various techniques for reducing methane emissions must be documented for the wide range of conditions that exist in the United States and around the world. These efforts are proceeding. Based on work up to this point, there is reason to hope that continued technological development and the implementation of profitable and low-cost options can substantially reduce methane emissions. By the end of the century, it should be possible to halt the increase in atmospheric concentrations of methane. □

Transportation: The Auto

by Deborah Bleviss

Our present transportation system in this country contributes significantly to the threat of global warming. The fossil fuels—principally petroleum—used by our transportation vehicles are a major source of emissions of the Greenhouse gas, carbon dioxide (CO_2). The refrigerants used to cool these vehicles are a source of another Greenhouse gas, chlorofluorocarbons (CFCs).

Highway road vehicles, principally cars and light trucks, account for nearly 75 percent of the energy used for transportation, and their numbers continue to climb. Not surprisingly, their contribution to Greenhouse-gas emissions is considerable. Nearly 25 percent of all CO_2 emissions and 13 percent of all CFC emissions in this country can be traced to these vehicles.

In considering how to reduce the global-warming threat posed by our present transportation system, we must focus on these vehicles. The recently implemented Montreal Protocol on Substances that Deplete the Ozone Layer agrees to a 50-percent reduction in production of CFCs in this country by the end of the century. In addition, the United States and other parties to the Protocol have called for a complete phaseout by the year 2000 if substitutes can be produced. The next step is to focus attention on controlling CO_2 emissions from transportation vehicles. There are three options for doing this:

- Improving the fuel efficiency of vehicles and the systems in which they operate.
- Converting to alternative fuels that produce little or no CO_2.
- Switching to more energy-efficient modes of travel.

(Bleviss is Executive Director of the International Institute for Energy Conservation and author of The New Oil Crisis and Fuel-Economy Technologies *(Quorum Books, 1988).)*

Only the first option can have a significant impact in the short term.

Improved fuel efficiency has a direct impact on Greenhouse-gas emissions: Doubling the fuel economy of a vehicle reduces its CO_2 emissions by half. The United States has already achieved a dramatic improvement in the fuel economy of its vehicles. In 1973, when the first oil crisis occurred, the average fuel economy of new cars was 14 miles per gallon (mpg); today, it has roughly doubled.

Nearly 25 percent of all CO_2 emissions and 13 percent of all CFC emissions in this country can be traced to these vehicles.

Fearing the prospect of new legislation to push for major strides once again in the fuel economy of new light vehicles (cars and light trucks), some have argued that the gains made in the past cannot be repeated. While it is true that future progress in fuel economy will not come as easily as past progress, the technological frontier in fuel economy is far from crossed.

The numerous high-efficiency "concept" cars developed in the early 1980s, mainly by European automakers, in reaction to the 1979-80 oil crisis offer ample evidence of this point. Most of these cars achieve a city fuel economy of at least 60 mpg and a highway fuel economy of at least 75 mpg. While they were never designed for mass production, these cars clearly demonstrate that we can do much better than the 28 mpg that typifies a car today. There is still substantial potential to increase engine and transmission efficiencies, to reduce aerodynamic drag, and to substitute lightweight materials for the steel that predominates in today's light vehicles. (Needless to say, as these technologies are pursued, care must be taken to meet the fuel-economy challenge without sacrificing other consumer needs, such as occupant safety in lighter vehicles.)

Yet while the technological potential for increasing fuel economy is great, the likelihood it will be achieved in an expeditious manner, without government intervention, is very small. Oil prices are low at present; hence interest in fuel economy is low. Even if prices were to rise, consumers are not likely to react quickly because fuel costs as a fraction of the cost of owning and operating a car are declining.

Instead, the government must act. It needs to offer incentives to manufacturers to improve the efficiency of the vehicles they produce. The practice of setting progressively tighter fuel-economy standards has worked in the past and could work again. By the end of the century, an average new-car fuel economy of 45 mpg and an average new light truck fuel economy of 35 mpg are feasible goals, and aggressive enough to have a substantial impact on reducing CO_2 emissions.

The government also needs to offer incentives to consumers to buy fuel-efficient cars. Strengthening the existing tax on the purchase of gas "guzzlers" and offering a financial incentive for the purchase of gas "sippers" are two strategic initiatives.

Finally, the government needs to stimulate research and development by the automotive industry to bring forward new fuel-efficient technologies for automobiles; a jointly funded, government/industry research program is one means of doing this.

In addition to improving the efficiency of vehicles, it is important to improve the efficiency of the systems in which they operate. No matter how efficient a vehicle is, it needlessly wastes fuel if it must stop at every traffic light. Computerized control of traffic lights offers promise in reducing this problem. Similarly, fuel is needlessly wasted by the slow speeds and stop-and-start patterns of congested roads and highways. Initiatives are now underway to develop "smart" traffic

Mark Pfoutz photo. MWCOG.

Energy-efficient modes of travel, such as van pools for commuters, can reduce the threat of global warming.

systems that will automatically reduce traffic flow to congested spots in order to maintain a continual flow of vehicles; these systems need to be actively pursued in the future.

The second option for reducing CO_2 emissions by the transportation sector is to switch to a clean and viable alternative fuel. Ultimately, for the long term, this is the only solution. Therefore, it is critical to begin significant research efforts now to develop cost-effective clean fuels; these would include hydrogen, biomass-based fuels (ethanol or methanol), and electricity from non-fossil fuel sources.

For the short term, however, there are problems with alternative fuels and the vehicles that use them. Electric cars continue to have problems with their limited range; moreover, fossil fuel-generating plants are the main source of the electricity that would power these vehicles today. The other fuels currently seen as potentially viable include compressed natural gas, methanol derived from natural gas, and ethanol produced from agricultural wastes such as excess corn supplies.

Converting our transportation fleet to methanol will not solve global-warming problems because methanol produces as much CO_2 per unit of energy burned as gasoline. Compressed natural gas would mean reduced CO_2 emissions as compared with gasoline (about 30 percent per unit of energy), but problems with storage of this fuel as well as the limited range of natural gas-fueled vehicles will necessarily inhibit its widespread use. Moreover, the reduction in CO_2 achievable per vehicle with the use of this fuel would probably be more than offset by the projected growth in the number of vehicles on the road.

Of all the alternative fuels commercially available today, ethanol—if produced from renewable sources such as corn or other feedstock—is the only fuel with the potential for generating no net CO_2 emissions. But it is very expensive. Moreover, U.S. agricultural waste would not provide sufficient feedstock to supply enough ethanol to meet our needs as drivers of ethanol-fueled vehicles. To meet these needs, a substantial amount of land presently used to grow food crops or to support forests would have to be diverted for the purpose of producing ethanol feedstock.

While today's alternative fuels will not solve the global warming problem, they are likely to be used to solve certain local air-pollution problems. Such cases should be closely watched and documented, for they will provide valuable insights into the infrastructural, social, and technical problems that will have to be addressed when clean fuels are developed to which the national fleet can be converted.

The final option for reducing the global warming impact of our transportation system is to switch to more efficient modes of travel. Over 70 percent of all trips today take place in a car or van occupied by just one or two persons—a very energy-intensive mode of traveling.

Many have suggested that a major shift to mass transit needs to occur to reduce the threat of global warming. Certainly this strategy should be pursued to its fullest extent. But within the United States, the use of cars so far exceeds the use of mass transit that even significantly shifting to public transit systems will not substantially reduce energy use for transportation. For example, if the size of mass-transit systems were tripled in this country—a sizeable financial commitment—and filled to capacity, energy use for passenger road transportation would fall by only 10 percent.

A more promising alternative is to increase the load factor in today's cars. The average number of persons traveling in a car today is 1.7; if the average were increased to four, energy used for passenger road transportation would drop by 45 percent. While promising, this scenario would require significant changes in personal behavior. Increasing the "high-occupancy vehicle" lanes on highways, requiring employers to establish vanpooling programs for their employees, and charging high fees for parking are some possible ways to increase the load factor in cars. These need to be tested now in pilot programs to determine their applicability for widespread use in the future.

Changes in our transportation infrastructure will require considerable time. Therefore, it is critical to act now to change our transportation system in order to minimize its contribution to global warming. □

Transportation: Mass Transit

by David B. Goldstein and John W. Holtzclaw

Larry Levin photo. WMATA.

Riding mass transit instead of driving means less CO_2 emissions. Many transit systems, such as METRO in the Washington, DC, area, report yearly increases in ridership.

Appropriately enough, most of the attention given to improving the efficiency of personal transportation has focused on bettering the fuel efficiency of automobiles. In the short run—for the next 5 to 30 years—this approach can produce the largest savings in Greenhouse-gas emissions. The reason is the relatively short lead times required for redesigning automobiles and replacing the current capital stock.

But a complementary approach that offers comparable savings potential over the long run is to develop urban infrastructures that minimize the use of private vehicles.

Conventional planning assumptions have focused on the need to accommodate continued growth in vehicle miles traveled as personal incomes rise. The implicit assumption is that the rate of growth in miles traveled is beyond policy control. But recent research has shown that the number of vehicle miles traveled per urban dweller is not a fixed function of income. Instead, policies concerning the taxation or subsidization of automobiles, mass transit, highways, and land use, for example, make immense differences in per-capita vehicle miles traveled in cities with comparable personal income.

In North America and around the world, those cities with the largest highway systems, the lowest densities of both residential and commercial development, and the lowest availability of mass transit have the highest per-capita auto use. Within the United States, cities with higher densities and better transit services have significantly lower rates of auto travel. For example, New York City residents drive only one-fourth (Manhattan denizens about one-seventh) as much as average Americans. Residents of Australian cities travel about half the per-capita vehicle miles of average Americans. In western European cities, per-capita vehicle miles amount to about one-quarter of the U.S. average; and in Japanese cities the fraction is about one-tenth.

Residents of Australian cities travel about half the per-capita vehicle miles of average Americans.

Reductions in personal vehicle miles traveled do not represent reductions in mobility; indeed, the reverse is often true. A recent study found that, even though average traffic speeds increase in low-density areas, the average time spent commuting increases because trip lengths also increase. This means more time wasted in cities that concentrate on improving traffic flow by constructing new highways. In short, the construction increases the *need* to travel more than it increases the *ability* to do so (resulting in higher energy use without raising living standards).

Expanding mass-transit service, focusing less on highway construction, and adopting land-use policies that encourage fairly high-density development patterns could produce much lower rates of per-capita vehicle miles traveled than current projections for the middle of the next century. Over 60 percent of the housing projected to exist in the United States by 2050 has yet to be built; along with more than 80 percent of the commercial development. Changes in policy could affect where and how these structures are built. Even a change that reduces projected travel miles by only 1 percent per year would lead to an almost 50-percent reduction by 2050, along with parallel reductions in the need for freight transportation due to higher densities and shorter commute distances.

In the developing world, urban growth will be faster, and policy decisions will make even more dramatic differences. Focusing more heavily on transit systems rather than highways in developing world cities will most likely not prevent vehicle travel miles from growing, even on a per-capita basis. But it could greatly reduce the rate of increase, with an immense effect on the amount of gasoline consumed and Greenhouse gases emitted. If developing world cities evolve to look more like Hong Kong than Brazilia or Athens, their transportation energy consumption could be curtailed by half.

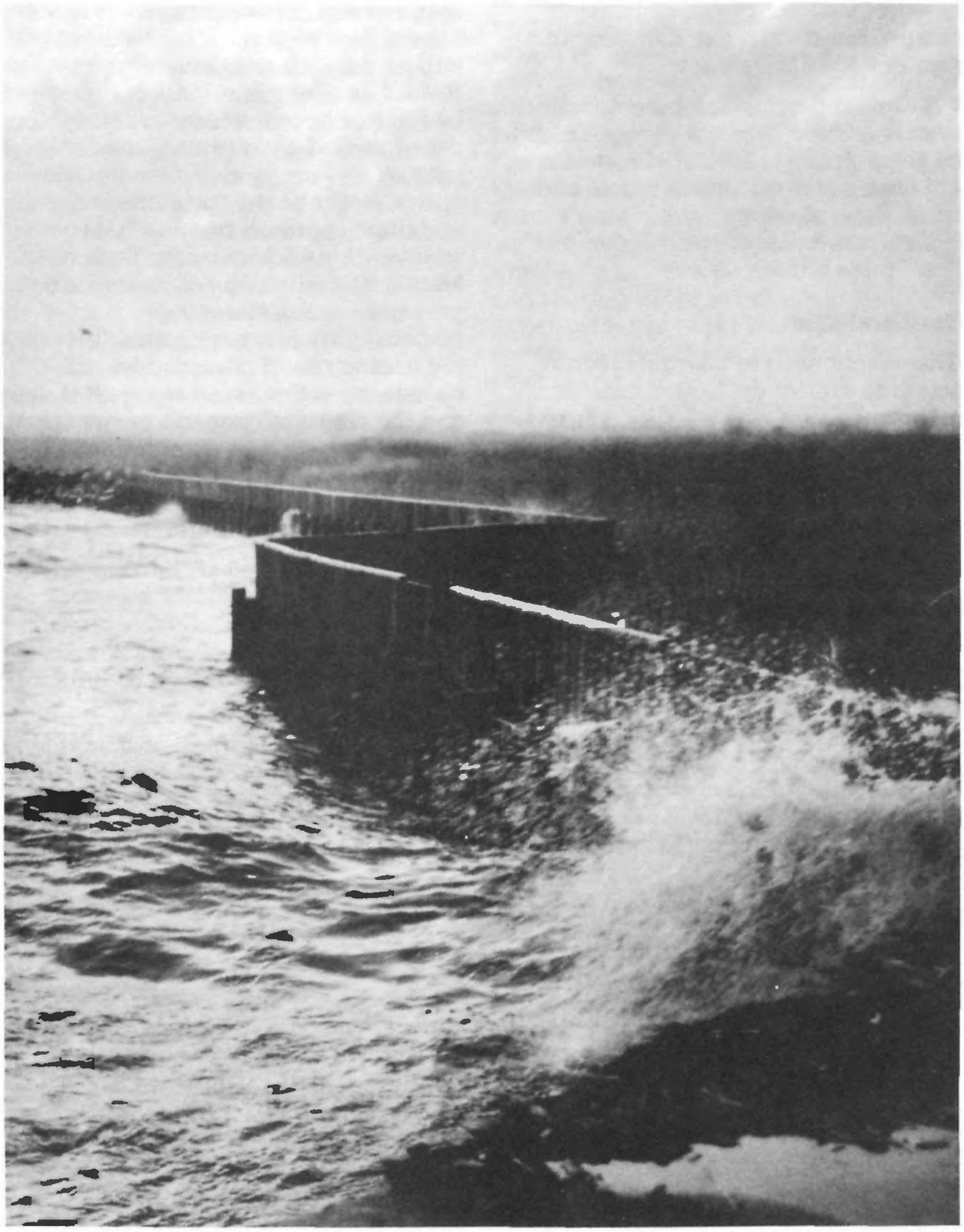
Mass transit as a means of reducing gasoline consumption can ultimately save more than energy. Generally, public transit facilities are significantly less costly than the highways and garaging and fueling facilities required for personal vehicle travel. They also rely more heavily on local labor and equipment than on imported products or services. These criteria are particularly important in cash-strapped developing countries.

Even the most efficient cars will still produce a significant Greenhouse problem by mid-century if autombile usage rates continue to increase as they have. But mass transit provides a long-run option that complements the energy savings potential of more efficient vehicles. □

(Dr. Goldstein is Director of the Energy Program for the Natural Resources Defense Council (NRDC) in San Francisco. Dr. Holtzclaw is a consultant to NRDC on urban development and transportation efficiency.)

Adaptation: Another Approach

by Joel B. Smith



Staten Island Register photo.

Global warming may bring a rise in sea level. To some extent, it may be necessary to adapt to the effects of climate change.

(Smith is Acting Chief of the Adaptation Branch within EPA's Climate Change Division.)

People usually do not talk about learning to live with pollution. Adjusting to smog or dirty water, for example, is just not an acceptable prospect. Instead, the point is to eliminate or reduce the problem.

To some extent, people may have to learn to live with global warming. Since the onset of the industrial revolution, the buildup in Greenhouse-gas concentrations in the atmosphere may have committed the planet to approximately a 1 °Celsius warming. And atmospheric Greenhouse-gas concentrations will likely continue rising. Even an aggressive set of emissions-control strategies would not stop the growth in Greenhouse-gas concentrations. Continued warming is therefore likely, and people will probably have to adapt to it.

If climate change is inevitable, one approach to adaptation is to wait until the climate actually changes, then make the necessary adjustments. This approach sidesteps the problem of predicting future climate: People would build sea walls as the oceans rise or switch to heat-resistant crops as the planet becomes hotter.

The problem with this strategy is that it may be impossible to reverse the damages of climatic change, and adaptation after the fact may be very costly. For example, a rapid climatic change might precipitate an increased rate of species extinction, since climate zones would probably shift faster than many plants and animals could migrate. Once a species becomes extinct, it cannot be replaced. A rise in sea level would probably drown many wetlands. Once wetlands are lost, they cannot easily be restored.

Moreover, many decisions made today concerning climate-sensitive systems may have a long-range impact. Forests planted today will take decades to reach maturity. A dam or reservoir built now may last for a century. During the lifetime of these projects, the climate may change enough either to threaten the survival of the forests or to reduce the usefulness of the reservoir. If the forest dies off, it cannot be quickly replaced; expanding the reservoir's capacity could be very expensive. Thus it makes sense for planners, faced with possible irreversible impacts or with costly responses, to try to anticipate climatic changes in order to minimize these impacts and responses.

Yet anticipating climatic change is easier said than done. There is a scientific consensus that increased Greenhouse-gas concentrations in the atmosphere will likely warm the Earth.

In general, actions that are inexpensive, feasible, and have benefits independent of global warming should be implemented first.

But how much warming will actually occur—and how rapid it will be—is uncertain. There is even more uncertainty about regional climatic change. For example, it is not known if all regions will be warmed or if precipitation in any specific region will rise or fall—not to mention *when* real impacts might be felt. Since adaptation would take place on a regional and local scale, these uncertainties make strategic planning particularly difficult.

How do we manage natural resources in anticipation of significant, but unknown climatic changes? As a beginning, it makes sense to explore management options that meet the following criteria:

- First, flexibility is needed. Since how climate will change is unknown, policies need to be successful under a wide variety of contingencies, including a scenario in which no change in climate occurs.

- Second, low-cost options are preferable. Measures taken today to anticipate climatic change should be relatively inexpensive; spending a lot of time or money preparing for impacts that may not occur for decades does not make sense. A reservoir should not be built now because it may be needed in 2030; however, if one is already being built, it may be prudent to enhance its flood- and drought-control capabilities in anticipation of future climatic change, rather than risk damages from greater floods of droughts.

- Third, options which have benefits even if climate does not change should be given priority. Even if climate does not change, we would not regret having taken these measures.

Some examples of options that meet these three criteria follow:

Sea-Level Rise

There is no need to take anticipatory action to protect developed coastal areas, such as New York City, since we can build sea walls as they are needed. However, planning is required to obviate significant ecological damage from sea-level rise. Although many wetlands would inevitably be lost, some wetlands could adapt to sea-level rise by migrating inland. However, such inland migration could be blocked by bulkheads and levees designed to protect development.

Planning and anticipatory measures are therefore required to allow for inland migration of wetlands. One simple measure is for coastal states to prohibit construction of bulkheads. Another measure is to restrict coastal development by adopting set-back requirements. However, since it is not known how high sea levels will rise, it will be difficult to calculate how far to restrict development. Indeed, it may not be feasible or economical to restrict the use of coastal areas prior to sea-level rises. A less costly and more flexible option might be the "presumed mobility" approach that has been adopted in principle by the State of Maine. Basically this means requiring property owners to assume responsibility for moving structures as the oceans rise. If climate does not change, no action is necessary. If it does and the sea rises, property owners must move structures that are threatened by the sea.

Plant and Wildlife Migration

To survive, many plants and animals would have to migrate northward as temperatures rise and suitable climate zones shift. Keeping up with a rapid rate of climatic change will be difficult

Rising ocean levels? Just more hogwash from the environmental alarmists!

and will be made even harder by the presence of cities, farms, and roads that block migration. While "presumed mobility" may be a viable concept to combat sea-level rise, wholesale removal of settlements, roads, and farms would not be feasible.

One way to facilitate migration and reduce the loss of plants and animals is to use migration corridors. Greenways and hedgerows are examples of corridors that would allow plants and animals to migrate as climate changes. Corridors should also be opened between wildlife refuges to reduce fragmentation of parks and reserves. Migratory corridors have short-term benefits in that they provide recreational opportunities for people and expanded habitats for wildlife.

In California, earlier snowmelt would reduce water supplies, while drier summers could reduce water availability everywhere.

Forests

Many trees planted today may not survive to reach maturity, especially those rooted in southern boundaries of forest ranges. A number of steps can now be taken by forest managers to minimize potential impacts. Shorter rotation times (harvesting trees at a younger age) would reduce the likelihood of trees being affected by climatic change. Harvesting trees as early as possible, then replacing them with more adaptable species, would help ensure adaptation to climatic change.

Mixing the types of trees planted to include heat- and drought-resistant species reduces the risk of climatic change affecting an entire forest. As long as the heat- and drought-resistant trees are still valuable species, there is little risk in planting them in addition to the trees currently grown. Harvesting of trees should leave a diversity of species uncut to enhance regrowth.

Finally, climatic change could increase fire frequency and pest infestations. Enhancing fire and pest monitoring, fire control, and pest-eradication programs would help reduce these impacts.

Water Use

Since scientists cannot predict changes in precipitation patterns, there is much uncertainty about how water resources would be affected by global warming. Very likely, however, snowpacks will be smaller and melt earlier, and there will be significant potential for increased summer dryness and drought. In California, earlier snowmelt would reduce water supplies, while drier summers could reduce water availability everywhere.

A number of measures could help safeguard water supplies. Water conservation could be promoted by pricing water at its replacement costs and allowing markets to allocate water to the most efficient users; this would reduce current demand for water. If demand is reduced, vulnerability to reduced supplies is also reduced.

Apart from the prospect of global warming, conserving water makes sense because it lessens the need for expensive new water projects. And as a backup mechanism, operators of adjacent water-management systems could be encouraged to share water supplies as needed during dry periods. Finally, planners should consider climatic change when designing water projects. Projects tend to be designed based on the historic record of floods and droughts. But global warming makes the historic record a less useful guide in planning. Planners should therefore evaluate the costs and benefits of marginal enhancements of water projects in view of potential climatic change.

Agriculture

In theory, farmers should be able to adapt quickly to climatic change: As the climate warms, farmers could simply switch to crops that are better adapted to higher temperatures and reduced soil moisture. Yet government policies may discourage such crop changes. Price supports and other programs encourage farmers to plant the same crops they have historically raised.

Modifying such programs would encourage farmers to react more quickly to climatic change. Government could also help farmers by maintaining an adequate supply of heat- and drought-resistant crops in reserve. Research on developing new strains of crops should be maintained.

By avoiding monocropping and practicing crop rotation, efficient irrigation, and conservation tillage, farmers can be better prepared for climatic change. In contrast to monocropping, multicropping reduces the chance that an entire harvest will fail. Some crops do well in wet years; others, in dry years. So planting a variety of crops is a good strategy for dealing with any year-to-year climatic changes that occur. Crop rotation and conservation tillage help improve the long-term sustainability of soils and improve water retention. Efficient irrigation reduces vulnerability to water shortages and to increases in the price of water. Pest-infestation control programs should also be prepared for northward shifts in pest locations.

Timing

Since the effects of climatic change may be delayed and the costs of response actions will vary considerably, it is not necessary to implement all actions immediately. Some actions can be delayed; others should probably be implemented in the short term. Research that enhances our understanding of the impacts of climatic change and the ability to adapt to them should receive high priority. For example, maintaining genetic diversity in crops will help ensure that appropriate crop varieties are available when needed.

In general, actions that are inexpensive, feasible, and have benefits independent of global warming should be implemented first. Thus, if climate does not change, little is lost. More expensive, less flexible measures can be delayed until there is more certainty about future impacts—or until climatic change makes action necessary. □

What We Can Do

by William K. Reilly

To address an issue as complex as global climate change, the full range of human activities will need to be considered, from transportation to energy use. This Los Angeles Harbor Freeway interchange is an example of the scope of modern-day projects, with implications for many aspects of the environment.

For hundreds of years, the ancient Greek city-states of Athens and Sparta were bitter enemies, kept at loggerheads by opposing cultures, values, and interests. The breach between the two was so complete that even today, implacable adversaries are sometimes referred to as being "like Athens and Sparta."

But in 479 B.C., Athens and Sparta joined forces to defeat the Persian army in a heroic battle to reclaim their independence from the Persian Empire. Neither city by itself could have prevailed against the more powerful Persians; but by putting aside their differences and joining forces, the Greeks were able to rout their mutual enemy.

This Greek example of synergy—literally, "working together"—has been repeated many times since then. In times of crisis, prudent societies have put aside their regional, professional, social, and other differences—their competing interests—and worked in concert to deal with a common foe.

At the end of the 20th century, the common foe for the people of every nation is the deterioration of the global environment. The need to join forces to confront this urgent problem is compelling.

President Bush recognized this in an article in the January/February 1990 issue of *EPA Journal*, in which he noted that a president "quickly learns to see policy in the broadest terms possible.

"Urban and housing policy must be related to transportation, transportation policy to energy, energy policy to agriculture, and so on," the President wrote. "Applying this same perspective, one cannot fail to see that deforestation, ozone depletion, ocean pollution, and the threat of global warming interconnect to challenge our future."

(Reilly is Administrator of EPA.)

As the President's comments suggest, we are living at a time when human activity may be affecting the global environment as profoundly as the billions of years of evolution that preceded our tenure on Earth.

In many ways, the ultimate cross-cutting policy challenge is global climate change—the buildup of heat-trapping gases in the atmosphere. It is an issue that transcends all the sectors into which our society tends to divide itself: public and private; federal, state and local; domestic and international; manufacturing and consuming; agriculture, energy, transportation and environment.

Simply stated, "no regrets" means: "Act toward the future in such a way that you will have no reason to regret the past."

The issue of global climate change illuminates, as few others do, the full extent to which the traditional policy sectors and interest groups that compete so hard with one another are actually closely interrelated. It reveals to us a fundamental, increasingly acknowledged truth: the fate of one is tied to the fate of all.

Unfortunately, our current state of knowledge of the global atmosphere is sketchy at best. We have a great deal of data, but we don't yet know for sure what they mean.

Yet there is growing scientific agreement that *something* significant is happening; six of the ten warmest years on record occurred in the past decade. Just a temporary warming cycle? Perhaps. But carbon dioxide (CO_2) in the atmosphere, a major contributor to climate change, has increased 25 percent in the last 100 years. In the opinion of the National Academy of Sciences, significant global climate change is at *least* as likely to occur as not. The Academy has estimated that if CO_2 levels double, global temperatures could increase by 1.5 to 4.5 degrees Celsius by the latter half of the next century.

And the possible consequences? *If* such increases were to occur—and that is by no means certain—EPA concluded in a report sent to Congress in January that significant, virtually irreversible changes in natural systems could result. Many forests could become grasslands; species extinction could increase and habitat loss accelerate; sea levels could rise; agricultural and water supply patterns could be disrupted; and adjustments to these changes could cost society hundreds of billions of dollars.

A great many uncertainties are associated with these findings. Our computer models are not yet able to tell us exactly *how* the atmosphere is changing, *why*, *how quickly* the changes are likely to occur, or *where* they will have the greatest impact.

To improve the base of knowledge on which to make better informed decisions, the United States is accelerating its scientific and economic analyses so that we get some answers to these questions.

The U.S. Government is spending $500 million on an interagency research program on global climate change this fiscal year; this includes $300 million for NASA's remote sensing and other monitoring programs, along with a number of EPA projects to evaluate potential effects and response strategies. And in his 1991 budget, the President asked Congress to double that amount in order to pick up the pace of global climate research.

This country also has made a firm commitment to the Intergovernmental Panel on Climate Change (IPCC), the international body that is assessing the scope of the problem. The United States chairs a key IPCC workgroup looking at

Los Angeles Convention and Visitors Bureau photo.

response strategies and options for reducing CO_2 and other emissions related to global atmospheric change.

President Bush—having already endorsed the need for a framework convention, or international treaty, on global climate change—offered in December at the Malta Summit with President Gorbachev to host the first negotiating session. And in February, an IPCC meeting was held in Washington to consider the legal, technological, economic, and educational measures needed to respond to global climate change; President Bush became the first head of state to address this group.

While we work to improve our knowledge of the causes and effects of climate change, there are many things we can do—and are already doing—to combat the problem.

Global climate change is, of course, only one of a number of troubling stresses on the global environment; others include tropical deforestation; the growing extinction of plant and animal species; loss of natural habitats caused by encroaching development; acid rain, which damages ecosystems; and growing contamination of air and water by toxic chemicals, especially in the cities of the developing world.

A number of activities already under way will help deal with these problems as well as with global climate change. For example, air pollution from fossil-fuel combustion—from automobiles, from utilities, from factories—damages the environment in many ways. Besides releasing heat-trapping gases, it contributes to urban smog, acid rain, and toxic air and water pollution. Thus, the President's proposed amendments to the Clean Air Act to reduce emissions from fossil-fuel combustion and promote energy conservation—while aimed primarily at smog and acid rain—will also reduce emissions of CO_2 and other heat-trapping gases.

President Bush's acid rain proposal is especially important in promoting energy conservation. The President's bill requires a 10-million-ton reduction in sulfur dioxide (SO_2) emissions by the year 2000. To preserve these gains, the bill also sets a cap on total emissions generated. Increased energy conservation would be a natural result from applying a cap to SO_2 emissions after the year 2000. Utilities will find it increasingly beneficial to seek more efficient means of power generation and to re-educate consumers about the importance of energy conservation.

And there are other examples of environmental serendipity: Phasing out chlorofluorocarbons (CFCs) to save the ozone layer will help limit global climate change because CFCs account for almost one-fifth of all heat-trapping gases. Working with the World Bank and other multilateral aid and lending institutions to curb deforestation and to reforest degraded lands not only will help prevent the release of CO_2 from the burning of trees but also will help grow new trees to absorb CO_2 during photosynthesis. And President Bush's "America the Beautiful" reforestation program—planting one billion new trees a year across the country—will help reduce soil erosion, improve air quality, and provide wildlife and recreation benefits and jobs, all while helping remove CO_2 from the atmosphere.

The Administration has coined a term to describe the fortunate and pervasive synergy between some of the policies we need to undertake to address global warming and those policies that are desirable in and of themselves for the country's overall environmental and economic good: "no regrets."

Simply stated, "no regrets" means: "*Act toward the future in such a way that you will have no reason to regret the past.*"

This is a policy of doing things that make sense environmentally for *many* reasons—pollution control, forest conservation, elimination of CFCs, reduction of waste through recycling. Each is an important and compelling policy in its own right; each also happens to reduce emissions that contribute to global climate change.

"No regrets" is not a bad way for us to think about the environment in a broader sense—about our individual roles and responsibilities for stewardship of our planet.

If the United States is to play a major role in the great cause of restoring the productive natural systems of this Earth and if we aspire to lead this effort, we must set a shining example here at home. Yet the energy we use and the waste we generate make this nation the source of a fifth of all heat-trapping gases.

To be a beacon to the world, we will have to do better. We in the United States produce twice the solid waste per capita of West Germany, and three times that of Italy. We use twice as much energy per capita as Switzerland and nearly three times as much as Japan. These are prosperous countries, which already are honing their competitiveness internationally by cutting waste and improving efficiency.

The fact is that there are *many* inefficiencies in the way we use energy—from how we burn fuel in our cars and trucks, to the bulbs we use to light our homes and offices. Together, these inefficiencies add up to a substantial and costly, yet correctable share of the emissions that contribute to climate change and other environmental problems. Many additional cost-effective steps can be taken—increased vehicle fuel efficiency, improved energy efficiency of appliances and lighting, beefed-up building insulation—that would reduce energy waste at little cost.

Despite the scope and complexity of the problems, I remain encouraged.

Global climate change, in my view, presents the United States and the community of nations with two key policy challenges. The first is getting governments to agree, among themselves and within, on a set of appropriate responses to these problems. The second and perhaps even greater challenge lies in convincing individual producers and consumers of the importance of their own everyday activities in helping to mitigate global climate change.

I believe that we human beings have an ethical obligation to practice environmental reciprocity—to protect, nourish, and sustain the natural systems that protect, nourish, and sustain us. Doing so is not just a job for government, or business, or farmers, or conservationists—it's a job for all of us.

Sixteen years ago, scientist James Lovelock popularized the Gaia hypothesis—the theory, named after the Greek goddess of Earth, that life, through its interaction with the physical environment, creates the conditions it needs to exist. Now international environmental problems like ozone depletion, global climate change, and environmental degradation in the developing world are putting that theory to a real test. Our response to these global challenges will tell us whether we are in fact able to protect the environment which sustains us—or whether we will be forced to adjust to a world that may be much different, perhaps much less hospitable, than the one we live in today.

Despite the scope and complexity of the problems, I remain encouraged. Working together in a spirit of international cooperation and goodwill, accepting our own individual responsibility for the well-being of our planet, we humans can and will succeed in putting aside our differences and cooperating to achieve both a sound, sustainable economy and a safe, healthy environment.

We will do so because, in the end, we have no choice: Our common enemy, the deterioration of our planet's environment, is at the gates. □

Views from Other Nations:

Any effective effort to deal with climate change must be a fully international one; the opinions and actions of all nations will influence the outcome. To provide the reader with some sense of what others are thinking about the global warming issue, the Journal invited representatives of six different nations to comment. The countries, which differ widely in terms of economics, geography, and contributions to the Greenhouse Effect, are Poland, Brazil, West Germany, the Netherlands, Japan, and India.

Each representative was asked these questions: From your perspective, how serious is the problem of global warming? In what way does your country contribute to it? What is your nation planning to do about this issue? The six commentaries follow:

Kassenberg

Sitnicki

Poland

by Andrzej Kassenberg and Stanislaw Sitnicki

Economic reform could enable Poland both to improve its living standards and to reduce the risk of global warming by curbing emissions of Greenhouse gases such as carbon dioxide (CO_2). Our nation is the world's eighth largest source of carbon emissions from burning fossil fuels. Yet low incomes and shortages of consumer goods make it unlikely that the control of CO_2 emissions will be in itself a high priority.

However, efforts to restructure the Polish economy could help cut Greenhouse-gas emissions by 20 percent. Policies which would help protect the environment while improving the economy include: reducing demand for fossil fuels by increasing energy efficiency; switching from coal to natural gas; and managing land and biomass resources more effectively.

Energy efficiency is a high priority for Poland. Heavy industrial production and lack of market signals have made the Polish economy two to three times more energy-intensive than Western European economies. In other words, the nation uses two to three times more energy than necessary to produce goods and services. Better use of energy could save Poland money by saving expensive-to-mine coal and imported oil and natural gas. Reduced energy costs would mean a healthier economy and, at the same time, lower CO_2 emissions.

Poland can save approximately one-quarter of its current energy consumption (1.4 quadrillion BTU) by purchasing new, more efficient industrial technology, installing space-heating controls, and plugging steam leaks. Studies show that gains in energy efficiency can be achieved for less investment than new coal mines cost to open or new power plants cost to build. However, loan money will be necessary to take advantage of these opportunities, and it is not clear where these funds will come from.

Fuel switching is also a high priority for Poland. Coal currently supplies 75 percent of Poland's energy demand, and producing it requires one-fifth of all Polish industrial investment capital. Mining places heavy demands on labor, materials, and electricity. Geological and mining conditions are deteriorating rapidly, and coal mines must be extended some 10 to 30 meters deeper each year. These economic factors impose strict constraints on the growth of this energy supply.

A shift to natural gas would reduce the economic burdens of coal mining and also reduce CO_2 emissions. Natural gas contains only half as much carbon per unit of energy as coal. Gas could be supplied by the Soviet Union, though Poland will have to develop exports to acquire the hard currency to pay for imported fuels.

Better land and forest management is becoming a higher priority in Poland. Land-use planning is needed to protect water supplies, forest resources, and agricultural productivity. Planning for the protection of natural areas can protect economic resources and, at the same time, protect forests and plants which, through photosynthesis, take CO_2 out of the air.

Changing land management practices to protect trees in reserves and to increase tree growth in both forests and wood-fuel plantations can improve Poland's economy, sequester carbon, and replace fossil fuel with plantation-grown wood, which serves to recycle CO_2. In addition, encouraging agricultural practices that collect carbon in soils can help improve soil productivity.

Of course, carbon emissions are not the only source of concern. Municipal solid waste generates methane, another important Greenhouse gas. Recycling policies could reduce this pollutant as well as save Poland energy, materials, and money. Studies are beginning to assess how management measures for recycling could be applied in the cities of the "Green Lung" of Poland, a relatively undisturbed area that covers almost 15 percent of the nation's total land mass. This northeastern region is called the "Green Lung" because it remains pastoral and forested and thus produces the purest air in Poland.

If Poland is able to save energy, switch from coal to natural gas, and better manage its land, forest, and agricultural resources, then carbon emissions will be reduced *as a result of* economic growth. Infusions of technology and investment capital from the West could speed Poland's progress toward these goals. Because the consequences of climate change will be global, it makes sense for the United States and other nations to consider their loss if Poland's efforts at economic reform, energy efficiency, and resource management fail for lack of help. □

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Brazil

by Antonio Carlos do Prado

Prado

Major contributors to global carbon-dioxide (CO_2) emissions include the United States, the Soviet Union, China, and Brazil. Brazil differs from these other countries in that its emissions are principally due to burning forests, not to fossil-fuel consumption.

Brazil does not have an official estimate of its contribution of Greenhouse gases. However, according to Jose Goldemberg, Secretary of Education for the State of Sao Paulo, Brazil may contribute a total of 5.5 percent of yearly human-induced emissions of CO_2. Nearly 4.5 percent may come from burning of the Amazon, with the energy sector making up the 1-percent difference.

The Brazilian government, like the majority of other governments, does not have an official policy, legislation, or national plan that is specifically or solely concerned with global climate change or emissions of Greenhouse gases. However, the government does officially recognize the problem of global climate change and the need to control Greenhouse-gas emissions.

Recently, on January 9-11, 1990, Brazil and the United States co-hosted a conference of the Intergovernmental Panel on Climate Change (IPCC) on response options concerning tropical forestry and global climate change. A major result of this conference was that the IPCC resolved to support the development of a forestry protocol to govern the use of all forest resources in the context of international treaty negotiations on climate change.

One conclusion that emerged from the recent IPCC conference in Brazil is that there are insufficient data on the actual rate of forest loss and the amount of carbon released from biomass when forests are burned. Data-gathering on these points will begin in 1990 as the world's top space agencies begin a remote sensing program, under Brazil's leadership, to determine the status of the world's tropical forests.

The Brazilian government's concern about forests and climate change is part of its broader recognition that sustainable use of forests is necessary for long-term economic and social development and preservation of environmental resources. Thus in April 1989, President Sarney announced the "Our Nature" program, an ensemble of different acts, regulations, and bills to promote better forest-management practices by bolstering previously existing laws and programs and creating new ones.

As part of this program, the Brazilian space and environmental agencies are cooperating in a fire-prevention program to prevent illegal burning of the Amazon. In 1988-89 satellite images were used to detect fires, and helicopters were dispatched to check for clearing permits; fines were imposed on violators. During this period, deforestation in the Brazilian Amazon declined by an estimated 30 percent, at least in part as a result of this program.

Among other initiatives, the "Our Nature" program also requires companies that manufacture forest products to create forest-management plans outlining how they will *sustainably* grow or harvest from the natural forest enough wood to meet 50 percent of their needs in 1990. The plans for subsequent years must show increasing increments of 10 percent a year until 1995, when 100 percent of wood needs must be met sustainably. Firms that fail to comply with this regimen are subject to closure or other penalties.

Of course, the prices of Brazil's wood products must rise on the international market to reflect the increased costs of sustainable production; Brazilian companies cannot be expected to compete with producers in other countries who do not use sustainable practices. Importers in developed nations could encourage widespread adoption of sustainable wood production techniques by setting appropriate conditions for all wood imports.

The Brazilian government is also taking numerous other steps to manage its forest resources. In February 1990, it announced a forthcoming program to establish an "extractive reserves" program to encourage the sustainable harvest of products from the forest. A national plan designating land for conservation will be launched soon. And while it is still early to characterize government policy directions under the new government of President-elect Fernando Collor de Mello, declarations show a willingness to consider proposals, such as debt-for-nature swaps, that have been previously rejected on the basis of national sovereignty.

In addition, under the Ministry of Mines and Energy, Brazil has instituted a number of programs to encourage energy efficiency. Again, however, these are not specifically targeted to the Greenhouse Effect. □

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West Germany

by Dietrich Kupfer

Kupfer

Many scientists are sounding the alarm on global warming. Others dispute that the consequences of the Greenhouse Effect are really as dramatic or potentially catastrophic as claimed. The leading opinion, however, is that significant changes must be expected. And the Federal Republic of Germany agrees.

The West German *Bundestag* has adopted the conclusions and recommendations of its inquiry commission as submitted in the report, "Anticipatory Action to Protect the Earth's Atmosphere." Basically, the commission concluded that despite the uncertainties underlying current forecasts and model calculations, effective measures to combat the Greenhouse Effect must be taken now.

While West Germany accounts for only 3.8 percent of the world's Greenhouse-gas emissions, our country's per-capita emission rate of 11.7 tons per year ranks comparatively high among nations. At present, industrialized countries shoulder the primary responsibility for the increase of man-made carbon-dioxide (CO_2) emissions. However, as Third World countries develop—striving to imitate the West—significant increases in emissions must be expected.

West Germany has already demonstrated the conservation ethic needed for the future. Although gross national product has risen by over 30 percent in real terms since 1973, there has been hardly any increase in the consumption of primary energy. During this period, our CO_2 emissions have actually *decreased* slightly. Nevertheless, the potential for energy-saving is still considerable, particularly in house heating (insulation), transportation, and industrial processing.

In order to save energy, the government has introduced legislation to provide economic incentives for energy-conservation strategies. A tax based on motor-vehicle emission levels has been proposed to motivate development of fuel-efficient engines. Other proposals are directed at creating more economical and rational use of energy.

In addition to addressing existing sources of CO_2, the government has encouraged the use of renewable energy resources for many years. Still, only 3 percent of the annual consumption of primary energy in West Germany is at present supplied by renewable energy resources. However, this does not mean the use of renewable energy resources is not a serious option in solving the climate problem. On the contrary, the way must be paved today towards increasing the share of renewable energy resources in our energy supplies.

Forests represent a further important factor in the global-warming equation. Every possible action must be taken to conserve forests around the globe since they are important "sinks" that soak up CO_2. Particular significance has been attached to tropical rainforests, and for 1989 and 1990, West Germany has doubled its monetary support for rainforest conservation. But it must be remembered that other types of forests are just as important for controlling global warming and therefore need protection. The government has implemented rigorous measures to reduce emissions of sulfur dioxide and nitrogen oxide from its power stations, which will benefit forests throughout central Europe.

The West German government supports the Montreal Protocol, which addresses the CFC-production problem. The protocol regulates the gradual, worldwide phaseout of a group of substances which not only is destroying Earth's protective ozone layer but also contributes significantly to the Greenhouse Effect. Stopping the production of CFCs worldwide will considerably lessen the Greenhouse Effect. The West German government advocates a drastic tightening of the Montreal Protocol at the forthcoming conference of participating countries. The aim should be to phase out all production and use of CFCs by the end of the century.

Because the Greenhouse Effect is a global phenomenon, efficient preventative measures to combat possible climate changes will succeed only if industrialized and developing countries adopt a parallel, well-coordinated approach. Realizing this, the West German government has played a decisive part in preparations for an international climate convention and emphatically supports the work of the Intergovernmental Panel on Climate Change (IPCC). Our aim is to get the Framework Climate Convention signed by 1992 as well as protocols for its implementation which set strict limits for CO_2 emissions and forest protection.

The West German government is convinced that climate problems can be solved. However, this will require considerable effort at national and international levels, and possibly the partial sacrifice of highly valued personal habits.

All governmental measures—including economic incentives, regulations, and bans—will have only limited impact if governments fail to make clear to the polluter the need for environmental protection. Therefore, providing comprehensive information and developing environmental awareness are extremely important. Without changing the habits of producers and consumers, all measures will remain patchwork and environmental policy will be fighting a losing battle. □

(Kupfer is head of the Section on Basic Questions of International Cooperation in the Federal Ministry for Environment, Nature Conservation, and Nuclear Safety, West Germany.)

The Netherlands

by Bert Metz
and Pier Vellinga

Metz

Vellinga

Like many other countries, the Netherlands is vulnerable to accelerated climate change. Much of the country is presently well below sea level. Yet the prospect of a rise in sea level is not our major concern among the potential consequences of the Greenhouse Effect. Over the centuries, the Netherlands has created an infrastructure capable of coping with an additional one-meter rise in sea level without major difficulties.

However, the secondary ramifications of global warming are likely to cause serious problems for the Netherlands—for example, salt intrusion into our ground water or changes in rainfall patterns that could affect river run-off and cause inland water management problems. In general, if scientific projections are right, climate change could threaten global security by disrupting ecosystems and food production systems around the world and increasing the risks of natural disasters such as floods and tornadoes: All of these impacts would seriously affect the Netherlands as well as other countries.

The Netherlands' contribution to the global increase in Greenhouse-gas concentrations is a little less than 1 percent—a relatively minor contribution. However, our per-capita emissions are among the largest in the European Community. As a framework for reducing Greenhouse-gas emissions, the government has developed a National Environmental Policy Plan.

The national plan commits the Netherlands to an 85-percent reduction in chlorofluorocarbon (CFC) emissions by 1995 and a total phaseout by 1998. It also calls for an 8-percent reduction in anticipated carbon-dioxide (CO_2) emissions by 1994-95, with continued reductions thereafter; this means that 1994-95 CO_2 emissions will be stabilized at 1989-90 levels.

Seventy-five percent of our target reductions in CO_2 emissions will depend on changes in the energy sector. A broad range of measures is being developed to achieve these emissions reductions. These include:

- Tightened building-code standards for better insulation
- Regulations to set energy-efficiency standards for appliances
- Subsidies for energy-conservation programs (e.g., residential building insulation and industrial conservation projects)
- Fuel switching from coal to natural gas for electricity generation
- Subsidy and tax-break programs for renewable energy and other high-efficiency energy-generation methods
- Matching funds for relevant research and development
- Energy-consulting services provided to industry
- A CO_2 tax in addition to existing fuel taxes.

About 20 percent of targeted emissions reductions will come from the transportation sector, where policies will encourage means of transport other than the automobile. Among the measures planned to achieve these emissions reductions are:

- Improving public transport systems for commutes and long-range travel
- Instituting plans to reduce automobile use by businesses and other institutions
- Upgrading bicycle facilities
- "Road pricing," meaning that toll rates will vary depending on the time of day and the day of the week
- Using zoning regulations to coordinate building locations with public transport.

The Netherlands has also instituted a national climate research program and a program of assistance to developing countries concerning global warming. The national research program will include atmospheric research, environmental impact studies, policy analyses, and studies on sustainable solutions. In providing assistance to developing countries, the Netherlands uses existing channels, including the Tropical Forestry Action Plan, the lending programs of the World Bank and other multilateral development banks, and bilateral aid programs.

The Netherlands is actively involved in international negotiations on climate change and in 1989 helped to initiate two major international conferences. In March 1989, at the initiative of the prime ministers of France, Norway, and Holland, a 24-country environmental summit conference was convened in The Hague. The resulting declaration of The Hague called for stronger global decision-making structures to address global environmental problems and stressed the need for technology transfer to poorer countries and adequate funding mechanisms for this purpose.

In November 1989, 67 countries and 11 international organizations met in Noordwijk, the Netherlands. The result was the "Noordwijk Declaration on Climate Change," adopted by consensus. The declaration calls for a stabilization of CO_2 emissions as soon as possible. It was agreed that target dates and stabilization levels should be addressed by the upcoming Second World Climate Conference in November 1990.

In summary, the Dutch government is vigorously pursuing an international treaty on global warming because only through the cooperation of all countries can this problem be addressed effectively. At the same time, however, the Dutch government is also taking unilateral action involving substantial financial sacrifice: Between now and 1994, an additional amount equal to $1,000 (U.S. dollars) per citizen will be spent on environmental issues, of which 20 percent is targeted to global-warming issues. □

(Metz is Counselor for Health and Environment at the Netherlands Embassy in Washington, D.C. Vellinga is Coordinator of the National Climate Programme for the Netherlands Ministry of Housing, Physical Planning, and Environment.)

Japan

by Keiichi Yokobori

Yokobori

No environmental challenge is as far-reaching as global warming. This holds true by any measure: scope, timeframe, and possible consequences. The required response, therefore, may be more comprehensive, more costly, and perhaps more controversial than any other action mankind has undertaken. On the other hand, the uncertainty of the science and economics of the Greenhouse Effect also far surpasses uncertainties surrounding other environmental problems.

Considered together, these dimensions of the global-warming problem underscore the importance of developing and implementing an equitable, flexible, long-term response strategy that provides insurance against the potential damage while also ensuring stable economic development.

These are the main concerns driving the ongoing international discussions. The Intergovernmental Panel on Climate Change (IPCC) is due to come out with its first assessment report in August. The report undoubtedly will play a crucial role in shaping future international and domestic action.

In light of these concerns, where does Japan stand on the global-warming issue?

First, we are taking all possible steps to limit Greenhouse-gas emissions and increase "sinks" for Greenhouse gases, such as more forested areas that can absorb carbon dioxide (CO_2) while striving for stable growth in the economy.

Second, we are actively participating in international efforts to reach consensus on concerted global action in the face of uncertainties.

Specifically what is Japan doing to meet the challenge?

The Japanese government, responding to the energy crisis, has provided a framework for energy conservation and fuel switching through two laws: the Law Concerning the Rational Use of Energy, and the Law Concerning the Development and Introduction of Alternative Energy. It has also actively promoted thermonuclear electricity plants. Japan is in the process of revising and extending its long-term energy scenario to the year 2010.

Japan has supported private-sector research in these areas through extensive financial and tax measures while maintaining exceptionally high energy taxes. For high-cost, high-risk technological development, where private-sector response is difficult, the government has sponsored the Sunshine Project for alternative energy and the Moonlight Project for energy efficiency. The New Energy Development Organization, overseen by our Agency of Natural Resources and Energy, within the Ministry of International Trade and Industry, helps to coordinate joint efforts between the government and the private sector in developing and promoting new energy sources.

As a result, Japan has one of the most emissions-efficient economies in the world: Per-capita emissions of CO_2 are very low, despite a high per-capita income.

Japan's achievement should be an encouragement to others, including developing countries, because CO_2 emissions were curtailed in the process of our economic development. At the same time, it suggests the potential for increased energy efficiency and fuel switching in many countries. To realize this potential, governments must have the will to act.

All of these measures, however, are short- and medium-term responses in terms of the global-warming timeframe with which we are dealing. We must come up with fundamental technological breakthroughs if we are to achieve a convergence of sound global environmental and economic policies.

For this reason, Japan is in the process of launching the Research Institute for Global Environment Technology. The institute will conduct and encourage the development of full carbon cycle technology and other environmentally benign materials and technology.

Helping developing countries is also of great importance. Emissions from the developing countries, which usually have poor energy efficiency, are growing far more quickly than those from the industrialized countries. Tropical forests, a major sink for CO_2, will continue their decline unless more is done. Assistance to developing countries, therefore, will be one of Japan's greatest concerns. Assistance from the industrialized countries should help the developing countries to carry their full share of the burden. Without this sharing of responsibility, there will be no truly effective answer to the problem.

For we all share the global environment. Let me end on a cautiously optimistic note: We will prevail if we all share fully in the protection of the planet. □

(Yokobori is Executive Director of the Research Institute of International Trade and Industry in Japan. He is also Co-Chairman of the Energy Industry Subgroup of the Intergovernmental Panel on Climate Change.)

India

by Dilip R. Ahuja

Ahuja

India's current contribution to emissions of Greenhouse gases from non-natural sources has been estimated to be 4 percent. Given that 16 percent of the world's population lives in India, this contribution, per person, represents one-fourth of the global average and just one-eighteenth of the contribution of an average American.

In India, Greenhouse-gas emissions consist predominantly of carbon dioxide (CO_2) (47 percent) and methane (38 percent). Coal-burning and rice cultivation are the primary sources of these emissions.

Policies to respond to the threat of climate change are still evolving in India. One school of thought favors a wait-and-see approach, influenced by conflicting opinions in the literature about the potential seriousness of the global-warming problem. For instance, one of the arguments against global warming as a significant problem is that negative climatic feedbacks may hold warming trends to negligible levels. Much of the literature that raises questions about global-warming projections comes from organizations that regard developing countries as potential allies in resisting emissions-reduction efforts.

Others cite pragmatic arguments against policy initiatives to mitigate the Greenhouse Effect—namely, the hypothesis that a global-warming trend may benefit India. For example, it is widely believed that increased temperatures will increase the total amount of rainfall over the subcontinent: More rainfall, coupled with higher CO_2 concentrations in the atmosphere, might work to enhance agricultural production. However, this hypothesis discounts other, undesirable effects that could complicate the scenario. Such effects might include regional shifts in rainfall patterns, increased run-off and soil erosion, and life-threatening floods and droughts in unexpected places.

The third and perhaps most compelling reason why India does not at this time have more pro-active policies for mitigating the Greenhouse Effect is the competition for limited resources by more pressing needs. This situation applies not only in India, but also in other developing countries. For this reason, the International Conference on Global Warming and Climate Change held at New Delhi in February 1989 made the following recommendation:

> The developing countries' contribution in response to the Greenhouse challenge should be carried out in a way that enhances, rather than diminishes, development prospects. Where these are in conflict, priority should be given to development . . . .

Thus, for India and other developing countries, the key is to determine what initiatives will help development and reduce emissions of Greenhouse gases and then to pursue these initiatives aggressively.

Realistically, given India's chronic shortages of electricity and unmet demands for energy services, it is unlikely that Greenhouse-gas emissions from the energy sector will be reduced in the near future. Most credible projections indicate that these emissions will grow at an average annual rate of nearly 4 percent, quadrupling over the next 40 years. However, with effective conservation and energy-efficiency policies, the rate of increase in emissions could be halved while still meeting the basic needs of an expanding population—currently growing at an annual rate of 2 percent.

The Indian government is taking steps to promote awareness of the Greenhouse issue. The government is also sponsoring research on the potential effects of climate change in India, especially in coastal areas that would be vulnerable to a rise in sea level. The possibility of flooding in densely populated coastal zones warrants special concern because it could cause very serious resettlement problems. In addition, researchers are participating in internationally coordinated studies on the potential effects of climate change on sea level and agriculture.

India is currently promoting the development of renewable energy sources such as biomass, small-scale hydroelectric power, and solar and wind energy. The government has also initiated several reforestation projects that will increase CO_2-absorbing tree cover in the country. In addition, it is subsidizing higher-efficiency cookstoves that have the potential to reduce fuelwood consumption in areas where wood is the dominant fuel. Some other actions that represent environmentally positive steps include using natural gas for electricity production, curbing energy losses during the transmission of electricity, and phasing out coal-driven locomotives. These policies can help hold back India's Greenhouse-gas emissions while they also make sense for other reasons.

In international negotiations on climate change, India is in favor of equitable agreements that, so far as possible, take into account each country's population, its recent cumulative contribution to all known Greenhouse-gas emissions, and its need to seek a reasonable standard of living for its citizens. Clearly, it will not be easy to reach consensus on this kind of agreement, but it is important to press forward with the negotiations.

One final point: Last year, India proposed that an international planet-protection fund be established to help finance the development and transfer of technology where it is most needed to mitigate climate change. Norway, Sweden, and the Netherlands have made proposals along similar lines. If appropriate institutional mechanisms for such a fund can be worked out in international negotiations, this would be a small step forward in dealing with the global-warming problem. □

(Dr. Ahuja is a Fellow of the Tata Energy Research Institute in New Delhi, currently on a sabbatical with the Bruce Company, a contractor to EPA's Climate Change Division.)

Lessons from "the Ozone Hole"

by Richard Elliot Benedick

Negotiated in 1987, the "Montreal Protocol on Substances that Deplete the Ozone Layer" set a precedent for preventive action on a global scale to protect the environment.

On September 16, 1987, a treaty was signed that was unique in the annals of international diplomacy. The "Montreal Protocol on Substances that Deplete the Ozone Layer" mandated significant reductions in the use of chlorofluorocarbons (CFCs) and halons.

At the time of the treaty's negotiation, these compounds enjoyed rapidly growing use in a wide range of industries, involving billions of dollars of investment worldwide. Scientists suspected, however, that CFCs might cause future damage to a remote gas—the stratospheric ozone layer—that shields life on Earth from potentially disastrous levels of ultraviolet radiation.

The existence of gaps in scientific and economic knowledge should not become an excuse for postponing the start of negotiations.

Perhaps the most extraordinary aspect of the Montreal Protocol was that it imposed substantial short-term economic costs in order to protect human health and the environment against speculative future dangers—dangers which rested on scientific theories rather than on proven facts. Unlike environmental agreements of the past, it was not a response to harmful events, but rather *preventive* action on a global scale.

The problem of Greenhouse warming, although admittedly more complex, shares some attributes of the threat to the ozone layer. The ozone negotiators confronted dangers that could affect every nation and all life on Earth, over periods far beyond the normal time horizons of politicians. At the time, however, these potential consequences could neither be measured nor predicted with any certitude.

Moreover, entrenched industrial interests claimed that new regulations would cause immense economic dislocations. Technological solutions either were nonexistent or were considered unacceptable by most major governments. The *scientific positions* taken by some parties were influenced by commercial self-interest, and scientific uncertainty was used by some as an excuse for delaying hard decisions. Many political leaders were long prepared to accept potential future environmental risks rather than to impose the certain short-term costs entailed in limiting products seen as important for modern standards of living.

Does all of this sound as familiar as recent headlines on the international debate over climate change? There were scoffers of the ozone-depletion hypothesis just as there are skeptics of the prospects for Greenhouse warming. Short-range political and economic concerns are formidable obstacles to international action based upon arcane theories and computer model projections. The Montreal Protocol was not an inevitability; knowledgeable observers had long believed it would be impossible to achieve.

Climate change does pose some unique challenges to international cooperation. Because the impacts of Greenhouse warming are so uncertain and distant, there is a possibility of "winners" and "losers" among nations. In addition, efforts to limit the magnitude and rate of temperature rise, and to adapt to the effects of warming, will require perhaps costly changes in energy, industry, agriculture, development, and population policies, as well as in consumer lifestyles. Further, as energy is so essential to the development of such heavily populated, low-income countries as China and India, they will be reluctant to forego fossil fuels unless economical alternatives are available.

Nevertheless, the international community's response to the ozone issue suggests several lessons for the

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new global diplomacy needed for addressing the heat-trap effect:

• *Scientists must assume an unaccustomed but critical role in international negotiations.* Science became the driving force behind ozone policy. The development of a commonly accepted body of data and analysis and the narrowing of ranges of uncertainty will also be prerequisites to a political solution on Greenhouse gases. In this process, close collaboration among scientists, policy makers, and diplomats will be crucial.

• *Governments must nevertheless act while there is still scientific uncertainty, based on a responsible appraisal of the risks and costs of delaying action.* Politicians need to resist a tendency to assign excessive credibility to self-serving economic interests that demand scientific certainty, insisting that dangers are remote and therefore unlikely. By the time the effects of ozone layer depletion and climate change are self-evident, it may be too late to forestall serious harm to human life and draconian costs to society.

• *Educating and mobilizing public opinion are essential to generate pressure on often hesitant politicians.* The interest of the media in the ozone issue and the use of television and press by U.S. diplomats, environmental groups, and legislators had a major influence on governmental decisions.

• *Strong leadership by a major country can be a significant force for mobilizing international consensus.* The United States is the largest emitter of both ozone-destroying chemicals and Greenhouse gases. Its influence in achieving the ozone treaty was enormous. The rest of the world expects, and would be responsive to, similar U.S. leadership on the Greenhouse issue.

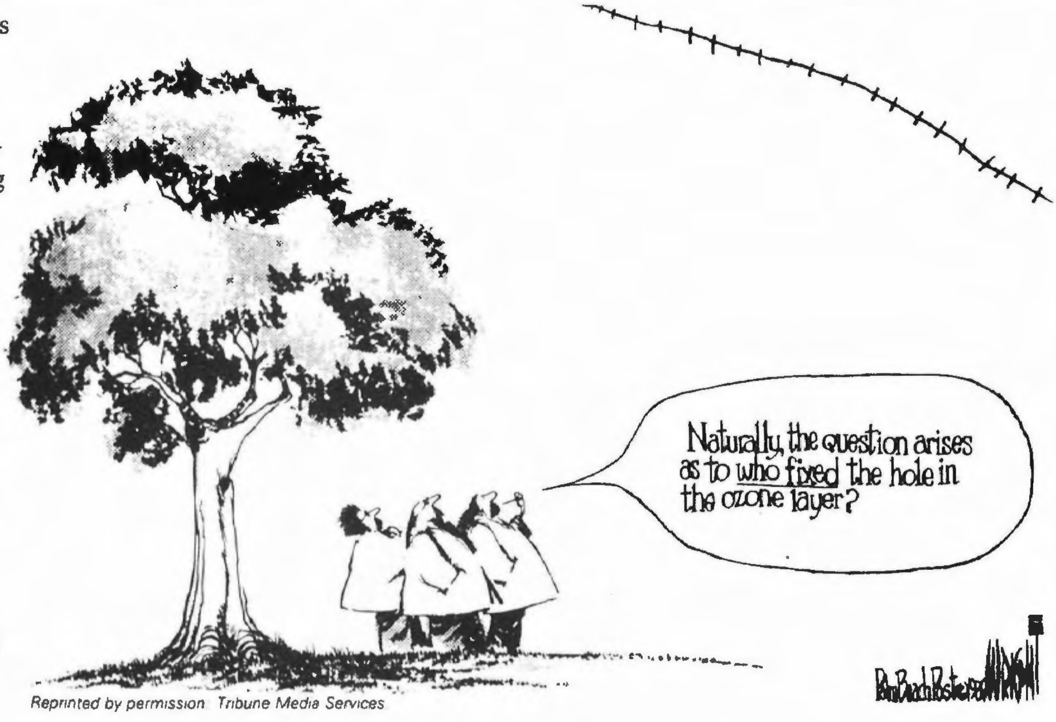
• *The catalytic and mediating functions of a multilateral institution can be critical when an issue, like ozone and climate, has planetary consequences.* The United Nations Environment Programme was indispensable for the Montreal Protocol and can be equally effective for coordinating international negotiations on climate.

• *Economic inequalities among countries must be adequately reflected in any international regulatory regime.* In the longer run, developing countries, with their huge and growing populations, could undermine efforts both to protect the ozone layer and to forestall Greenhouse warming. They did not cause these problems, and the rich nations that were responsible must now help them to participate in cooperative efforts without sacrificing their aspirations for improved living standards. It is now essential that ways be explored to transfer needed technology while maintaining intellectual property rights and incentives for private entrepreneurship to undertake research on new technologies.

• *A regulatory agreement is most effective when it employs the market mechanism to encourage technological innovation.* The ozone protocol set emission targets that initially appeared difficult; however, they effectively signaled the market that research into alternatives would be profitable. Similarly, market incentives—and disincentives—must be devised to stimulate producers and consumers toward investments and actions that reduce Greenhouse-gas emissions.

• *The Montreal Protocol broke new ground in the way it was planned and framed.* Complicated issues were separated into manageable components; informal fact-finding efforts—workshops, conferences, and consultations—built up gradual consensus and facilitated the formal negotiations. The protocol itself is a dynamic and flexible instrument, designed to be adapted to evolving conditions on the basis of regularly scheduled scientific and technical reassessments. Like the Montreal Protocol, an international accord on climate change should not be a static solution, but rather an ongoing process.

• *Finally, pragmatism, combined with firmness, can mean success in a complex diplomatic engagement.* The United States and other proponents of strong controls did not insist on a perfect solution to the ozone problem. They refrained from extreme positions and exaggerated claims but never relented in their pressure for a meaningful treaty. The basic objective



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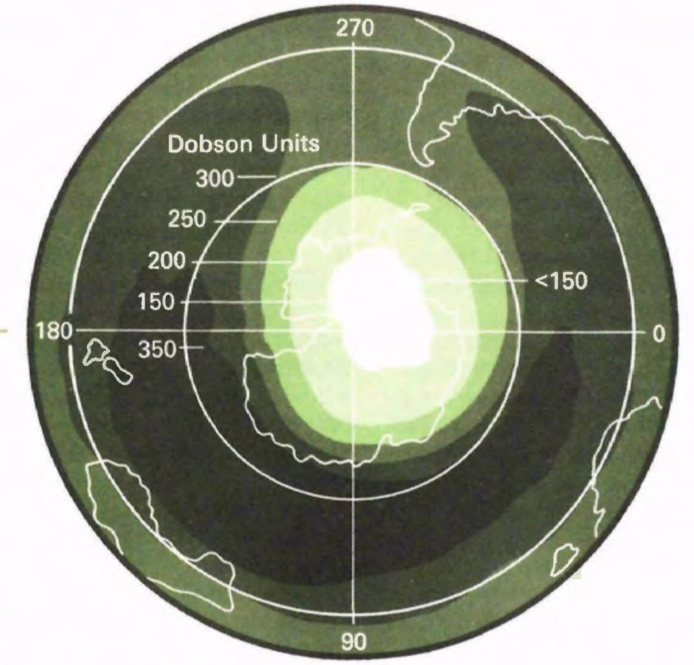


NASA/Goddard Space Flight Center, Laboratory for Atmospheres

When is a hole not a hole? Depicted as a white space in this diagram, the Antarctic ozone "hole" isn't exactly a hole. Worldwide, the ozone layer varies—depending on weather patterns—from 250 to 550 Dobson units (the Dobson unit is a measure of the "thickness" of the ozone layer). The Antarctic "hole" is an area where the stratospheric ozone level decreases drastically—a 50-percent reduction from normal levels—for a three-month period each spring in recent years.

was to get a reasonable agreement in place that could also serve as a framework for future action.

These lessons from the Montreal Protocol can definitely be applied to the current debate over global climate change. Indeed, the relevance of this experience has not been lost on the international community.

For example, the Intergovernmental Panel on Climate Change, with its varied participation from public and private sectors and multiple scientific, economic, and policy workshops, is analogous to the fact-gathering phase of the ozone history. Similarly, many governments announced their support last year for a framework agreement on climate change, comparable to the 1985 Vienna Convention on Protecting the Ozone Layer. Such a climate convention need not be a complicated undertaking, and it should be achieved at the earliest possible date. The existence of gaps in scientific and economic knowledge should not become an excuse for postponing the start of negotiations.

Ideally, a framework convention would enable governments to formalize agreement in principle on the dimensions of the climate problem and the scope of possible responses. Governments would undertake general obligations for actions to mitigate and adapt to global warming. They would also agree on coordinated research to develop additional data as guidelines for future measures.

It would be useful to go beyond the Vienna precedent at this stage and try to build into a climate convention some general targets and timetables. However, it would probably be problematical for advocates of stringent Greenhouse-gas controls to attempt to load a convention with overly detailed and still-controversial commitments. A premature insistence on optimal solutions could have the unintended effect of bogging down the negotiators and unnecessarily prolonging the entire process. On the other hand, an early convention would in itself set in motion an international momentum toward concrete actions.

The framework convention would provide the legal and logistical structure for the critical next step—corresponding to the Montreal Protocol—which would entail agreement on specific international regulations. Indeed, work on such protocols might well begin even before the convention itself is completed. Because of the complexity of the climate issue, it would not be realistic to attempt to achieve an ideal solution at a single stroke. Here again, the quest for perfection might only serve to delay action. Instead, the way to success may lie in incremental stages and partial solutions.

Thus, governments could negotiate several separate implementing protocols, each one containing specific measures for dealing with a different aspect of the climate problem. One example could be a treaty mandating greater energy efficiency in the transportation sector, which should be manageable as it need involve only a handful of manufacturing countries. The ozone accord itself exemplifies a partial solution to the climate problem by means of a constituent protocol: A recent National Air and Space Administration study estimated that if CFCs had continued to increase at the growth rates of the 1970s, they would by now exceed carbon dioxide (CO_2) in their Greenhouse impact.

It might be useful to establish standing negotiations under a permanent secretariat, similar to the arrangements for the Geneva disarmament talks. By this means, individual protocols could simultaneously be in the process of development, each at its own pace.

The climate convention and protocols need not be universal in membership—that is an unnecessary complicating factor. In actuality, the overwhelming proportion of carbon emissions from fossil fuels and deforestation is concentrated in a relatively small number of industrialized and developing nations.

Indeed, the major industrialized countries, who are primarily responsible for the world's current precarious ecological condition, could make a vital contribution by agreeing on pre-emptive actions even before a broader climate treaty is negotiated. North America, the Soviet Union, the European Community, and Japan together account for about 60 percent of carbon emissions from fossil fuels. By not delaying feasible actions to increase energy efficiency and reduce CO2 emissions, these countries could significantly slow the warming trend. This would buy time for technological innovation that could later be shared with poorer countries—principally China, Brazil, India, and Indonesia—to aid them in assuming their own responsibility.

In conclusion, in the realm of international relations, there will always be resistance to change and there will always be uncertainties—political, economic, scientific, psychological. The ozone negotiations demonstrated that the international community, even in the real world of ambiguity and imperfect knowledge, can be capable of undertaking difficult cooperative actions for the benefit of future generations. The Montreal Protocol may well be a paradigm for international cooperation on the challenge of global warming. □

This article is adapted from Ozone Diplomacy: New Directions in Safeguarding the Planet *(Washington: The Conservation Foundation and Georgetown University Institute for the Study of Diplomacy, 1990.)*

A Perspective on Costs and Benefits

by William D. Nordhaus

Many scientists are concerned about the possibility of a major human-induced climate change over the next century. In this article, I assume they are right and take a look at the economics of the Greenhouse Effect, including the projected impacts of climate change and the costs of preventing or slowing it.

What are the likely costs of climate change over the next century? In the United States, according to studies done by EPA and others, there are likely to be major impacts upon farming, forests, energy use, coastal areas, and some industries. On the other hand, most economic activity—such as manufacturing, mining, and communications—is not likely to be significantly affected by climate changes over the next 50 or 75 years.

Existing research indicates that the net economic damage from a global warming of 3 ^{0}Celsius, insofar as economic variables have been quantified, is likely to be less than 1 percent of U.S. national income. However, because it is difficult to quantify many activities which do not pass through markets—such as ecological, amenity, and health effects—the impact may be higher or lower than this estimate.

Strategic Options

What are the possible responses to the threat of Greenhouse warming? A first option—taking steps to slow or prevent a warming trend—has received the most public attention. Such steps would include reducing energy consumption, switching to non-fossil fuels, halting deforestation and planting new forests, and other measures.

A second option is to offset global warming through climatic engineering. Several schemes have been suggested over the last two decades, such as changing the reflectivity ("albedo") of the globe—for example by shooting particulate matter into the stratosphere or changing cultivation patterns in agriculture and forestry. Many environmentalists fault these proposals, saying that "you shouldn't fool with Mother Nature." But climatic engineering proposals deserve further analysis and should not be dismissed out of hand.

A third option is to adapt to the warmer climate. Such adaptation would take place gradually, in a decentralized fashion, through the automatic responses of people, institutions, or the marketplace as the climate changes and the oceans rise. If particular areas become unproductive, labor and capital would tend to migrate to more productive regions. As the sea level rises, unprotected settlements would gradually retreat inland. In addition, governments could take steps to preempt possible harmful climatic impacts by regulating land use or by investing in research on living in a warmer climate.

Most analyses treat adaptation and prevention as if they were parallel responses, but they differ in one crucial respect: While preventive policies must be taken before substantial global warming occurs, adaptative policies would be implemented more or less simultaneously with the advent of climate change. This distinction is crucial for the problem at hand for cause precedes effect by a half-century or more. If we are truly to stabilize climate, we must begin to act today; adaptations to climate change can take place gradually over the decades to come.

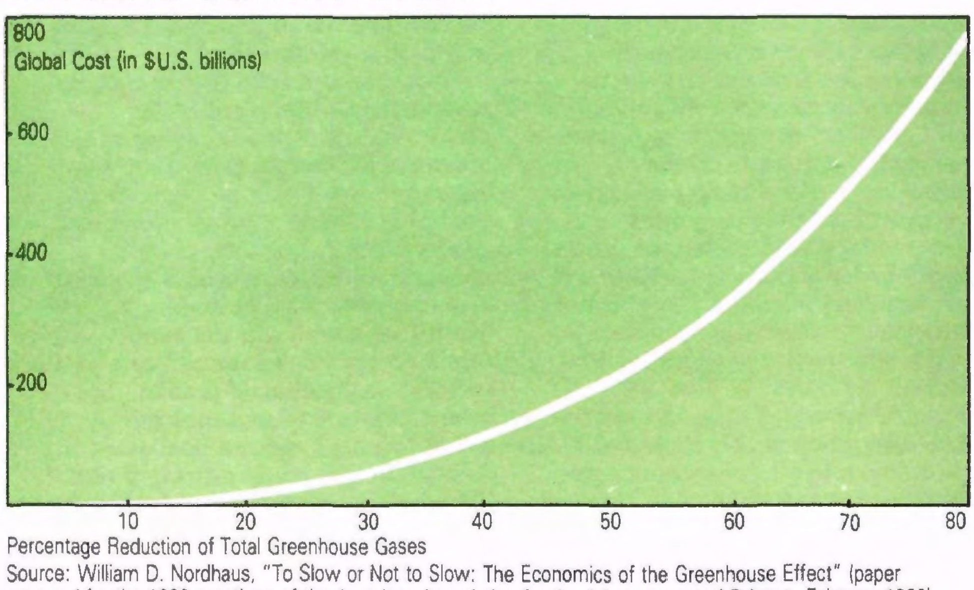
Yet our knowledge of the costs of slowing climate change is rudimentary. I have reviewed estimates of the costs of reducing global Greenhouse-gas emissions. Using 1989 emissions and world output as a base, the chart drawing shows estimated costs as a function of percentage reductions in Greenhouse-gas emissions.

The chart indicates that a substantial reduction, perhaps one-sixth, of Greenhouse-gas emissions can be attained at very low cost. Among policies to slow Greenhouse warming, the most cost-effective are curbing chlorofluorocarbon (CFC) production and preventing uneconomic deforestation. Beyond these relatively inexpensive strategies, reducing emissions rapidly becomes quite costly. I estimate that a 50-percent reduction in Greenhouse-gas emissions (relative to what emissions levels would be in the absence of policy controls) will in the long run cost around 1 percent of total world output. In other words, the annual cost would be around $200 billion annually at today's level of world output. A more modest goal, such as reducing Greenhouse-gas emissions by 20 percent (again relative to emissions levels in the absence of policy controls) will cost around $12 billion.

A Modest Proposal

Weighing costs, benefits, and uncertainties, I believe we should today take modest steps to slow global warming while avoiding precipitous and ill-designed actions that we may later regret. More precisely, I would suggest three specific policies to be acted on immediately—and a fourth that could be

Total Cost for Greenhouse Gas Control



Source: William D. Nordhaus, "To Slow or Not to Slow: The Economics of the Greenhouse Effect" (paper prepared for the 1990 meetings of the American Association for the Advancement of Science, February 1990).

(Dr. Nordhaus is Professor of Economics at Yale University.)

considered if the problem becomes more severe than this review suggests.

- First, continue to improve our understanding of Greenhouse warming. Our understanding has improved enormously over the last two decades, and further research will help prepare us for the tough decisions to be made in the future.

- Second, undertake research and development (R&D) investments in new technologies that will slow climate change. One area where the government has a particularly important role is in encouraging technologies that have low Greenhouse-gas emissions per unit of output. These technologies are today subject to underinvestment in the marketplace for a combination of reasons: The market underinvests both because of the inappropriability of the fruits of R&D and because Greenhouse gases are "public goods" that are underpriced in the market.

The major areas that require significant government support are basic and applied research on energy technologies to replace fossil-fuel use. Particularly promising here are "clean" nuclear power, solar energy, and energy conservation.

- Third, take "no-regret" steps to reduce Greenhouse-gas emissions. We should identify and accelerate those policy measures that are otherwise sensible and that would tend to slow global warming. Presently languishing on the back burner are a number of sound policies that our Greenhouse concerns should move to the front burner. They would impose little cost and would represent the first steps to slow global warming.

Among the steps to slow Greenhouse warming I would suggest the following: Strengthen international agreements that severely restrict CFCs; move to slow or curb uneconomic deforestation; take steps to slow the growth of fossil-fuel use; and pursue pollution-control strategies that emphasize combustion efficiency (such as low-sulfur coal instead of sulfur scrubbing).

Given the long agenda of pressing problems apart from Greenhouse warming, it is reasonable to stop with the first three items. If we must go further—perhaps because new evidence emerges to indicate that more stringent steps are warranted—we should go to another policy stage:

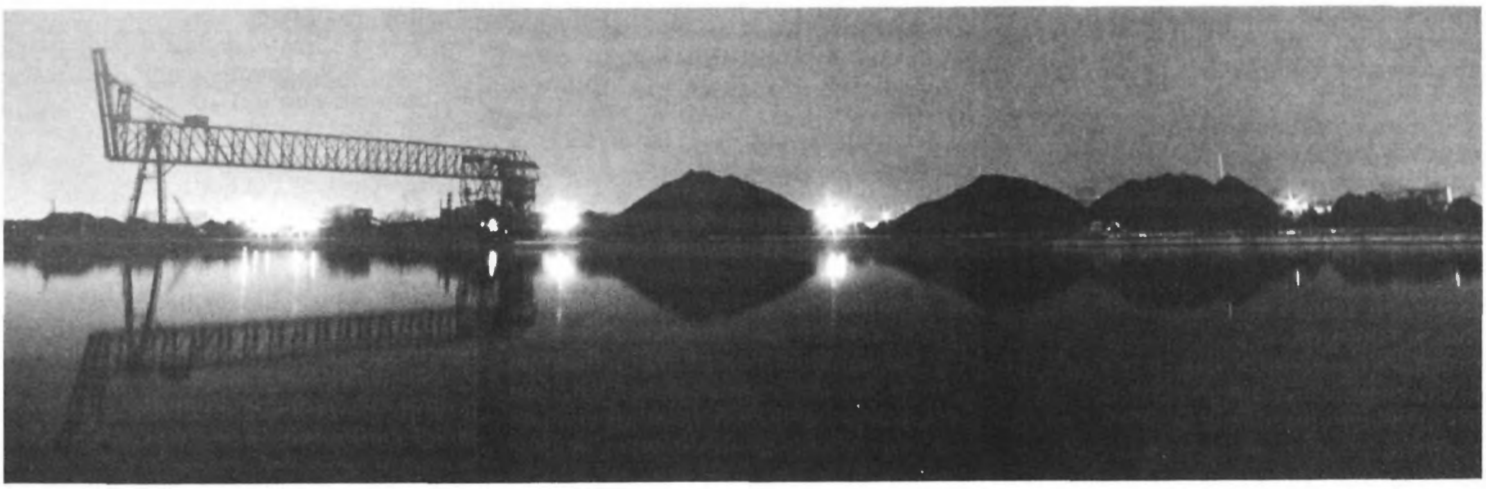
- Impose environmental taxes on emissions of Greenhouse gases. In order to slow Greenhouse-gas emissions, we should tax consumption or production of these gases. My analysis suggests that a tax on the order of \$5 per ton of CO_2 equivalent would be a reasonable response to the future costs of climate change. Among possible approaches, a carbon tax would be preferable to regulatory interventions because taxes provide incentives to minimize the costs of attaining a given level of Greenhouse-gas reduction. To reap the maximum advantage from a carbon tax, it should be applied by all major countries.

Some would argue that carbon taxes actually fall in the category of sensible economic policy. They have many economic and environmental advantages since they would tend to restrain fossil fuels use, encourage R&D on non-fossil fuels, lower oil imports, alleviate many other environmental problems, and reduce the trade and budget deficits. Indeed, a carbon tax is the exceptional tax that increases rather than reduces economic efficiency.

Why should we not go beyond these modest three or even four steps? The reason is not that the costs of climate change are insignificant. Rather, these steps must suffice given the immense call upon our resources and the limited scope for diverting investment to preventing climate change. Slowing climate change is but one contender for our investment resources—along with factories and equipment, training and education, health and hospitals, research and development, housing, and other environmental concerns. Given our urgent needs in other areas, I believe the modest proposal laid out above is a sensible goal for the next few years.

However, whatever steps are taken, my main advice would be as follows: Climate change is unwelcome, but steps to slow climate change are not free. Don't forget that humans have the capacity to inflict great damage on themselves through ill-designed economic and regulatory schemes, as the Communist experiment clearly shows. Gather information, move cautiously, and fashion policies flexibly so that you can throttle them up or down as new information becomes available. □

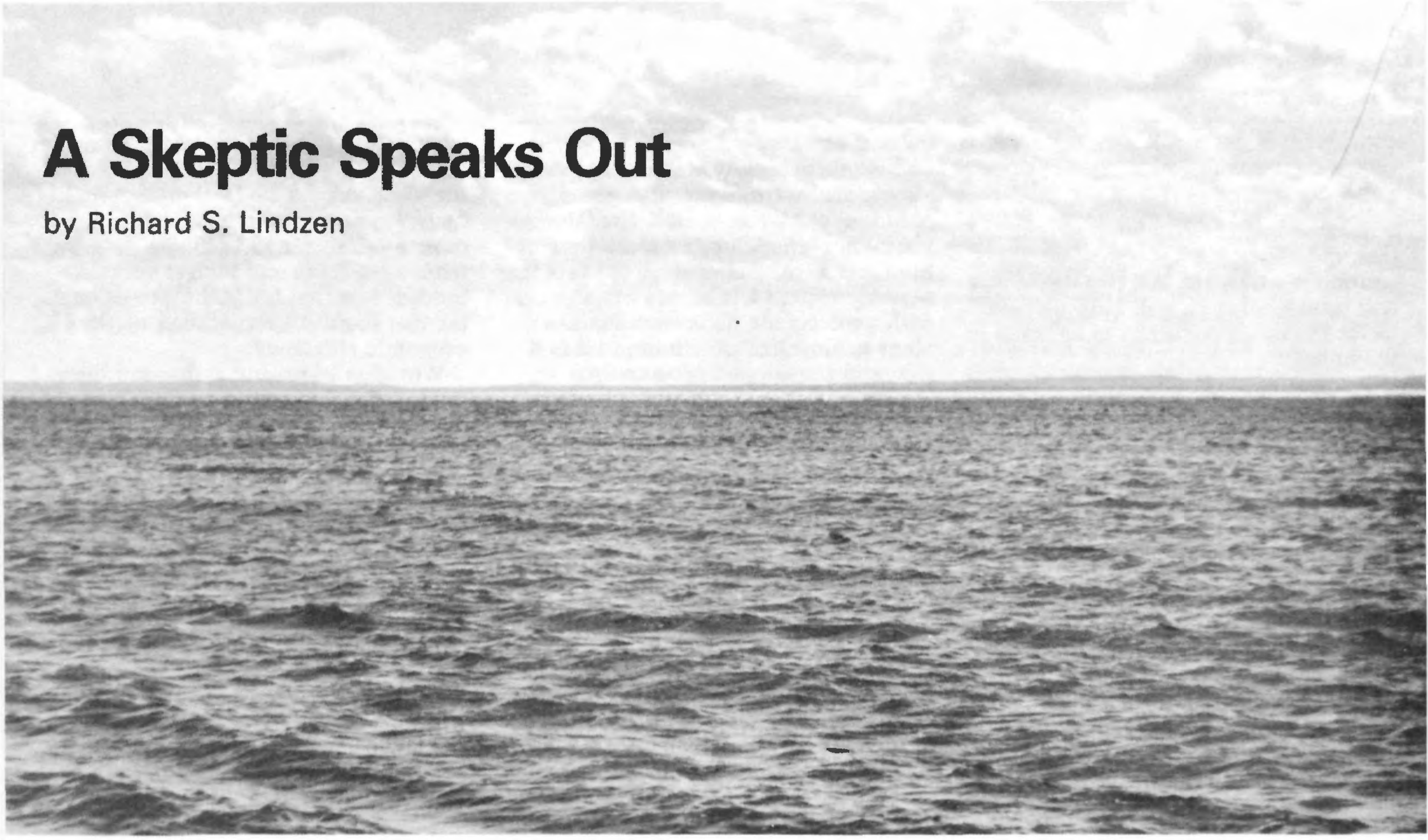
Coal, widely used as an energy source, is also one of the world's foremost sources of carbon-dioxide emissions. The author raises the prospect of carbon taxes if necessary to reduce emissions of this Greenhouse gas.



Mike Brisson photo.

A Skeptic Speaks Out

by Richard S. Lindzen



Christopher J. Johns photo.

Amidst the present thoughtful approaches to the purported coming global warming, one cannot help feeling that expressing doubts about the phenomenon is in distinctly poor taste. Risking this, I will nonetheless proceed.

There is, superficially, a basis for expecting Greenhouse warming. However, it is not evident that a few degrees' warming would indeed constitute a catastrophe. In the absence of an atmosphere, the Earth would have an average temperature of about -18 degrees Celsius. The actual average temperature is 15 ^{0}C. The difference is due to the presence of Greenhouse substances in the atmosphere.

Of these substances, the most important by far are water vapor and layer clouds. There are also minor Greenhouse gases like carbon dioxide (CO_2), methane, nitrous oxide, and chlorofluorocarbons, and these are known to be increasing in concentration. It seems only reasonable that the increase in these gases will lead to warming, and this suspicion is supported by complex computer models which predict that a doubling of CO_2 will lead to warming of about 1.5 to 5 ^{0}C. The lower value does not seem overly worrisome, but the larger value might be quite noticeable.

As reasonable as the above scenario may seem, there are serious reasons for believing that it represents a very substantial exaggeration. There are also ample reasons for believing that most viable strategies for mitigating a warming trend would have little impact on global temperature, regardless of which scenario one believes. Moreover, the present sense of urgency concerning such actions is supported by few facts.

The Greenhouse Effect is so powerful that the Earth wisely finds more efficient ways to cool its surface.

In discussing doubts about the warming scenario, it is difficult to know where to begin. However, a useful start might be to note that the Greenhouse Effect as it actually operates for the Earth is neither simple nor straightforward. The Earth is, as already noted, warmer than it would be in the absence of Greenhouse substances. However, if the Earth's surface were restricted to cooling only by radiating heat away from the planet (as represented in most explanations of the Greenhouse Effect), then the Earth would have an average temperature of 77 ^{0}C, given present concentrations of Greenhouse substances.

But the Greenhouse Effect is so powerful that the Earth wisely finds more efficient ways to cool its surface. For example, by means of air currents in cumulus clouds, storm systems, and large-scale circulations, it transports heat from regions of large Greenhouse-heat absorption (near the ground, and in tropical latitudes) to regions of much-reduced absorption (higher altitudes and latitudes), thus short-circuiting over 75 percent of the Greenhouse Effect.

Present climate models do not reproduce the intensity and distribution of these air currents adequately. As a result, they would, without gross adjustments, fail to predict the present temperature of the Earth. Even with such adjustments, however, the models still are likely to fail to properly apportion cooling between radiation and motion. The use of such models to predict the future seems unwise at best.

The situation is further complicated in that present models predict that the

(Dr. Lindzen is Sloan Professor of Meteorology at Massachusetts Institute of Technology.)

One point at issue in the Greenhouse debate is how the oceans, with their vast capacity to hold heat, may affect global-warming scenarios.

warming from simply doubling CO_2 is very modest (between 0.6 and 1.2 °C). The larger predictions come from so-called "positive feedbacks"—effects of global warming that would in turn exacerbate the warming trend. In the models, any warming is accompanied by increased water vapor, increased upper-level clouds, and decreased sea ice and snow—all of which act to amplify the warming.

Much scientific debate centers on the reality—or lack thereof—of these feedbacks. Model experiments show that small changes in the specifications of clouds can turn a positive feedback into a negative feedback. The standard equations for water vapor show that warming is indeed accompanied by increased water vapor near the ground; however, these equations also show that warming would be accompanied by decreased water vapor above about four miles.

As noted above, air currents short-circuit Greenhouse absorbers (especially water vapor) near the ground. Calculations performed at NASA show that water vapor above four miles is 100 to 1,000 times more effective (molecule for molecule) in determining surface temperature than is water vapor near the ground. Thus, the distinct possibility exists that the positive feedbacks could turn out to be negative and could actually reduce the already small direct response to increased CO_2. This is one vital area where we can reasonably expect much improved information within a few years.

Data from the last 100 years support the suspicion that existing models are exaggerating the predicted warming. The point here is that models which predict future warming on the order of 4.5 °C from a doubling of CO_2 also "predict" warming over the last century *on the order of 2 °C. A warming of 2 °C* has *not* occurred over the last hundred years. However, there is presently much debate over whether the temperature records over the past century indicate a warming of 0.5 °C or not. Such warming does appear in the land-based record for the globe; however, the warming mostly occurs before 1940, before the bulk of industrial additions of minor Greenhouse gases to the atmosphere.

Some scientists have noted that this warming may simply be a natural rebound from the "little ice age" of the 18th century. Others have noted that it could be an artificial result of poor sampling. Still others have noted that this record has not been adequately corrected for the temperature distortions characteristic of urbanization. Indeed, the temperature record for the continental United States—which *has* been carefully corrected for urbanization effects—does not show such warming. Finally, since fluctuations on the order of 0.5 °C occur from year to year within any climate record, the observed trend is still indistinguishable from normal climatic variability. Of course, all this debate obscures the obvious fact that 0.5 °C is less than the models suggest we should be seeing.

A possible explanation is that the oceans, with their huge heat capacity, may be delaying the warming. However, one model which has a sufficient adjustment for delay to be compatible with a warming of only 0.5 °C is grossly at odds with present oceanographic data. Moreover, the delay in this model is so great that even the 4.5 °C warming predicted for a doubling of CO_2 would be delayed for more than 100 years. Another model with a more reasonable specification of ocean delay predicts that we should have already seen a 1 °C warming. This model could be made compatible with a 0.5 °C warming only by eliminating almost all positive feedback factors. If, as seems entirely likely, even the 0.5 °C warming is an artifact, then this model would have to be still further adjusted to reflect negative feedbacks.

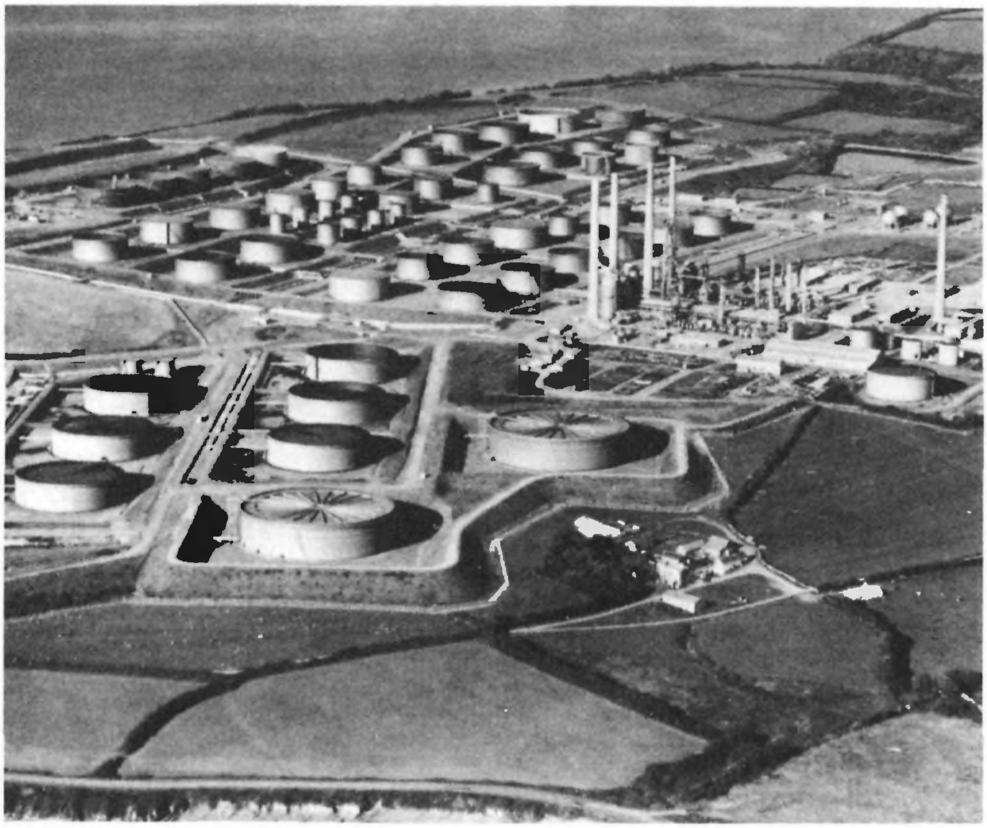
Where then does this leave us? At the very least, it leaves us with an unobserved phenomenon predicted by models operating beyond the limits of their credibility. For the reasons I have sketched, I feel there are substantial grounds for believing that any warming that may occur will actually be much smaller than predicted by current models. In either case, there is little basis for implementing draconian policy—especially if the nominally disastrous consequences of warming have also been exaggerated.

What about policies which are less than draconian? Should we not do at least something in case warming should prove to be a more serious problem than I am suggesting? Can there be any harm in implementing policies that should be implemented anyway? In answer to these questions, it must be understood that, according to those models which predict large warming, there is little that any non-draconian policy *could do* which would lead to significant mitigation. Under the circumstances, it is misleading to attach these policies to the problem of global warming. This is particularly dangerous for policies that are independently virtuous. The harm done in attaching such policies to warming is simply that it allows these policies to be discredited for irrelevant reasons.

In light of the above analysis, one may reasonably ask how the issue of global warming has generated such dramatic concern. At least part of the answer must lie in the fact that the Greenhouse hypothesis fits conveniently into the agenda of many groups who see that fear of this illusive phenomenon may help generate support for a wide range of activities. The dangers of this situation are evident. □

Industry's Position: One View

by Michael Redemer



In the United States, deliveries of motor gasoline from tank farms such as this currently total more than 288 million gallons each day. Gasoline and other fossil-based fuels could contribute to global warming.

Texaco, Inc., photo.

(Redemer is Coordinator for Air Quality Program, Texaco Inc., and also Chairman of the Global Climate Task Force, American Petroleum Institute.)

The atmospheric concentration of infra-red absorbing Greenhouse gases has been increasing since the industrial revolution. That incontestable fact is responsible for widespread concern over global warming. But its actual implications for the Earth's future climate and, more importantly, for the quality of human life, are unknown today. Current understanding of the forces influencing climate is inadequate to enable anyone to predict with any degree of confidence the magnitude, timing, and geographical distribution of future climate change.

That may seem to be a harsh judgment, but it is true. Even the best current computer models cannot accurately describe the Earth's climate. They cannot even reproduce the historic behavior of its average temperature over the past few centuries, to whatever extent that crude, ill-defined, and poorly measured proxy is known. That failure is not surprising, because climate is affected by a multitude of interactions among not only solar radiation and atmospheric gases, but also oceans, clouds, ice, vegetation, human and animal activity, and such wild cards as volcanic eruptions, varying solar activity, and long-term changes in the Earth's rotation. But it calls into question any far-reaching conclusions about the inevitability, magnitude, and effects of, and appropriate responses to, global warming.

Climate scientists agree that increasing concentrations of Greenhouse gases, looked at in isolation, would tend to increase the average global temperature. But it is still an open question, unanswerable by even the most advanced of today's climate models, how all the other factors involved in determining climate modify the rate and magnitude of the Greenhouse Effect. Even if the answer to that question were known, it would not tell us the significance of global warming for human life, which depends not on global average figures, but on changes in local climate. And current climate models are in glaring disagreement with each other when they try to describe the geographical distribution of the effects of global warming.

Certainly, some effects of global warming might be negative—rising sea levels and worse prospects for some crops in some places. But others could be positive—more CO_2 and higher temperatures encourage plant growth, and people in cold regions might enjoy milder winters. In short, the effects are uncertain but almost certainly mixed.

That means that global warming, as matters stand today, poses not a well-defined and imminent threat but rather a classic problem in public policy, where far-reaching decisions must be made in the absence of definitive information. Until we possess a far better understanding of climate than is the case today, it is surely premature to rush to make drastic and expensive changes in existing social and economic structures in the hope that their uncertain climatic benefits will exceed their costs.

Because some results of global warming might require changes in patterns of human habitation, agriculture, and lifestyle, concern is certainly appropriate. But the world is full of phenomena that call for concern. Sensible policymaking must go beyond concern to a realistic assessment of the likely magnitude of the problem and its relative urgency, accompanied by sober analysis of the options available to deal with it.

Some people argue that such a measured approach does not face up to the problem of climate change. Ignoring the fact that the magnitude of the problem is unknown, they maintain that its potential threat makes it imperative for the United States to reduce drastically its use of fossil fuels. A short examination of that proposal, however, shows that it would have little positive effect but carries major drawbacks. Its potential is quite limited because the United States now produces only 20 percent of total world CO_2 emissions, a fraction that is likely to diminish as the third world continues to industrialize. And on the negative side, forcing a major reduction in fossil-fuel use would be enormously expensive.

A recent study by Alan Manne of Stanford University and Richard Richels of the Electric Power Research Institute found, for example, that holding CO_2 emissions constant from 1990 to 2000 and then reducing them by 20 percent over the next 20 years would cost the United States about 3 percent of its national income—a sum comparable to cold war defense budgets.

But William Nordhaus of Yale has estimated the identifiable costs to the United States of a 3-degree Celsius increase in the 21st century (a figure typically cited by those who forecast a Greenhouse warming), taking into account effects on agriculture, sea-level rise, and increased demand for cooling energy and other goods and services, and arrived at a figure of only 0.25 percent of national income. In short, even if it is assumed that the costs of global warming may be considerably higher than Nordhaus has calculated, a strategy of preventing the warming by drastically reducing energy use is unlikely to be cost-effective.

Economic studies like these suggest that in many cases, strategies of accommodation to climate change may be more appropriate than those aimed at preventing it. That is a conclusion in accord with common sense and a historical perspective. The human race has a long record of coping with climatic variation, and over time, its ability to cope has grown immensely. As Thomas Schelling of Harvard points out, in 1860 only 2 percent of Americans lived outside temperate or subtropical zones, but by 1980, 22 percent did. The ability to cope has improved along with growing wealth and access to ever-advancing technology, a trend that is likely to continue.

If the Earth's temperature were to increase by a few degrees, the sea level were to rise, and more monsoons were to occur in the tropics, then the people living there would be better able to cope if they were economically better off, better housed, and more mobile than they are today. Using limited investment funds to produce that economic growth is more in their interest than spending it on expensive ways to reduce CO_2 emissions. In fact, economic growth will help them regardless of whether global warming occurs or not, because it will make them more able to cope even with today's climate.

That does not mean that we should not also take specific actions with the potential to reduce future global warming if they are sensible in their own right. For example, efficient ways of reducing CO_2 emissions do exist: One simple way is to encourage the use of natural gas in applications where it is cheaper than other fossil fuels. And it may prove practical in additional ways to reduce other Greenhouse gases. For example, emissions of CFCs, which absorb infrared radiation much more intensely than CO_2, will automatically decline as a consequence of the recently adopted agreement that resulted from international discussions. And reforestation may present the possibility of increasing absorption of CO_2.

Furthermore, advances in technology occurring on a wide variety of fronts are likely to improve our ability to mitigate the consequences of global warming. For example, genetic engineering techniques have the potential to develop plant strains that are able to cope with conditions of temperature and rainfall different from those that have occurred in the past. In short, emphasizing human problem-solving ability is likely to prove a more fruitful approach than fearing the worst and closing options.

Taking a truly global view suggests that both the United States and the world will be better off if our global warming agenda avoids apocalyptic rhetoric and concentrates on the threefold approach of intensified, high-quality research, cost-effective action, and international cooperation. □

Industry's Position: Another View

by Margaret G. Kerr

There is little doubt that concern is growing about the environmental dangers of the Greenhouse Effect. But, so far, the sheer magnitude of the problem has meant that any solutions are necessarily piecemeal. While collective effort is ultimately required, the first step requires each industry to acknowledge its individual role in creating the problem. The second step is to accept responsibility for eliminating future pollution by developing new manufacturing techniques that are environmentally benign.

Over the past two years, Northern Telecom, a Toronto-based telecommunications company, has tackled the challenges of one Greenhouse-related issue: the reduction and elimination of chemicals that both destroy the ozone layer and contribute to the Greenhouse Effect.

Expressed in the simplest terms, the ozone layer is being attacked by chlorine and bromine derived from chlorofluorocarbon compounds (CFCs) rising into the stratosphere. As a direct result, the chemical destruction of the ozone layer allows ultraviolet rays to reach ground level, where they present a danger to all living organisms.

While the electronics industry accounts for only 16 percent of worldwide CFC use, the consequences of ozone depletion and the Greenhouse Effect demand effective, long-term solutions from all quarters. In July 1988, Northern Telecom started a comprehensive program to eliminate CFC-113 cleaning solvents from its 42 manufacturing plants worldwide. Today, the company is more than halfway toward reaching its goal of total elimination and expects to be 100-percent free of CFC-113 by the end of 1991, well before any regulatory obligation to do so. Northern Telecom was the first company in the electronics industry to announce a program to completely phase out CFC-113.

Northern Telecom's experience in this specific area of environmental problem-solving has taught us some practical lessons that may be useful to other industries confronting the need to reduce Greenhouse-gas emissions worldwide.

After 18 months we have achieved a 50-percent reduction in CFC use—right on target.

From Northern Telecom's perspective, there are three general thrusts that must underpin any successful industry program.

- *There must be management commitment to change at the highest levels of the organization.* Companies must adopt a "fast-track" management approach and give their environmental experts the mandate to devise innovative solutions. In our case, the driving force of our CFC program is a senior executive of the corporation.
- *Companies must actively encourage and support suppliers in their efforts to develop products and services that do not harm the environment.* That means, among other things, being willing to allow suppliers access to the company's plants and investing in pilot projects using alternative technologies and processes.
- *Companies must foster better cooperation between their manufacturing and environmental engineers—internally and externally—by building partnerships with public and private organizations.*

Our involvement in the Industry Cooperative for Ozone Layer Protection (ICOLP) is one example of such partnerships among companies. ICOLP, a consortium of nine of the largest North American electronics companies, will be making available the latest information on CFC alternatives through seminars, databases, and technical reports. Although several ICOLP companies are competitors, they share the common cause of finding alternatives to CFC-113.

Before Northern Telecom could make real progress toward CFC elimination, there were several obstacles to overcome. For example, amassing resources across a decentralized corporation with global operations presented some formidable organizational challenges.

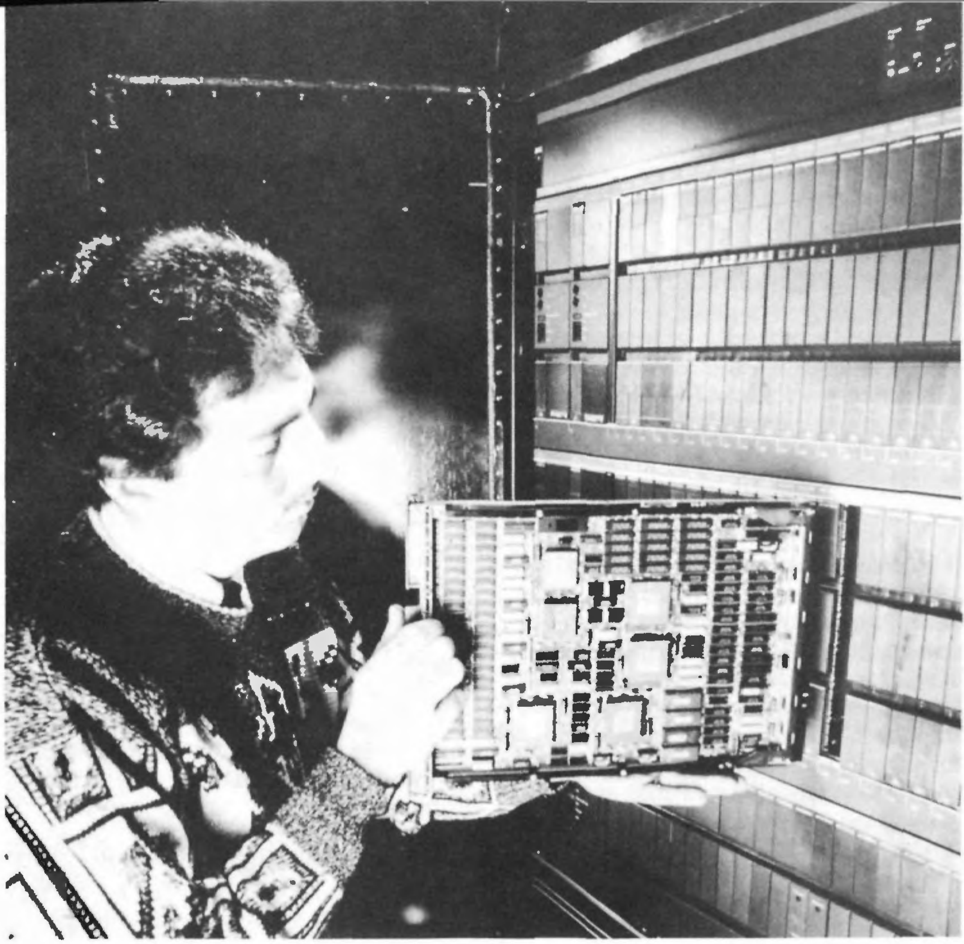
In our experience, people are not motivated by policy statements alone. The key message—the need to reduce CFC-113 use—was communicated effectively in various company forums and media.

The first task was to collect information to support the position that changes in operating practices were needed. We conducted a company-wide survey to assess the volume and costs of our CFC use. Our 1987 purchases of CFCs were approximately 1 million kilograms—of which 97 percent was CFC-113, used principally for cleaning printed circuit boards and wiring assemblies.

The next step was a two-day CFC seminar involving senior technical experts, representatives from EPA and Environment Canada, and several consultants. As a result of these meetings, our efforts became focused on three key areas: conservation options, longer-term alternatives to CFC-113, and outreach programs to other companies and organizations.

Drawing on the results of our survey and the full support of senior

(Dr. Kerr is Vice-President for Environment, Health, and Safety at Northern Telecom Limited.)



Northern Telecom photo

Northern Telecom uses a new soldering process, called "no-clean" technology, that reduces the amount of residue or "flux" on printed circuit boards. This eliminates the need for cleaning with CFC-based solvents.

management, our team of environmental specialists and engineers began to work closely with representatives in each company facility.

After 18 months we have achieved a 50-percent reduction in CFC use—right on target. An 80- to 85-percent reduction appears to be attainable in the near future: We will achieve this by improving our conservation techniques and investing in alternative "no-clean" manufacturing technology. (No-clean technology is a soldering process that dramatically reduces the amount of residue or flux on the printed circuit board, thus eliminating the need for CFC-based cleaning solvents.) The plan is to eliminate the remaining 15 percent through more experimental concepts currently under evaluation.

As part of our outreach program, Northern Telecom presented a report on the development of CFC solvent substitutes in the electronics industry at an October 1988 workshop held by the United Nations Environment Programme (UNEP) in The Hague, Netherlands.

Our participation in The Hague workshop led to an invitation to become a working member of the UNEP Solvents Technical Options Committee. This committee was formed in response to provisions in the 1987 Montreal Protocol, the CFC-reduction agreement now ratified by more than 50 countries. The committee's recently published report describes, for various industries, the technical progress made through mid-1989 in reducing CFC solvents and in finding alternatives.

By providing test materials and engineers, Northern Telecom was also a key participant in a joint initiative involving industry, the U.S. Department of Defense, and EPA. This initiative is expected to result in the rewriting of U.S. military specifications for the cleaning of printed circuit boards and wiring assemblies to permit the use of acceptable substitutes for CFC-113.

Northern Telecom has written and co-published with EPA a manual on CFC-solvent management practices. The manual is now being provided to small- and medium-sized users of CFC-113. Additionally, our experts are routinely participating in technology-transfer seminars around the world.

We are frequently asked at these seminars, "What are the costs of such initiatives?" To date, savings on reduced CFC consumption are impressive. Our reductions in CFC-113 represent \$1.5 million in direct savings. In addition, we have also saved on approximately \$1 million in CFC consumption taxes, which are now being imposed in the United States. In the final analysis, our CFC elimination program is not a factor in either improving or detracting from our competitive performance. We have accelerated some capital-spending programs, but these costs are more than offset by money saved using less CFC-113.

We believe, however, that as consumers become more sensitive to environmental concerns, a heightened awareness of these issues will prove to be a competitive advantage.

While Northern Telecom has achieved measurable results with CFCs, the challenges in other areas will require even more concerted, sustained effort to change entrenched attitudes and instill new corporate values with respect to the environment. The Greenhouse Effect has global implications, and, as such, requires solutions involving an unprecedented level of international cooperation among governments, industry, environmental groups, and affected sectors of society.

To date, scientists, governments, and environmental groups have been in the vanguard in identifying the problems associated with the Greenhouse Effect. These organizations have pressed for sense of urgency and corporate responsibility in finding effective solutions. As the engine driving economic growth, the industrial sector faces hard decisions about the production methods that provide the goods and services associated with our current standard of living.

To fulfill our responsibilities, industry must now demonstrate sustained environmental leadership. Individual companies can contribute by serving as catalysts for fundamental changes in manufacturing practices and philosophies. That, in our view, is the real measure of leadership. □

The Challenge Facing the Developing World

by Mohan Munasinghe

Developing countries share the worldwide concerns about environmental degradation; some have already started to bring management of their natural resources in line with the goal of sustaining their economic development. However, these countries also face urgent issues like poverty, hunger, and disease, as well as rapid population growth and high expectations.

The paucity of resources available to address all these problems reduces the ability of developing countries to contribute to the protection of the global commons. The crucial dilemma is how to reconcile development and the elimination of poverty—which require increased use of energy and raw materials—with stewardship of the environment. The per-capita GNP of low-income countries, which include half the world population, averaged \$290 in 1987, or less than one sixtieth the U.S. per-capita GNP of \$18,530. In the two largest developing countries, India and China, per-capita GNP was \$300 and \$290, respectively. Correspondingly, the U.S. per-capita energy consumption of 7,265 kilograms-of-oil-equivalent in 1987 was 35 and 15 times greater, respectively, than the same statistic in India and China.

Economic growth has already placed a heavy burden on humankind's natural resource base; fossil fuel carbon-dioxide (CO_2) accumulation in the atmosphere is a good example. Developed countries accounted for more than 80 percent of this accumulation in the period 1950 to 1986. On a per-capita basis, they emitted more than 11 times the cumulative CO_2 as developing countries. The latter's share would be even smaller if emissions prior to 1950 were included. Clearly, any growth scenario for developing nations that followed the same material-intensive path as the industrialized world would result in unacceptably high levels of Greenhouse-gas accumulation as well as a general depletion of natural resources.

(Munasinghe is Chief of The World Bank's Environmental Policy and Research Division. Until recently, he also served as Senior Advisor to the President of Sri Lanka.)

In the area of policy reform, especially pricing, developing countries are showing a greater willingness to use market forces more effectively.

Scientific analysis has provided only broad and rather uncertain predictions about the degree and timing of global warming. However, it is generally accepted that mankind would be prudent to buy an "insurance policy" in the form of mitigatory actions to reduce Greenhouse-gas emissions.

Ironically, environmental degradation might affect developing countries more severely since they depend more on natural resources while at the same time they lack the economic strength to prevent or respond quickly to such problems as flooding, drought, and soil erosion. From their viewpoint, an attractive insurance premium would be a set of inexpensive measures that would address a range of national and global environmental issues without hampering development efforts. However, the adoption of mitigatory measures to reduce Greenhouse warming that went beyond their own immediate economic interests would constitute crossing a definite "pain threshold."

In the area of policy reform, especially pricing, developing countries are showing a greater willingness to use market forces more effectively. Typically, by raising the subsidized price of a scarce resource like energy to reflect real economic costs, it is possible to signal to consumers that this resource is valuable and should be conserved. Further, governments could take steps to protect the environment in cases where market forces have not worked. One example is the overuse of a common resource, such as the excessive discharge of noxious gases into the air. Here, restructuring the market to make the polluter pay or limit the discharges is essential.

Improved natural-resource management also requires laws that go beyond the short-term concerns of political leaders. Implementation of environmental regulations is a serious problem, too, requiring cooperation among public and private organizations with multi-disciplinary teams. Finally, enlightening the public is necessary if citizens are to participate actively in making and implementing environmentally sound decisions.

Economic efficiency is critical in obtaining the maximum value from the scarce resources of a developing country's economy. When market incentives are brought to bear, and the costs of growth-related environmental damage are considered, economic efficiency can help to protect the environment as well. Energy issues are especially illustrative, because energy is a primary cause of the current global ecological crisis, and in most developing countries, energy use is growing rapidly. In many, energy is wasted. For example, more than one third of electricity generated is often lost before reaching consumers; an acceptable norm might be less than one tenth. Devices ranging from sophisticated industrial boilers to simple woodstoves consume fuel inefficiently. Energy policies aimed at improving methods of supply, managing demand, and encouraging end-use conservation could lead to simultaneous gains in efficiency, conservation, and environmental protection.

Particularly in rural areas, which in developing countries contain more than 70 percent of the population, per-capita energy consumption is low, and potentially profitable energy uses are constrained by lack of supply. In such cases, it may be necessary to promote energy consumption in order to raise output and incomes. Other social goals complicate the decision-making process even further. For example, most countries want to satisfy the basic needs of their citizens, especially the low-income populations. In the energy sector, this may have to be achieved by providing a minimum of energy to all families at a price that is well below its economic cost.

Several proposals have been made for setting up a global environmental fund to help developing countries, and some industrialized countries have indicated their willingness to contribute. Currently, discussions are under way to define criteria and mechanisms for both generating and disbursing funds from such a fund. While agreement will not be easy to reach, global financing might be approached in terms of several criteria: affordability or "pain threshold" considerations, fairness or "equity," and economic efficiency.

Developing countries cannot afford to finance their existing energy-supply needs. Assuming 4.5 percent annual economic growth and a continuation of techno-economic trends, the power sector capital requirements alone could average $100 billion annually in the 1990s, compared to the $50 to 60 billion being spent currently, of which less than $10 billion is official foreign aid. Even though better management could reduce this burden significantly, some growth in energy use is inevitable. The adoption of pollution-abatement policies that further increase energy costs—thereby crossing the "pain threshold"—will not be feasible without external funding. Further, such assistance should be additional to existing conventional aid received by developing countries.

In terms of the global commons, the fairness criterion recognizes that historically, growth in the industrialized countries emphasized needs rather than resource limitations. Development of these societies exhausted a disproportionately high share of global resources, including physical resources consumed in productive activity, as well as the waste-absorbing capability of the global ecosystem. Indeed, this resource-intensive historical growth pattern suggests that developed countries owe an "environmental debt" to the larger global community. Applying this criterion could help determine how remaining global resources might be shared equitably and used sustainably.

The final consideration is economic efficiency. To the extent that global environmental costs of human activity can be quantified, the "polluter pays" principle may be applied to generate revenues. If total emission limits are established under a permit system, then emission permit trading among nations and other market mechanisms could help increase efficiency.

Pressures to address environmental issues, especially global ones, place a severe burden on developing countries. Even with additional external assistance, the near-term response cannot extend much beyond sound economic management of natural resources that is consistent with both developmental and environmental goals. Thus, the energy policies of these countries in the 1990s are likely to focus mainly on conventional supply efficiency improvements, pricing, demand management, and end-use conservation.

The developed countries, particularly the United States, can facilitate this process by providing financial and technical assistance based on the principles described above. They can also show leadership by trading some growth for improved environmental quality and pioneering the use of advanced technologies that will usher in the less material-intensive economies of the future. The example set by industrialized countries would help convince the developing countries to undertake more costly abatement measures and cross this "pain threshold" early in the 21st century. □

Non-mechanized farming in Sri Lanka uses little fuel. However, as agriculture modernizes here and in other developing countries, energy use and pollution will increase.

World Bank photo.

Western Know-How Can Help

by Jack Vanderryn

Many of the most serious impacts of global climate change will occur in developing countries. These countries are much more dependent for their economic well-being on natural resources and natural systems (for example, agriculture, fisheries, forests, and grazing lands) than the industrialized world, and these systems in turn are heavily dependent on climate.

Yet in many developing countries both people and ecosystems already lead a perilous existence. Furthermore, the poorer countries lack the financial, technical, institutional, and human resources to make the costly and difficult changes that adapting to climate change would require. Finally, many developing countries are particularly vulnerable to floods, droughts, tornadoes, rising sea levels (a large fraction of their population lives in coastal areas and this will increase in the future), and other weather events that could increase in severity with further increases in emissions of Greenhouse gases.

Economic growth, while it means heavier energy demand, potentially greater pollution, and increased natural resource use, is nevertheless the most effective response developing countries have to combat climate change. Economic growth means increased capability to implement new options and increased resiliency to change. It can provide opportunities to increase energy production and use while minimizing Greenhouse-gas production, invest in pollution-control technologies,

A major global energy-efficiency initiative, involving both developed and developing countries, is needed.

and adopt improved agricultural practices which reduce natural resource degradation. But this will require increased collaboration between industrialized and developing countries and increased foreign assistance to markedly increase the efficiency of energy production and use and to improve forest management, step up tree planting, and foster agricultural practices that would enhance crop production on existing lands and thus reduce forest destruction. The need for improved energy and natural resource policies, always critical in developing countries, has increased since concerns arose over the Greenhouse Effect.

Much of what developing countries must do to meet the global climate change challenge is not new. Foreign assistance programs have already resulted in more realistic pricing of energy and improved efficiency and management of energy systems; in addition, research has been sponsored on more sustainable agricultural systems. But much more needs to be done and can be done. Sound use of energy, plus sustainable natural resource and environmental management, must pervade all aspects of foreign aid programs. A key component in efforts to achieve both goals will be technology transfer: the transfer from the developed world to the developing world of ecologically advanced technologies and the

Nathan Benn photo. Woodfin Camp, Inc

(Vanderryn is the Director for Energy and Natural Resources at the U.S. Agency for International Development.)

know-how to make them work.

Energy Efficiency

Energy production and use is the single largest contributor to global warming. Currently, developing countries' energy systems—electricity production, heat and mechanical energy generation (for example, for industrial processing and water pumping), and transportation—all depend heavily on fossil fuels, principally coal and oil. Significant efficiency improvements in these energy systems are possible particularly because many of them are outdated and their performance has deteriorated.

A major global energy-efficiency initiative, involving both developed and developing countries, is needed. Targets for such an initiative span a wide spectrum—from the highly inefficient woodburning cookstove used by almost 2 billion people in developing countries to coal-burning power plants and electrical transmission lines. The fuel efficiency of the millions of automobiles and trucks in use, and the efficiency of industrial plants in developing countries that manufacture cement, steel, or chemical products, can be greatly improved with existing techniques and technology. Woodstoves are now available which can improve energy efficiency by a factor of six (from 5 percent to 30 percent) while providing the same amount of useful heat for cooking. The efficiency of industrial processes in many developing countries can be readily improved by 15-30 percent through good "housekeeping" measures (insulating piping, repairing steam leaks, installing controls, etc.) and the installation of more efficient boilers, heat exchangers, and similar devices. The additional cost of such equipment can often be paid off in one to three years from savings in fuel costs.

Improved efficiency in developing countries' transportation systems can result from improved operations and maintenance of vehicles. Increased availability of equipment for maintenance, such as spare parts and engine test equipment would help significantly. Buildings can be more effectively designed to use less energy for lighting, heating, and cooling. Based on technology transfer from the United States and elsewhere, developing countries have begun to improve some of their commercial buildings. It is possible to design a large air-conditioned office building in a tropical environment which uses only half as much energy as a "standard" air-conditioned building in the same city. (An example is the PCJ Resource Center in Jamaica, designed with support from the U.S. Agency for International Development (AID) and opened in 1986.)

To reduce Third World dependency on high Greenhouse gas-emitting fuels such as coal and oil, a major assistance effort needs to be undertaken to accelerate the use of natural gas, which produces less CO_2 per unit of useful energy output, and the use of renewable energy sources such as photovoltaics (which convert sunlight directly to electricity), wind, solar, and geothermal energy, all of which produce *no* CO_2. In addition, burning biomass (such as the residues from sugar and rice production) to produce heat and electricity yields no net CO_2 since biomass absorbs CO_2 in its growing cycle and returns it to the atmosphere when burned.

But thorough public education and training programs, coupled with local and national campaigns to promote energy efficiency, are essential for any efforts in energy-related technology transfer. To raise awareness, there will be a need for stronger national and local institutions, more competent manpower, increased availability of information, and a vigorous training program so that all levels of society—from farmers to schoolchildren, from teachers to high-ranking public officials—understand the significance of environmentally sound development and both the technologies and the everyday practices that make it possible. One way of getting started is to establish energy-efficiency organizations in both the private sector and the government. AID, the U.S. foreign assistance agency, has already helped initiate such efforts. For example, it supported setting up an energy-efficiency group in the Ministry of Energy in Pakistan, and it helped establish a professional society of energy auditors in the Philippines.

Natural Resource Management

In the realm of natural resource management, there is a pressing need to increase investments in developing forestry management systems and technologies that can help protect forests while simultaneously deriving economic benefits from them for people in the rural areas. We need more efforts to identify and develop new tree species and learn more about the environments they need to grow best.

Some technologies and management systems are evolving that can help increase tree cover and increase and sustain agricultural production while helping to protect and manage natural resources. These include:

- Community forestry, in which local populations manage forest areas for sustained yields, prune and harvest trees for wood, graze livestock, and harvest non-wood forest products such

A car factory in Pupyang, South Korea. As countries industrialize and gain the symbols of affluence, must they repeat the pollution history of the West?

as nuts and plant materials for medicinal purposes.

- Agroforestry, in which fast-growing and nitrogen-fixing trees are intercropped with food crops in order to produce sustained yields of food, forage, and wood.

- Alley-cropping, an agroforestry system in which hedgerows of fast-growing and nitrogen-fixing trees or shrubs are planted on the slopes between which food crops are grown. This helps to stabilize the soil, while the leaves from the trees or shrubs are mixed into the soil.

The development of management systems and technologies such as these will reduce the need to clear forest land for food crops, and the increased tree planting will increase the absorption of CO_2 from the atmosphere. A significant expansion of tropical forestry research is being planned by the international forestry and agricultural community, to be supported by donor agencies.

Population

Another priority action that developing countries should take to help minimize climate change is already fundamental to their development agenda: reducing their rate of population growth through voluntary family planning and improved birth-control technologies. Third World environmental degradation is accelerated by rapidly increasing populations destroying forests to clear land for additional food, using pesticides excessively and thus polluting water resources, etc. The United Nations estimates that by the year 2025, the world will grow from its present 5.3 billion people to between 7.6 and 9.4 billion. And 90 percent of that growth will take place in developing countries.

The United Nations estimates that by the year 2025, the world will grow from its present 5.3 billion people to between 7.6 and 9.4 billion.

The United States has been the world leader in providing family-planning assistance to developing countries and supporting research on new and improved contraceptive technologies to make available to them (e.g., the Norplant subdermal implant, a new copper IUD with a six-year lifetime, and improved injectable contraceptives). U.S. organizations are also providing assistance in contraceptive manufacturing (e.g., condom production in China and IUD production in India). This form of technology transfer needs to be not just continued but expanded.

To build a future that is environmentally and economically sound, collaboration between the industrialized and developing countries seems essential. Shown is an alarm clock factory in Anshan, Manchuria.

Audrey Topping photo. Photo Researchers.

Looking Ahead

Sound technologies are already available to help minimize Greenhouse-gas production in developing countries, and others need to be developed requiring additional resources for research and development. But for impacts to be significant, a major collaborative undertaking between developed and developing countries is needed to accelerate the joint development, transfer, and implementation of technologies and policies essential to stimulating their use. This will require political commitment in the Northern and the Southern Hemispheres, additional financial resources from the industrialized world, and significant strengthening of developing-country institutions and their staffs. New and innovative approaches are needed to accelerate these efforts.

For example, establishing a major global energy-efficiency program, supported by an international energy-efficiency foundation or fund or a multi-donor coordinated effort, and implemented through expansion of existing national or regional centers, would provide a major push for the single most important area which can reduce Greenhouse-gas emissions. Intensified research and demonstration of renewable energy systems is also needed. The United States could be a leader in stimulating such worldwide efforts.

Most important of all is collaboration between the industrialized and developing countries. We share the responsibility for a more environmentally sound future, and thus our agenda needs to be one of cooperative and joint undertakings, supported by those who can best afford to ensure a healthier and more stable planet for mankind. □

The Task Ahead

by Prime Minister Margaret Thatcher

London Press Service photo. Central Office of Information

In a recent speech to the United Nations General Assembly, Great Britain's Prime Minister Margaret Thatcher urged a global effort to protect the environment. If pollution of the planet continues, she argued, profits and quality of life will suffer.

During his historic voyage through the South Seas on the *Beagle*, Charles Darwin landed one November morning in 1835 on the shore of Western Tahiti. After breakfast, he climbed a nearby hill for a vantage point to survey the surrounding Pacific. The sight seemed to him like "a framed engraving," with blue sky, blue lagoon, and white breakers crashing against the encircling coral reef.

As he looked out from that hillside, he began to form his theory of the evolution of coral. Since then, 154 years after Darwin's visit to Tahiti, we have added little to what he discovered. What would he have learned as he surveyed our planet from that altitude? From a moon's eye view of that strange and beautiful anomaly in our solar system that is Earth?

Of course, we have learned much detail about our environment as we have looked back at the world from space, but nothing has made a more profound impact on us than these two insights:

• *First*, as the British scientist Fred Hoyle wrote long before space travel was a reality, "Once a photograph of the Earth taken from the outside is available . . . a new idea as powerful as any other in history will be let loose."

That powerful idea is the recognition of our shared inheritance on this planet. We know more clearly than ever before that we carry common burdens, face common problems, and must respond with common action.

• *Second*, as we travel through space, as we pass one dead planet after another, we look back on our Earth, a speck of life in an infinite void. It is life itself, incomparably precious, that distinguishes us from the other planets.

It is life itself—human life, the innumerable species of our planet—that we wantonly destroy. It is life itself that we must battle to preserve.

For over 40 years, this has been the main task of the United Nations: To bring peace where there was war; comfort where there was misery; life where there was death.

The struggle has not always been successful. There have been years of failure. But recent events have brought the promise of a new dawn, of new hope. Relations between the Western nations and the Soviet Union and her allies, long frozen in suspicion and hostility, have begun to thaw.

In Europe, this year, freedom has been on the march.

In Southern Africa—Namibia and Angola—the United Nations has

The challenge for our negotiators on matters like this is as great as for any disarmament treaty.

succeeded in holding out better prospects for an end to war and for the beginning of prosperity.

And in Southeast Asia, too, we can dare to hope for the restoration of peace after decades of fighting.

While the conventional, political dangers—the threat of global annihilation, the fact of regional war—appear to be receding, we have all recently become aware of another insidious danger. It is as menacing in its way as those more accustomed perils with which international diplomacy has concerned itself for centuries. It is the prospect of irretrievable damage to the atmosphere, to the oceans, to Earth itself.

Of course, major changes in the Earth's climate and the environment have taken place in earlier centuries when the world's population was a fraction of its present size. The causes are to be found in nature itself—changes in the Earth's orbit; changes in the amount of radiation given off by the sun; the consequential effects on the plankton in the ocean; volcanic processes. All these we can observe, and some we may be able to predict. But we do not have the power to prevent or control them.

What *we* are now doing to the world—by degrading the land surfaces, by polluting the waters, and by adding Greenhouse gases to the air at an unprecedented rate—all this is new in the experience of the Earth. Mankind and his activities are changing the environment of our planet in damaging and dangerous ways.

Of course, there are examples of environmental degradation from the past. Indeed we may well conclude that it was the silting up of the River Euphrates which drove man out of the Garden of Eden. Or consider the tragedy of Easter Island, once covered by primeval forests. Humans landed, the population surged to more than 9,000, and pressure on the island's resources eventually left it mostly barren and uninhabitable.

The difference now is in the *scale* of the damage we are doing.

We are seeing a vast increase in the amount of carbon dioxide (CO_2) reaching the atmosphere. The annual increase is three billion tonnes. And half the carbon emitted since the industrial revolution still remains in the atmosphere.

At the same time, we are seeing the destruction on a vast scale of tropical forests that are uniquely able to remove CO_2 from the air.

Every year, an area of forest equal to the whole surface of the United Kingdom is destroyed. At present rates of clearance, we shall, by the year 2000, have removed 65 percent of forests in the humid tropical zones.

The consequences of this become clearer when one remembers that *tropical* forests absorb more than 10 times as much carbon as do forests in the temperate zones.

We now know, too, that great damage is being done to the ozone layer by the production of halons and chlorofluorocarbons (CFCs). But at least we have recognized that reducing and eventually stopping the emission of CFCs is one positive thing we can do about the menacing accumulation of Greenhouse gases.

It is true, of course, that none of us would be here but for the Greenhouse Effect. It gives us the moist atmosphere that sustains life on Earth. We need the Greenhouse Effect—but only in the right proportions.

When I was born, the world's population was some 2 billion. My grandson will grow up in a world of more than 6 billion. Put in its bluntest form, the main threat to our environment is more and more people—and their activities:

- The land they cultivate ever more intensively
- The forests they cut down and burn
- The mountain sides they lay bare
- The fossil fuels they burn
- The rivers and seas they pollute.

The result is that future change is likely to be more fundamental and more widespread than anything we have known hitherto: change to the sea around us, change to the atmosphere above, leading in turn to change in the world's climate. These interacting changes could alter the way we live in the most fundamental way of all.

That prospect is a *new* factor in human affairs. It is comparable in its implications to the discovery of how to split the atom. Indeed, its results could be even more far-reaching.

The problem of global climate change is one that affects us all, and action will be effective only if it is taken at the international level. It is no good squabbling over who is responsible or who should pay. Whole areas of our planet could be subject to drought and starvation if the pattern of rains and monsoons were to change as a result of the destruction of forests and the accumulation of Greenhouse gases.

We have to look forward, not backward. And a vast, international, co-operative effort is needed.

Before we act, we need the best possible scientific assessment. Otherwise we risk making matters worse. We must use science to cast a light ahead so that we can move, step by step, in the right direction.

The United Kingdom has taken on the task of co-ordinating such an assessment within the Inter-Governmental Panel on Climate Change. This assessment will be available to everyone by the time of the second World Climate Conference next year.

But that will take us only so far. The report will not be able to tell us where the hurricanes will strike; who will be flooded; or how often and severe the droughts will be. Yet we will *need* to know these things if we are to adapt to future climate change.

That means we must expand our capacity to model and predict climate change. We can test our skills and methods by seeing whether they would have successfully predicted past climate change for which historical records exist.

Britain has some of the leading experts in this field, and I am pleased to tell you that the United Kingdom will be establishing a new Centre for the Prediction of Climate Change, which will lead the effort to improve our prophetic capacity. It will also provide the advanced computing facilities that scientists need. And it will be open to experts from all over the world—and especially from the developing countries—who can come to the United

In addition to the science, we need to get the economics right.

Kingdom and contribute to this vital work.

In addition to the science, we need to get the economics right. That means first we must have continued economic growth in order to generate the wealth required to pay for the protection of the environment. But it must be growth which does not plunder the planet today and leave our children to deal with the consequences tomorrow.

Second, we must resist the simplistic tendency to blame modern multinational industry for the damage being done to the environment. Far from being the villains, industry has a critical role to play in doing research and finding solutions. It is industry that will develop safe alternative chemicals for refrigerators and air-conditioning, devise bio-degradable plastics, and find the means to treat pollutants and make nuclear waste safe.

The multinationals *have* to take the long view. There will be no profit or satisfaction for anyone if pollution continues to destroy our planet.

As people's consciousness of environmental needs rises, they are turning increasingly to ozone-friendly and other environmentally safe products. The market itself acts as a corrective. The new products sell, and those which caused environmental damage disappear from the shelves.

And by making these new products and methods widely available, industry will make it possible for developing countries to avoid many of the mistakes which we older, industrialized countries have made.

On the basis of sound science and sound economics, then, we need to build a strong framework for international action.

It is not new institutions that we need. Rather we need to strengthen and improve those which already exist: in particular the World Meteorological Organization and the United Nations Environment Programme (UNEP).

The United Kingdom has recently more than doubled its contribution to UNEP. We urge others—who have not done so and who can afford it—to do the same.

The most pressing task facing us at the international level is to negotiate a framework Convention on climate change—a sort of good conduct guide for all nations. We should aim to have it ready for the World Conference on Environment and Development in 1992.

The 1992 Conference is indeed already being discussed among many countries in many places. I draw particular attention to the very valuable discussion which members of the Commonwealth had under the Prime Minister of Malaysia's chairmanship at our recent Commonwealth Heads of Government Meeting in Kuala Lumpur.

But a framework is not enough. It will need to be filled out with specific undertakings (or "protocols," in diplomatic language) on the different aspects of climate change.

These protocols must be binding, and there must be effective regimes to supervise and monitor their application. Otherwise those nations which accept and abide by environmental agreements, thus adding to their industrial costs, will lose out competitively to those who do not.

The negotiation of some of those protocols will undoubtedly be difficult. And no issue will be more contentious than the need to control emissions of CO_2, the major contributor—apart from water vapor—to the Greenhouse Effect.

The United Kingdom therefore proposes that we prolong the role of the Inter-Governmental Panel on Climate Change after it submits its report next year. The panel could thus provide an authoritative scientific basis for agreements to reduce Greenhouse gases. And these agreements should allow all our economies to continue to grow and develop.

The challenge for our negotiators on matters like this is as great as for any disarmament treaty.

Before leaving the area where international action is needed, let me make a plea for a further global Convention: one to conserve the infinite variety of species of plant and animal life that inhabit our planet.

The tropical forests contain half of the species in the world, so their disappearance is doubly damaging. It is astonishing but true that our civilization, whose imagination has reached the boundaries of the universe, does not know, to within a factor of 10, how many species the Earth supports.

What we do know is that we are losing them at a reckless rate—between three and 50 each day on some estimates—species which could perhaps be helping us to advance the frontiers of medical science. We—as nations—should act together to conserve this precious heritage. No-one can opt out.

We should work through the United Nations and its agencies to secure world-wide agreements on ways to cope with the effects of climate change, the thinning of the ozone layer, and the loss of precious species.

We need a realistic program of action and an equally realistic timetable. Each country has to contribute, and those countries who are industrialized must contribute more to help those who are not. The work ahead will be long and exacting. We should embark on it hopeful of success, not fearful of failure.

I began with Charles Darwin and his work on the theory of evolution and the origin of the species. Darwin's voyages were among the high-points of scientific discovery. They were undertaken at a time when men and women felt with growing confidence that we could not only understand the natural world, but master it too.

Today, we have learned rather more humility and respect for the balance of nature. But another of the beliefs of Darwin's era should help to see us through: the belief in reason and the scientific method.

Reason is humanity's special gift. It allows us to understand the structure of the nucleus. It enables us to explore the heavens. It helps us to conquer disease. Now we must use our reason to find a way in which we can live with nature, not dominate nature.

We need our reason to teach us today that we are not, that we must not try to be, the lords of all we survey. We are not the lords, we are the Lord's creatures, the trustees of this planet, charged today with preserving life itself—preserving life with all its mystery and all its wonder. □

(This article is adapted from Mrs. Thatcher's address to the 44th session of the United Nations General Assembly on November 8, 1989.)

Appointments

Henry B. Frazier III is EPA's new Chief Administrative Law Judge.

Judge Frazier has been an Administrative Law Judge for EPA since 1987. Prior to his appointment, he served as a member of the Federal Labor Relations Authority for eight years; from 1984 to 1985 he was Acting Chairman.

From 1970 to 1979, Judge Frazier worked for the Federal Labor Relations Council; the last six years of that time he was the Council's Executive Director. An Air Force veteran, he held several civilian positions in the Department of the Army before joining the Council.

Judge Frazier earned his bachelor's degree in political science at the University of Virginia. He holds a law degree from George Washington University Law School and an LL.M. in labor law and a Master of Laws in taxation from Georgetown University Graduate Law Center.

Jerry Eisner Studio/Rockville, MD.

The new Deputy Associate Administrator for EPA's Office of Communications and Public Affairs is **Christina M. Kielich.**

Immediately prior to joining the Agency, Kielich was a senior communications advisor to the Federal Maritime Commission. From 1988 to 1989, she was the Assistant Administrator for Public Communications at the U.S. Small Business Administration. She was president of *WINNING IMAGE*, a public affairs and media consulting firm, from 1985 to 1988.

Kielich was Director of Outreach at the Department of Energy's Office of Civilian Radioactive Waste Management from 1984 to 1985; Special Assistant to the Administrator for Public Affairs at the General Services Administration in 1984; and the Director of Public Affairs at the U.S. Peace Corps from 1982 to 1984.

A 1973 graduate of Trinity College in Washington, DC, Kielich worked as Legislative Assistant to Representative Jack Kemp from 1974 to 1980 and as Administrative Assistant to Representative Jim Jeffries of Kansas in 1981. □

Letter to the Editor

To the Editor:

Congratulations on your November/December 1989 issue devoted to success stories in improving environmental quality.

The goals of most of the programs described were not controversial and indeed laudatory—ranging from cleaning up a dry cleaning operation to finding a way to keep jet fuel out of a salmon stream. The article on plastics recycling by the manager of the plastics plant was the one piece that stood out as praising a highly questionable operation.

Nationally, the plastics industry is mobilizing a public relations campaign to establish in the public consciousness the idea that plastics can be "recycled." Your magazine is contributing to that campaign by publishing the article, and you should in the future feature a more objective look at the whole plastics recycling issue.

The extraction, transportation, and processing of oil from which plastics come and the plastic production process all have terrific environmental costs. The supply of oil itself is a nonrenewable resource best not spent on a lot of superfluous packaging.

So-called "recycling" of plastics is not really recycling, which implies a continuous cycle of use and reuse. Apparently, reused plastics go into dead-end final use as a park bench or loose-fill protective packaging, as mentioned in the article.

Finally, many throw-away plastic products are better never produced in the first place, a conclusion the plastics industry would prefer that we not make. The classic example is, of course, those "clam shell" burger containers which have a useful life of maybe 30 seconds. Burger King has stopped using those things, and we are none the worse.

The readers of your magazine deserve a more balanced piece on the controversial topic of plastic recycling.

Thank you for your consideration of my views.

Sincerely,
Dana F. Gumb, Jr.
New York City

Karin Kreider photo. Rainforest Alliance

This tropical rain forest in Costa Rica is protected as a national park. However, many other such forests worldwide are being destroyed every day, adding to carbon-dioxide levels in the atmosphere.

Back cover: The seasons: A colorful reminder. Photo by Kim Heacox for Woodfin Camp.