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A POLICY RESPONSE TO GLOBAL WARMING

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A META PLAN: A POLICY RESPONSE TO GLOBAL WARMING

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EXECUTIVE SUMMARY

This paper outlines a policy strategy for the global warming problem - a problem of massive dimensions. That is the consequence and scope of the problem as well as the costs and scope of any policy directed at ameliorating the problem is massive. Because of these costs, the United States cannot afford policies that do not work as intended or achieve a given result at unnecessarily great expense.

The paper begins by reviewing the science of the greenhouse problem and its possible impacts on temperature, sea rise, coastal wetlands, and regional climate. While there is much uncertainty surrounding the science - one must conclude that humanity is on new ground. Economic development has attained such a scale that certain of the most basic and essential

activities can have a profound impact on the earth and its environment.

Clear evidence of warming will not be available for several decades. Clear evidence of harm may lie several decades beyond that. Reducing greenhouse emissions to a level consistent with a steady state temperature level is like steering a very large ship which has so much momentum that the helmsman must begin the turn long before the curve is reached. Further, the uncertainty surrounding the effects of global warming means that the curve up ahead is obscured by fog. We feel fairly certain that the curve exists, but where is uncertain. Therefore, the initial policy framework selected by the nations of the world is crucially important.

The potential massive size of the problem and the international nature of the sources of greenhouse gases dictate that the chosen policy be cost effective and global in reach.

The development and diffusion of more benign technology are the basis of any successful response to the problem. Any policy chosen should have the property that it encourages the evolution of appropriate technology. Past U.S. experience with both environmental and energy policy is replete with examples of policies being captured and distorted by vested interests.

Government decision processes, particularly democratic ones, don't seem to make good technology choices. One has only to look at the U.S. experience with synfuels and Brazil's with gasohol.

Finally, the inherent uncertainty of our knowledge about the problem and its consequences plus the high probability of surprises in the future demand a policy framework that encourages effective international policy responses to new information.

Given these goals, we propose that the following steps be taken.

- 1) The OECD nations should commission a multilateral study which, within a specified time period, develops a model tax structure for controlling CO₂ emissions.
- 2) The CO₂ tax should be uniform, but should be implemented individually by each nation.
- 3) The tax proceeds would be transferred to the "International Environmental Fund" (IEF), administered by the World Bank, IMF, UN or an agency created for this purpose.

- 4) The IEF administrator, in consultation with OECD and developing nations, should establish CO₂ abatement incentives, congruent with OECD tax levels, for developing nations.
- 5) A portion of the funds from the IEF would be used to support global warming research and to buy CO₂ abatement in the rest of the world.
- 6) As scientific knowledge permits, the OECD nations would include other greenhouse gases in this program.
- 7) Periodically, the OECD nations would meet to adjust the level of the environment tax.

Because no one country can insulate itself from warming effects through its own emission control, individual national action is discouraged. There is a strong temptation to let others solve the problem and "free ride" on their effort. A tax per unit of emission resolves this problem. It is competitively neutral - in that the industries of each country will be paying a tax equal to the agreed upon costs of the damages they cause.

Any program which does not effectively include LDCs is probably doomed to failure. Therefore, it is critical that the OECD countries, support the efforts of developing and Eastern Bloc nations in reducing greenhouse emissions. Designing an appropriate scheme to be funded by the proposed IEF will be a difficult, but not impossible task

I. INTRODUCTION*

The purpose of this paper is to outline a policy strategy for the global warming issues. We begin with the premise that the global warming problem is very real and potentially massive. That is, massive as to the consequences and scope of the problem and massive in terms of the cost and scope of any policy directed to ameliorate the problem. Therefore, it is imperative that policies be effective and highly conservative of resources. The United States and the world can't afford policies that don't work as intended or that achieve a given result at unnecessarily great expense. It is the authors' view that the United States, in particular, has in the past usually done badly with its energy and environmental policies. Since the United States will likely play a leadership role in developing global policies, its experience is extremely relevant. We will explore these historical failures in some detail. Further, since any

meaningful resolution of these issues involves international cooperation, governments need policy mechanisms which are not only efficient but which also facilitate our political decision making rather than exacerbate differences.

We will present our views in five pieces. First, we will lay out the scientific framework for the greenhouse effect to establish context and attempt to structure the problem so as to render it accessible to a policy analysis. Next, we will focus on a critical feature of the scientific evidence: uncertainty as to results and impact. Third, we outline and examine the policy consequences of the scientific evidence, and review the failure of U.S. political and regulatory institutions to solve similar problems in the past. Fourth, we discuss the importance of policy and technology development. Finally, we outline and explain what we believe to be a coherent and achievable policy strategy. In short, we propose a policy framework which has an environmental tax as its core. We believe this framework will facilitate reasoned decisions, achieve critical efficiency goals, and provide for other critical needs as well.

II. THE GREENHOUSE PROBLEM

The science of the greenhouse effect starts with some indisputable facts. Certain gases, principally carbon dioxide, methane (also carbon based), and ozone, long present in the earth's atmosphere, have played a very important role in determining the earth's climate. The other greenhouse gases are nitrogen oxide, two forms of chloroflorohydrocarbons (CFC13, CF₂CI₂), carbon monoxide, water vapor, and nitrous oxides. These gases have the property of allowing electromagnetic radiation of relatively high frequency, i.e., light, to pass relatively unimpeded through the earth's atmosphere. When this radiation strikes the earth it turns into heat, which is also electromagnetic radiation, but of lower frequency. The greenhouse gases in the atmosphere tend to reflect back this lower frequency radiation to the earth rather than let it escape into space. The obvious result is to make the earth warmer than it otherwise would be. If these gases were at a much lower level of concentration in the earth's atmosphere, its climate would be much colder; more like the planet Mars. If the concentration were much higher the climate would be much hotter, more like Venus.

Life as it exists on earth has evolved in relation to a relatively stable range of climate and global temperatures. The degree of stability of temperature has depended in part on the

existence of the greenhouse gases, and presumably on the relatively stable concentration of these gases in the atmosphere.

The quantity of greenhouse gases in the atmosphere is, however, potentially subject to change via a variety of natural processes. It may be that very early in the earth's history there were greater levels of carbon dioxide concentration. This concentration was reduced as the oceans formed--a great deal of CO₂ is contained in inert mineral deposits (limestone or calcium carbonate for example) which were formed as CO₂ borne in water reacted with elements in the earth's crust.

Global life processes, which are dependent on the greenhouse effect, themselves affect the level of greenhouse gases, especially CO₂ and methane. A carbon dioxide cycle is in fact the central mechanism of living chemistry. A fundamental feature of plant life is its capacity to combine energy, in the form of absorbed sunlight, with absorbed CO₂ and water so as to construct much more complicated molecules, such as cellulose, carbohydrates, and proteins, which are used to build the structure of the plant. Animal life has the capability to ingest plant (and animal) materials, as well as water and oxygen, disassemble the constituent molecules so as to provide the building blocks for their own structures, and oxidize some of the material to provide energy to animate the animal. A byproduct of this energy production is carbon dioxide and water, hence a cycle.

A great deal of carbon, obtained by plants from atmospheric CO₂ is contained in the physical bodies of living things, principally plankton in the ocean, trees in forests, and to a much lesser extent, animal life. If the total quantity of carbon in living things increases, the atmospheric level of CO₂ is less than it might otherwise be, and vice versa. Much of the carbon in living things is ultimately recycled after death into CO₂ by decomposition processes (or fire, etc.). However, some quantity of biologic material has become semipermanently buried in the earth's crust by geologic processes in the form of coal, oil, and gas deposits, etc. Again, such deposits constitute a sink for ambient carbon and cause the level of CO₂ to be lower than it would otherwise be.

There is a tendency for global life processes to act as a buffer on the level of CO₂ in the environment. That is, life processes in the aggregate have a systematic tendency to help maintain those very environmental conditions which they depend on for existence. It works like this: hypothesize a sudden increase in atmospheric CO₂. The immediate effect would be a warming of the earth. However, countervailing forces would also be set in motion. First, some of the CO₂ would dissolve in the oceans. In addition, the higher concentration of CO₂

and the warming effect would cause a higher level of biologic activity, which would remove CO₂ from the air and ameliorate the initial increase in CO₂. Over the long term, more biologic activity would deposit greater quantities of carbon in sedimentary sinks. Hence, one could tend to expect that the level of CO₂ in the atmosphere, which is critical, is (fortunately for us) made more stable by an intricate cyclic process.

Industrial society is altering this subtle balance of atmospheric greenhouse gases and increasing their concentration. Most expert scientists fear that there will be, as a consequence, a greenhouse effect or warming of the earth. There are several forces driving this process. The principal action is the burning of fossil fuels, all of which contain some carbon in varying proportions. The combustion process generates energy by combining carbon with oxygen, and thereby creating CO₂. Thus part of the global "stock" of carbon which was "safely" stored in the earth, has been freed and converted to CO₂. Another action is deforestation, particularly deforestation through burning. Some of the global "stock" of carbon is physically and safely stored in the bodies of living plants. Burning a forest converts this stored carbon into atmospheric CO₂.

Much the same is observed with regard to the other greenhouse gases. Their atmospheric concentration has been highly stable. Mankind's activity has provided an additional source of each of them. In the case of chlorofluorohydrocarbons (CFC's) industrial activity is the only source; the historic "stable" concentration level was zero. As a consequence the concentration of each of the greenhouse gases is increasing. Each, like CO₂, is subject to natural processes in the environment which eventually decompose or remove the material. Unlike CO₂, these are not necessarily biologic or cyclic processes.

There are quantitative estimates of the underlying balance, and man's disturbance thereof. For these purposes, CO₂, the most understood of greenhouse gases, is the best focus. It is both the major culprit and a good proxy for all the greenhouse gases: the trends are similar. There are about 740 billion metric tons (BMT) of carbon contained in CO₂ in the earth's atmosphere. Plants located on land absorb about 110 BMT per year. Animal life respirates back about 55 BMT of carbon, and another 54 to 55 BMT is emitted by organic decomposition of biological material. About 93 BMT of carbon is absorbed by chemical and biological processes within the oceans. About 90 BMT is released back. Mankind, through burning of fossil fuels, adds about 5 BMT; deforestation adds another one to two BMT.¹

On this scale, mankind's contribution looks relatively small. Yet these are additions to a system essentially in balance--hence it causes a net increase. (Note that the net 3 BMT

absorbed by the ocean is caused by the higher atmospheric concentration.) Further, the very large number, 740 BMT, represents the total stock of CO₂ in the atmosphere. The five BMT produced by mankind is a flow which occurs each and every year. Thus over 100 or even 200 years, mankind generates a quantity of CO₂ on a scale of the existing stock in the atmosphere. Even if one assumes that a large percentage of the CO₂ (such as 50%) is absorbed by the ocean, the number is still large.²

This, however, is not nearly the whole story. Since 1950, mankind's emissions of CO₂ have approximately tripled. If this rate of increase were to occur for another 100 years, total emissions over that time period would be on the order of 4000 BMT, not 500. This trend projects to 27 times the energy use in 2090 that occurs today (CO₂ emissions would contain 135 BMT of carbon), based on the assumption that the world economy would employ similar technologies for basic energy creation as used today, and a host of other assumptions as well. This is not, however, an attempt to make a serious prediction of future CO₂ production, but rather simply to illustrate that the accumulation of time and economic growth will have a profound impact on the level of CO₂ emission.

Serious estimates of world CO₂ emissions are significantly lower than above, ranging from 10 BMT to 27 BMT by 2050.³ (The "naive" example above would suggest 45 BMT.) A summary of all these projections has led to a common view that a doubling of atmospheric CO₂ will occur sometime between the middle and the end of the next century.⁴

The atmospheric concentration of CO₂ and other greenhouse gases is not the ultimate issue, of course. The key question is what effects are to be expected from higher emission levels and greater concentrations of greenhouse gases. These effects can be easily described qualitatively. They are: ocean level increases and climatic changes, both related to increases in the earth's average temperature.

There is no doubt that the potential level of impact is quite great, given greenhouse gas concentration levels under discussion. A common estimate of the effect of a CO₂ level doubling (including similar increases in other greenhouse gases) is an increase in the mean global temperature level of 3.5 degrees Centigrade. Whether or not this sounds like a large temperature change, it is. The temperature difference between the climate the earth enjoys today and that in the middle of an ice age is about 5-10 degrees Celsius.⁵

One of the changes that can be expected from this increase in temperature is a sea level change of about .8 meters. The primary mechanism of the sea level change is an expansion of the ocean waters as a result of warming. Additional rises are expected from the

melting of Greenland's ice cap and, to a much lesser extent, the melting of mountain glaciers. This water flowing into the sea raises its level. The North Polar ice cap will also melt, but will have no such effect because it already "floats" on the Arctic Sea, and displaces a quantity of water equal to its mass. There is also a fear that huge pieces of the Antarctic ice cap, such as that overhanging the Weddel Sea in West Antarctica, may periodically break loose and slide into the sea. This would dramatically increase ocean levels by several inches at one time. (Current scientific thought heavily discounts this possibility.)⁶

An .8 meter increase in sea level implies a coastline regression throughout the world, which is of course more severe in river deltas and wetland areas where flat plains meet the sea. This effect would be differentially distributed throughout the world. Indonesia, for example, is thought to be especially vulnerable, comprising something like 15 % of the earth's coastlines. In addition to submersion, these coastal areas will become more vulnerable to periodic inundation as a result of storm surges and other transient effects. These will also erode the coastline. Salt water will penetrate farther into onshore groundwater supplies.

Such an increase in ocean water levels might seem small to the casual observer. However, such a rise could submerge 25% of Manhattan. Many coastlines in the United States would move back half a mile. While partial submerging of our great cities and valuable coastline are the most spectacular potential effect of global warming, rising sea levels will also have a devastating effect on our existing coastal wetlands; they could be submerged and drowned. These wetlands are critical breeding and gestation grounds for vast *quantities* of aquatic life. Mankind depends on these areas for a great deal of food.⁷

One might expect that the receding coastline will simply cause the creation of new wetlands to replace the old. This is unlikely to happen for two reasons. First, like almost everything else in nature, the phenomena designated as "the wetlands" is the result of a complex and interactive balance of life forces which has evolved over a long period of time. With global warming, one must contemplate significant change in venue for coastal estuaries of the correct water depth over the course of 50 to 100 years. Evolution of these natural cornucopias is in fact measured in thousands of years, not centuries. Global warming may cause change more quickly than nature can keep up.

Second, much of our coastal area exists on continental shelves which have been flattened out over the course of thousands of years. The incline of land, not too far from the coast, often increases significantly. Until this is worn down, again a process of thousands of

years, the coastal wetlands effectively disappear. A most likely policy response to water encroachment on our sea coasts is building dikes and levees such as those in Holland. Such can be effective to a point for that limited purpose. However, the impact of such actions on the wetlands would be to exacerbate rather than ameliorate their destruction.⁸ All in all, it's been estimated that 3 % of the earth's surface land will in some way be subject to these effects as a result of an .8 meter sea level rise. These lands tend to be highly productive and may harbor one billion people.⁹

Another category of effects from a temperature increase will be regional climatic changes. Obviously average temperature will rise in most if not all areas. More significantly, the pattern of the great flows of air in the atmosphere, and the great flows of water in the oceans, could be profoundly affected by such a temperature change. Some observers expect mid latitude, mid- continent areas, such as the Great Plains of the United States, to experience a drying effect. High latitude areas will receive more winter precipitation. Scientists believe quite strongly that some such effects will occur as a consequence of warmer temperatures because they have occurred before. Such changes in regional climate are associated with past ice ages and past warming periods.¹⁰

All of the estimated consequences of global warming, and even the warming itself, are speculative at this point and are subject to substantial uncertainty. The clearest conclusion that can be reached is that humanity is on new ground. Economic development has attained such a scale that certain of the most basic and essential activities can have profound impact on the earth and its environment. To a degree, the earth will become what we make it.

III. UNCERTAINTY

Given the basic scientific facts, it's difficult to ignore the greenhouse problem. Many people are in fact alarmed. However, one must first face the fact that the degree and significance of the effect is far from certain.

While scientists have learned a great deal about the earthly environment, and while that accumulation of knowledge has accelerated, they have also learned it is an immensely complicated system. Any particular event is likely to have a myriad of unforeseen consequences. Many of these often offset, at least to a degree, the initial effect while others may exacerbate it. There aren't (at least yet) any good general theories about the global environment which significantly simplify analysis and guide analysts. The results appear to

be a sum total of an intricate interaction among many, many factors. Consequently, there may never be a general theory on global climate. All and all, the current knowledge base falls far short of what is required to estimate the consequences of various actions with significant accuracy. All predictions are highly uncertain and extremely wide ranges are possible for very key values.

The CO₂ cycle, for example, is rich with intricate feedback effects. First, higher atmospheric concentrations of CO₂ will cause more CO₂ to dissolve in the oceans. The global CO₂ balance numbers cited above assume, based on good evidence, that about half of excess atmospheric emissions will be so dissolved. Higher global temperatures, whether caused by greenhouse gases or any other phenomena, will lead to greater biological activity both in the oceans and on land. Greater biological activity will increase the stock of carbon in living things, and therefore reduce the concentration of CO₂ in the atmosphere from what might otherwise have been the case. This could also lead to increased deposition of carbon-bearing materials into ocean and estuary sediments, effectively removing some carbon from the cycle.

The induced warming will have other effects as well. Higher temperatures will increase the quantity of water vapor in the atmosphere. Water vapor itself is a greenhouse gas, so the warming effect could be exacerbated. On the other hand, it could also lead to the greater formation of cloud cover. Clouds reflect some of the sun's energy back into space. Greater cloud cover could therefore ameliorate global warming.¹¹

Global warming is likely to change, probably reduce, the amount of snow and ice covering the earth's surface over the course of the year. Such change could increase the amount of heat absorbed. The result could be a positive feedback or exacerbating effect from the warming. Overall, the effect of warming on the albedo, or reflective capacity of the earth, is highly significant.¹²

Major uncertainty also exists with regard to the impact of other greenhouse gases. Principal among them is methane. It is known that a given quantity of methane has significantly greater greenhouse impact of CO₂. It is also quite clear that there is an upward trend in atmospheric methane. The sources of methane are not well understood.¹³ The greatest source appears to be decomposition of animal waste and biologic activity in rice paddies. The number of sheep and cattle feeding and clothing mankind increases as mankind's numbers increase. A secondary but significant source is fossil fuel recovery and transportation.¹⁴

Nor is it understood what will happen to atmospheric methane as the concentration increases. It appears to be processed into CO₂ and water over about a 10 year period.¹⁵ Thus if methane emissions could be reduced, atmospheric methane concentration would quickly fall. This might quickly and cheaply offset some greenhouse effect.

Other greenhouse gases have been identified. Their potential long term impacts are even less certain than that of methane. Unfortunately, these uncertainties imply a range of variation in critical effects, such as temperature change, which is substantial and significant. For example, scientists differ as to whether the warming effect of greenhouse emissions has as yet been reliably observed in global climate, even though the last century's increase in atmospheric greenhouse gases should imply an increase of .3 to 1.1 degrees Celsius in global temperatures.¹⁶

Part of the reason for the uncertainty is that we are still in a very early phase of what looks like a substantial increase in greenhouse gases. There is also a substantial time lag in the observation of effects. For example, were today's greenhouse gas concentration levels to be fixed, the earth would continue to warm for several decades before it reached an equilibrium temperature. The oceans act as a heat sink, initially cooling the atmosphere and moderating the temperature increase. Over time, the oceans warm and absorb less heat and temperatures slowly rise. This effect makes it more difficult to observe currently the temperature effect that will eventually be caused by existing greenhouse gas concentration levels.

The degree of scientific uncertainty is quite significant. The range of possible temperature increases associated with a doubling of greenhouse gas concentration is estimated to be 1.5 to 5.5 degrees Celsius.¹⁷ This range encompasses dramatic differences in potential effects. Translating these effects into sea level changes yields a range from .2m to 1.65m (from 7 inches to 5 feet.)¹⁸

This uncertainty of effect, coupled with the slow response of the environment, is quite disturbing. If it is true that mankind is entering an era in which he must take responsibility for his environment, it must be noted that the political processes through which that responsibility will be discharged are not well attuned to the task. Political processes work best responding to clear and immediate crises.

Clear evidence of warming will not be available for several decades. Clear evidence of harm may lie several decades beyond that. At that point, an action so extreme (and impossible) as to eliminate greenhouse emissions instantaneously would not forestall

additional warming, which would continue for several decades. But even to reduce the increase in atmospheric greenhouse gases will take substantial intervention in the economy. Reducing greenhouse emissions to a level consistent with a steady state temperature level would require additional decades. It's like steering a very large ship which has so much momentum that the helmsman must begin the turn long before a curve is reached. The uncertainty as to global warming effects means that the curves up ahead are obscured by fog. It's fairly certain there are curves ahead, but where exactly is unclear. It is not clear whether action should be taken now, or 20 years from now, or how much action is appropriate.

This has several implications for using the political process in taking action on the global warming issue. First, because of the uncertainty of effect and timing, it is going to be very difficult to achieve a focused and effective decision. A likely result is for a political compromise to form around a specific program, say energy efficiency standards, which are more symbolic rather than effectual. This will permit everyone to vote for the environment without confronting real costs.

The second implication is that whatever is done now is almost certain to be wrong, either too little or too much. Consequently, to the extent policy action is taken, one would like to put in place a mechanism which can be adjusted as the path ahead becomes clearer. A third implication is that this is an issue that won't go away. As evidence and effects accumulate, the nation and the world will go through rounds two, three and four of the global warming debate.

IV. The Policy Framework

However, this wide range of uncertainty should not obscure the fact that many scientists are warning that global warming will in fact occur and will have very serious and significant consequences. This is bad news indeed. Production of CO₂ is inextricably tied to most of the energy production throughout the world. Energy consumption is tied to economic growth and vitality throughout the world. Intensive energy use is directly responsible for developed nations' high standard of living, and is essential to all those who aspire to such.

Addressing this problem will require massive intervention into the technical workings of economies. U.S. policy efforts have failed to do this very successfully on other occasions on a national level. The greenhouse effect requires, in addition, coordinated intervention on a global level. Finally, just as the greenhouse effect has the potential for massive impact,

combating it has proportionate potential for massive cost.

CARBON DIOXIDE ABATEMENT

The means to ameliorate the greenhouse effect are quite unclear. For example, there is no straightforward process, such as scrubbers for SO_x, to capture CO₂ from combustion processes. The volume of CO₂ generated by combustion is typically 10 to 20 times that of SO_x. Once captured, the question becomes what to do with it. The most obvious treatment is to split the carbon atom from the oxygen atom. But this can't possibly work. The purpose of combining them in the first place is to generate energy. Breaking them apart must absorb more energy than combining them. Any such process therefore must bear a very high economic burden. Of course a simple reduction in the use of energy through conservation or achievement of greater energy efficiency is possible. The energy "crisis" of the late 1970's and early 1980's demonstrated that significant energy conservation and greater efficiency were possible. However, it is also clear that these gains came at a cost, and that many of the cheap and relatively beneficial measures have already been taken.

Substitution away from carbon based fossil fuels, given current technology, would essentially mean much greater reliance on nuclear power. Significant electric power production from photovoltaic cells is not likely to be feasible for many years, if ever. Hydropower alternatives exist, but are limited. The best sites are already being used.

All of this seems to suggest that while alteration of CO₂ emission levels is by no means impossible, it is likely to be very expensive. Manne and Richels have attempted to systematically measure the cost of abating CO₂ emissions. Their target was to hold U.S. emissions of greenhouse gases constant at 1985 levels. Their estimate is that such an effort would cost the U.S. economy a net present value of \$3 trillion (yes, trillion, not billion).¹⁹ Of course, such an effort is not nearly enough to completely mitigate a greenhouse effect. The U.S. economy is responsible for only about 22 percent of the emissions problem. Further, even if emissions were capped worldwide, CO₂ concentration would still continue to increase, and global warming, while slowed from the current expected path, would still continue.

Given the potential economic disruption and costs associated with abatement of greenhouse gases, and given the uncertainty surrounding the timing and extent of their impact, it has been suggested that adaptation rather than abatement is a preferred solution.

Adaptation, for example, means building dikes to protect critical coastal areas, moving agricultural activity in response to regional climate changes, and ultimately moving populations. Adaptation to climate change and sea level rises need occur only when those events are near at hand. One avoids the mistake of incurring abatement costs to avoid warming impacts which are illusory or highly exaggerated.

Choosing between adaptation and abatement, however, is really a false dichotomy. Some adaptation is certain to be necessary. Unless scientists are quite wrong (of course, they could be), a significant rise in temperature will occur regardless of what policy actions are taken. The consequences of policy actions taken in the 1990's will most likely be to begin ameliorating temperature increases somewhere in the 10's or 20's of the next century. Consensus estimate (which could be very wrong) would suggest it's unlikely that the temperature increases can start to be reversed before the end of the next century.

The proper role of abatement is to reduce the costs of adaptation and ameliorate those effects which cannot be adapted to. Abatement may not stop temperature increases, but it will surely slow them. Slowing temperature increases reduces the rate of necessary adaptation. This not only defers costs to the future, it could also reduce costs. Moving a city 10 miles inland every 10 years means abandoning valuable capital stock. Moving every 100 years may simply require building replacement facilities in a new location.

Clearly, controlling greenhouse gas emissions will require a substantial intervention into the world economy. However, the track record of government policy has been particularly weak. There have been two major episodes in the United States' recent past which have required similar, but smaller, interventions into the economy than will likely be required to reduce CO₂ emissions. In the late 1960's, the U.S. government sought to improve the nation's air quality with a set of regulations that controlled the emission of SO_x, particulates, and unburned hydrocarbons and other contributors to urban smog. The second effort was the policy response to the energy crisis in the mid to late 1970's, President Carter's "moral equivalent of war." Both of these efforts were subject to terrible flaws.

The United States has enjoyed benefits from environmental gains as a result of control efforts in the 1970's and 1980's. The abatement strategy has aptly been described as "command and control." Laws and regulations have specified in great detail the emissions control technology to be employed by specific plants. These regulations have certainly held emissions to levels lower than would otherwise have been the case. Yet these gains have come at very high cost, and the public appears to have concluded that not nearly enough has

been accomplished. The nation is again in the midst of a clean air debate.

The energy policy record is more dismal. It is difficult to conclude that there has been any result of energy policy but waste and misdirection. Oil imports did finally fall and oil prices with them. However, energy prices have fallen more in spite of U.S. policies rather than because of them. Meanwhile, the country is left with an overhang of expensive and now uneconomic projects.

It is our contention that these policy failures were systemic rather than accidental.

Understanding why those failures occurred may prevent repetition of the same mistakes.

THE ENVIRONMENTAL POLICY RECORD - UNITED STATES

The most immediate and direct parallel to the current concern over global warming is the earlier explosion of attention to the environment in the late 1960's, which led to the existing U.S. air emission legislation. In several key respects, that policy has been revealed to have critical shortcomings.

The basic elements of this policy were established by Congress and approved by the President. The Congress sought to delegate many of the detailed decisions to the EPA, but set out a framework for the EPA to make those decisions. Congress established seven criteria pollutants and directed the EPA to determine ambient air quality standards for each of them. These were intended to be ceiling standards, set to protect the health of even the most sensitive citizens, without regard to cost. Deadlines were established by which time standards were to be met. The task of meeting the standards fell to state control agencies, who were to establish plans for this purpose.

In many areas the deadlines were not met. The Clean Air Act was amended in 1977 to extend the deadlines and to designate those areas failing to meet the standards as nonattainment areas. The counterbalance was that nonattainment areas suffered particularly stringent restrictions on new pollution sources. They were (or are) required to maintain "lowest achievable emission rate" (LAER) which is part of any state plan.

The amended Act also required that even in areas meeting the standard, controls were to be put in place to "prevent significant deterioration" of air quality. To prevent such deterioration, new sources must employ "best available control technology" (BACT). Again, the states were to implement LAER and BACT standards, but the EPA established new source performance standards, which were intended to be minimum standards, subject to

improvement with state implementation. Already existing sources of pollutants remain subject to what frequently are more lenient standards of the original state plans.

Thus, at the end of the 1970's, the air pollution policy had two main features: first, a policy that grandfathered most preexisting sources (i.e., subjected them to less stringent standards), and second, a set of central government specified technologies for abatement of new sources. Quite appropriately, the term "command and control" has been coined to describe this type of regulatory methodology.²⁰

This construct can usefully be interpreted as a high level political compromise between the opposing sides. On one side was industry: principally the coal industry and its unions; coal- using or -serving industries, such as the electric power generation companies; and associated labor organizations. Arrayed against them were various environmental groups who effectively lobbied Congress. Included among these was a nascent EPA. (This lineup is, of course, pretty similar to today's round two of the acid rain debate, and global warming round one.)

The political reality of the situation was that the public in its wisdom was demanding environmental action from Congress and the President. Under these circumstances legislation is inevitable: Congress will respond. On such extremely difficult matters, Congress prefers to enact a compromise worked out between the contending parties.

The compromise achieved did make political sense for both sides. The very notion of new source performance standards gave a great deal to industry and labor--it preserved substantial existing property values and jobs. Many currently active plants and associated economic activities were effectively grandfathered, presumably to phase out in due course, leaving only "new sources" which met performance standards. This protection extended to high sulfur coal assets: the mandate of technological standards meant that new users of low sulfur coal received little economic advantage for doing so, despite lower SO_x emissions. They bore the same costs of installing BACT or LAER facilities.

Obviously the compromise had to work for "environmentalists" also. They have gained in two substantial ways. First, they gained the ability to clearly and unambiguously achieve results. Causing changes in the technology employed by virtually every electric, utility in the country, and every other large user of coal, was clearly an accomplishment. It was both empowerment and achievement, at least in a political sense -- a heady mixture. There was also a more subtle advantage of the compromise. Environmentalists' political strength ultimately lies with their representation of the very strong public desire for a clean

environment. But there is a catch. Everyone is in favor of a better environment: it's like motherhood. The issue really cuts when one begins to ask, "How much are we willing to pay to get a better environment?"

This question has been a hidden fear of environmentalism since its inception. Their fear is that a better environment is an idea which is very popular in the abstract, but that people speak a different tune when the cost must be borne in terms of their own salaries and jobs, and becomes identified on their utility bills. New source performance standards neatly dodge the issue: the immediate impact is small, the long term cost builds slowly and is buried in the cost of new plants. Few jobs are visibly lost immediately, few plants lose value or are shut down, and few consumers immediately see a utility bill which has "environmental charges" identified on it.

Thus, the compromise which resulted certainly makes political sense and in its way is brilliant in that regard. The only problem is that it hasn't worked too well as a policy. The economic incentives are wrong. The grandfathered power plants and industrial boilers have a competitive advantage over new plants with BACT abatement equipment. Instead of fading away, those plants have tended to stay in operation much longer than expected. They have continued to generate emissions in huge quantities, essentially unabated. The operation succeeded, but the patient is still sick.

The poor performance of "command and control" emissions regulation has led to proposals for alternative approaches to improving ambient air quality standards in non-attainment areas. One of these is "emissions trading" or use of a "bubble" concept. Under this regime, new sources, i.e., plants or factories, are permitted to emit pollutants as long as they arrange an "offset" within the defined area. An offset is a reduction in emissions from another source(s). Since these offsets effectively constitute a required permit to operate, new sources are willing to pay for them. The environmental authorities help arrange the trades. A principle reason this makes sense is that the grandfathered polluters, who've had little incentive to reduce emissions, can in fact do so at a relatively low cost, given an economic incentive. The new businesses bribe old businesses to cut pollution.²¹

THE ENERGY POLICY RECORD - UNITED STATES

The U.S. energy problem of the 1970's occurred because the United States ran short of domestic low priced oil, and a cartel of oil exporters effectively and dramatically raised the

price of imported oil. Higher oil prices, of course, led to higher prices for competing fuels. Three administrations (Nixon, Ford, and Carter), pursued essentially the same stated policy goal in response: to find ways to substitute away from imported oil, i.e., reduce oil imports, and thereby achieve energy security. Economists recommended that the U.S. prices be allowed to rise at least to the level of world prices, and that further discouragement of oil use, if desired, be achieved by placing increased taxes on oil products, as had been done by much of the rest of the world. The logic was quite simple: higher prices should discourage demand; higher prices to the extent passed on to producers could also encourage the domestic supply of oil and gas, the development and growth of substitute fuels, and conservation.

The U.S. policy essentially reversed this recommendation of economists. The prices of domestic oil and gas were kept low, and the low priced oil was used to average down the price of imported oil. Prices still rose, but not as quickly or high as in most of the rest of the world. This led to a rapid increase in U.S. natural gas demand and a fall off in domestic production. Gas shortages soon resulted, which were significantly exacerbated by federal controls on allocation of scarce supplies. Similar controls related to emergency oil supply allocation also led to gasoline shortages in the early 1970's and again in 1979.

In addition to establishing perverse price incentives in response to the energy crisis, U.S. officials sought to achieve results directly through the formation of a National Energy Policy process. Reduced to its most basic level, this was simply a process by which the Department of Energy, as its primary mission, developed a list of approved policies and programs for intervention into the economy to reduce oil imports.

As with environmental regulation, there existed a strong impulse to intervene directly to achieve results. This was in part driven by a sense of urgency resulting from the dual gas/oil shortages, the stubborn failure of oil imports to decline, and probably a naive confidence in the ability of centrally-directed technology forcing to achieve change.

Case in Point #1 - COAL GASIFICATION DEMONSTRATION

The sine qua non of this policy was a coal gasification unit built at a cost of \$2 billion near Beulah, North Dakota. It was completed July 28, 1984, ahead of schedule, under budget, and with 11 % more capacity than expected. The initial investors were five energy companies and the Federal Government, which put up \$1.5 billion in loan guarantees.

The theory was that this would be a demonstration project that would lead the private

sector to build more. It was demonstrated, to no one's surprise, that a proven technology which had worked for years on East German and South African soil with their coals, could also work on U.S. soil with U.S. coals. On August 1, 1985, the private sponsors withdrew from the project and defaulted on the loan, basically because of low energy prices. DOE came into possession of the facility and sought to return it to the private sector. In 1988, the House Subcommittee on Energy and Power conducted a hearing on the proposed sale, to assure that the facility "remain in operation as a test facility and cornerstone of the North Dakota economy, and to prevent federal taxpayers from being shortchanged." ²²

The facility is currently operating and selling gas at \$3.24/MMBTU, based on long term purchase contracts with gas pipeline companies. The current spot price of gas (May 1990) is about \$1.50/MMBTU.

Case in Point #2 - SYNFUELS CORPORATION (UNITED STATES)

On June 30, 1980, President Carter signed into law the Energy Security Act which initially authorized \$20 billion to stimulate the production of synthetic fuels based on the extensive domestic coal and shale resources.

This program was driven by the energy crisis in general, and specifically by the recent events in Iran. The rapid escalation in world oil prices in 1979 naturally focused attention on the development of a domestic synfuels production as an alternative to insecure imported oil. The Synfuels Corporation created by ESA was given the goal of achieving production of 500,000 barrels per day and 2,000,000 barrels per day by 1987 and 1992 respectively. It was clear at the time that those production levels could only be reached by some form of government subsidization of private sector activities.

Like most Federal initiatives, there were several different rationales for this new program. First, from a geopolitical perspective, turmoil in the Middle East drove the United States to grasp for "secure energy." Second, proving the producibility of significant quantities of synthetic fuels at some price would establish a backstop which would serve to limit energy prices over time. Third, it was believed that there should be a "premium" over the market price of oil that we in the United States should be willing to pay to reduce imports. Finally, there were the traditional arguments for government sponsored research and development.

The development of synfuels production had been an objective from the beginning of the energy crisis in 1973. The government sold leases on tracts of federal land endowed

with significant amounts of oil-bearing shale in 1974. Proposed legislation to achieve one million barrels a day of synfuel production nearly passed in 1976. Portions of the synfuel technology had been pursued through federally-sponsored research and development.

The synfuels program was different from both traditional research and development activities and from prior federal energy research. Synfuels development was to proceed to commercialization and was to be accomplished in the private sector with development-specific subsidies from the Synfuels Corporation.

The Corporation was set up on a much different basis than other federal agencies. The salary structure was different and higher than the Civil Service. The initial appropriation of \$20 billion was approved without any requirement for the Corporation to submit to the discipline of annual authorization and appropriation. Projects could be stimulated by production price guarantees, direct loans, and loan guarantees. Projects could be selected by competitive response to solicitation and by direct bilateral negotiation under certain circumstances. It seemed clear that the purpose of these differences was to create an elite agency relatively immune from the normal pull and tug of pork-barrel politics. Ironically, these very differences became irritants which helped generate political opposition to the existence of the Corporation.²³

The Synfuels Corporation lasted five and a half years and was able to stimulate continuing production of synthetic fuels in only four projects, two of which it generated through its own solicitation/negotiation process and two of which it inherited in the form of priorly-approved D.O.E. projects. In 1984, after a controversy involving alleged conflict of interest, Victor Thompson, the President of the Synfuels Corporation, resigned. His resignation left the Corporation with less than the required quorum necessary to approve any new projects. The appropriated funds available to the Corporation were cut back to \$8 billion and the production goals of the enabling act were eliminated. On December 19, 1985, the Synfuels Corporation was closed down, with the residual responsibility to manage the federal role in the existing projects transferred to the Treasury Department. All of this occurred during a period of rapidly declining energy prices.

The Corporation's solicitation/negotiation process proved to be disappointingly slow from almost any perspective. Over a five-year time period, the Corporation issued 12 separate solicitations of proposals for financial assistance to aid the construction and/or operation of synthetic fuels projects. In response to these solicitations, there were 204 specific proposed projects. Four of the solicitation rounds were general in nature and the

other eight rounds were quite specific (e.g., eastern bituminous coal gasification). The targeted solicitations were driven to generate at least one project with the desired technology by providing "a level of certainty for project sponsors with respect to the Corporation's program priorities and the form, timing and amounts of possible assistance awards."²⁴ In addition to soliciting proposals, the Corporation attempted to directly negotiate projects for target technologies when no acceptable proposal was produced by solicitation. This whole process ultimately led to only two working plants producing synfuels.

The two projects which were developed de novo by the Corporation were the Cool Water Coal Gasification project and the Dow Syngas Coal Gasification project. Both of these projects produced medium btu gas which was subsequently burned to produce electricity. The gasification processes in both projects were new technology and proved to be technically feasible. In neither case did the technology lend itself to a sufficiently broad application to produce a synfuels backstop.

The Cool Water project was driven in large measure by the need to find a technology that would allow the use of coal in generating electricity under California's air quality regulations. The project did prove up a commercial scale of Texaco's gasifier-radiant cooler and demonstrated a technology that could displace oil consumed in California's power stations.²⁵

The principal opportunity for application of the Cool Water technology outside of California was as an alternative to flue-gas scrubbed conventional coal-fired power plants. This application would not displace oil consumption and should be dominated by lower cost alternatives allowed under the pending Clean Air Bill.

The Dow Syngas project was driven by Dow's desire to prove a technology that would allow eventual replacement of natural gas by coal in the generation of steam and electricity in its petrochemical complexes. This project used a gasifier technology (slurry-feed entrained flow) identical to the Cool Water project, differing only in that the Dow project used sub-bituminous coal instead of bituminous coal. The technology could be applied to petrochemical complexes displacing natural gas but did not prove commercial production of synthetic liquid fuel. The Dow gasification process had already been proven with a pilot project and prototype plant (60% of the scale of Dow's commercial project), so the risks and advance of technology were not huge.²⁶

Evaluated against its original goals, the Synfuels Corporation is to be judged a

failure. It did not come close to establishing the technology that would provide a synthetic fuel backstop to influence world energy prices. It developed only a small portion of the technical frontier, displaced precious little imported oil, and was very slow in doing either. It is only fair to observe that even the best managed efforts would probably have failed to develop massive synfuels production because of the rapid fall in energy prices from 1982 through 1985.

A lesson that we draw from this episode is that in our political system it is extremely difficult to effectively drive technology with a government agency. Picking winners/technologies/projects is difficult enough from a purely technical perspective. Moreover, political considerations are ignored at peril to the long-run viability of the agency. There will always be a tendency for Congress to pull expenditures back into the normal legislative appropriations channels, which generates more political than economic outcomes.

A final ironic note about the Synfuels Corporation is that in view of our current conventional wisdom about the global warming problem, we are fortunate indeed that we failed to develop massive production of coal or shale based fuels. The inherent inefficiencies in any known synfuels process dictate that more CO₂ is produced in the synfuels cycle than by directly burning fossil fuel.

Case in Point #3 - EVOLUTION OF TECHNOLOGY IN DEVELOPING NATIONS-BRAZIL'S ALCOHOL FUEL PROGRAM

During the energy crisis, Brazil developed a large domestic industry producing alcohol from sugar cane and resulting in a substantial conversion of its automobile fleet to alcohol fuel.²⁷ This industrial development was interesting both in its magnitude and its pattern through time. It was a portentous development from our perspective, because it illustrates a phenomenon that appears all too common in modern times.

This phenomenon, which we call "the camel's nose," consists of the rapid expansion of a limited government policy/program in response to a perceived crisis far beyond its original scope and with little consideration of its cost effectiveness. The expansion of these programs seems to be driven primarily by significant rent-seeking interests. Further, these programs are almost impossible to curtail after significant private investment has been made. We would cite any number of such programs from the U.S. experience. Examining the

phenomenon in a developing nation illustrates that it is not unique to the United States.

Brazil's alcohol program began in 1975 in response to two economic blows to the Brazilian economy. The price and volume of sugar, Brazil's major export, had fallen sharply and the price of imported oil had quadrupled. The initial phase of the program consisted of subsidies to build distillery capacity at existing sugar mills to produce alcohol, and price subsidies to induce further use of alcohol as a blended component of automobile fuel. The fall in Brazilian sugar exports created substantial excess capacity and economic distress in the sugar industry. Brazil had extensive experience with the use of alcohol blended fuel and it could displace up to 20% of its gasoline consumption with existing technology.²⁸

From the beginning the program was probably not cost-effective even if all existing sugar industry investment was considered to be sunk cost.²⁹ It was limited in that there was no change in the automobile fleet and no expansion of sugar cane production. If sugar and oil prices returned to the historic norms, alcohol production and consumption would be cut back. Following the Iranian Revolution and the ensuing run-up of oil prices, the Brazilian alcohol program expanded dramatically. Proponents of alcohol expansion included the Brazilian automobile industry, which had "publicly" committed itself to producing alcohol-only engines, as well as sugar cane producers. Government subsidies were much more extensive, developing autonomous alcohol-only distilleries and the expansion of sugar cane production. The price of alcohol was set well below the price of gasoline. There was an initial boom in alcohol production and the sale of alcohol-burning autos.

By June of 1981, the boom in the sale of alcohol-burning cars ceased as oil prices leveled off, sugar prices increased, the government raised the price of alcohol and suspended credits for new distilleries. After a brief pause, the various subsidies were restored in 1982 in the face of rapidly falling oil prices. In 1983, 75 % of all new autos burned only alcohol and 17 % of the Brazilian budget was spent on alcohol fuel in one way or the other.³⁰ Brazil's commitment to alcohol continued in spite of the continuing decline of oil prices through the 1980's.

By the end of 1989, the alcohol program had created a massive crisis in Brazil. The subsidized price of alcohol fuel, which cost the economy approximately \$2.5 billion annually, had created a fleet of 4.5 million autos burning only pure alcohol. The government, responding to its soaring international debt, cut subsidies to sugar-cane producers but maintained alcohol fuel prices at 65 % of gasoline prices in the late 1980's. Farmers shifted

into other crops from sugar cane and recently diverted a larger portion of their cane output to produce sugar for export as world sugar prices rose. The bizarre consequences of these policies are that there is a growing shortage of alcohol fuel. Brazil exports gasoline and the government tries to find imported alcohol substitutes while consumers scramble to convert their auto engines to burn gasoline.³¹

It is interesting to note that in 1980 the United States committed itself to heavy subsidization of alcohol fuel primarily by eliminating the excise tax on gasohol, a blend of 10% alcohol and 90% gasoline. The resulting subsidy of \$.60/gallon of alcohol augmented by similar excise tax reductions by some states has produced a modest alcohol fuel program of 800 million gallons a year.³² The structure of the subsidy for gasohol provides a decreasing subsidy for higher levels of alcohol per gallon of fuel and there never was support for alcohol-burning automobiles by the auto industry. This program, supported strongly by corn producers and processors, has recently been extended by a Treasury ruling that the use of ETBE (ethyl tertiary butyl ether) as an octane booster will also qualify for excise tax reduction on the blended fuel because it is produced from alcohol. Through 1989, federal and state tax subsidies to gasohol totalled nearly \$5 billion. Seventy-five percent of the gasohol was produced by a single supplier, Archer Daniels-Midland.³³

In both Brazil and the United States, the energy crisis provided a smoke screen which allowed strong interest groups to create large subsidies for a special technology. In both countries the subsidies persisted long after the original crisis had faded from view. Unfortunately, the manifestation of significant environmental problems arising from global warming will provide the nations of the world ample opportunity to replicate the "camel's nose."

CONSEQUENCES

The policies devised by the United States to deal with the energy crisis had, in the end, arguably little effect on oil imports. Oil imports did eventually fall, but it is widely agreed that the primary cause was energy conservation and fuel substitution engendered by oil price increases. Presumably, this might have occurred more quickly if U.S. government policy had not held prices down. Ironically these effects became most strongly manifested after world oil prices had already fallen--as a result of worldwide oil finding, and more successful conservation efforts in other countries. All of this was in response to higher prices. Thus, economists' often repeated policy recommendations were supported. These

developments also emphasized that patience, not a political virtue, is required in order to give the economy time to adjust to changes in the prices of basic factors of production.

These ineffective energy policies, fortunately for the United States, did no permanent, substantial harm. Losses were simply the funds spent on implementing the ineffective policies - - maybe \$4 or \$5 billion a year spent out of the \$10 billion DOE budget that would otherwise not be spent. There also was an overhang of regulatory restrictions, most of which has been subsequently cleared away. The losses due to misdirected environmental policies have been excessive expenditures caused by inefficient abatement strategies. One could further argue that the losses include environmental impacts that might have been avoided had more effective policies been adopted.

Among the factors which contributed to earlier energy and environmental policy formation were a strong political impetus to act and achieve quick results; a set of complex technical issues which tempted a variety of clever individuals and groups in and outside of government to become meddlers, or to actively manipulate the political process to serve a vested interest; and political impatience with problems which can only be resolved over the long term. All of these factors are present in the global warming debate.

V. MEETING THE TECHNOLOGY TRANSFER CHALLENGE

Effective policy on the global warming must simultaneously induce technological change, transfer that new technology, and itself be adaptable under such change. Perhaps the best hope for controlling greenhouse effects is a vast improvement in control technologies, and/or changes in the mix of currently used fuels and technologies, as well as alternative means of generating energy. An effective policy must provide substantial rewards and support for finding, developing and implementing any such technology. Further, if and as such technology evolves, policy must be easily adaptable to the changed circumstance wrought by that technology. A terrible--but all too likely--outcome is that those with vested interests in old technologies will use whatever means available in a political process to resist and slow new technology. U.S. energy and environmental policies have been singularly unsuccessful at inducing technology change. Our examples show the tendency for bad technology to become vested in the political solutions to technical problems.

A global warming policy must also foster a technological evolution in the developing world, principally in Asia, but also in Eastern Europe and the Soviet Union. Newer energy

technologies, such as combined cycle power generation with natural gas, tend to be both more energy efficient, and more hydrogen based than carbon based. Each effect ameliorates CO₂ emissions. New abatement and new energy technologies, if and as they become available, will almost certainly be discovered in the developed economies, and must be transferred to developing economies. This too is an area of policy which has been fraught with failure in the past.

It may not be immediately obvious, but technology transfer is in fact a very critical issue. The underlying case for global warming is primarily predicated on greenhouse gas emissions caused by future economic growth. Over the next 50 to 100 years, world economic activity, as indicated above, is expected to increase by 300 - 1300%.³⁴ Hypothetically, that growth will principally occur in Asia, i.e., China and India. This part of the world contains a huge, growing population base. In addition, Asia seems poised for a sustained period of rapid, catch-up, economic growth. If the underdeveloped giants of Asia evolve to developed status in the next 50 years and do so with existing energy technology, they will have been responsible for a huge increase in greenhouse gas emissions. Failure to effectively transfer relevant control technology, or to transfer new energy technology, is tantamount to failing to control the greenhouse gas problem. It is, therefore, critical that greenhouse policy create incentives for effective technology transfer.

VI. AN ENVIRONMENTAL TAX AS A POLICY FRAMEWORK

We propose that a broad-based environmental tax form the framework for policy on mitigation of global warming effects. The term framework connotes that the tax is to be used as the primary mechanism of policy. We are not proposing a particular level for such a tax, but rather that such a tax mechanism be created and that, therefore, the tax level become the key issue of the global warming debate and the essence of policy.

A tax mechanism offers such great advantages that it behooves all parties to the debate to buy into it. These advantages are: first, it is a means to implement a given policy (expressed as a tax level) of greenhouse gas abatement in a most effective and efficient manner. No other mechanism is likely to work nearly as well, nor is so simple and easy to understand. Second, by virtue of its directness it would discipline a political process which has shown itself to be subject to ineffective compromises which hide exorbitant costs. Third, it is technologically "neutral". Finally, it will provide a source of funding to support parallel

initiatives. First among these initiatives should be to provide developing nations with incentives for greenhouse abatement. It will also provide critical funding for research into mitigation of regional impacts.

In very broad scope, we propose that the following steps be taken:

1. OECD nations agree that a tax mechanism be the principle means of controlling greenhouse effects.
2. OECD nations commission a multilateral study which, within a specified time period, develops a model tax structure for controlling CO₂ emissions.
3. OECD nations agree to a uniform CO₂ tax level and individually implement the tax mechanism.
4. The tax proceeds are transferred to the "International Environmental Fund" (IEF), administered by the World Bank, IMF, United Nations, or an agency created for this purpose.
5. The IEF administrator, in consultation with OECD nations and developing nations, will establish a mechanism of CO₂ abatement incentives, congruent with OECD tax levels, for developing nations. The IEF will implement and administer the program.
6. The IEF will establish and fund a program of global warming research.
7. As scientific knowledge permits, the OECD nations will adapt the established tax mechanism to include other greenhouse gases. The IEF will act in parallel fashion with its incentive policy.
8. Periodically, the OECD nations will meet to adjust the level of the environmental tax. The IEF will act in parallel.

ENVIRONMENTAL TAX FUNDAMENTALS

An environmental tax is the economic profession's solution to pollution problems. Economic theory predicts that the free interplay of market forces, each participant following his own self interest, leads to an aggregate result which achieves a maximum utilization of society's resources, i.e., no misdirected activity, no waste. Pollution emission violates a key assumption which yields this result. Economists assume that those engaged in economic activity bear all of the costs associated with pursuing a particular activity. Pollution emission, however, imposes costs on others in society. The economic paradigm of efficiency breaks down under these conditions. Imposing a tax on pollutant emissions equal to the societal

costs caused by those pollutants reestablishes the logic of efficiency.

The key to the efficacy of an environmental tax is that it gives exactly the right incentive to polluters to limit their emissions. The basic form of the tax is a charge per unit of emission. By reducing emissions the polluter reduces his tax payments. He is therefore willing to make expenditures on abatement technology in order to reduce costs. Ideally he reduces pollutant emissions right up to the point where the additional cost of abating a quantity of pollutant just equals the tax he would otherwise have to pay. If the tax has been set at the "right" level, a level which is equal to the costs imposed on the rest of society by pollutant emission, the polluter has been led to make exactly the proper decision as to abatement expenditures. (This assumes the tax level is correct. A discussion of how the tax level can be set at the "correct" level appears a bit later in the text.)

In addition to making the right choice, the polluter also has a systematic incentive to lower his costs, and he is free to do so, and has the ability to make choices as to which methods are best given his particular circumstances. For example, an electric power generator located in an area where coal is relatively inexpensive and natural gas relatively expensive might choose to generate electricity with a higher cost, less polluting fuel, gas, in order to avoid higher abatement costs and taxes associated with coal use.

Even more important, the tax strongly encourages technological innovation in treatment methods or in production methods which are inherently less polluting. Mandating specific abatement technologies, which has been a U.S. practice, offers no such encouragement for innovation.

In the global warming context an environmental tax also has the distinct advantage of relative simplicity of implementation. There are many different sources of greenhouse gases comprising very different production technologies and potentially requiring different specification as to abatement of emissions or alteration of technology. Thus, determining industry abatement technology standards is a massive task which dwarfs previous efforts. However, the impact of global warming is, of course, global: the effect of additional CO₂ (or other) emissions is essentially the same regardless of where it is emitted. This means that greenhouse gas emissions are especially suited to use of an environmental tax as a policy tool. A single tax level is all that's required for literally every emitter of CO₂ and other greenhouse gases in the world. (The environmental tax should be adjusted for each type of gas in proportion to the relative warming impact of that gas.)

Another emissions control technique involves setting source specific emissions

standards. Typically, the limit varies with the scale of production established at a given site. Again, setting source specific standards for a variety of production technologies and gases is administratively burdensome. In addition, it tends to create vested interests in specific limits and specific abatement technologies. An industry which has invested large sums to meet a given limit "x", will rise up in arms if the limit needs to be reduced to $1/2$ "x", which requires additional sums for retrofit, or a whole new technology. The tax framework equivalent of tightening the standard is simply raising the tax. Rather than face exorbitant retrofit costs, a particular firm can simply choose to pay some additional tax.

Many of these advantages of an emissions tax system have been known for some time. Yet it has not often been used in the past. A logical question is why not, and why might it be adopted now.

An emissions tax policy is thought to be beneficial because it incorporates a decentralized decision-making process. The idea is to get the incentives right and then leave the detailed implementation to the individual actors in the economy. The advantages to this approach are very much the same advantages that explain the superior performance of market-oriented economies as compared to centrally-directed economies. In an American political debate, however, this approach, ironically enough, is at a significant disadvantage as a possible policy option. Exactly because it depends on the decisions of a disparate group of decision makers, political players view key results as uncertain.

From the economist's point of view, the result is not uncertain at all: he will confidently predict that, if the tax level is correct, the level of abatement will be correct, and the impact on the rest of the economy will be, overall, the least harmful possible (and the net benefit of the policy will be as great as possible).

The interest groups involved in the political debate, however, view the outcome as uncertain, and for them it is uncertain. When the economist says the outcome is the best possible, the electric power company asks what will happen to its plants and its shareholders. The economist doesn't know and doesn't think it matters. The environmentalist asks how exactly these pollutants will be abated, and how much emissions will be reduced. The economist replies that the pollutant may be abated in some instances and not in others, and by exactly which means and by how much, he is uncertain. He is highly certain only that the outcome will be the best result, and that an appropriate amount of abatement will occur.

Such explanations don't satisfy political interest groups. If a tax is seriously posed as an alternative, everyone can and does make estimates of the consequences of the tax. But

these can only be estimates which are by necessity uncertain. In this circumstance everyone has a tendency to assume the worst outcome for himself, i.e., industry tends to assume that costs and competitive impact will be worse than is likely, and environmentalists that emissions will be greater than is likely. This makes compromise harder.

Command and control policy options look more attractive in this context because they appear to have relatively detailed plans as to what exactly will occur: what new equipment will be installed and by whom, for example. Thus political compromise is often fostered. Of course, these specific plans will inevitably have significant unintended consequences and are not nearly so certain as their precision leads participants to believe.

Given this, how can one expect that a tax, whatever its advantages, could pass political muster now? One could of course appeal to the players to submerge their individual fears and concerns in order to promote the common good. More to the point, however, we believe that the potential scale of the global warming problem changes the players' incentives. Global warming has a potential impact two or three orders of magnitude larger than any environmental issue considered previously. Size changes things.

The potential for massive greenhouse gas abatement costs comes about partly because of scope: there are many more significant greenhouse gas emitters than other airborne pollutants. Costs will also be high because individual point source abatement expenditure will be high. The political trade off for industry and labor is whether to try to carve a special deal out of a wasteful command and control framework versus getting internal control of the problem with a tax framework. Given the broad scope of the problem, any carve-out attempt automatically has a large number of opponents, (i.e., everyone else affected by the policy and not included in the "carve out".) This makes the "carve out" strategy much harder to employ. Alternatively, this tradeoff could be posed as follows: Is a given industry better off leaving a business problem of this magnitude to their Washington lobby group, or would it be preferable to put it in the hands of business people by giving them a tax they can flexibly adapt to? The problem is large enough that industry has a collective interest in reducing and focusing the role of the political process in order to minimize waste: a tax framework does that.

The environmental tax also raises, and appropriately so, the visibility of the costs associated with global warming abatement. This will tend to limit, again appropriately, the public desire for environmental legislation. The cost can and will be translated directly into

what it means in terms of individual electric bills, fuel costs, etc.

An environmental tax framework has even more to offer the environmentalist side of the debate. Again, size matters. First, the scale of the problem gives urgency to the issue of cost effectiveness. The point will ultimately be reached when the cost to society can't be hidden and could call a halt to progress. More can be done if it's done more efficiently.

Much more importantly, establishing an environmental tax for global warming will create a framework which will serve the environmental cause well as this issue evolves long term. The weakest part of the pro- abatement argument currently is the uncertainty of the global warming impact. Translated into political reality this means that the first round of policy actions that get legislated is going to be a very watered-down version of what might be necessary. As further scientific inquiry narrows the range of uncertainty, and assuming the expected impact remains about the same (or increases), there must be a round two. In fact, it's likely that rounds three, four and five, etc. will be needed. Adjustment to changes in scientific understanding under a tax regime means simply adjusting the tax level -- a relatively easy political task, and a procedure attuned to the gradual accumulation of global warming knowledge. It's made easy by virtue of the fact that the framework is in place, and can be easily adapted.

A command and control framework, on the other hand, is likely to require starting all over again from ground zero each time a significant change is needed. That is what is being done now with Clean Air II. The technological solutions must be reconsidered, and the specific requirements renegotiated. Adjusting command and control of greenhouse type policies, as science and technology changes, will become a painful process, and will become politically tiresome. It would be optimistic indeed to imagine that much precious time won't be wasted, and optimistic to expect that very efficacious results will be achieved.

Environmentalists should also fear policies which lock in specific technologies or create entitlements. The result is vested interests which may resist needed change. For example, consider an emissions trading regime. As indicated above, it is another alternative to command and control regulation. It has most of the efficiency advantages ascribed to a tax framework. The key variable is a total emissions target rather than a tax level. The target is quantitatively distributed to existing polluters as what amounts to a right to emit, up to an individual limit. New and existing businesses are allowed to purchase these rights from those who have reduced emissions below the limit. New

businesses which pollute must purchase them to operate.

This framework provides the proper incentive at the margin to induce polluters to minimize the cost of achieving the level of abatement determined by setting the target. It also provides an incentive for technical innovation in abatement. However, it has a fatal flaw given the uncertainty surrounding the global warming issues. The emissions trading mechanism works because it creates de facto property rights or entitlements--an allocation of the right to pollute within the overall limit established by the national or regional goals. The property right is then monetized, and appropriate incentives created. The global warming situation will very likely require, both politically and technically, an adjustment of the standard over time. However, it is almost a political law that entitlements, once granted, are impossible to take away. Those who have entitlements will become staunch opponents of program revisions. Consider what might happen as greenhouse gas abatement policies are extended to gases other than CO₂. If it is found that abatement for methane or other gases is relatively inexpensive, sensible policy might dictate very stringent targets for other greenhouse gases, and relaxed standards for CO₂. But efficient CO₂ abaters may well resist such change because it will reduce the value of their tradeable emissions permits.

Efficient abaters of particular pollutants have an interest in more stringent controls being applied to "their" pollutant. The key here is that an emissions trading policy, applied to a spectrum of cofactor pollutants, must make technology choices when targets are distributed among the pollutants. Implicit in that choice is an estimate of the relative cost of abating each pollutant. It is exactly that sort of technology choice which can become politicized, and vested with special interest--and lead to a bad choice. Application of an emissions tax requires only a relative weight of impact among the gases. (Emissions trading requires this as well.) No vested interests are created.

One additional advantage of the tax framework that does not directly affect the interests of the adversaries is that it makes good use of government. If agreement can be reached that the tax mechanism provides the right set of ground rules, then the political debate becomes centered on the question of the right level of the tax.

With the issue framed as a tax question, the political system and the executive branches of government would be confronted with tasks they can in fact advantageously perform. The opposite is true of command and control. Congress, when faced with a complex command and control issue, tries to resolve the matter by stating some guidelines and principles and then hands the matter off to a regulatory agency or administrative decision-

making process. The closer Congress gets to incorporating technical detail into legislation, the farther they are from their area of competence, and the more ill-served the nation. Very often, the regulatory agency, following its own procedural dynamic, takes excruciatingly long to do its task--a bad result in and of itself when something needs to be done. In addition, that process may result in decisions which are very different than parties to the political decision thought they had bought into. This tends to throw matters back again to Congress for more detailed technical specification. Just the opposite of what makes sense.

On the other hand, Congress can resolve matters very clearly and simply by setting a tax level. Further it is hard to think of a better method or forum to resolve exactly this question. Let the uncertain evidence be weighed, let everyone push and shove, but in the end, let Congress vote and the issue be resolved, at least for the moment. Indeed, given the high level of uncertainty, let's do put it to a vote. A vote on a tax level is a clear weighing of global warming concern against economic cost. The costs and benefits, as best they are understood, are clearly on the table at the same time. Similarly, a tax regime would give the administrative side of the government what it needs: a clear and simple mission to enforce the tax. Again this would be a task to which an EPA is well suited. Changes in policy, i.e., the tax levels, which are likely to be necessary, will not require alteration of the policy framework or enforcement mechanisms.

INTERNATIONAL COOPERATION

To this point we have cited a number of advantages associated with using an environmental tax as the key policy instrument for dealing with the global warming issue. We argue that the potential size and great uncertainty of the global warming problem turn these virtues into necessities. All of this, however, is just in reference to U.S. policy formulation. The pervasive international context of global warming issues strongly amplifies the imperative for an environmental tax.

A critical feature of the global warming problem is that it is indeed global. The emission of a quantity of CO₂ in the United States is no more or less harmful than emission from Bangladesh. Consequently, reduction of emissions in one country or group of countries cannot solve the problem. The United States is responsible for only 22% of CO₂ emissions. The rest of OECD emits 26 %, the Eastern Bloc (including the Soviet Union) 25 %, and the

remainder of the world has 27%.³⁵ The U.S. share is highly likely to decline dramatically in the future as Asian economies develop rapidly and catch up. This problem cannot be adequately addressed by individual nations, or blocks of nations. Fortunately, there does appear to be a strong international concern regarding the environment, and global warming in particular, with which to form some basis for cooperation.

However, there are also strong countervailing incentives that will hamper and could cripple international action. Because no one country can insulate itself from warming effects through its own emission control, individual national action *is in* effect discouraged. *In* addition, there is the temptation to let others solve the problem and "free ride" on their efforts. Industries and workers in countries which undertake the most strenuous emissions controls will suffer competitive disadvantages in world markets.

Concern regarding these effects has already turned up in international negotiations addressing air emissions problems. The United States and Japan have taken the view that they have already initiated unilateral control actions which exceed those of the European nations. They express unwillingness to begin discussions about further reductions from a starting point which disadvantages them.

It is even possible to infer how groups of countries will tend to divide. The OECD nations are likely to argue about the effect of emissions controls on relative competitive positions. The third world and the Eastern Bloc are much more likely to be concerned about the total costs and their impact on the growth of their national economies. Without minimizing the difficulty of reaching international agreements on global warming, we would suggest that an environmental tax framework could be structured to facilitate cooperation rather than exacerbate differences.

An obvious advantage of cooperation is that each nation can, in effect, leverage its own global warming expenditures. For example, consider the United States, which is responsible for about 20% of CO₂ emissions. International cooperation means the United States would expect five times the benefits from global warming abatement expenditures than it could obtain unilaterally. If the share of CO₂ emissions declines in the United States and other OECD nations as expected, their leverage will increase.

OECD COOPERATION

An environmental tax should provide a useful focal point for OECD nations. A tax

per unit of emission equitably calls forth emissions control in each nation. Relative to a given level of abatement with a given technology, it is competitively neutral. That is, nations will suffer cost and competitive harm in proportion to the damage they cause from emissions. Countries which contribute less to the problem (say per unit of GNP) will suffer relatively less. Those who have already undertaken abatement efforts will suffer less additional cost.

Alternative emissions control policies would, on the other hand, obscure equity comparisons. To the extent that countries engage in command and control emissions policies, or establish target policies, comparisons of effort levels become much more difficult. Different command and control regimes, and perhaps different technologies, must be compared one to another. This provides a wide venue for both honest and self-serving differences in views as to basic facts.

Suppose, for example, that the United States required that 50% of all new electric generating facilities use natural gas as opposed to coal, whereas Germany requires that 25 % of new power plants capture CO₂ emissions for well disposition. How is one to estimate whether these constitute equal efforts toward abatement? By emissions avoided per capita? Per unit of GNP?

By expenditure per unit of emissions avoided? It might even be argued that the United States is not reducing emissions on the grounds that, based on economic considerations, 50% of the new generating capacity would have been gas fired without controls. Emissions targets present similar problems. Is the numeraire of target setting to be emissions per capita, per unit of GNP, or per unit of abatement expenditure?

If environmental taxes are equalized, however, everyone is clearly equal in the following sense: the industries of each country will be paying a tax equal to the agreed upon costs of the damages they cause. Further, each country's industries will have the same incentive to abatement of greenhouse gases, and that incentive will properly reflect the damages that such gases cause.

Thus, the first step in achieving our proposal is that the OECD nations agree to an environmental tax related to the emission of greenhouse gases. Presumably the first stage would be a tax on CO₂ because of its dominant greenhouse effect and the administrative feasibility of such a tax. It is important that each country's tax collections be paid to a central international environmental fund. Unless this is done, a given country could use the tax proceeds to establish economic offsets for affected industries, and partially (or totally) negate the desired incentive effect of the tax.

AN INTERNATIONAL ENVIRONMENTAL FUND

The second implementing step would involve the use of the proceeds of the International Environmental Fund (IEF). The primary purpose of the Fund would be to support the efforts of developing and Eastern Bloc nations in reducing greenhouse emissions. The support might go directly to governments and be designed to reward them for reducing emissions by whatever means. It could also be used to provide a payment, related to emissions reduction, made directly to affected industries. By this mechanism, developing nations and Eastern Bloc nations would be provided an incentive to reduce emissions, without that effort imposing a cost to their economies.

An environmental tax will provide the means to achieve results in the less developed world. Any program which does not effectively include LDC's is probably doomed to failure.

In principle, a payment incentive mechanism is more difficult to implement than a tax disincentive. The tax system simply requires the imposition of a tax per unit of pollutant emitted. In order to provide an equivalent payment, an emission baseline needs to be established for each polluter. This is relatively simple in a static world. The polluter is then paid for the quantity of emissions reduced. Similar incentives to cut pollution exist under both regimes. In a world with economic growth, however, the baseline becomes a growing target. The payment, in principle, should provide an incentive to reduce emissions below the level that would have otherwise occurred. Definition of "would have otherwise occurred" obviously becomes difficult. Technological change makes it even murkier.

Emergence of a new technology can alter the relationship between economic growth and emission levels. For example, consider the development of combined cycle electric power generation techniques, coupled with natural gas finding in the third world. These are circumstances which are, in fact, juxtaposed in a number of regions. This may well alter the economically preferred power generation technology from CO₂ emission intensive coal plants to less CO₂ intensive gas fired plants. When and where such a technology option becomes available, baseline emissions levels should logically be reduced.

Making such judgements about appropriate emission baseline levels for a large number of countries, in an international political context, is potentially subject to a debate as divisive and tortuous as negotiating international emissions standards. However, the IEF payment mechanism does not need consensus among target nations to achieve results. It can proceed via a series of bilateral or multilateral agreements. Further, the authority

administering the Fund has the upper hand in any negotiation; it has the power of the purse. The authority can simply assign a baseline and make an offer. Where economies are relatively open, the authority could even approach industry without dealing with the government. Of course, this does require a fairly detailed and sophisticated knowledge of economies around the world and technologies appropriate for those economies. Fortunately, such expertise already exists, and is housed in the World Bank, the International Monetary Fund, and the United Nations.

In recent years the economic development activities of these agencies have become increasingly sophisticated. Over the years, each has observed and participated in a variety of development projects, some of which have worked and some of which have not. They have learned through failure, and have become much more market-oriented in their approach to projects. One of the sources of development project failure has been achieving effective transfer of new and sophisticated technologies to third world environments. Since new, efficient technologies seem to generate fewer greenhouse gases, a third world emissions reduction effort may in effect involve a substantial degree of technology transfer even at its inception. As discussed above, greenhouse gas abatement in the third world is critical to success. The World Bank, U.N., and IMF have had experience in failing to achieve such transfer, and also in achieving it.

The IEF should also be used to support several other critical tasks. Extensive, continuing research is required in three areas. First, support is required for the study of the mechanisms of global warming and its relationship to economic activity and natural processes, thus reducing our uncertainty about its impact. Second, support is required for global climate studies to assess the regional impact of global warming induced climate change. This also reduces uncertainty as to impact, but it also helps authorities plan for adaptation to climate change. Finally, support is needed for research into non-polluting energy sources. As has been indicated above, no feasible policy for greenhouse gas abatement is going to prevent increased concentration of greenhouse gases over the next 20-50 years.

Consequently, it is highly probable that there may be some significant global warming impacts. Indeed, depending on the cost of abatement, it may be less costly to bear some impact rather than increase abatement efforts. The costs of pollution reduction typically increase per unit of reduction as emission levels are reduced. It may become very costly to

reduce emissions of greenhouse gases below certain limits. Thus, accepting some impact, appropriately mitigated by adaptation, is necessary and may well be sensible.

It is virtually impossible that such damages will be distributed by nation in proportion to the greenhouse gas emissions. Consequently, some nations will have a rightful claim that they have been disproportionately forced to bear the cost of adaptation by the actions of others. Indeed, in certain developing nations the cost of adaptation may constitute a substantial economic burden. The International Environmental Fund would provide a source of funds to offset the costs of adaptation. Again, this compensation program should be administered by international agencies.

TECHNOLOGY AND POLITICS

A powerful impetus that any global warming policy must seek to create is technology change in the form of new development and transfer. As has been discussed above, the past is replete with examples of policy being captured and distorted by vested interests. Government decision processes, particularly democratic ones, don't seem to make good technology choices.

We've presented examples of how this has occurred in the United States and Brazil. Well- designed policies should minimize the need for such government choices. We believe our proposal does so. An environmental tax for OECD nations is as technologically neutral as a policy can be. The environmental incentive for less developed nations will require decisions regarding technology. However, the key decisionmakers will not be party to or have a vested interest in the economic and political systems for which those choices will be made. This will assure a high, though less than perfect, degree of technological neutrality.

VII. CONCLUSION

It should be clear that the authors take global warming concerns quite seriously. Nonetheless, we urge caution in choosing our initial policy responses. We advise caution for two reasons. First, a sense of deja vu; the United States has been down this path before, and its initial policies failed miserably in past crises. Second, given the necessary scope and scale

of global warming, taking the wrong path could be very, very expensive.

Our caution is not synonymous with inaction. Rather, we propose that the first action be an investment in infrastructure. Specifically, that time and effort be expended to establish a policy framework (our suggestion is an environmental tax) which has two critical attributes. One is to have a policy framework which is susceptible to effective and efficient implementation. The other is to facilitate cogent political decisionmaking under uncertainty. The critical policy question regarding global warming is exactly this: given the facts and given the uncertainty, how much are people willing to pay to offset the probable effects. Our proposal should allow the world's people to provide a fairly informed answer to that question.

Environmentalists may well perceive that the course we outline will cause delay. It will. Establishing the tax mechanism will cause delay. Debating and negotiating the tax level will cause delay. The level of a tax is, at least initially, likely to be less than many think necessary. The people's representatives may be less willing to vote positive on the environment when they have to tie it directly to higher taxes. A less comprehensive rifle shot technical "fix" can certainly be pushed through more quickly. But, as we've argued, that sort of fix will be ineffective and may be expensive. In return for an investment of time, we will get a policy that works, and which can be adapted to new circumstances without starting from ground zero each time.

REFERENCES

Barzelay, Michael. The Politicized Market Economy: Alcohol in Brazil's Energy Strategy. Berkeley: University of California Press, 1986.

Comprehensive Strateav Report, U.S. Fuels Corporation. June 1985.

Fosters Report No. 1684. August 11, 1988.

Hearing before Subcommittee on Fossil and Synthetic Fuels of the Committee on Energy and Commerce, House of Representatives, 99th Congress on H.R. 935.

New York Times. December 30, 1989.

New York Times Magazine. Part 2. April 1, 1990.

Rosenberg, Easterling, Crosson and Darmstadter. "Greenhouse Warming: Abatement and Adaptation." Resources for the Future. Proceedings of a Workshop. June 14-15, 1988.

Tietenberg, T.H. "Uncommon Sense: The Program to Reform Pollution Control Policy." From Leonard W. Weiss and Michael W. Klass (eds.), Regulatory Reform: What Actually

Happened. Boston and Toronto: Little, Brown and Company, 1986.

U.S. Department of Agriculture. Ethanol - Economic and Policy Tradeoffs. January 1988.
Warrick, Bolin, and Jager, Doos. The Greenhouse Effect. Climatic Change and Ecosystems.
Chichester, West Sussex: Scientific Committee on Problems of the Environment SCOPE.
1986.

NOTES

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1. Stephen H. Schneider, "The Changing Climate," Scientific American September 1989: p.73
2. Bolin Warrick and Doos Jager, The Greenhouse Effect, Climatic Change and Ecosystems (Chichester, West Sussex: Scientific Committee on Problems of the Environment SCOPE, 1986) p. 14.
3. Ibid., p. 62.
4. Ibid., p. 149.
5. Ibid., p. 262.
6. Ibid., p. 355.
7. Stephen H. Schneider, Global Warming: Are We Entering the Greenhouse Century? (San Francisco, CA: Sierra Club Books, 1989) pp. 154-155.
8. Ibid., pp. 154-155.
9. Rosenberg, Easterling, Crosson and Darmstadter, "Greenhouse Warming: Abatement and Adaptation," Resources for the Future, Proceedings of a Workshop (June 14-15, 1988) p. 50.
10. See Warrick and Jager, note 2,
11. Ibid., p. 222.
12. Ibid., pp. 215-216.
13. Ibid., pp. 162-166.
14. Ibid., p. 163.

15. Ibid., p. 168.
16. Ibid., p. 262.
17. Ibid., p. 362.
18. Ibid., p. 355.
19. The discussion relies on T.H. Tietenberg's fine article, "Uncommon Sense: The Program to Reform Pollution Control Policy," in Leonard W. Weiss and Michael W. Klass (eds.), Regulatory Reform: What Actually Happened (Boston and Toronto: Little, Brown and Company, 1986) p. 274.
20. Ibid., pp. 273-277.
21. Ibid., pp. 280-295.
22. Fosters Report No. 1684 (August 11, 1988) pp. 21-22.
23. Hearing before Subcommittee on Fossil and Synthetic Fuels of the Committee on Energy and Commerce, House of Representatives, 99th Congress on H.R. 935, p. 222.
24. Comprehensive Strategy Report, U.S. Fuels Corporation (June 1985) p. E-21.
25. Ibid., p. F-27.
26. Ibid., p. F-33.
27. Much of this discussion is drawn from Michael Barzelay, The Politicized Market Economy; Alcohol in Brazil's Energy Strategy (Berkeley: University of California Press, 1986).
28. Ibid., p.22.
29. Ibid., p. 30.
30. Ibid., p. 239.
31. New York Times (December 30, 1989) L4.
32. U.S. Department of Agriculture, Ethanol - Economic and Policy Tradeoffs (January 1988) p.v.
33. The New York Times Magazine, Part 2 (April 1, 1990) p. 20.
34. See Warrick and Jager, note 2, p. 67.
35. See Rosenberg, Easterling, Crosson and Darmstadter, note 9, p. 36.

