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Climate Chaos

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CLIMATE CHAOS

by David A. Wirth

For the past several years scientists have issued ominous warnings about the future of the earth's climate. Predictions of dramatic global change arising from the continued dumping of industrial by-products into the atmosphere and forest loss of massive scale can no longer be ignored. Compelling scientific evidence now strongly suggests that world climate patterns, previously regarded as reliably stable, could be thrust into a state of turmoil. Emissions of natural and synthetic gases are increasing the heat-trapping capacity of the atmosphere through a phenomenon known as the greenhouse effect.

The projected effects of this worldwide climatic disruption dwarf many of the environmental problems of the past and augur political, economic, and social disruptions on an enormous scale. Global warming could have catastrophic consequences for the habitability and productivity of the whole planet. The accompanying strain and upheaval on the international scene in turn could have serious foreign-policy consequences for all countries.

Broad scientific agreement exists on the underlying theory of climate change, although the nature and magnitude of future effects from greenhouse warming as predicted by computer models remain in debate. Some of these, such as a rise in the sea level, have been established with greater certainty than others. Nonetheless, the range of consequences is sufficiently clear and the magnitude of the resources at stake so enormous that policy action is required sooner rather than later. Once a crisis has been reached, it will be too late to act.

The international political and legal system remains ill-equipped to offer a solution that will assure the integrity of the earth's climate.

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Although the greenhouse theory of warming has been accepted for about a century, policymakers have only recently become aware of its significance for the global environment. The international community cannot afford to continue to delay elevating the greenhouse effect to the top of the foreign-policy agenda. Arresting the impending climate instability will require a concerted international agenda and a reorientation of energy and development priorities in virtually all countries of the world. Heading this agenda for action should be a global multilateral agreement that sets strict, binding standards for national emissions of greenhouse gases.

Human activities since the Industrial Revolution have dramatically altered the composition of the global atmosphere. A number of gases, emitted in small but significant amounts, absorb infrared radiation reflected from the surface of the earth. As the concentrations of these heat-absorbing gases increase, average global temperatures will rise.

Emissions of carbon dioxide (CO_2) are the single largest cause of elevated terrestrial temperatures from the greenhouse effect, accounting for approximately one-half of the problem. Concentrations of CO_2 in the range of 280 parts per million (ppm), together with water vapor in the atmosphere, established the preindustrial equilibrium temperature of the planet. Since the middle of the 19th century atmospheric CO_2 levels have increased by about 25 per cent to approximately 350 ppm and are continuing to rise by approximately .4 per cent per year. Elevated CO_2 concentrations result primarily from the intensified burning of fossil fuels—coal, oil, and natural gas—which liberates the chemical in varying amounts. Coal burning releases the most CO_2, while the combustion of quantities of natural gas and oil needed to produce the same amount of energy results in only about 57 per cent and 83 per cent as much CO_2, respectively.

The world's forests are vast storehouses or "sinks" for carbon. Worldwide loss of forest cover, by releasing this vast stockpile of carbon into the atmosphere as CO_2, aggravates the greenhouse problem. Deforestation in

Third World countries is particularly severe, with the destruction of tropical forests in developing countries like Brazil and Indonesia exceeding 27 million acres annually from activities such as burning, logging, and conversion to agricultural and pastureland. Indeed, the release of CO_2 into the atmosphere as a result of deforestation amounts to 2–10 billion tons annually.

Concentrations of a second important greenhouse gas, nitrous oxide (N_2O), have also been rising, probably because of heavier fossil-fuel use, greater agricultural activity, and other ecological disturbances. Average global atmospheric levels of N_2O at the end of 1985 were approximately 300 parts per billion (ppb) and are increasing at an annual rate of .2 per cent. Both CO_2 and N_2O, unlike some conventional pollutants, are very stable compounds. CO_2 remains in the upper atmosphere for decades after its release and N_2O for considerably more than a century. Consequently, without major reductions in emissions of these gases with long atmospheric lifetimes, their concentrations will continue to grow.

The international community cannot afford to delay elevating the greenhouse effect to the top of the foreign-policy agenda.

A group of volatile chemicals known as chlorofluorocarbons (CFCs) is believed to be currently responsible for 15–20 per cent of the global warming trend. These chemicals, unlike CO_2, are strictly synthetic and are not known in nature. They have a number of uses as refrigerants, propellants, solvents, and thermal insulators. A related class of bromine-containing chemicals called "halons" are found in fire-extinguishing systems. Average global atmospheric concentrations of CFC-11 and CFC-12, two of the most commercially important chlorofluorocarbons, in 1985 were approximately .22 ppb and .38 ppb, respectively. Atmospheric concentrations of CFC-11 and CFC-12 are growing at a rate of more than 7

per cent annually as a result of increased world production in recent years.

Although their concentrations are small relative to that of CO_2, CFCs are up to 10,000 times more potent in absorbing infrared radiation. After release, CFCs and halons reside in the atmosphere for close to a century, or sometimes more, because of their great chemical stability at low altitudes. Consequently, an immediate 85 per cent reduction in emissions of CFC-11 and CFC-12, for example, would be necessary merely to stabilize their atmospheric concentrations. With their long atmospheric lifetimes, CFCs and halons eventually reach the upper atmosphere. There, they are the principal culprits in the worldwide loss of the protective stratospheric ozone layer, which shields life on earth from harmful levels of ultraviolet solar radiation.

Methane, the principal component of natural gas, is another significant climate-modifying chemical. It has an atmospheric residence time of about 11 years. Average global concentrations of methane were approximately 1,700 ppb at the end of 1985 and are increasing by about 1 per cent per year, the highest rate of any naturally occurring greenhouse gas, for reasons that are not now clear. Animal husbandry and rice cultivation have been identified as major sources of increased methane emissions. Coal mining and landfills are also significant sources, with large potential for rapid growth in the future.

Low-level ozone is another greenhouse gas. Although ozone in the stratosphere is beneficial, this highly unstable chemical is the leading component of photochemical smog pollution at the earth's surface.

While greenhouse gases are dispersed relatively quickly throughout the global atmosphere after release, industrial emissions of these heat-absorbing chemicals are highly concentrated in the developed world. In 1985, 23 per cent of total global CO_2 emissions of more than 20.5 billion tons of CO_2 originated in the United States—the single largest emitting country and the highest per capita contributor among industrial countries to the greenhouse problem. The second biggest contribution came from the Soviet Union, with 19 per cent

of total CO_2 emissions. Western Europe emitted 15 per cent of the total, Japan 5 per cent, and the People's Republic of China 11 per cent. Other developing countries together accounted for only 20 per cent of total industrial CO_2 emissions.

Emissions of CFCs are even more strongly skewed. In 1980 the United States produced roughly 28 per cent of the global total of approximately 817,300 tons of CFC-11 and CFC-12. Western Europe produced about 30 per cent, industrialized Asian countries 12 per cent, and the East-bloc countries an estimated 14 per cent. The entire developing world accounted for just slightly more than 2 per cent of this amount.

Consequences of Greenhouse Warming

An international scientific consensus now supports the assertion that the accumulation in the atmosphere of CO_2, N_2O, CFCs, methane, and low-level ozone could have sweeping and far-reaching effects on the earth's climate.[1] By as early as the year 2030, the heat-retaining capacity of the atmosphere may have increased by an amount equivalent to doubling preindustrial concentrations of CO_2. By

[1] *Much of the scientific information in this article is drawn from the following reports: World Meteorological Organization and United Nations Environment Programme,* Developing Policies for Responding to Climatic Change *(Summary of workshops held in Villach, Austria, 28 September–2 October, 1987, and Bellagio, Italy, 9–13 November 1987 under the auspices of the Beijer Institute, Stockholm), 1988; International Council of Scientific Unions, United Nations Environment Programme, and World Meteorological Organization,* Report of the International Conference on the Assessment of the Role of Carbon Dioxide and of Other Greenhouse Gases in Climate Variations and Associated Impacts *(Report of a conference held under the auspices of the World Climate Program at Villach, Austria, 9–15 October 1985), 1986; U.S. Environmental Protection Agency and United Nations Environment Programme,* Effects of Changes in Stratospheric Ozone and Global Climate *(Proceedings of a conference held at Leesburg, Virginia, 16–20 June 1986); U.S. Environmental Protection Agency,* Assessing the Risks of Trace Gases That Can Modify the Stratosphere, *vol. 3: chaps. 6–18, prepared for the Office of Air and Radiation by John S. Hoffman (Washington, D.C., 1987); and Irving M. Mintzer,* A Matter of Degrees: The Potential for Controlling the Greenhouse Effect *(Washington, D.C.: World Resources Institute, 1987).*

the middle of the next century, average global temperatures may have risen by as much as 3°F–9°F. The absolute magnitude of these temperatures, as well as the rapidity of temperature change, will exceed any previously experienced in human history.

The effects of a greenhouse-driven climate disruption will be characterized with complete certainty only after significant damage has already occurred. However, among the most dramatic effects likely to ensue from greenhouse warming is an unprecedented rise in sea level resulting from thermal expansion of the oceans and melting of glaciers and polar ice. Over the past century the average global sea level has increased less than 6 inches. By contrast, the sea level will have accelerated considerably, producing a total increase of up to 1–7 feet by 2075, depending on the degree of global warming that occurs.

The impact of sea-level rise in the United States is likely to be severe. The anticipated increase in the elevation of the oceans could permanently inundate low-lying coastal plains, accelerate the erosion of shorelines and beaches, increase the salinity of drinking-water aquifers and biologically sensitive estuaries, and increase the susceptibility of coastal properties to storm damage. An increase of 5–7 feet in sea level would submerge 30–80 per cent of America's coastal wetlands, which are crucial to the productivity of commercially important fisheries. Extensive existing coastal development may prevent the widespread formation of new wetlands. Even in undeveloped coastal areas, the rapidity of the predicted sea-level rise will mean that existing wetlands would be lost faster than new ones can be created.

The increase in elevation of the oceans will also seriously affect the approximately 50 per cent of the earth's population that inhabits coastal regions. Entire countries, such as the Maldives, could disappear. A rise in sea level of only 3 feet could flood an area of the Nile Delta that constitutes 12–15 per cent of Egypt's arable land, produces a similar portion of the Egyptian annual gross national product (GNP), and is home to a comparable percentage of the country's 51.4 million peo-

ple. In Bangladesh, a 3-foot rise would inundate 11.5 per cent of the country's land area, displace 9 per cent of the 112.3 million people in this densely populated country, and threaten 8 per cent of the annual GNP.

The range of uncertainties associated with local climatic changes is substantially larger than for global averages. The dramatic anticipated increases in global temperature are virtually certain to cause a wide variety of modifications in regional climates. In middle latitudes, where the continental United States lies, summertime temperature increases are expected to exceed the global average by 30–50 per cent. Forests, many of them economically productive, could begin to die off as early as the year 2000 if they prove unable to adjust to rapidly shifting climatic zones. Regions of agricultural productivity could shift at the expense of the American Midwest, which currently has some of the most fertile soils in the world. A warming of only 3.6°F could decrease wheat and cereal yields by 3–17 per cent. Computer models predict continental drying in middle latitudes, which means that parched soils, scorching droughts, and massive heat waves, like those that devastated crops in the Midwest in summer 1988, could become commonplace. Water levels in the Great Lakes could drop by a foot, interfering with navigation for ocean-going vessels. Extreme temperatures have been shown to elevate human mortality. Some models also project disruptions in atmospheric and ocean circulation patterns. The impact of these changes is highly unpredictable.

Countries with tropical climates could experience especially severe consequences. Semiarid areas like much of sub-Saharan Africa might suffer from even lower rainfall. Many semiarid areas are already marginal for agriculture, are highly sensitive to changes in climate, and have had severe droughts and famines for the last several decades. Tropical humid climates could become hotter and wetter, with an increase in the frequency and severity of tropical storms. Floods, which between 1968 and 1988 killed more than 80,000 people and affected at least 200 million more, could worsen. Natural disasters such as floods,

now unusual, could become increasingly common.

Indeed, climate disruption caused by the greenhouse effect may already be evident. Global temperatures in 1988 were again at or near the record for the period of instrumental data, with temperatures elevated by .7°F relative to the average for the 30-year period beginning in 1950. The five warmest years in this century all occurred during the 1980s. Moreover, the rate of global warming for the past two decades was higher than any in recorded history. Whether the planet is already experiencing greenhouse-driven warming as measured against a background of natural temperature variability is still a subject for debate. However, because there is a lag on the order of decades between emissions of greenhouse gases and their effects, the level of heat-absorbing chemicals already released into the atmosphere has irrevocably committed the world to an additional .9°F–2.7°F increase over the next 50 years even if the atmosphere's composition were stabilized today.

The greenhouse effect, if unchecked, is likely to cause unpredictable disruptions in the balance of power worldwide, exacerbating the risk of war. The projected climate disturbance and its accompanying impacts are sufficiently dramatic in quality, magnitude, and rapidity that policymakers should give the most serious consideration to the security implications of the ongoing failure to anticipate and arrest greenhouse warming. The oil crises of the 1970s were widely perceived as a national security issue because excessive dependence on foreign oil threatened the American economy. Prevention of global climate disruption demands the immediate attention of U.S. leaders for the same reason. But so far, the implications of the greenhouse phenomenon have not played the slightest role in long-term strategic planning by the government.

The odds are strongly stacked against every country in the game of climate roulette. Contrary to some speculation, it is very unlikely that any region of the world will be a net "winner" from climate change. The very concept of "winning" implies the existence of a stable warmer climate, which will not occur

unless the warming trend is halted. Even the limited goal of a steady-state warmer climate will require major policy reform. Otherwise, greenhouse-gas concentrations and global temperatures will continue to increase indefinitely, nullifying any short-term benefits.

Even if a stable warmer climate were identified as a policy goal, the rate of climate change resulting from greenhouse gases already in the atmosphere would be faster than ever experienced in human history. This climate alteration would undoubtedly result in decades of destruction resulting from an inability to alter human behavior, such as agricultural techniques, fast enough to take advantage of new weather patterns. The transition to warmer climates is expected to be highly disruptive and accompanied by an increase in the frequency, intensity, duration, and geographic extent of extreme weather events like droughts and storms. Moreover, sea-level rise would be certain to entail net harm the world over. No region or individual country should place the health and well-being of its public and environment at stake in what amounts to a crapshoot.

While all countries are likely to be losers in the global climate gamble, some countries have more at stake than others. The United States has a particularly large investment in the status quo. Its current pre-eminence in world affairs ultimately derives from the strength of the country's economy. The productivity of the country's natural resources, such as the incomparably valuable farmland of the Midwest, was an essential prerequisite to America's elevation as a dominant superpower in the latter half of the 20th century. Impending climate change means that this productivity can no longer be taken for granted. The greenhouse effect threatens the overall health of the American economy and could require a massive diversion of resources to nonproductive adaptive activities.

The United States has one of the most productive agricultural sectors on earth, producing nearly 50 per cent of the world's corn and nearly 60 per cent of its soybeans. The United States is also the world's leading exporter of wheat and corn. By contrast, the

USSR is now the planet's largest importer of wheat and its second largest importer of corn. Climate models, however, suggest that this pattern could change dramatically if the Midwest became 10–20 per cent drier and crop yields were reduced. The drought of 1988 demonstrated that falling crop yields are a very real possibility. U.S. Department of Agriculture forecasts for the 1988–89 marketing year project that domestic consumption and exports of U.S. grain and soybeans will exceed production by approximately 4.2 billion bushels. At the same time, Soviet agricultural areas, located considerably farther north, could suffer smaller losses in productivity relative to their American counterparts. The difference between last summer's events and the effects of greenhouse-induced climate change would be that the latter is permanent and worsening, not just an isolated calamity.

Adapting to future climate change is also likely to require significant resources in the United States. Fighting the effects of a rising sea level on the heavily developed coasts of the United States, where about 75 per cent of the U.S. population will reside by 1990, will be phenomenally expensive. Maintaining threatened shorelines just on the American East Coast by measures such as diking cities could cost $10–$100 billion for a 3-foot rise. Seven out of the 10 most populous cities in the United States are located either on the coasts or on coastal estuaries that would be severely affected by sea-level rise. By contrast, the USSR, which has relatively less exposed shoreline and considerably less investment in expensive coastal infrastructure, would suffer little damage. Only 1 of the 10 largest Soviet cities—Leningrad— would face significant problems from an elevation in sea level. Moreover, the Soviet Union could benefit greatly from improved navigability in its polar coastal areas as Arctic ice melts.

The effects of greenhouse warming will also be felt in other parts of the world, potentially fueling turbulent regional conflicts that could upset the existing global balance of power. Loss of low-lying territory could create refugee problems of an unprecedented scale. Inundation of just the tiny island country of the

Maldives would require the relocation of nearly 200,000 people. Competition over territory and natural resources launched by those displaced by sea-level rise could create or exacerbate regional strife. Pressure from the 10 million individuals in Bangladesh that would be uprooted by a 3-foot sea-level rise could heighten regional tensions. Famine created by greenhouse-driven crop failures could also generate regional clashes that might encourage the major powers to take sides. Such an acceleration in showdowns among the superpowers would destabilize the world political balance in highly unpredictable ways, tempting those countries that already have a tendency toward global adventurism and placing U.S. security interests at risk.

Arresting Climate Change

The worst effects of a greenhouse-induced climate cataclysm can be averted. And the sooner action is taken, the more effective it will be. Conversely, the longer a policy response is delayed, the greater the warming that will have accumulated "in the bank" and the more radical the measures that will be required to prevent further climatic upheaval.

CFCs and halons are by far the easiest component of the greenhouse problem to eliminate. Motivated by concern over the pivotal role these chemicals play in depleting the stratospheric ozone layer, 45 countries and 1 international organization have signed the Montreal Protocol on Substances That Deplete the Ozone Layer, which took effect at the beginning of 1989 after negotiations sponsored by the United Nations Environment Programme. The agreement overcame a serious lapse of concern about this issue by U.S. and European policymakers in the early 1980s and a complete breakdown of negotiations in 1985. Aside from representing a diplomatic milestone for international cooperation on environmental problems, the Montreal Protocol is also an important precedent for a multilateral strategy on the more challenging issue of greenhouse warming.

The Montreal Protocol requires an incremental 50 per cent reduction in the consumption of five ozone-depleting CFCs by the end

of this century. Beginning in July 1989 consumption of these substances must be frozen at 1986 levels. A reduction of 20 per cent must be achieved beginning 4 years later and an additional 30 per cent beginning in July 1998. The agreement permits each country to implement these requirements as it chooses through recycling, destruction, or abandonment of unnecessary uses of these chemicals. However, the overall strategy is to stimulate the development of alternatives to existing CFCs by constricting supply. The Montreal Protocol contains ground-breaking trade incentives for broad participation, including a ban on imports of controlled substances from countries that are not party to the accord. Its provisions dealing specifically with developing countries resolve delicate equity issues by allowing Third World countries a 10-year grace period to make required reductions.

Despite the precedential importance of the Montreal Protocol, the agreement is inadequate. Because of loopholes and leakages built into the document, the actual reductions in emissions of substances controlled by the protocol will be only about one-third under even the most optimistic assumptions. Consumption of halons, which are up to 10 times as destructive of ozone as the strongest CFC, is merely leveled off and not reduced. The agreement explicitly specifies that production—as distinct from consumption—of CFCs and halons may actually increase by as much as 10 per cent over the 1986 level.

It is now clear that emissions of CFCs and halons must be virtually eliminated because of the overwhelming risks these chemicals pose to climate and stratospheric ozone. Soon after the Montreal Protocol was signed in September 1987, a seasonal thinning of 50 per cent of the ozone layer over Antarctica—the ozone "hole"—was conclusively connected to CFCs. New and widely accepted scientific evidence documents that average global losses in stratospheric ozone of about 3 per cent—two to three times that previously predicted by computer models—have already occurred.[2] Even

[2]*U.S. National Aeronautics and Space Administration, "Executive Summary of the Ozone Trends Panel," 1988.*

if CFCs and halons are phased out within 5–7 years, the long atmospheric lifetimes of these chemicals mean that the environment could take up to a century to recover. Moreover, even if production of these dangerous chemicals were to be eliminated altogether, they would continue to seep out of the existing stock of refrigerators, air conditioners, insulation, and other repositories.

To stabilize global concentrations of CO_2 gas it will be necessary to cut global emissions of CO_2 by at least one-half. Burning fossil fuels releases most of the excess CO_2 in the atmosphere. Because no economical technology for removing CO_2 from waste-gas streams is now available, cutting back releases of CO_2 will require a lower total energy consumption and a shift in energy sources toward low- or non-CO_2-emitting technologies. Greenhouse impacts should be an explicit part of all future decision-making processes in the energy sector. Reductions in fossil-fuel use will also help to ease other environmental problems associated with current patterns of energy use, such as acid rain and local air pollution.

Even with the most optimistic assumptions about economic growth, major reductions in CO_2 emissions from industrialized countries can be achieved with energy conservation, efficiency technologies, and renewable energy sources. For example, the 1,200 kilowatt-hours per year used by a typical frost-free refrigerator can be reduced to only 500 with a state-of-the-art model. Current technology can light an office building with an expenditure of only .55 watts per square foot, as little as one-fifth of today's average. It is now possible to produce motor vehicles—which currently account for more than one-fourth of greenhouse gases released in the United States—that have fuel economies of up to 98 miles per gallon, 2–5 times as efficient as those now on the road.

Efficiency improvements have meant that the amount of energy used in the United States today is about the same as in 1973, despite a 40 per cent increase in GNP during the same period. Application of existing efficiency technologies could reduce U.S. CO_2 emissions by 14–18 per cent by the end of the century. In California alone, a steady improve-

ment in efficiency of 3.4 per cent per year has been achieved over the past 12 years with only mild encouragement from state and local governments through policy measures to encourage conservation and efficiency. Through a strategy involving efficiency improvements, national progress could be much faster.

Nuclear energy has been proposed in some quarters as the preferred solution to the problem of greenhouse warming. Although atomic power is a CO_2-free technology, its other risks currently make it the least attractive alternative to fossil fuels. Nuclear energy carries the inherent danger of weapons proliferation. The current generation of nuclear reactors still entails the unacceptable danger of accidents and suffers from a critical lack of public confidence in an increasingly large number of countries. The problem of disposing of waste that will remain hazardously radioactive for many hundreds of thousands of years has yet to be adequately solved. Of the alternative strategies for reducing CO_2 emissions, nuclear energy is among the most expensive. Moreover, to reduce CO_2 emissions by 50 per cent by the year 2020 solely through the expansion of the nuclear industry would require bringing a new plant on line somewhere in the world at the rate of almost one a day starting in the mid-1990s—clearly a practical impossibility. While the nuclear option may be worthy of consideration as part of the public debate on ultimate solutions to the greenhouse problem, increased reliance on nuclear power at present would be both politically infeasible and irresponsible when major, cheap reductions in CO_2 emissions are available with existing technologies.

Reversing deforestation and creating new forested areas will help to offset current levels of CO_2 emissions. New forests, in absorbing CO_2 from the air during photosynthesis, will contribute to climate stabilization by serving as supplementary reservoirs for carbon. Aggressive policies to conserve existing forests and create new forested areas will yield other significant environmental benefits, including erosion control and the preservation of a rich diversity of species whose genetic potential is only now becoming accessible to humankind.

The fundamentals of the greenhouse phenomenon are now well understood and the need for swift policy responses firmly established. While these responses are being implemented, the development and dissemination of technologies to combat climate disturbance—such as CFC-free, energy-efficient refrigerators and low-methane strains of rice—should be a high priority. Increased basic research to resolve remaining uncertainties concerning the magnitude, rate, and effects of greenhouse warming should also be undertaken.

The Role of Developing Countries

An equitable response to the special needs of developing countries is crucial to removing greenhouse threats to the global climate. On the one hand, developing countries have caused little of the problem and industrialized countries must bear the bulk of the blame. On the other hand, as economic development accelerates, Third World countries may account for the preponderance of greenhouse-gas emissions by the middle of the next century. An international solution that provides incentives for the participation of developing countries while fairly distributing the responsibility for implementing solutions is essential to a successful global strategy for combating greenhouse warming.

The consequences of the greenhouse effect strongly suggest that it is in the self-interest of Third World countries to re-examine expeditiously their energy priorities. Developing countries, with fewer resources to adapt to environmental disturbances, stand to suffer disproportionately from a rapid climate change. For example, the productivity of common rice varieties falls off dramatically at temperatures just a few degrees higher than those currently prevailing in many rice-growing areas.

Tapping the tremendous potential for conservation and improved end-use efficiency in the developing world would contribute to a solution for greenhouse warming while meeting much of the Third World's growing energy needs. This strategy also avoids other serious environmental and social problems, such as land degradation, local air pollution,

and population displacement, that accompany the building of fossil-fuel-fired power installations. By the year 2020 it may be possible to achieve a universal standard of living far beyond that necessary to satisfy basic needs with little or no increase in global energy consumption from today's levels.[3] However, many developing countries use energy in a highly inefficient manner. Macroeconomic policies in many developing countries, such as electricity price subsidies, discourage conservation and efficiency improvements. Firms in Brazil, where electricity prices are subsidized, manufacture energy-efficient air conditioners for export but cheap, inefficient models for domestic consumption.

Investments in efficiency gains are extremely attractive from many points of view. They require less capital and less foreign exchange than do comparable amounts of new power supply, contributing to overall economic productivity. Through efficiency and conservation, developing countries could avoid at least $1.4 trillion in power-supply expansion costs between now and the year 2008.

Efficiency investments represent a major opportunity for donors like the United States and the World Bank to assist developing countries in making energy choices that both avoid mistakes made earlier in the developed world and reduce risks to the entire planet from greenhouse warming. Nonetheless, development assistance in the environmentally sensitive energy sector often exacerbates the threat of greenhouse warming by emphasizing conventional sources of energy, such as massive fossil-fuel-fired power plants.

The World Bank, which controls an annual energy lending portfolio averaging $3.5 billion, is one of the principal donors supporting power generation projects in the Third World. Through measures such as pricing reforms and improvements in the operation of existing power plants and distribution sys-

[3] *See, for example, World Bank,* End-Use Electricity Conservation Options for Developing Countries, *Energy Department Paper no. 32 (Washington, D.C., 1986); and José Goldemberg et al.,* Energy for a Sustainable World *(Washington, D.C.: World Resources Institute, 1987).*

tems, the Bank has already made a commitment to encourage conservation and the efficient use of energy. There is, however, considerably more that the Bank can do.

The Bank requires preparation of a "least cost plan" to precede investments in the energy sector. Current methodologies for these studies primarily address strategies for increasing energy supply. Support for demand reduction measures, such as end-use efficiency improvements, which are often economically as well as environmentally superior to investments in supply, have not consistently been considered as alternatives to conventional power generation projects in Bank energy-sector strategies. Expanding the universe of alternatives to include demand reduction options would simultaneously help developing countries reduce the rate of growth in their power-generating capacity and reduce greenhouse-gas emissions without sacrificing the energy needed for economic development. Additional staff trained in strategies for encouraging end-use efficiency improvements would significantly increase the Bank's capabilities in this crucial area.

Forest policy is another area where development assistance can provide benefits to Third World countries while simultaneously cutting emissions of greenhouse gases. While there has been great concern in North America and Western Europe about destruction of tropical forests, donor countries historically have devoted little capital to conservation of this crucial resource and have earmarked even less for the creation of new forest areas. Case studies have documented that projects financed with little regard for the integrity of natural resources by donors such as the World Bank have seriously exacerbated forest loss in key countries such as Brazil and Indonesia. Industrialized countries can also help to reverse tropical deforestation and encourage reforestation through changes in domestic policies. Developed countries provide the primary market for tropical hardwoods, virtually all of which are unsustainably harvested, and firms based in industrialized countries often reap the profits of this trade. Governments of industrialized countries can take a serious look

at controlling trade in tropical woods and compensate exporting countries for lost revenues through alternative investments.

The Third World debt crisis presents major opportunities for encouraging better forest management in developing countries. As the market value of such debt has fallen, a number of private banks have sold debt owed to them by Third World governments to private conservation organizations, which have then forgiven the debt in return for specific promises by the governments concerned, such as a commitment to conserve a particular area and to support its maintenance with a stream of payments in local currency. Such "debt for nature" swaps are already in place in Bolivia, Costa Rica, and Ecuador, and more are under negotiation. Governments can adopt policies, such as tax incentives, that encourage creditor banks to sell debt for swaps. Creditor governments can reduce interest or principal on sovereign debt in return for promises of policy reform in this critical sector.

Coordinating policies on the international level to fight greenhouse warming will maximize environmental and foreign-policy benefits. Unilateral reductions in releases of greenhouse gases by large emitters such as the United States and the Soviet Union will go a long way toward arresting global climate disruption. However, a multilateral consensus strategy will further the crucial goals of creating incentives for universal participation and establishing an equitable balancing of responsibility for solving the problem.

Existing international mechanisms are an important part of such a strategy. A reassessment of the Montreal Protocol, a process that is provided for by the document itself, is the most expeditious way to eliminate the contributions CFCs and halons make to the global warming problem. The World Bank's institutional structure also includes mechanisms for member countries to redirect priorities in the critical energy and forest sectors.

The remainder of the greenhouse problem could be handled most effectively through a multilateral treaty, with standards binding under international law that would require each country to take prescribed actions to

reduce and halt greenhouse warming. Considerable precedent is now in place for multinational environmental agreements containing strict regulatory standards. In addition to the Montreal Protocol, which is an ancillary agreement to the 1985 Vienna Convention for the Protection of the Ozone Layer, several other international agreements establish requirements for controlling emissions of specific air pollutants. The Protocol on the Reduction of Sulphur Emissions or Their Transboundary Fluxes by at Least 30 Percent and the Protocol Concerning the Control of Emissions of Nitrogen Oxides or Their Transboundary Fluxes—both auxiliary agreements to the 1979 Convention on Long-Range Transboundary Air Pollution—set out precise regulatory limitations on releases of specified chemicals. Principles established in the case law of international tribunals and in the 1972 Stockholm Declaration adopted by the United Nations Conference on the Human Environment also discouraged countries from acting in ways that could harm the environment in another's territory.

A multilateral treaty designed to arrest global climate change should satisfy several basic requirements. First, it must require reductions in releases of greenhouse gases of a magnitude and speed sufficient to stabilize the earth's climate. The most important gas to control is CO_2, for which global reductions of at least 50 per cent are necessary. Participating countries should accomplish these reductions by means of environmentally and economically sound technologies that do not present unacceptable risks to public health or global security. The creation of new forested areas might be encouraged by allowing credits against reductions of CO_2 emissions that would otherwise be required and by provisions establishing or promoting forestry programs. Because the agreement could be expected to cover a large number of emissions sources, it should mandate strict mechanisms for enforcement through reporting of emissions, on-site audits, and internationally controlled remote sensing.

Second, the responsibility for making reductions must be distributed equitably.

Among the criteria that could be applied is relative national wealth as measured by per capita GNP. Another test could be per capita emissions of CO_2, with the highest reductions required of those countries with the highest emissions per unit of population. Another possibility would be to require the imposition of a fee for carbon emissions, either as a primary mechanism for achieving reductions or as a supplementary measure. Any of these formulas would require proportionally greater cutbacks by the wealthiest countries and leave the poorest countries with the fewest constraints on CO_2 emissions. All countries would be encouraged to use existing energy supplies more efficiently.

A treaty should also require a commitment from the wealthier countries for increased research into non-CO_2 energy supply technologies and development assistance to help poorer countries meet the requirements imposed on them by the agreement. One mechanism for generating the necessary capital is to require countries to contribute to a fund in proportion to their CO_2 emissions. Restricting access to this fund to those countries that accepted the obligations of the treaty would create incentives for broad participation.

Considering the importance of the resources at risk, it would be nothing short of reckless to continue with business as usual. A failure to respond to the threat of greenhouse warming would amount to an affirmative decision to wager the health and well-being of current and future generations against overwhelming odds.