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Global Climate Change

June 1997

Global Climate Change
30 May 97

Divider Title: 1

Fact Sheet

What's happening to the climate?

- **Climate Change in the last century**:
  -- Global temperatures have increased between 0.3 and 0.6 degrees Celsius
  -- Sea levels have risen between 10 and 25 centimeters
  -- Experts believe these changes are unlikely to be entirely natural in origin

- **Estimated Climate Change over the next century**:
  -- Within a reasonable range of emissions scenarios, global temperatures are likely to increase between 1 and 3 degrees Celsius
  -- Sea levels may rise between 50 and 94 cm.
  -- Because of the temperature inertia of the earth, climate change would continue for some time even with drastic immediate action.

Why is it happening?

- **Four gases account for 99.5%** of anthropogenic sources of greenhouse gases. They are, in descending order of importance, carbon dioxide, methane, nitrous oxide, and fluorocarbons. These gases remain in the atmosphere for a long time (decades to centuries).

- **Greenhouse gases have been accumulating:** Atmospheric concentrations of GHGs have grown significantly (1750-1992): Carbon dioxide -- 30%; methane 145%; nitrous oxide -- 15%.

Concentrations of Greenhouse Gases (parts per million)

Gas	Preindustrial (1750)	1992	2100 (upper bound, business-as-usual)
Carbon Dioxide	280	358	650
Methane*	-	43	77
Nitrous Oxide*	-	92	119
Fluorocarbons	0	.04	.18

* in CO2 Equivalent concentrations

The US Situation

US responsible for 21% of global GHG emissions (25% of the CO2 emissions from fossil fuel burning).

Breakdown of GHG Emissions:

By Gas (mmtce)		By Sector	
Carbon Dioxide	1406	30%	Utilities
Methane	178	27%	Transportation (fastest growing)
Nitrous Oxide	40		

Carbon Dioxide represents 86% of the global warming potential of US emissions.

Emissions of Carbon by Energy Source:

Energy Source	Average Carbon Produced (metric tons of carbon)
one metric ton coal	.63
one gallon motor gasoline	.00267
1bbl crude oil	.119
one mcf natural gas	.0145

Emissions predicted to be 200 million metric tons (mmt) over 1990 levels by 2000

Economics of a Climate Change Policy

Effect of Carbon Tax, *$100 carbon tax would increase, in the short run*:

- gasoline -- $0.27/gal (currently $1.14 for unleaded regular)
- coal -- $63/ton (currently $27/ton CIF)
- petroleum -- $12 per bbl (currently $17/bbl)
- natural gas -- $1.45 per 1000 cf (currently $2.04 at wellhead)

- electricity from coal-fired plants -- $.10/kwh (currently $.03/kwh)
- electricity from natural gas combined cycle (NGCC) -- $.0035/kwh (currently $.040/kwh)

Energy Infrastructure Costs

Coal fired generating capacity in 1993 was 302,000,000 kw
Capital costs for NGCC plants is $500/kw, for coal fired plants is $142/kwh
Rough Estimate: Replacing 10% of coal fired plants with NGCC plants

Industries Most Affected by Reducing CO2 Emissions

coal mining	gas and oil producers	agriculture
petrochemicals	steel	automobile
utilities	aluminum	cement

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Divider Title: 2

A Brief Overview of Global Climate Change Issues
30 May 97

Scientific consensus: There is now fairly wide scientific consensus that anthropogenic global warming is occurring. While uncertain, the effects of climate change on crop yields, sea levels, disease patterns, and storm frequency could nevertheless be far-reaching. For the policy maker, climate change offers a somewhat imposing set of complications: the potential for irreversible damages or costs, a very long planning horizon, long time lags between emissions and effects, a global scope, wide regional variations, and multiple greenhouse gases of concern. This memo focuses on the economic impacts of climate change, with particular attention given to modeling the cost of achieving various mitigation goals and targets, the economic instruments available to lower greenhouse gas emissions, and the consequences on global climate change of non-compliance on the part of non-Annex I countries.

Timing: The U.S. is currently engaged in international negotiations concerning limits on greenhouse gas emissions with the goal of signing an agreement in Kyoto, Japan in December 1997. Some key equity and efficiency issues will need to be addressed in a somewhat limited amount of time.

Modeling: Numerous models have been developed to examine the potential economic impacts of stricter greenhouse gas mitigation requirements. However, there is no clear consensus in the literature on what the economic impacts may actually be. Estimated global CO_2 abatement costs relative to the baseline projection range from a 0.1% loss of GNP for a 14% reduction of emissions to a 5.7% loss of GNP for an 88% reduction of emissions. Studies of U.S. CO_2 abatement costs relative to the baseline projection range from a 1.2% gain in GNP for a 21% reduction in emissions to a 10.9% loss of GNP for a 96% reduction in emissions. These results indicate a serious lack of consensus on the magnitude of the impact that anthropogenic warming will have on the domestic and international economy.

In a recent study by Stanford's Energy Modeling Forum (EMF), researchers compared a diverse group of economic models employing different methodologies. Standardizing these models by assuming common exogenous parameters yielded remarkably similar results. This suggests that the choice of methodology is secondary to the choice of values for population growth, per capita income, energy intensity, and technical progress.

In particular, assumptions of the rate of improvement in the energy/GDP ratio have caused some degree of controversy in certain economic impact models. Current studies typically focus on the rate of autonomous energy efficiency improvement (AEEI), which tends to be a good approximation of the rate of change in the energy/GDP ratio when energy prices remain relatively flat. Long term historical evidence suggests a number in the range of 0.5 to 1.0 percent per year. The modeling group (Interagency Analysis Team--IAT) believes that the announcement of a global warming accord and the need to meet these strict mitigation goals will prompt businesses to accelerate the implementation of energy efficient methods of production. This alleged "announcement effect" is incorporated in these models by assuming a rate of improvement in the energy/GDP ratio of between 1.25 and 1.75 percent per year. This more closely approximates the

1973 to 1985 average in the U.S. of 2.0 percent per year, which provides the modelers with a justification for using a relatively high value of energy/GDP. However, after adjusting for the quadrupling of energy prices over that time period, the implied AEEI from 1973 to 1985 becomes 0.5 percent. This weakens considerably the assumption that energy/GDP falls in a range of 1.25 to 1.75 percent per year.

Goals and Targets (emission budgets): Two key terms are floating around in the discussions to set mitigation goals and targets. The first is the level of greenhouse gas emissions, which is a flow. The second is the level of greenhouse gas concentrations, which is a stock. It is important to note the difference in the implications of the two measures. For a long time now, the concentration of greenhouse gases in the earth's atmosphere has been increasing. This comes from a past flow of emissions above the implied steady state flow necessary to maintain a stable climate. In order to bring the concentration of greenhouse gases down to what scientists consider a more environmentally stable level, it becomes necessary to decrease current emissions well below the steady state rate.

Many different emission reduction requirements have been suggested. A recent Dutch proposal would cut EU emissions of six greenhouse gases to 10% below 1990 levels in 2005 and to 15% below 1990 levels by 2010. Similar plans have been proposed for the U.S., with the Climate Change Action Plan (CCAP) designed to reduce domestic emissions to 1990 levels by the year 2000. Some analysts point to a need for designing a mitigation proposal capable of providing some degree of equity across countries. It has been suggested that industrialized countries be required to decrease their level of energy/GDP while permitting developing countries to increase this same measure. However, it becomes increasingly difficult at the global level to incorporate high levels of both efficiency and equity into any mitigation proposal.

Economic Instruments: It is clear that a desire to lower greenhouse gas emissions necessitates the creation of certain economic incentives for the U.S. as well as for the rest of the world. Economic instruments available to achieve the required reductions in emissions range from simple command and control mechanisms to carbon taxes to a system of tradable permits. For a global treaty, a tradable permit system that is subject to enforcement is the only potentially cost-effective arrangement where a dictated level of emissions is attained with certainty. It is widely believed that a choice of tradable permits at the international level would provide maximum flexibility for instrument choice at the domestic level.

Non-Annex I Cooperation: Considerable scientific evidence suggests that no single country is sufficiently important or powerful enough to control global carbon emission in the short term or in the long run. If non-Annex I countries (those countries not characterized by advanced industrialized economies) do not alter their emissions path, global emissions levels will continue to increase even if all industrialized countries completely eliminate all emissions. This situation is exacerbated by the fact that, if controls of some sort were adopted only in the industrialized countries, "dirty" industries would migrate to the non-Annex I nations. Clearly, the U.S. would bear the costs of eliminating domestic CO_2 emissions but global emissions would continue to rise without cooperation from non-Annex I countries.

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Divider Title: **3**

Common Economic Perspectives on Climate Issues:

Many economists believe that the risks posed from global climate change are a real. But given the level of uncertainty surrounding the predictions, they also argue that it seems best to proceed pragmatically--taking out a small insurance premium (i.e., carbon tax) as we learn more about the magnitude of climate change, its translation into changes in climates around the globe, and the impacts of those climate changes on human welfare and natural environment. The key features that most economists agrees with are:

1. *The relevant economic and physical processes operate globally and over decades rather than years.* Few observers foresee substantial climate change for at least several decades, after emissions and atmospheric concentrations have increased substantially. Most plausible emissions scenarios involve a significant human-induced increase in climate change over the next century, with much of the increase coming from emissions of countries that are not now wealthy.

2. *Important and probably long-lived uncertainties are ubiquitous.* There are numerous unanswered questions about the biophysical systems, potential thresholds, and economic impacts. We do not know which regions will get warmer, which will cooler; which will get wetter, which will get drier; which will get stormier; which will get calmer.

3. *The climate issue involves potentially huge stakes, both economic and environmental.* It would be mad to experiment with the survival of the human race. However, models predict annual costs on the order of several percent of world income, dwarfing the costs of reversing the ozone hole (CFCs). Developed countries are looking at 1-2% drop in GDP; developing countries will not agree to transform their energy sectors unilaterally given that it will reduce that rate at which they could increase per capita wealth. The developing countries face health risks from poor drinking water and malaria right now that demand their immediate attention. Economic growth is the main engine to reduce these real risks happening today.

4. *Analyses of globally optimal climate policies generally do not support imposing burdensome emission reduction policies over the next decade or so, though very stringent policies may be optimal thereafter.* Since damages seem to depend on long-term concentrations, the argument for an optimal emissions reduction path is we should start off slow and then drop like a stone. The rationale is that in the future we will know more about the consequences of our actions, we will have developed cheaper abatement methods, we will have had time to invest to prepare for their use, and we will be wealthier.

5. *Any serious program to control global emissions is almost certain to involve substantial international transfers, the pattern of which may change over time.* The modeling runs suggest that with a trading system the US will be buying over $ billion dollars worth of permits from the former Soviet Union. Congress may not look kindly on this size transfer.

6. *Whatever the merits of the case for doing so, there is currently little political support for devoting substantial resources to the issue, and there is no obvious reason to expect this to change anytime soon.* Convincing the public that a $0.25-$0.40 increase in gas prices is a good idea will be a significant challenge.

Some Economics of Global Warming

By THOMAS C. SCHELLING*

Global warming from carbon dioxide was an esoteric topic 15 years ago, unknown to most of us. But in a few years, helped along by some hot summers, it has climbed to the top of the international agenda. Cabinets, Parliaments, and heads of government have issued pronouncements on reducing carbon emissions, and in June of this year more than a hundred governments will be represented by ministers or heads of government at a great United Nations Conference on Environment and Development to be held in Rio de Janeiro. Together with nongovernmental organizations representing labor, business, students, environmentalists, scientists, and groups concerned with health and child development and family planning, these representatives are expected to need 25,000 hotel rooms. A "framework agreement" is widely expected, together with some institutional arrangements that will keep global environmental issues permanently on every government's agenda. And at the center of these issues will be the phenomenon that has come to be known as the "greenhouse effect."

The greenhouse effect itself is simple enough to understand and is not in any real dispute. What is in dispute is its magnitude over the coming century, its translation into changes in climates around the globe, and the impacts of those climate changes on human welfare and the natural environment. These are beyond the professional understanding of any single person. The sciences involved are too numerous and diverse. Demography, economics, biology, and the technology sciences are needed to project emissions; atmospheric chemistry, oceanography, biology, and meteorology are needed to translate emissions into climates; biology, agronomy, health sciences, economics, sociology, and glaciology are needed to identify and assess impacts on human societies and natural ecosystems. And those are not all.

There are expert judgments on large pieces of the subject, but no single person clothed in this panoply of disciplines has shown up or is likely to. So, I venture to offer my judgment.

I

First on the principle. The metaphor of the greenhouse is not quite appropriate, but the basic idea is not in dispute. The earth is bathed in sunlight, some reflected and some absorbed. If the absorption is not matched by radiation back into space, the earth gets warmer until the intensity of that thermal radiation matches the absorbed incoming sunlight. Some gases in the atmosphere that are transparent to sunlight absorb radiation in the infrared spectrum, blocking that outward radiation and warming the atmosphere. When the atmosphere has warmed enough to intensify the thermal radiation so that it matches the absorbed incoming sunlight, equilibrium is achieved at the higher temperature. These so-called "greenhouse" gases can be identified in the laboratory. Carbon dioxide is one of them; methane is another, as is nitrous oxide, as are the chlorofluorocarbons (CFC's).

The principle has been in practice for decades. On a clear day in January, the earth and its adjacent air in Orange County California warm nicely, but the warmth radiates rapidly away during the clear nights, and frost may threaten the trees. Smudge pots, burning cheap oil on a windless night, produce substances, mainly carbon dioxide, that absorb the radiation and protect the trees with a blanket of warm air. Greenhouses, in contrast, mainly trap the air warmed by the earth's surface and keep it

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from rising to be replaced by cooler air. The phenomenon should have been called the "smudgepot effect," but it is too late to do anything about it.

A first step in pursuing this phenomenon is to assess how much warming might go with an enhanced concentration of these gases. That cannot be done in the laboratory; there are too many feedbacks. A warmer atmosphere will contain more water vapor; water vapor itself is a greenhouse gas. Changes in temperature and humidity will change cloud cover; clouds can reflect or absorb incoming or outgoing light according to their composition and altitude. The average temperature is only one dimension; temperatures at different altitudes and different latitudes matter. But a starting point has been the change in average surface atmospheric temperature expected to accompany a specified increase in the concentration of greenhouse gasses; and arbitrarily, but reasonably, the base case is taken as a doubling of the concentration.

A moment on why a doubling is the benchmark. To compare estimates of warming, people must use the same hypothesized concentration of greenhouse gases in the atmosphere. (Alternatively, they could use the same hypothesized temperature increase and estimate the corresponding concentration.) Doubling, like a half-life in reverse, is a natural unit if it is within the range of practical interest, and it is. A doubling is expected sometime in the next century, so it is temporally relevant; and a doubling is estimated to make a substantial but not cataclysmic difference. If fixation on a doubling seems to imply an upper limit on any expected increase, the implication is unfortunate: enough fossil fuel exists to support several doublings.

In 1979, a committee of the National Academy of Sciences (NAS) (1979 p. 2) estimated the change in average temperature to accompany a doubling of carbon dioxide in the atmosphere: three degrees Celsius, with a range of 1.5 degrees to either side. (In the last 15 years other greenhouse gases have received attention; these other gases can be converted to their carbon dioxide equivalents and the original estimate applied to the mixture.) The NAS appointed another committee a few years later to reexamine that estimate, and the new committee saw no reason to change it (NAS, 1982 p. 51). An intergovernmental panel on climate change (IPCC), consisting of scientists from many nations, revisited the estimate in 1990 and concluded, from the several climate models they had examined, that "the models results do not justify altering the previously accepted range of 1.5 to 4.5 degrees C" (IPCC, 1990 p. xxv). Thus, the estimate appears to be robust over time, but the spread of uncertainty remains large: the upper limit is three times the lower limit. (No quantitative interpretation of these upper and lower "limits" has been made public. Both National Academy reports referred to them as "probable error.")

II

The uncertainties are even greater in translating a temperature change into climates. The media support a popular view that things will just get hotter; a news magazine cover was a sweating global face. But the laboratories that do the meteorology do not simply predict warming; they do not even predict that the most noticeable effects will necessarily be temperature changes. Among the great driving forces of weather and climate is the temperature differential between equatorial and polar regions; convection currents coupled with the rotation of the earth are engines of atmospheric circulation and, ultimately, ocean circulation. The models predict greater temperature change in the polar regions than near the equator. This change in gradient can drive changes in circulation. The results may be warmer in some places and colder in others, wetter in some places and drier in others, cloudier in some places and sunnier in others, stormier in some places and less stormy in others—generally a complex of changes that would bear no easy relation to an average change in global temperature.

The change in average temperature is useful as an *index* of climate change. It is

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thought, and the models demonstrate, that the greater the change in average temperature the greater the departure of current climates from what they are now. Thus, while it is wrong to think that what is going to happen can be readily characterized as "warming" it is not erroneous to take that average warming as a rough measure of the extent or severity of change to be expected. Unfortunately the widespread reference to "global warming" promotes the notion that things will simply get hotter. (Interestingly, virtually all public discussion is on hotter summers, not warmer winters; a hundred years ago popular discussion of a warming trend would likely have concentrated on the milder winters to be expected.)

If three degrees Celsius is taken as an index of climate change to come within the next century or so, how big is that compared with what has happened within the last century, or the last 10,000 years? From what I have just said, this cannot be answered in terms of whether anyone would notice the difference if every night and every morning, every winter and every summer, temperatures were exactly three degrees higher than they otherwise would have been. The question is: how would a three-degree change in a global average compare with what has been experienced in the past?

The answer is that for 10,000 years, since the disappearance of the last ice age, average temperature appears never to have varied over anything like three degrees. A band of one degree Celsius would cover the current estimates of what average temperatures have been since the dawn of recorded history. We will be moving into a climatic regime that has never been experienced in the current interglacial period.

"Mankind will undergo greater climate change in the next 100 years than has been experienced in the last 10,000." Properly qualified, the statement is true; what it neglects is that peoples have been migrating over great distances for at least several thousand years. Goths and Vandals, Huns, West Europeans who populated North and South America, Southerners who went North during the Great Depression, and Northeasterners who moved southwest after World War II all experienced changes in climate greater than any being forecast by the models. Almost everybody who attends this lecture in New Orleans will have undergone a greater change in the past few days than is expected to occur in any fixed locality during the coming century.

The changes that the models produce are *gradual* both in time and in space. The models do not produce discontinuities. Climates will "migrate" slowly. The climate of Kansas may become like Oklahoma's, Nebraska's like that of Kansas, South Dakota's like Nebraska's, but none of these is expected to become like the climates of Oregon, Louisiana, or Massachusetts.

A caution: the models probably cannot project discontinuities—just gradual change—because nothing goes into the models that will produce *catastrophes*. There may be phenomena that could produce drastic change, but they are not known with enough confidence to introduce them into the models. So the reassuring gradualness may be an artifact of the methodology. I will return to this point later.

This greenhouse problem, if problem it proves to be, is truly one of the "global common." A ton of carbon emitted anywhere on earth has the same effect as a ton emitted anywhere else. And carbon dioxide has a long residence time in the atmosphere: a century or more. There may be ways to remove it, but it doesn't disappear. The greenhouse influence on any national territory depends solely on the global concentration, not in any way on what part of the total is due to a nation's own emissions.

As I shall detail later, the costs of reducing carbon emissions will be large compared with any other emissions that have caused concern. The costs of phasing out CFC's will be in the billions of dollars per year for some years, and complete elimination is expected to be feasible. The cost of reducing sulfuric acid may be in the tens of billions of dollars. Proposals to hold emissions of carbon dioxide constant (with a linear increase of concentration in perpetuity) or to reduce emissions by 50 percent below what they would otherwise be, beginning perhaps in 2010, are expected to cost in the hundreds of billions in perpetuity.

There are a few numbers worth carrying in mind. There are 700 billion tons of carbon in the atmosphere. (Quotations are sometimes in tons of carbon dioxide, rather than carbon; the figure is then $3\frac{2}{3}$ times as large, about 2,600 billion.) Annual emissions are 6 billion tons. Close to half disappears somewhere, and a little over half remains in the atmosphere; so the concentration is increasing by one-half percent per year. It has increased 25 percent in the last hundred years. (Concentration is reported more often than tonnage; it is currently about 350 parts per million.) And there are upwards of ten trillion tons of carbon fuels out there to be burned; if it were all burned and half stayed in the atmosphere, the concentration could double at least three times.

If the carbon in the atmosphere has already increased by a quarter, has the average temperature gone up as predicted? And were the recent hot American summers that stirred popular interest harbingers of greenhouse summers to come?

To the first question, the answer is that average global temperature—summer and winter, both hemispheres, night and day—has apparently risen by half a degree in the last hundred years, but whether "as predicted" depends on what qualifications one reads into the predictions. The pattern differed between the Northern and Southern Hemispheres. The global average rose during the first 40 years of this century, was level for the next 40 years, and rose during the past decade. This pattern demonstrates that, whether or not we are witnessing the greenhouse effect, there are other decades-long influences that can obscure any smooth greenhouse trend. (The carbon concentration is not at issue; it is well measured and shows steady rise on a decade scale.) There are known phenomena that could account for the irregular temperature increase of the past century, and whether we are witnessing the "signal" probably depends on whether one wants high confidence to reject a null hypothesis or is about to bet money on whether, another 25 years from now, looking back, all doubt will have been removed. I don't know what bets are being placed by "greenhouse scientists," but they are cautious in public on the question.

To the second question—do the hot American summers of the past few years announce the arrival of a greenhouse, confirming predictions?—the answer is in two parts: maybe it's the greenhouse; but it's not what the greenhouse models predict. The global average in the four hot years of the past seven was only 0.2 degrees above the level of the preceding 40 years; and sudden hot American summers are not what the models predict.

III

In anticipating the impact on human welfare or natural systems, two kinds of uncertainty are unlikely to be dispelled soon. One is simply the question of what the changes will be in each region or locality. Current models are severely limited in their agreement with each other, in their handling of such topographical variables as mountain ranges, and in the fineness of the grids they superimpose on the globe. There is no great confidence that the models will be greatly improved within the next decade or two. A chaos-like process may defeat efforts to improve local predictions; and uncertainties in gross phenomena, such as the behavior of ocean currents under changed climatic conditions, may not be much better understood soon.

Even if we had confident estimates of climate change for different regions of the world, there would still be uncertainties about the kind of world it is going to be 50, 75, or 100 years from now. Imagine it were 1900 and the climate changes associated with a three-degree average temperature increase were projected to 1992. On what kind of world would we superimpose either a vaguely described potential change in climate or even a specific description of changes in the weather in all the seasons of the year, even for our own country. There would have been no way to assess the impact of changing climates on air travel, electronic communication, the construction of skyscrapers, or the value of California real estate. Most of us worked outdoors: life expectancy was 47 years (it is now 75); barely a fifth of us lived in cities of 50,000 or more. Anticipating the automobile, we might have been concerned with whether wetter and drier seasons would bring more or less mud, not anticipating that the nation's roads would become thoroughly paved. The assessment of effects on health would be without antibiotics or inoculation. And in contrast to most contemporary concern with the popular image of hotter summers to come, I think we would have been more concerned about warmer winters, later frost in autumn, and earlier thaw in the spring.

If the world, both North America and the other continents, is going to change as much in the next 90 years as it has changed in the 90 just past, we are going to be hard put to imagine the effects of climate changes.

Another thought experiment: suppose the kind of climate change expected between now and, say, 2080 had already taken place since 1900. Ask somebody 50, 60, or 80 years old what is different compared with when he or she was a child. Would the mate change be noticed? Even ask a 70-year-old farm couple living on the same farm where they were born: would the change in climate be among the most dramatic changes in either their farming or their lifestyle? I expect changing from horses to tractors and from kerosene to electricity, the arrival of the telephone and the automobile and the paving of roads, the development of pesticides and artificial fertilizer, the discovery of soy beans and the development of hybrid corn, and even improvements in outdoor clothing, veterinary medicine, and agricultural practices generally would swamp the climate change. And if instead of living and working conditions we inquire about changes in wildlife and natural ecosystems, changes in regional climates would have been competing, in their impact on nature, with population growth and economic development.

A conclusion we might reach is that a climate change would have appeared to make a vastly greater difference to the way people lived and earned their living in 1900 than to the way people live and earn their living today. Today very little of our gross domestic product is produced outdoors, susceptible to climate. Agriculture and forestry account for less than 3 percent of GDP, and little else is much affected. Some activities —tourism and holidays, professional sports, and school teaching—are seasonal, but many of the seasonalities are conventions that reflect the influence of climate in earlier times. (Children were needed in the fields in summer and could start school when the harvest was in; hockey and basketball used to be winter sports because one depended on ice and the other could fit in a building.)[1]

Manufacturing rarely depends on climate, and where temperature and humidity used to make a difference, air conditioning has intervened. When Toyota chooses among Ohio, Alabama, and Southern California for locating an automobile assembly, geographical considerations are important, but not because of climate. Minerals are extracted where they happen to occur, and oil fields and coal mines inhabit all kinds of climates and are little affected. The U.S. Postal Service's vow that neither snow nor rain nor heat nor gloom of night will "stay these couriers from the swift completion of their appointed rounds" sounds quaint in the era of e-mail and fax.

Finance is little affected by climate; similarly for health care, or education, or broadcasting. Transportation can be affected, but improvements in all-weather landing and take-off in the last 30 years are greater than any differences that climate makes. If the average effect is a warming, iced waterways and snow removal may decline in importance. Construction is affected, mainly by cold, and if the average effect is in the direction of warming, construction may benefit slightly.

It is really agriculture that is affected. But even if agricultural productivity declined by a third over the next half century, the per

[1]An imaginative discussion is in Jesse H. Ausubel (1991).

capita GNP we might have achieved by 2050 we would achieve only in 2051. Considering that in most of the developed countries—the United States, Japan, France, the United Kingdom, the Netherlands, and Israel—the agricultural problem has been protecting farmers, that agricultural productivity in most parts of the world continues to improve, and that many crops and cultivated plants will benefit directly from enhanced photosynthesis due to increased carbon dioxide, one cannot be certain that the net impact on agricultural productivity will be negative or, if negative, will be noticed in the developed world.

I conclude that in the United States, and probably Japan, Western Europe, and other developed countries, the impact on economic output will be negligible and unlikely to be noticed.[2] And there is no reason to believe that in these countries there could be a noticeable impact on health. Any influence of climate on health in this country would be more in the regional distribution of the population than in changes in local and regional climates.

Comfort is worth considering. Fortunately, the climate models predict a greater warming in winter than in summer. Most people in the United States, Japan, and Western Europe go south for vacation, both summer and winter; and when people move upon retiring in the United States they typically move toward warmer climates. In future years, elderly people may suffer more heat stroke in summer in St. Louis, but we can hope for fewer broken bones from ice in Boston. (Inhaling air richer in carbon dioxide has no effect on health.)

IV

This complacent assessment cannot be extended to the much larger population of the underdeveloped world. The livelihoods earned in agriculture and other climate-sensitive outdoor activities, 3 percent in the United States, comprise 30 percent and more of all livelihoods in most of the developing world. Reliable forecasts of likely climate changes in the different areas so dependent on agriculture are simply not available, so no assessment, region by region, of the effect on productivity can be provided. There is no strong presumption that the climates prevailing in different regions 50 or 100 years from now will be less conducive to food production. But there is also no assurance that climate changes will not be harmful, and even if on balance the impact is neutral, there may be large areas with large populations that suffer severely. Those people are vulnerable in a way that Americans, Western Europeans, and Japanese are not.

Nor can the impact on health be dismissed or readily subsumed among generally improving health conditions, as for the developed world. Numerous parasitic and other vector-borne diseases affecting hundreds of millions of people are sensitive to climate. Again, there is no strong presumption that malaria mosquitos, to take an example, will on balance benefit from climate changes, but the risk is there.

It is with the less-developed countries that we have to be most careful about superimposing the climates of the future on the economies and societies of today. As it was in our own country during this century, the trend in developing countries is to be less dependent on agriculture and less vulnerable to climate in transportation and other activities and health. If per capita income growth in the next 40 years compares with the 40 years just past, vulnerability to climate change should diminish, and the resources available for adaptation should be greater. I say this not to minimize concern about climate change, but to anticipate the question of whether developing countries should make sacrifices in their development to minimize the emission of gases that may change climate to their disadvantage. Their best defense against climate change may be their own continued development.

This is a point worth emphasizing. Some environmentalists argue that developing

[2] A comprehensive discussion of both impacts and costs of abatement is provided by William D. Nordhaus (1991a). A carefully argued opposing view is that of William R. Cline (1992).

untries should sacrifice some of their hopes for economic development in the interest of slowing the climate change that may prove disastrous. But the advice contains a contradiction Any disaster to developing countries from climate change will be a disaster to their economic development. What is desired is to optimize development by investing in greenhouse-gas abatement only when that appears, subject to all the uncertainties, to contribute more to their development in the future than the alternative direct investment in development. It is not economic growth versus environment; it is growth with the environment taken into account.

A related point: population growth is important for the climate change, in two respects. One is that carbon emissions in developing countries are positively driven by population; population growth does not merely dilute carbon emissions per capita, but for a number of reasons more people means more carbon. If China succeeds in holding population growth to near zero for the next couple of generations, it may do as much for the earth's atmosphere as would a eroic Chinese anticarbon program coupled vith 2-percent annual population growth.

The other population effect is simply that the most likely adverse impact of climate change on human productivity and welfare would be on food production. In the poorest parts of the world, the adequacy of food depends on the number of mouths and stomachs. In a hundred years, adverse changes in climate for food production would be far more tragic if the countries we now associate with the developing world had populations totaling 12 billion than if they totaled 9 billion. For the developing world, the increasing concentration of people is probably more serious than the increasing concentration of carbon dioxide.

At this point, I appear to have reached the conclusion that the *developed* world has no self-interest in expensively curtailing carbon consumption and that the *developing* world cannot afford to incur economic penalties to slow the greenhouse effect. There is a mismatch between those who may be vulnerable to climate change and those who can afford to do anything about it.

V

Why should the rich developed countries care enough about climate change to do anything about it? The answer must depend partly on how expensive it is going to be to do anything about it. Abatement programs have been examined in a number of econometric models that suggest we might want to treat as pertinent the sacrifice of perhaps 2 percent of world GNP in perpetuity.

A strong argument for trying seriously to slow climate change is that the developing countries are vulnerable and we care. Developed countries are currently providing $50 billion per year of assistance to the developing world; we would be talking about expending or forgoing perhaps 4–8 times that much to slow emissions and slow climate change. Whether people in the developed democracies could be mobilized to contribute so much to benefit, half a century from now, the people in the countries we now call developing I do not know, but I believe that if the developed countries were prepared to invest, say, $200 billion per year in greenhouse-gas abatement, explicitly for the benefit of developing countries 50 years or more from now, the developing countries would clamor to receive the resources immediately in support of their continued development. There would undoubtedly be abatement opportunities so cheap that they could compete with direct aid to developing countries, but it would be hard to make the case that the countries we now perceive as vulnerable would be better off 50 or 75 years from now if 10 or 20 trillions of dollars had been invested in carbon abatement rather than in their economic development.

A second argument for an expensive program of carbon abatement is that, while our production of material goods and services may not suffer from climate change, our natural environment may be severely damaged. Natural ecosystems will be destroyed; plant and animal species will become extinct. Places of natural beauty will be degraded. Valuable chemistries of plant and animal life will be lost before we learn their genetic secrets. And the earth itself deserves our respect. For many people, something close to religious values are at stake.

This issue is doubly difficult to assess. It is difficult to know how to value what is at risk, and it is difficult to know just what is at risk. Even if climate changes at each point in time could be predicted accurately, the impacts on natural ecosystems could not yet be determined. And the benefits of slowing climate change by some particular amount would be even more uncertain. We know that carbon fuels are not going to be discontinued; the issue is the marginal gains, from carbon abatement and a slowing of climate change, in the survival of species and ecosystems and the preservation of enjoyable environments. This is an issue that simply has not been addressed.

The third argument for spending heavily to slow climate change is that the conclusions I reported earlier may be quite wrong. I said that the climate models predict that climates will change slowly and not much; the models do not produce discontinuities, surprises, *catastrophes*. What is known about weather and climate constitutes an equilibrium system.

The possibility has to be considered that if global temperature increases, not by the median estimate of three degrees Celsius for a doubling of carbon in the atmosphere, but by four or five degrees and continues to rise beyond the doubling because carbon fuels are still in use worldwide, some atmospheric or oceanic circulatory systems may switch to alternative equilibria, producing regional changes that are both sudden and extreme.

Have any such possibilities been thought of? One that was thought of but diminished upon further investigation was the possibility that the west Antarctic ice sheet might glaciate into the ocean and raise the sea level by 20 feet. As recently as 15 years ago, the best scientific judgment was that this could happen within 75 years as a result of global warming. This prospect naturally attracted attention, and further investigation with the help of newly available satellite sensing of glacial movement led to reassuring estimates that if that catastrophic rise in sea level were to happen it would take at least a few hundred years and be gradual, not sudden. But there isn't any scientific principle according to which all alarming possibilities prove to be benign upon further investigation.

A currently discussed likely source of discontinuous change is in the way oceans behave. Amsterdam is north of Newfoundland, yet is warmer, courtesy of the Gulf Stream. There is some indication that in earlier interglacial periods ocean currents may have pursued different courses. If a current like the Gulf Stream, or the Japanese Current for the United States, switched into an alternative pattern, the climatic consequences might be both sudden and severe. (Paradoxically, global warming might freeze Western Europe.)

Insurance against catastrophes is thus an argument for doing something expensive about greenhouse emissions. But to pay a couple percent of GNP as insurance premium, one would hope to know more about the risk to be averted. I believe research to improve climate predictions should be concentrated on the extreme possibilities, not on modest improvements to median projections.

I said that current estimates suggest that it might cost a couple percent of GNP to postpone the doubling of carbon in the atmosphere by several decades. Is 2 percent a big number or a small one?

That depends on your perspective and on what the comparison is. In recent years 100 billion dollars per year in budgets or taxes has been a politically unmanageable magnitude in the United States. On the other hand, subtracting 2 percent from GNP in perpetuity lowers the GNP curve by not much more than the thickness of a line drawn with a number-two pencil, or to formulate it as I did earlier, it postpones the GNP of 2050 until 2051. I say this not to belittle the loss of 10 trillion dollars from the American GNP over the next 60 years, but only to point out that the insurance premium, if we choose to pay it, will not send us to the poorhouse. The proper question is whether, if we were prepared to spend 2 percent of our GNP in the interest of protecting against damage due to climate change, we might find better use for the money.

I have mentioned one use: directly investing to improve the economies of the poorer countries. Another would be direct investment in preserving species, ecosystems, or wilderness areas. There is concern that many ecosystems could not migrate as rapidly as climate may change in the coming century; there has been little investigation of what might be done to facilitate the migration of ecosystems if the alternative is to invest 5 or 10 trillions of dollars in the reduction of carbon emissions.

VI

What can be done to reduce or offset carbon emissions? Reducing energy use and the carbon content of energy have received, I believe properly, most of the attention, especially the attention of economists. There are other possibilities to mention.

Trees store carbon. In growing, they take it out of the atmosphere. When they rot or burn it goes back into the atmosphere. A new forest will absorb carbon until it reaches maturity (i.e., maximum carbon density) in 75 or 100 years. If it then merely replenishes itself, with new growth replacing the oxidized dead trees, it holds its carbon but does not absorb more. If trees are harvested, the lumber that becomes house frames or furniture may last a hundred years or more; removing mature trees and storing them anaerobically is possible but expensive. The most recent report of the National Academy of Sciences considered that reforestation in the United States might sequester 2–3 percent of current global carbon dioxide emissions.[3] The prospects for that kind of reforestation in the rest of the world are not nearly so promising, and we should conclude that reforestation can contribute, but not greatly.

Stopping or slowing *deforestation* is important for reasons other than carbon emissions but is quantitatively more important than reforestation. Reforestation is unlikely to take up as much as 100 billion tons of carbon; deforestation, in areas where deforestation is likely, could contribute several hundred billion tons of carbon, partly because forest subsoils contain carbon typically greater than the amount in the trees themselves, and this carbon is subject to oxidation when the trees are removed.

Carbon can be "scrubbed" from stack gases, probably not with any known technology that would make such removal economically competitive with reducing emissions. (Part of the expense is disposing of sludge; where gaseous carbon might be pumped into the ocean or into underground cavities, economical disposal may prove feasible.) Parallel to reforestation is the idea of enhancing oceanic photosynthesis, by "fertilizing" the oceans, possibly with iron, if enough of the carbon residues from the enhanced growth will sink rather than remain near the surface. Experiments would probably be reversible and modest in scale; their political acceptability may be tested in the near future.

Finally—although nothing is final in a subject as new as the one we are talking about—there are numerous possibilities for putting substances or objects in orbit or in the stratosphere to reflect something like 1 percent of incoming sunlight to offset a large part of the radiation imbalance caused by greenhouse gases. Some of these are as apparently innocuous as stimulating cloud formation, and some are as dramatic as huge mylar balloons in low earth orbit. Until very recently these possibilities were nearly unmentionable, but they have recently been dignified by inclusion, along with caveats about "large unknowns concerning possible environmental side effects," in the 1991 report of the National Academy of Sciences. I shall not pursue them here, except for two observations. First, if in decades to come the greenhouse impact begins to confirm the more alarmist expectations, and if the economic sacrifices required to reduce

[3]Their estimate is 10 percent of U.S. emissions at "low to moderate cost" on economically or environmentally marginal crop and pasture lands and nonfederal forest lands in the United States (National Academy of Sciences, 1991 p. 57). A review of the issues in both afforestation and deforestation by Andrew Plantinga is in Joel Darmstadter (1991); an optimistic estimate of the afforestation option is that of Robert J. Moulton and Kenneth R. Richards (1990).

emissions prove unmanageable for economic or political reasons, some of these "geoengineering" options will invite attention. Second, if they do, and especially if they prove to be within the budgetary capabilities of individual nations, international greenhouse diplomacy will be transformed.

VII

What remains nearly certain is that the main responses to the greenhouse threat will be adapting to climate as climate changes and reducing carbon emissions. (CFC's are potent greenhouse gases and, if unchecked, might rival carbon dioxide in decades to come; but international actions are making good progress and are among the cheapest ways of reducing greenhouse emissions.)

Like estimates of warming, estimates of the costs of reducing emissions require some common but arbitrary objective to be comparable. A doubling of carbon became the conventional benchmark for warming estimates; no such benchmark for reduced carbon emissions has been adopted for estimating costs. (In principle, the estimates could adopt that doubling: the issue could be formulated as the cost of retarding the doubling time by a decade, two decades, or half a century.) Most estimates take as their target a reduction of emissions either to a specified fraction of what they would be in the absence of controls, or to some fixed ratio to the emissions of 1990 or the projected emissions of 2000 or 2010. The estimates examine minimum-cost trajectories, implicitly or explicitly assuming something like a uniform tax on the carbon content of fuel as the policy instrument. They typically make some assumption about a "fallback" energy technology, at least for electricity, available at some price in some decade of the next century. They have to project estimates of non-price-induced improvements in the use or avoidance of energy by industries and households. And if they deal with global emissions, they have to make some assumption about the distribution of abatement efforts among nations, especially among the developing countries, which, including China, account for about a quarter of emissions now and would be expected to account for half by the middle of the next century.

Any estimate of the cost of abatement needs therefore to specify at least half a dozen target assumptions. Furthermore, the estimates are produced by people and institutions that do not simultaneously estimate the costs associated with climate change, either damages or costs of adapting; the estimates do not optimize the combined costs of abatement and climate change. A "not unreasonable" target for reduction might be delaying a doubling by, say, four decades. One decade might be too trivial, a century too ambitious, and four decades an objective in which most audiences would be interested. But nobody who makes such an estimate wishes to be interpreted as proposing that when all the uncertainties about climate changes and their impacts have been resolved, if they ever are resolved, the optimum reduction in emissions will be found to retard doubling by 40 years, or any other specified period of time.

All I can do to summarize a multitude of estimates is to specify an order of magnitude that many economists and the Congressional Budget Office would not consider outrageous. That is the figure I mentioned earlier, possibly 2 percent of GNP for the developed countries and a similar, but even much more uncertain, percentage of GNP for the developing world. The uncertainty for the developing world is partly due to the estimates being mainly derived from the American economy.[4]

Two characteristics of these estimates need to be emphasized. One is that they tend to assume optimal technological adjustment, as in response to a carbon tax. To the extent that carbon emissions are controlled by direct regulatory measures, there may be the usual expected inefficiencies, and I leave the reader to make his own adjustment.

[4]Several critiques and surveys of different abatement-cost estimates are available (see Congressional Budget Office, 1990; Joel Darmstadter, 1991; William D. Nordhaus, 1991b; Energy Modeling Forum, 1992).

The second is that, since the early years of the energy crisis in the 1970's, there have been enthusiastic portrayals of currently available technologies, ranging from light bulbs to electric motors, double-glazed windows and improved internal-combustion engines, that for some reason have not been successfully marketed. The interest continues, and the recent National Academy of Sciences study gave sympathetic attention, but no analysis, to a number of proposals for residential, commercial, industrial, and transportation energy management and for improved electricity production and fuel supply and concluded that, including reductions in CFC's, "The United States could reduce or offset its greenhouse gas emissions by between 10 and 40 percent of 1990 levels at low cost or at some net saving, if the proper policies are implemented" (1991 p. 73).

All of these ideas are completely orthogonal to the econometric estimates. The Academy panel that produced the report was unable to offer an explanation for why these low-cost or negative-cost technologies have not caught on. Its quantitative assessment, including an allowance for elimination of CFC's, ranged from as little as 10 percent to as much as 40 percent of current U.S. emissions; CFC's aside, their range of possibility is from zero to about 30 percent. Whatever the correct figure, this is probably a once-and-for-all backlog of accumulated technologies, which once exploited may be permanent but not progressive. But the strong suggestion is that there is a lot to be accomplished in the next two or three decades.

VIII

With these qualifications, let us look at that 2 percent of GNP as a permanent reduction over the coming century. I consider it altogether improbable that the developing world, at least for the next several decades, will incur any significant sacrifice in the interest of reduced carbon (nor would I advise developing countries to do so). Anything done to reduce emissions in China, India, or Nigeria will be at the expense of the richer countries.

Financing energy conservation, energy efficiency, and switching from high-carbon to lower-carbon or noncarbon fuels in Asia and Africa would not only be a major economic enterprise but a complex effort in international diplomacy and politics. If successful, it would increase the costs to the developed world by at least another percent or two on top of the 2 percent I mentioned. It is furthermore not easy to hide the transfer of resources on the order of a couple of hundred billion dollars, dollars "budgeted" somehow or other, compared with hiding some of the costs due to regulation, such as automobile fuel-efficiency standards in the United States. The kind of thing we are talking about is inducing the Chinese, through our somehow offsetting their cost, to forgo a massive electrification based on coal and the cheapest coal-combustion technology. Without engaging in blackmail, the Chinese can assert that it is not in their interest to do that at their own expense, even if they are the keystone of a "social contract" and no other nation will do anything unless the Chinese fully participate.

I shall sketch what I can imagine as a major attack on the greenhouse problem. And I should be explicit about what I cannot imagine. For reasons that I would be delighted to elaborate but for which I cannot take space here, a universal uniform carbon tax is not a solution that I can imagine. My reason is simple. A carbon tax sufficient to make a big dent in the greenhouse problem would have to be roughly equivalent at least to a dollar per gallon on motor fuel, and for the United States alone such a tax on coal, petroleum, and natural gas would currently yield close to half a trillion dollars per year in revenue. No greenhouse taxing agency is going to collect a trillion dollars per year in revenue; and no treaty requiring the United States to levy internal carbon taxation at that level, keeping the proceeds, would be ratified by the Senate. Reduce the tax by an order of magnitude and it becomes imaginable, but then it becomes trivial as greenhouse policy.[5]

[5]A careful treatment of the universal carbon tax is provided by James M. Poterba (1991).

Tradable permits have been proposed as an alternative to the tax. There are two main possibilities: (i) estimating "reasonable" emissions country by country and establishing commensurate quotas or (ii) distributing tradable rights in accordance with some "equitable" criterion, such as equal emissions per capita (a possibility that has actually been discussed). Depending on how restrictive the aggregate of such tradable emission rights might be, the latter is tantamount to distributing trillions of dollars in discounted value and making, for a country like Nigeria, the outcome of its population census the country's major economic policy. If, instead, quotas are negotiated to correspond to every country's currently "reasonable" emissions level, they will surely be renegotiated every 5 or 10 years, and selling an emissions right will be perceived as evidence that a quota was initially too generous. It is unlikely that governments will engage in trades that acknowledge excessive initial quotas.

I do not foresee negotiated national quotas subject to serious enforcement, especially enforcement through financial penalties. I think any international regime for carbon abatement can seriously include only the developed countries, and I exclude from this category the countries that we used to call the Eastern Bloc. I can easily imagine institutional arrangements that are universalist, some kind of "framework agreement" to which every country subscribes, with specific commitments to be negotiated later. But I expect serious commitments to be undertaken only by the countries that can afford to, and I am undecided whether an institutional pretense of a universalist system has advantages or, instead, the developed world should proceed independently and unencumbered with the need for a universalist facade.

The model that I find most helpful in conceptualizing a greenhouse regime among the richer countries is the negotiations among the countries of Western Europe for distributing Marshall Plan dollars among themselves and the negotiations, beginning in 1951, on "burden sharing" in NATO. There was never a formula for distributing Marshall Plan dollars; there was never an explicit criterion, such as equalizing living standards, equalizing growth rates, maximizing aggregate output or growth, or establishing a floor under levels of living. Baseline dollar-balance-of-payments deficits were a point of departure, but the negotiations took into account investment needs, traditional consumption levels, war-induced capital needs, opportunities for import substitution and export promotion, and opportunities to substitute intra-European trade for trade with hard-currency countries.

The United States insisted that the recipients argue out and agree on shares. In the end, they did not quite make it, the United States having to make the final allocation. But all the submission of data and open argument led, if not to consensus, to a reasonable appreciation of each nation's needs. The negotiations were professional; they were assisted by a proficient secretariat. The resources involved for most recipient countries were immensely important. Good relations were observed throughout; and proficiency in debate, acceptance of criteria, and negotiating etiquette steadily improved.

That is the only model I find plausible, and I believe distribution of Marshall Plan and defense-support funds to Europe is the only model of multilateral negotiation involving resources commensurate with the cost of greenhouse abatement. (In the first year, Marshall Plan funds were about 1.5 percent of U.S. GNP and—adjusting for overvalued currencies—probably 5 percent of OEEC GNP).

What that model suggests is that the main participating countries in a greenhouse-abatement regime would submit for each other's scrutiny and cross-examination plans for reducing carbon emissions. The plans would be accompanied by estimates of emissions or emissions reduction from some projected level, but any commitments undertaken would be to the policies, not the emissions. And not all of the plans would necessarily be commitments.

The United States, for instance, could present a plan for the introduction of a new generation of nuclear power reactors beginning sometime in the next century, but it is difficult to see how the federal government can commit itself to what reactors public utilities will be purchasing 20 years from now. The United States can have a plan to mandate fuel-efficiency standards for automobiles, but it takes 10 years for the standards to work their way into the automobile fleet, and there is no accounting procedure that will estimate the effect on motor-fuel consumption of any level of average fuel efficiency a decade from now.

The current popular expectation is that participation in any greenhouse regime will take the form of commitments to specified percentage reductions of emissions below those of some specified year, like 1990 or 2000. I cannot help believing that adoption of such a commitment is an indication of insincerity. A serious proposal would specify policies, like taxes, regulations, and subsidies and would specify programs (like research and development), accompanied by very uncertain estimates of their likely effect on emissions. In an international public forum, governments could be held somewhat accountable for the policies they had or had not put into effect, but probably not for the emissions levels achieved.

Such a modest beginning will require finding a way to sublimate the current international enthusiasm for a new universalist greenhouse regime into institutional arrangements that are helpful but noncommittal when the U.N. Conference on Environment and Development convenes next June. This will require an understanding among the developed countries that it is initially up to them to find a way to mobilize their populations in support of national greenhouse policies.

IX

A major commitment to financing emissions abatement in the developing world is surely too far away to need specific plans now. A developing-world carbon-abatement effort would, in principle, be altogether different from foreign aid as we have known it since World War II. In principle it would all be directed, from whatever sources and through whatever channels, to protecting that same global common. There would be, for the first time, a single criterion: economizing carbon. In the abstract, aid recipients in the war on greenhouse gases would not compete; they would not make India–Pakistan comparisons, or Arab–Israel, or Poland–Czechoslovakia. All would in principle benefit equally from maximum carbon conservation, wherever it could be achieved. Trees may grow more rapidly, in carbon content, in Madras or Szechuan or Borneo or Alaska or South Carolina, but if someone were willing to finance the growth of a tree to absorb carbon dioxide, the citizens of those states should not have the slightest care where the tree were to be planted; they all benefit solely from the carbon fixed in the tree and benefit more, the faster the tree grows, no matter where it grows.

It wouldn't work that way, of course. Somebody gets the shade, or leases land for the tree; and if it's not a tree but a nuclear power plant to supplant coal, there are local impacts that make huge differences, and negotiations over sharing the cost differential between the coal and the nuclear plants. But it is worth noticing that if there were a "pure" carbon-abatement or carbon-absorbing technology, one that accomplished nothing else, there should be no dispute about locating it wherever it would be most effective. That is new in foreign aid and foreign investment.

If the developed countries ever manage to act together toward the developing countries, their bargaining position is probably enhanced by the fact that cleaner fuels and more efficient fuel technologies bring a number of benefits other than reduced carbon, and recipients of greenhouse aid will be actively interested parties, not merely neutral agents attending to the global atmosphere. At the same time, large nations like India and China will be aware of the extortionate power that resides in ambitious coal-development projects.

On a greatly reduced scale, there may be something constructive to do more immediately. There is a huge difference between transferring "technology" and transferring capital goods that embody technology or, going further, financing entire investments (local construction, etc.) in which the technology is embedded. The difference in cost is at least an order of magnitude. While the developed countries are feeling their way into some common attack on their own carbon emissions, a tangible expression of their interest and an effective first step would be to establish a permanent means of funding technical aid and technology transfer for developing countries, as well as research, development, and demonstration in carbon-saving technologies suitable to those countries. Eventually the rural Chinese household may cook more efficiently with nuclear-powered electricity, but for another generation or two what is important is less carbon-wasteful ways of cooking and heating.

Maybe there is a role here for the carbon tax. Western Europe, North America, and Japan will be burning 3 or 4 billion tons of carbon per year for the next decade. Taxing themselves, that is, contributing in proportion to the carbon they consume, at one, two, or three dollars per ton, they could contribute to a fund that might begin at $3 billion per year and grow to $10 billion. The carbon tax is a little arbitrary here, and a U.S. administration ~~may~~ be wary about a precedent that carries over when the tax rises an order of magnitude, but compared with alternative criteria for sharing costs it might not even be a bad precedent.

REFERENCES

Ausubel, Jesse H., "Does Climate Still Matter?" *Nature*, 25 April 1991, *350*, 649–52.

Cline, William R., *The Greenhouse Effect: Global Economic Consequences*, Washington, DC: Institute for International Economics, 1992 (forthcoming).

Darmstadter, Joel, "The Economic Cost of CO_2 Mitigation: A Review of Estimates for Selected World Regions," Discussion Paper ENR91-06, Resources for the Future, Washington, DC, 1991.

Moulton, Robert J. and Richards, Kenneth R., "Costs of Sequestering Carbon Through Tree Planting and Forest Management in the United States," General Technical Report WO-58, Forest Service, U.S. Department of Agriculture, Washington, DC, December 1990.

Nordhaus, William D., (1991a) "Economic Approaches to Greenhouse Warming," in Rudiger Dornbusch and James M. Poterba, eds., *Global Warming: Economic Policy Responses*, Cambridge, MA: MIT Press, 1991, pp. 33–66.

______, (1991b) "The Cost of Slowing Climate Change: A Survey," *Energy Journal*, 1991, *12* (1), 37–66.

Poterba, James M., "Tax Policy to Combat Global Warming: On Designing a Carbon Tax," in Rudiger Dornbusch and James M. Poterba, eds., *Global Warming: Economic Policy Responses*, Cambridge, MA: MIT Press, 1991, pp. 71–97.

Congressional Budget Office, *Carbon Charges as a Response to Global Warming: The Effects of Taxing Fossil Fuels*, Washington, DC: U.S. Government Printing Office, 1990.

Energy Modeling Forum, "Global Climate Change: Energy Sector Impacts of Greenhouse Gas Emission Control Strategies," Energy Modeling Forum Report No. 12, Stanford University, 1992 (forthcoming).

Intergovernmental Panel on Climate Change, *Climate Change: The IPCC Scientific Assessment*, J. T. Houghton, G. J. Jenkins, and J. J. Ephraums, eds., Cambridge: Cambridge University Press, 1990.

National Academy of Sciences, *Carbon Dioxide and Climate: A Scientific Assessment*, Washington, DC: National Academy of Sciences, 1979.

______, *Carbon Dioxide and Climate: A Second Assessment*, Washington, DC: National Academy Press, 1982.

______, *Policy Implications of Greenhouse Warming*, Washington, DC: National Academy Press, 1991.

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Divider Title: **4**

A Brief History of the Administration Position on Global Climate Change

1. **Global Climate Change**. Growing concentrations of greenhouse gases are believed to result in global climate change. The possible risks include loss of coastal areas from rising sea levels; changes in rainfall and agricultural productivity; and an increased incidence of diseases such as malaria, yellow fever, and cholera. Carbon dioxide (CO_2) accounts for approximately 86% of the total global warming potential of all U.S. anthropogenic emissions not covered by the Montreal Protocol to protect stratospheric ozone. Combustion of fossil fuels, primarily coal and oil, is the main source (85% of all emissions).

2. **Climate Change Action Plan.** In June 1992, the United States signed the Framework Convention on Climate Change whose primary objective is to stabilize "greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate." In October 1993, President Clinton announced the Administration's Climate Change Action Plan (CCAP) with a goal of stabilizing U.S. anthropogenic emissions of greenhouse gases at 1990 levels by 2000 . The plan blends market incentives, voluntary initiatives, research and development, improved regulatory frameworks. Voluntary programs include the Green Lights program to improve lighting efficiency and Climate Challenge program to inventory emissions by utilities. The US is not on target to achieve this CCAP goal; emissions are predicted to be about 200 million metric tons (mmt) over 1990 levels by 2000.

3. **Wirth's Statement**. In July 1996, Under Secretary of State Tim Wirth expressed concern that the Convention goals were not being met and announced that the "United States recommends that future negotiations focus on an agreement that sets a realistic, verifiable and binding medium-term emissions target." Wirth also called for the use of "market -based solutions that are flexible and cost-effective." The Administration also stated at this time that the call for binding targets does not imply that it is abandoning voluntary programs under the CCAP.

4. **The Kyoto Treaty**. Negotiations to amend the Rio Treaty or to sign a protocol are scheduled for completion by December 1997. The U.S. issued a position paper for the latest preparatory meeting (December, 1996) which expands on the Wirth's July 1996 statement. The major points were:

   (1) The need to examine an international greenhouse gas emissions trading system among annex I (OECD plus former Soviet block) countries.
   (2) Joint implementation (projects that reduce emissions below baseline in host country which are credited to the target of the partner country) between annex I and the rest of the world.
   (3) The need for a concerted global effort that eventually would mean targets for all countries.
   (4) Support for multi-year, rather than single year, targets.
   (5) Urge consideration of a right to bank and borrow permits.

5. Interagency Analysis Team (IAT). Since last fall the Interagency Analysis Team (IAT), chaired by Ev Ehrlich, Undersecretary of Commerce, has been modeling the economic impacts of alternative options for the Kyoto treaty. Three models were used to compare two basic cases:

- The base case -- i.e., with no new policies.
- The climate treaty case, in which the U.S. caps total greenhouse emissions, and then allows domestic firms to trade rights to emit carbon ("cap and trade"), with several variations.

Variations examined to date include:

--cap U.S. emissions at 1990 levels by 2010; hold emissions constant after that;
--cap U.S. emissions at 1990 levels by 2010, plus or minus 10 percent;
--cap U.S. emissions at 1990 levels by 2020;
--auction permits, or give them to existing emitters ("grandfathering");
--use auction proceeds to reduce the deficit or to reduce business and personal taxes;
--allow no trading, trading only within Annex 1, or worldwide trading.

The modelers have produced comparisons of several variables: levels of GDP, of real consumption, fuel consumption and price by fuel type, and price of carbon permits. The variable most likely to be displayed is the price of carbon permits (the implicit tax on carbon), together with changes in price of different fuels.

For example, to stabilize emissions at 1990 levels in 2010, one of the models (SGM) calculated the following permit prices ($1995) per ton of carbon for the year 2010:

	---rate of energy efficiency improvement---	
case	base case	very fast
U.S. stabilizes without trading	110	57
with Annex 1 trading only	96	55
with worldwide trading	n/a	19

The same model calculates that permit prices in Western Europe would be about three times as high for each variation.

Speed of technical change. CEA and Treasury have been concerned for some time that the IAT is assuming very fast technical change in its modeling of climate control costs. We believe the chosen range is much higher than the historical evidence can support. In the base case, the energy/GDP ratio improves at one percent annually, which we believe is on the high side of historical experience; econometric estimates of the rate of energy efficiency improvement, apart from price effects, range from 0.5 to 1.0 percent annually. In the policy cases, the energy/GDP ratio improves at 1.25 to 1.75 percent annually.

Announcement effect. The IAT asserts that the rate of energy efficiency improvement will jump from 1 percent to 1.25 percent annually solely because of the "announcement effect"--i.e., merely from the government's announcement of a policy. The idea is that once the U.S. signs a treaty limiting carbon emissions, more money will flow into R&D on energy efficiency. This assumption means that we will reach one-third of our reduction goal for free. Most economists, however, would say that people will not respond to an announcement unless they believe it would be costly not to. People may very well invest more in innovation, but at some cost. Treasury and CEA staff have sent a memo to Ev Ehrlich asking that the models also be run using rates of technical change consistent with historical evidence.

Emission banking and borrowing. An efficient trading program requires *when* and *where* flexibility. This means *emission banking*, allowing firms save or borrow emission credits. A minimum-cost control path would allow higher emissions in the near term in exchange for lower emissions later. In contrast, an early-action control path is expensive for three reasons: it requires the premature retirement of the capital stock, it fails to take advantage of technological changes, and it crowds out other productive investment. Unfortunately, intertemporal trading has not been discussed recently, and no longer seems to be on the agenda. Jeff Frankel has pressed the idea of emissions *windows* rather than single-year targets. If the window is wide enough, this is equivalent to emissions banking.

6. **Statement by Arrow, Solow, Nordhaus, et al.** During the IAT modeling effort, on February 13, the press carried a story that 2000 economists, including six Nobel laureates, signed a statement supporting measures to reduce the threat of climate change. The statement endorses conclusions from last year's report by the Intergovernmental Panel on Climate Change (IPCC), that governments should take steps to reduce the threat of damage from global warming, that proper policies can significantly reduce greenhouse gas emissions without harming the American economy, and that market-based policies can significantly lower the costs of control. Some within the Administration have claimed that this statement endorses the Administration's position. In fact, the statement is far more ~~general~~ than the Administration's position.

ECONOMISTS' STATEMENT ON CLIMATE CHANGE

"We the undersigned agree that:

I. The review conducted by a distinguished international panel of scientists under the auspices of the Intergovernmental Panel on Climate Change has determined that "the balance of evidence suggests a discernible human influence on global climate." As economists, we believe that global climate change carries with it significant environmental, economic, social, and geopolitical risks, and that preventive steps are justified.

II. Economics studies have found that there are many potential policies to reduce greenhouse-gas emissions for which the total benefits outweigh the total costs. For the United States in particular, sound economic analysis shows that there are policy options that would slow climate change without harming American living standards, and these measures may in fact improve

U.S. productivity in the longer run.

III. The most efficient approach to slowing climate change is through market-based policies. In order for the world to achieve its climatic objectives at minimum cost, a cooperative approach among nations is required --- such as an international emissions trading agreement. The United States and other nations can most efficiently implement their climate policies through market mechanisms, such as carbon taxes or the auction of emissions permits. The revenues generated from such policies can effectively be used to reduce the deficit or to lower existing taxes."

Divider Title: **5**

Economic Impacts

NO TREATY. Briefly, the short-term US economic impacts of **NO treaty** will not be that large--only 3% of US livelihoods are earned in agriculture and other climate-sensitive outdoor activities. Nordhaus estimated that there would be a 1% drop in US GNP for a 3°C warming. Agriculture and forestry have been estimated to benefit from climate change. The impact on developing countries would be larger given that their economies are much more dependent on agriculture.

TREATY. The short-term economic impacts of a **treaty** could be significant (0.5 - 1.5% annual drop in GDP) if the US gets locked into a tight emissions budget without flexibility (i.e., no emission trading, no joint implementation). [This estimate is based on the more objective results from the Energy Modeling Forum (EMF) in Stanford. The percentage result is robust across different modeling runs. The IAT results are within the lower range]. In the medium term, the worst-case scenarios predict a 2.6% drop in GDP by the year 2020. CEA prepared a review of published literature indicating the estimated range of impacts. The median price of carbon in these studies was $82 per ton. The median impact on GDP by 2020 was -0.6% of GDP.

Schmalensee's back of the envelope-- take the EMF results and make two adjustments--add in the costs of short term transition costs and the costs associated with the fact that we are not likely to have very efficient regulatory regime. The likely costs could double.

Overestimation of costs. Some proponents of a tight emissions budget will claim that economists always overestimate the costs of compliance (e.g., the SO2 market where current permit prices ($120) are considerably less than predicted prices ($750-500)). It is often true--estimates of economic costs of tighter environmental protection are often too high relative to actual costs. Usually this is due to a combination of factors including changing market fundamentals (e.g., lower energy prices), changes in the actual design of the program. While control costs may not be as high as predicated, these people ignore the fact that environmental regulation has still been a significant drag on the US economy (about 0.2% annual decline).

Innovation and technological solutions. Some will argue that the costs of carbon policy will not be significant because tighter environmental regulations will induce innovative technological silver bullets that will reduce overall costs. But these innovative offsets do not cover the costs of the extra compliance. While case studies can be found to support the innovation offset argument, the real question is whether there is a ubiquitous free lunch across the smorgasbord of US firms? The evidence suggests the answer is "no." US firms and the federal government currently spend at least $100 billion on pollution abatement and control. The magnitude of the cost offsets, as measured by the Commerce Department's Bureau of Economic Analysis, is about $2 billion, less than 2 percent of estimated environmental expenditures. Even if the cost offsets are doubled, tripled, or quadrupled to account for unreported benefits, *net annual spending* on environmental protection is still about $100 billion (in 1992).

Another counter to the claim is that technological solutions are also exaggerated. Recall the days of nuclear power when the slogan was that with nuclear power electricity would be "too cheap to meter."

What actions will decrease the costs of any given emission budget.

- **Flexibility** through carbon trading systems and joint implementation.
  CEA has fought hard for flexibility so that the most cost-savings can be attained.

- **Faster** technological change.

- **Increased** capital investment.

EPA's strategy. In the Domestic meetings, the EPA argues that the costs of a carbon policy will be low given the existence of flexible programs such as emission trading and JI. In the International meetings, EPA then argues for overly strict standards for trading and JI; these high transaction costs will prevent the substantial potential costs reductions to go unrealized because few nations will want to participate. In effect, they say "look the costs will be low if flexibility exists", but their actions are to restrict flexibility. The EPA is saying let's have a policy but let's keep the carbon reductions at home--make the US economy pay its own way.

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Divider Title: **6**

Removed IAT Rept

5/14 draft

A Technical Point on Technological Change
30 May 97

- There is a key technical assumption embedded in the IAT modeling efforts---the assumed *autonomous* rate of technological change. Firms are assumed to adopt more energy-efficient, less carbon-intensive production activities (e.g., use less coal and more natural gas); consumers are assumed to adopt more energy-efficient, less-carbon intensive consumption patterns (e.g., electric cars that get 55 mpg). This autonomous rate is often measured by the energy-to-GDP ratio (E/GDP); it is also measured by the carbon-to-GDP ration (C/GDP).

- The *autonomous* rate of technological change is assumed to be **independent** of the relative prices in the model. This is the so called "announcement effect," where people change their preferences in light of the global climate change treaty. I have dubbed this behavior the "theory of non-price policy response." People see the light once they have been awakened by the Kyoto treaty. And they then lower their marginal rates of time preference or lower their risk aversion, thus causing them to use more energy-efficient technologies that they would have otherwise ignored because they were too costly.

"announcement effect": we shouldn't acquiesce.

- The **faster** the rate of this autonomous technological change the **softer the blow** to the economy when the regulator introduces a carbon tax. The autonomous progress pushes the economy into more energy-efficient, less carbon intensive activities for free. Therefore, the higher the rate the lower the price shock from a carbon policy. The price shock is lower because the economy has already been moving toward the goal of less carbon on its own. The more people adjust independent of price, the smaller the blow when the carbon policy pushes the economy the rest of the way to the goal by changing relative prices. If we assume people are already on board, they do not need as big of a push. This is a critical assumption because it can be manipulated to reduce the estimated GDP losses from alternative emission budgets.

- The historical rate of **autonomous** technological change is between -0.1 and -0.5% drop in E/GDP per year. Note that the historical **total rate** of change (price-induced and non-price induced) ranges between +0.2 to -2.9% drop in E/GDP per year. Most of this rate is price-driven around the time of the two oil crises in the 1970s. Some researchers have explained all the variation in the E/GDP ratio by price and input substitution, implying that the autonomous rate is near zero.

- The IAT modelers have assumed two autonomous rates of change: -1.25% and -1.75% drop in E/GDP once the Kyoto treaty is announced. **CEA and Treasury** have argue from the beginning that these autonomous rates are too large; and do not match up with historical rates. We have dubbed this the "great leap forward." In effect what these rates do is push a larger fraction of the economy into more energy-efficiency for free than we should expect given historical evidence. Therefore, when we introduce the carbon policy, the shock to the system is softened.

- For example, consider the Markal-Macro model. The table below shows that the "starting point" assumption of 1.25 E/GDP yields an implied carbon tax of $145 in 2010 (which translates into a 39 cent gas tax). If a very faster autonomous rate is assumed (1.75), the carbon tax falls to $77 in 2010 (21 cent gas tax). Now if we go the other way and assume an autonomous rate (0.75) closer to historical non-price rates (0.1 to 0.5), carbon tax increases to $162 (45 cent gas tax). **This is a significant range.**

Markal-Macro Model (stabilize at 1990 levels in 2010 without international emission trading)

Autonomous technological change (E/GDP)	**Carbon price in 2010 (per ton)**	**Equivalent gas tax (2010)**	**Carbon price in 2020 (per ton)**	**Equivalent gas tax (2020)**
High (0.75)	$162	$0.45	$192	$0.52
Higher (1.25)	$145	$0.39	$130	$0.35
Very high (1.75)	$77	$0.21	$35	$0.09

- The other two models, DRI and SGM, have even lower carbon prices because they have also presumed that the economy is shifting toward more energy-efficiency independent of price. In fact, the DRI model reduces its energy use by about 10% in 2010 independent of price. Therefore, it should be no surprise that when the carbon policy shifts relative prices, the shock to the economy is smaller than would otherwise be expected. EPA has started to rationalize this autonomous rate as a "change due to expected price increases." If that is the case, the models are double counting the price effect--once with the expected-price-autonomous change and once with the actual price effect. They cannot have it both ways.

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Divider Title: **7**

Divider Title: **8**

Glossary

Activities Implemented Jointly A pilot program to test the feasibility of joint implementation projects.

Annex C Gases A list of greenhouse gases, their global warming potential (GWP), and sources and sinks of those gases. (e.g. carbon dioxide, methane, nitrous oxide) This list will exclude those gases for which there is insufficient information on GWPs or monitoring and measurement methods do not exist.

Annex I Countries Nations listed in Annex I of the FCCC; includes countries who were members of the OECD in 1992, 11 countries in transition to a market economy, and the European Economic Community.

Australia	Austria	Belarus
Belgium	Bulgaria	Canada
Czechoslovakia	Denmark	European Economic Community
Estonia	Finland	France
Germany	Greece	Hungary
Iceland	Ireland	Italy
Japan	Latvia	Lithuania
Luxembourg	Netherlands	New Zealand
Norway	Poland	Portugal
Romania	Russian Federation	Spain
Sweden	Switzerland	Turkey
Ukraine		
United Kingdom of Great Britain and Northern Ireland		
United States of America		

Autonomous Energy Efficiency Index (AEEI) Rate of technology progress independent of energy prices.

Budgets National budgets would determine total allowable emissions over a fixed multi-year period. Each nation would have an initial allocation which could be added to or subtracted from through emissions trading, joint implementation projects, or banking between budget periods.

Banking and Borrowing If a nation does not use all of its emissions permits in a budget period, they may be applied to the next budget period (saved). Alternatively, if a nation exceeds its budgeted amount, it must borrow emissions credits from its next budget allocation.

Carbon Emission Trading A program (international or domestic) to allow the trading of emissions credits between entities -- the tradeable unit would be a "tonne of carbon equivalent emissions allowed."

Climate Change Action Plan (CCAP) The US plan (announced Oct. 1993) to respond to climate change, coordinated through the EPA, DOE, etc.. Goal is to stabilize U.S. anthropogenic emissions at 1990 levels by 2000.

Early Credit When actions taken prior to the first budget period receive credit against obligations in that period.

Energy/GDP Ratio Energy intensity, the ratio of total domestic primary energy consumption or final energy consumption to GDP.

Evolution Process by which non-Annex I (developing) nations are brought into the formal binding portion of the regime.

Framework Convention on Climate Change UN convention to coordinate an international response to global climate change. Signed in Rio during the "Earth Summit," the convention entered into force in March 1994, and has been ratified by nearly 160 countries.

Global Warming Potential (GWP) The potential of a given greenhouse gas to cause global warming relative to a ton of carbon dioxide over a 100 year period.

Imputed Value of Carbon The implicit carbon tax.

Intergovernmental Panel on Climate Change (IPCC) An assessment group of international experts brought together by the World Meteorological Organization (WMO) and the United Nations Environment Program (UNEP) to assess scientific information on climate change and the environmental and socio-economic impacts of climate change.

Joint Implementation (JI) A system for granting emissions credits to a country for implementing emissions reductions projects in other countries. This differs from emissions trading in that credits are generated through specific projects and can be carried out between parties with budgets and those without budgets. Activities Implemented Jointly (AIJ) is a current pilot test of such a system.

Paper Tons In a cap and trade system, nations whose annual emissions have gone down since the base year would have immediate surplus emissions credits. These credits are called paper tons.

When & Where Flexibility Refers to the choices nations will have to reduce emissions geographically (where) and temporally (when).

Revenue Recycling Using revenues generated through carbon taxes or permit programs to reduce the federal deficit, or business or personal taxes.

Sinks Processes, such as forest growth, that absorb greenhouse gases.

Acronyms

AIJ	Activities Implemented Jointly
AEEI	Autonomous Energy Efficiency Index
CCAP	Climate Change Action Plan
FCCC	Framework Convention on Climate Change
GHG	Greenhouse gases
GWP	Global Warming Potential
IPCC	Inter-Governmental Panel on Climate Change
IAT	Interagency Analysis Team
MMTCE	Million Metric Tonnes of Carbon Equivalent
PPM	Parts Per Million
TCE	Tonne of Carbon Equivalent
UCE	Units of Carbon Equivalent