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[Climate Change] [Binder 2] [1]

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TESTIMONY OF DR. JANET YELLEN
CHAIR, COUNCIL OF ECONOMIC ADVISERS
BEFORE THE HOUSE COMMERCE COMMITTEE
ON THE ECONOMICS OF THE KYOTO PROTOCOL
MARCH 4, 1998

Thank you, Mr. Chairman. The President has said that we can work to avert the grave dangers of climate change, while at the same time maintaining the strength of our economy. I agree and am pleased to have this opportunity to appear before the Committee to elaborate on the Administration's views on these issues.

The international agreement that was reached in Kyoto this past December is a crucial step forward in addressing global climate change. But it is only one step in a journey. Since the international effort to reduce greenhouse gas emissions is still in some respects a work-in-progress, it is not yet possible to provide a full authoritative analysis of it. Many of the specifics in several crucial areas are not completely resolved in the diplomatic arena, forcing analysts to make a variety of assumptions about the ultimate form of the international regime. In my testimony today, I will attempt to identify key elements of the agreement and the Administration's policy, such as international emissions trading, meaningful developing country participation, inclusion of land-use activities that absorb carbon ("sinks") and six categories of gases, as well as domestic initiatives, that together can ensure that reductions in global greenhouse gas emissions are consistent with continued strong economic growth. I will explain the reasoning underlying our conclusion that, under these conditions, economic impacts are likely to be modest relative to the potential benefits.

The Administration is strongly committed to ensuring that these key elements are reflected in our domestic and international climate change policies. We are firmly committed to meaningful developing country participation, the ability of sinks to offset emissions requirements and emissions trading both domestically and internationally. And as you know, the President's (1) FY 1999 budget includes a $6.3 billion package of tax cuts and R&D investments over the next 5 years; this package makes good sense in terms of energy policy and will jumpstart our efforts. A final component of the President's climate change policy is his support for electricity (1.5) restructuring in a manner that will offer approximately $20 billion in cost savings to electricity consumers, while offering modest reductions in greenhouse gas emissions. CCTI

I. Basic Economic Rationale of the Kyoto Treaty

To begin our analysis, it may be worth stepping back and examining the larger question of the basic rationale, from an economist's perspective, for the Kyoto Protocol.

The earth's surface appears to be warming from the accumulation of greenhouse gases from myriad sources worldwide. None of these emitters presently pays the cost to others of (1.75) warming's adverse effects -- a classic externality in the language of economists. As a result of these distorted incentives, disruption of the Earth's climate is likely to proceed at an excessive pace and if left uncontrolled may pose substantial costs in terms of harm to commerce and the ERP

BUDGET

BUDGET OF THE UNITED STATES GOVERNMENT

Fiscal Year 1999

4. PROTECTING THE ENVIRONMENT

> *There is a new understanding today in the world between the bonds that connect human beings and their natural environment. We know we have to preserve them, and we know that in the end economic development itself cannot occur unless the environment is preserved.*
>
> President Clinton
> May 1997

With the historic December 1997 international agreement in Kyoto calling for cuts in greenhouse gas emissions, the Administration capped a remarkable year of environmental successes. History has shown that the Nation does not have to choose between a strong economy and a clean environment. The President's policies have contributed to five years of both strong economic growth and a cleaner, healthier environment.

Along with the Kyoto Protocol, the Administration has issued new, more protective air quality standards to better safeguard public health and the environment, and has strengthened our citizens' right to know about toxic chemical releases. It has continued its efforts to protect our natural treasures, such as Yellowstone National Park, the Everglades, Grand Staircase National Monument, and the Headwaters redwoods, from environmental threats. It has secured $699 million in the Land and Water Conservation Fund for acquiring Headwaters Forest, the New World Mine near Yellowstone, and other high-priority land acquisitions to protect key natural, cultural, and historic resources. It has cleaned up more toxic waste sites in its first four years than the previous two administrations did in 12, and it is continuing to advance toward the President's goal of 900 site cleanups by the end of year 2001.

While Americans want a Government that helps protect the environment and our natural resources, they do not want to burden business unduly, choke innovation, or waste taxpayer dollars. If sensibly designed and flexibly implemented, environmental initiatives can cost less while providing unforeseen economic opportunities. Americans have met environmental challenges because we innovate, we compete, and we find solutions to problems in ways that promote entrepreneurship and strengthen the economy.

To implement his vision for the environment and our natural resources, the President is proposing an Environmental Resources Fund for America to support increases for many of the Nation's key environmental programs. The Fund provides for enhanced construction, maintenance, and land acquisition for national parks, forests, refuges and other public lands; a new multi-agency initiative to improve our Nation's water quality; infrastructure funding for community drinking water and wastewater facilities; and resources to clean up abandoned hazardous waste sites. The budget also includes a new, ~~five-year~~ $6.3 billion program to implement the President's commitment to prevent global warming, as well as increased resources to protect endangered species, carry out pollution control programs, and preserve the global environment. 1 plus see next page

Approaches for Environmental Success

Preventing Global Warming: In December, the United States reached an historic agreement with other nations to meet the challenge of global warming. The Kyoto Protocol establishes realistic, achievable, and binding commitments to reduce greenhouse gas emissions and reflects the Administration's commitment to use market mechanisms to tackle the problem in innovative and flexible ways.

Improving Air Quality: In July 1997, the Administration took the most far-reaching

Environmental and Natural Resource Investments

The budget proposes to boost funding for high-priority environmental and natural resources programs by five percent, compared to 1998 levels (see Table 4–1).

Reducing Greenhouse Gases and Promoting Energy Efficiency: Last fall, the President announced a nine-point plan to begin addressing climate change, including a five-year package of tax incentives and research and development spending to spur energy efficiency and help develop low-carbon energy sources. With the historic agreement in December 1997 to reduce greenhouse gas emissions, the President now proposes a $6.3 billion package of tax incentives and research spending. The budget provides $1.7 billion in 1999 for the Climate Change Technology Initiative, nearly doubling the 1998 level, as a down-payment on the President's five-year commitment. (For a more detailed discussion of the Administration's climate change efforts, see Chapter 6, "Promoting Research.") (1)

Creating the Environmental Resources Fund for America: The budget proposes the Environmental Resources Fund for America, an innovative financing mechanism for environmental initiatives. It provides $7.7 billion, 14 percent more than in 1998, for many key environmental restoration programs and is financed, in part, by the proposed renewal of taxes that support the Superfund program. The Fund includes:

- *Land, Water, and Facility Restoration Initiative:* National parks, refuges, forests, and public lands are the heart of the Nation's natural, cultural, and historical legacy. As custodians of these resources, Federal land management agencies face growing demands to invest more to restore lands and rehabilitate an aging infrastructure of public facilities and trails. These needed investments would protect wildlife habitat, maintain historic sites, and preserve the many national treasures, from the Acadia National Park in Maine to Independence Hall to the California Desert, that constitute our legacy for future generations. The budget proposes a $92 million, or eight percent, increase for construction and maintenance for national parks, forests, refuges, public lands, and Indian schools, with which the agencies will focus on top priorities and control costs through better management. It also includes a broad initiative to invest more in land acquisition and historic preservation—a 43-percent increase in spending over the next five years from the Land and Water Conservation Fund and a 12-percent increase from the Historic Preservation Fund.

- *Clean Water and Watershed Restoration Initiative:* Commemorating the 25th anniversary of the Clean Water Act, the Vice President last October announced a Clean Water Initiative—an action plan to focus on three remaining challenges to restore and protect the Nation's waterways: (1) preventing polluted runoff; (2) protecting public health; and (3) ensuring community-based watershed management. USDA and EPA are leading an inter-agency task force to develop the plan by February 14, 1998, relying on better coordination and targeting of Federal activities and resources, public participation, and innovative approaches to pollution control.

  The budget includes $568 million, a 35-percent increase over the 1998 level, for this multi-agency initiative, including more mandatory funding for USDA's Environmental Quality Incentives Program to help farmers prevent polluted runoff; for the Forest Service and the Interior Department to better address water quality problems on Federal lands; for EPA to provide grants to States to implement water quality improvement projects; for the National Oceanic and Atmospheric Administration (NOAA) to help States and local communities protect their coasts from the pollution that leads to degradation; for Interior's U.S. Geological Survey and USDA to increase water quality monitoring and research, with a focus on nutrient pollution; and for the Army Corps of Engineers to begin a new riverine ecosystem initiative—"Challenge 21"—to plan and implement projects that restore watersheds while providing flood hazard mitigation for communities.

Economic Report of the President

Transmitted to the Congress
February 1998

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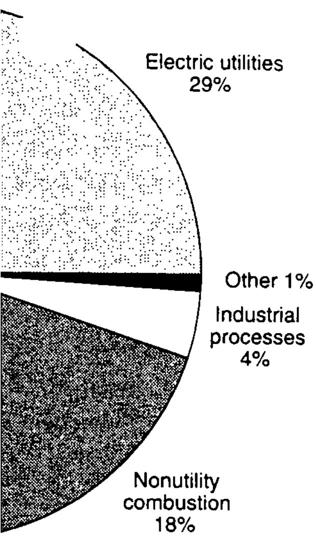

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sions trading could undercut the effectiveness of pollution controls if it resulted in shifting emission reductions farther upwind. Trading ratios that weight the reductions made at different sources according to their distance from the downwind nonattainment area might be considered to address this problem. In reality, however, there are a large number of nonattainment areas spread out over the region, and several different weather patterns and wind conditions characterize the ozone pollution episodes that the program is trying to remedy. Sources affect multiple nonattainment areas in a variety of directions from them, and it affects any single nonattainment area differently under different weather conditions. The polycentric nature of this problem complicates the identification of a unique and stable set of trading ratios that would work for all relevant cases. Thus, striking the proper balance between achieving the cost savings from larger geographic scope and limiting the potentially significant adverse environmental effects of trading is an ongoing challenge.

Like most air pollution control programs, NO_X trading programs would require an estimate of emissions from each regulated source in order to ensure compliance. The estimation method can have significant implications for cost-effectiveness, both directly, through the cost of performing the estimate, and indirectly. One indirect implication is that more costly requirements may limit the number of sources that could meet the estimation requirements and participate in trading, and thereby raise costs. On the other hand, a more reliable estimation method may offer regulators and sources greater confidence in the permits, and thereby increase the willingness of sources to buy them or offer them for sale. For example, the SO_2 program requires continuous emissions monitoring to provide precise information on emissions. Such monitoring is expensive and impractical for many smaller sources and thus may effectively exclude such sources from participating. But such precise monitoring may not always be necessary. Methods for estimating emissions that provide unbiased, although less precise, estimates of emissions may be accurate enough to ensure accountability.

CLIMATE CHANGE

1.75

Climate change is a global environmental externality: warming of the earth's surface results from the accumulation of greenhouse gases from myriad sources worldwide, none of which presently pay the cost to others of warming's ill effects. The Intergovernmental Panel on Climate Change, jointly established by the World Meteorological Organization and the United Nations Environment Programme, concluded in 1995 that "the balance of evidence suggests that there is a discernible human influence on global climate." Current concentrations of carbon dioxide (SO_2), methane, nitrous oxide (N_2O), and other so-called greenhouse gases have reached levels well above those of

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environment alike. The fundamental economic logic of the Kyoto Protocol is thus that without such an international agreement, individual nations will not have the proper incentives to address the threats from global climate change.

II. Costs of Climate Change

In evaluating efforts to mitigate global warming, the first step is to consider the costs of inaction. These costs --and they are significant-- provide the primary motivation for actions to reduce greenhouse gas emissions.

(2) [The Intergovernmental Panel on Climate Change (IPCC) jointly established by the World Meteorological Organization and the United Nations Environment Programme, concluded in 1995 that "the balance of evidence suggests that there is a discernible human influence on global climate." Current concentrations of carbon dioxide, methane, nitrous oxide, and the other so-called greenhouse gases have reached levels well above those of preindustrial times. Of these, carbon dioxide (CO_2) is the most important: net cumulative CO_2 emissions resulting from the burning of fossil fuels and deforestation account for about two-thirds of potential warming from changes in greenhouse gas concentrations related to human activity. ER?

Climatic Impact

If growth in global emissions continues unabated, the atmospheric concentration of CO_2 will likely double relative to its preindustrial level by midway through the next century.] ER?

(3) As a result of the increased concentration of CO_2, the IPCC estimates that global temperatures will increase by between 2 to 6 degrees Fahrenheit in the next 100 years, with a best guess of about IPCC WG-I

(4) 3.5 degrees Fahrenheit. While scientists believe that human activities are leading to a gradual warming of the *average* temperature of the earth, the change in temperature in a given region at a given time may differ substantially from this average. ~~ADD~~ (5) Indeed, models predict warming will be greater in high latitudes than in the tropics ~~and~~ (6) in winter greater over land than ocean. Many models ~~also~~ ~~predict greater surface warming of the land than of the sea in winter, and increased precipitation and soil moisture in high latitudes in winter.~~ (6)

(1) [Potential consequences associated with this shift in climate include a rise in sea levels, greater frequency of severe weather events, shifts in agricultural growing conditions from changing weather patterns, threats to human health from increased range and incidence of diseases, changes in availability of freshwater supplies, and damage to ecosystems and biodiversity.] ER?

Economic and Monetary Damages

The derivation of quantitative or monetary estimates of the damages from such a change in the climate is extremely difficult given the capacity of today's models. Estimates of the economic damages from climate change fall into the following broad areas: agriculture, sea-level rise, air conditioning and heating, water supply, human life and health, air pollution, and other costs (hurricanes, relocation costs, human amenity, construction, leisure activities, Cline, Nordhaus

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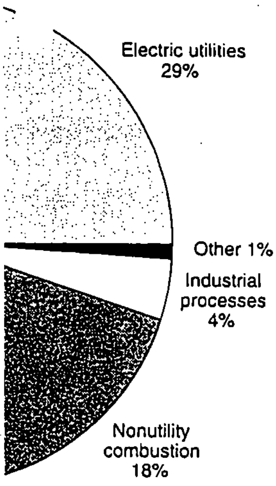

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Like most air pollution control programs, NO_X trading programs would require an estimate of emissions from each regulated source in order to ensure compliance. The estimation method can have significant implications for cost-effectiveness, both directly, through the cost of performing the estimate, and indirectly. One indirect implication is that more costly requirements may limit the number of sources that could meet the estimation requirements and participate in trading, and thereby raise costs. On the other hand, a more reliable estimation method may offer regulators and sources greater confidence in the permits, and thereby increase the willingness of sources to buy them or offer them for sale. For example, the SO_2 program requires continuous emissions monitoring to provide precise information on emissions. Such monitoring is expensive and impractical for many smaller sources and thus may effectively exclude such sources from participating. But such precise monitoring may not always be necessary. Methods for estimating emissions that provide unbiased, although less precise, estimates of emissions may be accurate enough to ensure accountability.

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(2) also see next page...

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see next page

preindustrial times. Of these, CO_2 is the most important: net cumulative CO_2 emissions resulting from the burning of fossil fuels and deforestation account for about two-thirds of potential warming from changes in greenhouse gas concentrations related to human activity. If growth in global emissions continues unabated, the atmospheric concentration of CO_2 will likely double, relative to its preindustrial level, midway through the next century.

The accumulation of greenhouse gases poses significant risks to the world's climate and to human well-being. ~~Potential impacts include a rise in sea levels, greater frequency of severe weather events, shifts in agricultural growing conditions from changing weather patterns, threats to human health from increased range and incidence of diseases, changes in availability of freshwater supplies, and damage to ecosystems and biodiversity.~~

Climate change is a complex, long-term problem requiring global cooperation and a long-term solution. No single country has an incentive to reduce emissions sufficiently to protect the global environment against climate change. Even if the United States sharply reduced its emissions unilaterally, greenhouse gas emissions from all other countries would continue to grow, and the risks posed by climate change would not be significantly abated. Since many of these gases remain in the atmosphere for a century or more, the climatic effects of actions taken today will primarily benefit future generations. But delaying action to reduce greenhouse gas emissions until the disruptive effects of climate change become widespread will considerably reduce the options for remedial or preventive measures.

The Framework Convention on Climate Change

The threat of disruptive climate change has led to coordinated international efforts to reduce the risks of global warming by reducing emissions of greenhouse gases. The first international agreement to address global warming was the Framework Convention on Climate Change signed during the Earth Summit in Rio de Janeiro in 1992. This convention established a long-term objective of limiting greenhouse gas concentrations and encouraged the established industrial countries to return their emissions to 1990 levels by 2000. Since then it has become clear that the United States and many other participating countries will not meet this goal.

To address the lack of progress among many industrial countries toward meeting this first target, the United States and approximately 159 other nations, in negotiations held in Kyoto, Japan, last December, agreed to take substantial steps to stabilize atmospheric concentrations of greenhouse gases. The Kyoto agreement, which requires the advice and consent of the Senate, would place binding limits on industrial countries' emissions of the six principal categories of greenhouse gases: CO_2, methane, N_2O, sulfur hexafluoride, perfluorocarbons, and hydrofluorocarbons. Each industrial country's "1990

of change are also inconsistent with those expected for solar and volcanic forcing.

- Our ability to quantify the human influence on global climate is currently limited because the expected signal is still emerging from the noise of natural variability, and because there are uncertainties in key factors. These include the magnitude and patterns of long-term natural variability and the time-evolving pattern of forcing by, and response to, changes in concentrations of greenhouse gases and aerosols, and land-surface changes. Nevertheless, the balance of evidence suggests that there is a discernible human influence on global climate.

F. The Prospects for Future Climate Change

F.1 Forcing scenarios

Projections of future anthropogenic climate change depend, amongst other things, on the scenario used to force the climate model. The IS92 emission scenarios are used here for projections of changes in global mean temperature and sea level. The IS92 scenarios include emissions of both greenhouse gases and aerosol precursors (see Section B.9.1) and for the first time both factors have been taken into account in the global mean temperature and sea level projections (Section F.2).

In many coupled model experiments the forcing scenario is simplified by summing the radiative forcings of all the trace gases (CO_2, CH_4, O_3, etc.) and treating the total forcing as if it came from an "equivalent" concentration of CO_2. The rate of increase of "equivalent CO_2" in these experiments is often assumed to be a constant +1%/yr (compounded). For comparison the IS92a Scenario, neglecting the effect of aerosols, is equivalent to a compounded rate of increase varying from 0.77 to 0.84%/yr during the 21st century.

The projections of global mean temperature and sea level changes do not come directly from coupled atmosphere-ocean models. Though these are the most sophisticated tools available for making projections of future climate change they are computationally expensive, making it unfeasible to produce results based on a large number of emission scenarios. In order to assess global temperature and sea level projections for the full range of IS92 emission scenarios, simple upwelling diffusion-energy balance models (see Box 2) can be employed to interpolate and extrapolate the coupled model results. These models, used for similar tasks in IPCC (1990) and IPCC (1992), are calibrated to give the same globally averaged temperature response as the coupled atmosphere-ocean models.

The climate simulations here are called *projections* instead of *predictions* to emphasise that they do not represent attempts to forecast the most likely (or "best estimate") evolution of climate in the future. The projections are aimed at estimating and understanding responses of the climate system to possible forcing scenarios.

F.2 Projections of climate change

F.2.1 Global mean temperature response to IS92 emission scenarios

Using the IS92 emission scenarios, which include emissions of both greenhouse gases and aerosol precursors (Section B.9.1) projected global mean temperature changes relative to 1990 were calculated for the 21st century. Temperature projections assuming the "best estimate" value of climate sensitivity, 2.5°C, (see Section D.2) are shown for the full set of IS92 scenarios in Figure 18. For IS92a the temperature increase by 2100 is about 2°C. Taking account of the range in the estimate of climate sensitivity (1.5 to 4.5°C) and the full set of IS92 emission scenarios, the models project an increase in global mean temperature of between 0.9 and 3.5°C (Figure 19). In all cases the average rate of warming would probably be greater than any seen in the last 10,000 years, but the actual annual to decadal changes would include considerable natural variability. Because of the thermal inertia of the oceans, global mean temperature would continue to

$2 \times 1.8 = 3.6$
(4)
$0.9 \times 1.8 = 1.6$
$3.5 \times 1.8 = 6.3$
(3)
$1°C = 9/5 °F$
$= 1.8°F$

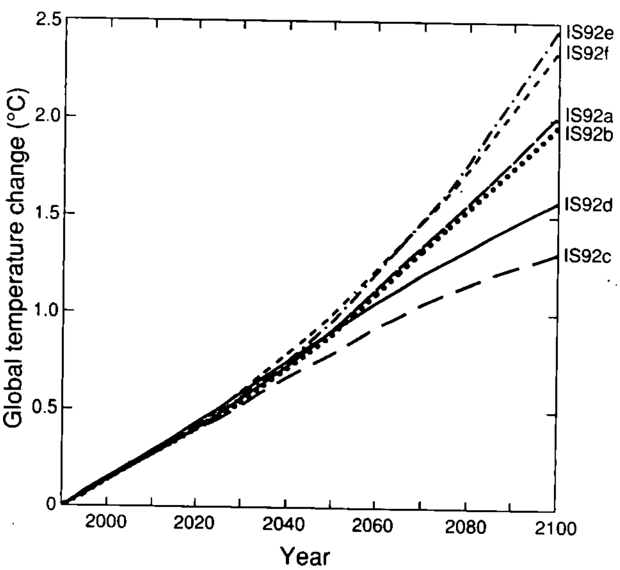

Figure 18: Projected global mean surface temperature changes from 1990 to 2100 for the full set of IS92 emission scenarios. A climate sensitivity of 2.5°C is assumed.

POLICY FORUM

Uncertainties in Projections of Human-Caused Climate Warming

J. D. Mahlman

Mankind's activities have increased carbon dioxide (CO_2) in the atmosphere. This increase has the potential to warm the earth's climate by the "greenhouse effect" (*1*) in which CO_2 absorbs infrared radiation and then re-radiates it back toward the surface of the planet. Other gases also act as greenhouse gases and may warm the climate even further (*2*), although human-produced airborne sulfate particles can cause cooling that offsets some of the warming (*3*). Computational models that include these factors predict that the climate will warm significantly over the next century.

These forecasts of likely climate changes have forced a realization that it is necessary to reduce human-caused emissions of greenhouse gases. But because of the potential social disruptions and high economic costs of such reductions, vigorous debate has arisen about the size and nature of the projected climate changes and whether they will actually lead to serious impacts.

A key element of these spirited—and often acrimonious—debates is the credibility (or lack thereof) of the mathematically and physically based climate models (*4*) that are used to project the climate changes resulting from a sustained buildup of atmospheric CO_2. Some skeptics ask, to put it bluntly, why should we believe such models' attempts to describe changes in such a dauntingly complex system as Earth's climate? The cheap answer is that there are no credible alternatives. But the real answer is that the climate models do a reasonably good job of capturing the essence of the large-scale aspects of the current climate and its considerable natural variability on time scales ranging from 1 day to decades (*4*). In spite of these considerable successes, the models contain weaknesses that add important uncertainty to the very best model projections of human-induced climate changes.

I express here a "policy-independent" evaluation of the levels of current scientific confidence in predictions emanating from climate models. This climate model uncertainty is distinct from the high social uncertainty associated with future scenarios of greenhouse gas and airborne particle concentrations. I assume that detailed future greenhouse and airborne particle scenarios are part of the policy question and thus do not discuss them further.

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A fair-minded and exhaustive attempt to find a broad consensus on what science can say about this problem is contained in the most recent 1996 IPCC Working Group I Assessment (*3*). Some of my evaluations differ in detail from those of IPCC 1996, mostly because of the addition of new research insights and information since 1994. A good guideline for evaluating contrary "expert" opinions is whether they use the IPCC science as a point of departure for their own analysis. In effect, if we disagree scientifically with IPCC, we should explain why. Without such discipline, contrary arguments are not likely to be scientifically sound.

Virtually Certain "Facts"

These key aspects of our knowledge of the climate system do not depend directly on the skill of climate model simulations and projections:

- Atmospheric abundances of greenhouse gases are increasing because of human activities.
- Greenhouse gases absorb and re-radiate infrared radiation efficiently. This property acts directly to heat the planet.
- Altered amounts of greenhouse gases affect the climate for many centuries. The major greenhouse gases remain in the atmosphere for periods ranging from a decade to centuries. Also, the climate itself has considerable inertia, mainly because of the high heat capacity of the world ocean.
- Changes in other radiatively active substances offset somewhat the warming effect of increased greenhouse gases. Observed decreases in lower stratospheric ozone and increases in sulfate particles both produce cooling effects. The cooling effect of sulfate particles remains insufficiently quantified.
- Human-caused CO_2 increases and ozone decreases in the stratosphere have already produced more than a 1°C global average cooling there. This stratospheric cooling is generally consistent with model predictions.
- Over the past century, Earth's surface has warmed by about 0.5°C (±0.2°C).
- The natural variability of climate adds confusion to the effort to diagnose human-induced climate changes. Apparent long-term trends can be artificially amplified or damped by the contaminating effects of undiagnosed natural variations.
- Significant reduction of key uncertainties will require a decade or more. The uncertainties concerning the responses of clouds, water vapor, ice, ocean currents, and specific regions to increased greenhouse gases remain formidable.

I further illustrate these climate uncertainties using two extrapolations of the IPCC idealized scenarios of increases of 1% equivalent atmospheric CO_2 concentration per year (*5*). The first case levels off at a CO_2 doubling after 70 years; the second levels off at a CO_2 quadrupling after 140 years. Both correspond to simple extrapolations of current trends in greenhouse gas emissions. Considering the long residence time of CO_2 at such large concentrations, these leveled-off scenarios are physically plausible but are presented as illustrations, not as social predictions.

Virtually Certain Projections

These projections have a greater than 99 out of 100 chance of being true within the predicted range (*6*):

- The stratosphere will continue to cool significantly as CO_2 increases. If ozone continues to decrease, the cooling will be magnified. There is no known mechanism to prevent the global mean cooling of the stratosphere under these scenarios.
- Global mean amounts of water vapor will increase in the lower troposphere (0 to 3 km) in approximately exponential proportion (roughly 6% per 1°C of warming) to the global mean temperature change. The typical relative humidities would probably change substantially less, in percentage terms, than would water vapor concentrations.

Very Probable Projections

These projections have a greater than 9 out of 10 chance of being true within the predicted range:

- The global warming observed over the past century is generally consistent with *a posteriori* model projections of expected greenhouse warming, if a reasonable sulfate particle offset is included. It is difficult, but not impossible, to construct conceivable alternate hypotheses to explain this observed warming. Using variations in solar output or in natural climate to explain the observed warming can be appealing, but both have serious logical inconsistencies.
- A doubling of atmospheric CO_2 over preindustrial levels is projected to lead to an equilibrium global warming in the range of 1.5° to 4.5°C. These generous uncertainty brackets reflect remaining limitations in modeling the radiative feedbacks of clouds,

details of the changed amounts of water vapor in the upper troposphere (5 to 10 km), and responses of sea ice. In effect, this means that there is roughly a 10% chance that the actual equilibrium warming caused by doubled atmospheric CO_2 levels could be lower than 1.5°C or higher than 4.5°C. For the answer to lie outside these bounds, we would have to discover a substantial surprise beyond our current understanding.

■ Essentially all climate models predict equilibrium global temperature increases that are nearly linear in the logarithm of CO_2 changes. This effect is mainly due to increasing saturation of many of the infrared absorption bands of CO_2. That is, a quadrupling of CO_2 levels generally produces projected warmings that are about twice as large as those for doubled CO_2.

■ Models predict that by the year 2100, global mean surface temperature changes under these two idealized scenarios would be 1.5° to 5°C.

■ Sea level rise could be substantial. The projections of 50 ± 25 cm by the year 2100, caused mainly by the thermal expansion of sea water, are below the equilibrium sea level rise that would ultimately be expected. After 500 years at quadrupled CO_2 levels, the sea level rise expected due to thermal expansion alone is roughly 2 ± 1 m. Long-term melting of landlocked ice carries the potential for considerably higher values but with less certainty.

■ As the climate warms, the rate of evaporation must increase, leading to an increase in global mean precipitation of about 2 ± 0.5% per 1°C of global warming.

■ By 2050 or so, the higher latitudes of the Northern Hemisphere are also expected to experience temperature increases well in excess of the global average increase. In addition, substantial reductions of northern sea ice are expected. Precipitation is expected to increase significantly in higher northern latitudes. This effect mainly occurs because of the higher moisture content of the warmer air as it moves poleward, cools, and releases its moisture.

Probable Projections

The following have a greater than two out of three chance of being true:

■ Model studies project eventual marked decreases in soil moisture in response to increases in summer temperatures over northern mid-latitude continents. This result remains somewhat sensitive to the details of predicted spring and summer precipitation, as well as to model assumptions about land surface processes and the offsetting effects of airborne sulfate particles in those regions.

■ Climate models imply that the circum-Antarctic ocean region is substantially resistant to warming, and thus little change in sea-ice cover is predicted to occur there, at least over the next century or two.

■ The projected precipitation increases at higher latitudes act to reduce the ocean's salinity and thus its density. This effect inhibits the tendency of the water to sink, thus suppressing the overturning circulation.

■ Very recent research (7) suggests that tropical storms, once formed, might tend to become more intense in the warmer ocean, at least in circumstances where weather and geographical (for example, no landfall) conditions permit.

■ Model studies project that the standard deviations of the natural temperature fluctuations of the climate system would not change significantly. This indicates an increased probability of warm weather events and a decreased probability of cold events, simply because of the higher mean temperature.

Incorrect Projections and Policy Implications

There are a number of statements in informal writings that are not supported by climate science or projections with high-quality climate models. Some of these statements may appear to be physically plausible, but the evidence for their validity is weak, and some are just wrong.

There are assertions that the number of tropical storms, hurricanes, and typhoons per year will increase. That is possible, but there appears to be no credible evidence to substantiate such assertions.

Assertions that winds in midlatitude (versus tropical) cyclones will become more intense do not appear to have credible scientific support. It is theoretically plausible that smaller-scale storms such as thunderstorms or squall lines could become stronger under locally favorable conditions, but the direct evidence remains weak.

There is a large demand for specific climate change predictions at the regional and local scales where life and life support systems are actually affected. Unfortunately, our confidence in predictions on these smaller scales will likely remain relatively low. Much greater fidelity of calculated local climate impacts will require large improvements in computational power and in the physical and biological sophistication of the models. For example, the large uncertainty in modeling the all-important responses of clouds could become even harder at regional and local levels. Major sustained efforts will be required to reduce these uncertainties substantially.

Characterizations of the state of the science of greenhouse warming are often warped in differing ways by people or groups with widely varying sociopolitical agendas and biases. This is unfortunate because such distortions grossly exaggerate the public's sense of controversy about the value of the scientific knowledge base as guidance for the policy deliberation process.

It is clear that much is known about the climate system and about how that knowledge is expressed through the use of physically based coupled models of the atmosphere, ocean, ice, and land surface systems. This knowledge makes it obvious that human-caused greenhouse warming is not a problem that can rationally be dismissed or ignored. However, the remaining uncertainties in modeling important aspects of the problem make it evident that we cannot yet produce a sharp picture of how the warmed climate will proceed, either globally or locally.

None of these recognized uncertainties can make the problem go away. It is virtually certain that human-caused greenhouse warming is going to continue to unfold, slowly but inexorably, for a long time into the future. The severity of the impacts can be modest or large, depending on how some of the remaining key uncertainties are resolved through the eventual changes in the real climate system, and on our success in reducing emissions of long-lived greenhouse gases.

References and Notes

1. The greenhouse effect for CO_2 was first calculated over 100 years ago by S. Arrhenius, *The London, Edinburgh and Dublin Philosophical Magazine and Journal of Science* **41**, 237 (1896).
2. Intergovernmental Panel on Climate Change, *Climate Change, the IPCC Scientific Assessment*, J. T. Houghton *et al.*, Eds. (Cambridge Univ. Press, Cambridge, 1990).
3. Intergovernmental Panel on Climate Change, *Climate Change 1995, The Science of Climate Change*, J. T. Houghton *et al.*, Eds. (Cambridge Univ. Press, Cambridge, 1996).
4. Climate models are mathematically based models that attempt to calculate the climate, its variability, and its systematic changes on a first-principles basis. The fundamental equations solved are the conservation of mass, momentum, and energy. The interactions among the atmosphere, ocean, ice, and land surface systems are calculated on rather widely separated computational points on Earth (typical spacings are 200 to 400 km in the horizontal and 1 to 3 km in the vertical).
5. S. Manabe and R. J. Stouffer, *Nature* **364**, 215 (1993); *J. Clim.* **7**, 5 (1994).
6. The approach used here was tested and challenged in E. Barron, *Forum on Global Change Modeling, U.S. Global Change Research Program Report 95-02* (U.S. Global Change Research Program, Washington, DC, 1995). Earlier evaluations were published in J. D. Mahlman, *Climate Change and Energy Policy*, L. Rosen and R. Glasser, Eds. (American Institute of Physics, Los Alamos National Laboratory LA-UR-92-502, New York, 1992) and in J. D. Mahlman, U.S. Congressional Record, 16 November 1995, House Science Committee Hearing on Climate Models and Projections of Potential Impacts on Global Climate Change (1995).
7. T. R. Knutson, R. E. Tuleya, Y. Kurihara, in preparation.

global mean surface air temperature relative to 1990 of about 2°C by 2100. This estimate is approximately one third lower than the "best estimate" in 1990. This is due primarily to lower emission scenarios (particularly for CO_2 and the CFCs), the inclusion of the cooling effect of sulphate aerosols, and improvements in the treatment of the carbon cycle. Combining the lowest IPCC emission scenario (IS92c) with a "low" value of climate sensitivity and including the effects of future changes in aerosol concentrations leads to a projected increase of about 1°C by 2100. The corresponding projection for the highest IPCC scenario (IS92e) combined with a "high" value of climate sensitivity gives a warming of about 3.5°C. In all cases the average rate of warming would probably be greater than any seen in the last 10,000 years, but the actual annual to decadal changes would include considerable natural variability. Regional temperature changes could differ substantially from the global mean value. Because of the thermal inertia of the oceans, only 50-90% of the eventual equilibrium temperature change would have been realised by 2100 and temperature would continue to increase beyond 2100, even if concentrations of greenhouse gases were stabilised by that time.

- Average sea level is expected to rise as a result of thermal expansion of the oceans and melting of glaciers and ice-sheets. For the IS92a scenario, assuming the "best estimate" values of climate sensitivity and of ice melt sensitivity to warming, and including the effects of future changes in aerosol, models project an increase in sea level of about 50 cm from the present to 2100. This estimate is approximately 25% lower than the "best estimate" in 1990 due to the lower temperature projection, but also reflecting improvements in the climate and ice melt models. Combining the lowest emission scenario (IS92c) with the "low" climate and ice melt sensitivities and including aerosol effects gives a projected sea level rise of about 15 cm from the present to 2100. The corresponding projection for the highest emission scenario (IS92e) combined with "high" climate and ice-melt sensitivities gives a sea level rise of about 95 cm from the present to 2100. Sea level would continue to rise at a similar rate in future centuries beyond 2100, even if concentrations of greenhouse gases were stabilised by that time, and would continue to do so even beyond the time of stabilisation of global mean temperature. Regional sea level changes may differ from the global mean value owing to land movement and ocean current changes.

- Confidence is higher in the hemispheric-to-continental scale projections of coupled atmosphere-ocean climate models than in the regional projections, where confidence remains low. There is more confidence in temperature projections than hydrological changes.

- All model simulations, ~~whether they were forced~~ with increased concentrations of greenhouse gase and aerosols or with increased concentrations o greenhouse gases alone, show the following features greater surface warming of the land than of the sea ir winter; a maximum surface warming in high northern latitudes in winter, little surface warming over th Arctic in summer; an enhanced global mea hydrological cycle, and increased precipitation an soil moisture in high latitudes in winter. All thes changes are associated with identifiable physica mechanisms.

(6)

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should you choose to keep it in

- In addition, most simulations show a reduction in th strength of the north Atlantic thermohalin circulation and a widespread reduction in diurn range of temperature. These features too can b explained in terms of identifiable physic mechanisms.

- The direct and indirect effects of anthropogen aerosols have an important effect on the projection Generally, the magnitudes of the temperature a precipitation changes are smaller when aeros effects are represented, especially in northern mi latitudes. Note that the cooling effect of aerosols not a simple offset to the warming effect greenhouse gases, but significantly affects some the continental scale patterns of climate change, m noticeably in the summer hemisphere. For examp models that consider only the effects of greenho gases generally project an increase in precipitati and soil moisture in the Asian summer monso region, whereas models that include, in additi some of the effects of aerosols suggest that mons precipitation may decrease. The spatial and temp distribution of aerosols greatly influence regio projections, which are therefore more uncertain.

preindustrial times. Of these, CO_2 is the most important: net cumulative CO_2 emissions resulting from the burning of fossil fuels and deforestation account for about two-thirds of potential warming from changes in greenhouse gas concentrations related to human activity. If growth in global emissions continues unabated, the atmospheric concentration of CO_2 will likely double, relative to its preindustrial level, midway through the next century.

The accumulation of greenhouse gases poses significant risks to the world's climate and to human well-being. Potential impacts include a rise in sea levels, greater frequency of severe weather events, shifts in agricultural growing conditions from changing weather patterns, threats to human health from increased range and incidence of diseases, changes in availability of freshwater supplies, and damage to ecosystems and biodiversity.

Climate change is a complex, long-term problem requiring global cooperation and a long-term solution. No single country has an incentive to reduce emissions sufficiently to protect the global environment against climate change. Even if the United States sharply reduced its emissions unilaterally, greenhouse gas emissions from all other countries would continue to grow, and the risks posed by climate change would not be significantly abated. Since many of these gases remain in the atmosphere for a century or more, the climatic effects of actions taken today will primarily benefit future generations. But delaying action to reduce greenhouse gas emissions until the disruptive effects of climate change become widespread will considerably reduce the options for remedial or preventive measures.

The Framework Convention on Climate Change

The threat of disruptive climate change has led to coordinated international efforts to reduce the risks of global warming by reducing emissions of greenhouse gases. The first international agreement to address global warming was the Framework Convention on Climate Change signed during the Earth Summit in Rio de Janeiro in 1992. This convention established a long-term objective of limiting greenhouse gas concentrations and encouraged the established industrial countries to return their emissions to 1990 levels by 2000. Since then it has become clear that the United States and many other participating countries will not meet this goal.

To address the lack of progress among many industrial countries toward meeting this first target, the United States and approximately 159 other nations, in negotiations held in Kyoto, Japan, last December, agreed to take substantial steps to stabilize atmospheric concentrations of greenhouse gases. The Kyoto agreement, which requires the advice and consent of the Senate, would place binding limits on industrial countries' emissions of the six principal categories of greenhouse gases: CO_2, methane, N_2O, sulfur hexafluoride, perfluorocarbons, and hydrofluorocarbons. Each industrial country's "1990

Since IPCC (1990), a greater appreciation has been developed of the uncertainties in making projections at the regional scale. There are several difficulties:

- The global climate models used for future projections are run at fairly coarse resolution and do not adequately depict many geographic features (such as coastlines, lakes and mountains), surface vegetation, and the interactions between the atmosphere with the surface which become more important on regional scales. Considerable spread exists among model projections on the regional scale even when climate model experiments are driven by the same future radiative forcing scenario.

- There is much more natural variation in local climate than in climate averaged over continental or larger scales. This variation arises from locally generated variability from storms, interactions between the atmosphere and the oceans (such as ENSO), and from variations in soil moisture, sea ice, and other components of the climate system. Series or ensembles of model predictions started from different initial conditions allow both the mean climate and the superimposed variability to be determined.

- Because of their uneven spatial distribution, human induced tropospheric aerosols are likely to greatly influence future regional climate change. At present, however, there are very few projections of climate change with coupled atmosphere-ocean models (the type of model that gives more reliable information on the regional scale) which include the radiative effects of aerosols. Those that have been run include a very simplified representation of aerosol effects.

- Land-use changes are also believed to have a significant impact on temperature and precipitation changes, especially in the tropics and subtropics. Climate model experiments have shown the likelihood of substantial local climate change associated with deforestation in the Amazon, or desertification in the Sahel. Changes in land-use on small scales which cannot be foreseen are expected to continue to influence regional climate.

Because of these problems, no information on future regional climate change is presented here. However, this situation is expected to improve in the future as a result of:

- more coupled atmosphere-ocean model experiments with aerosol effects included;
- improvements in models, both from increased resolution and improved representation of small-scale processes;
- more refined scenarios for aerosols and other forcings.

F.3.3 Changes in variability and extremes

Small changes in the mean climate or climate variability can produce relatively large changes in the frequency of extreme events (defined as events where a certain threshold is surpassed); a small change in the variability has a stronger effect than a similar change in the mean.

Temperature

A general warming tends to lead to an increase in extremely high temperature events and a decrease in extremely low temperatures (e.g., frost days).

Hydrology

Many models suggest an increase in the probability of intense precipitation with increased greenhouse gas concentrations. In some areas a number of simulations show there is also an increase in the probability of dry days and the length of dry spells (consecutive days without precipitation). Where mean precipitation decreases, the likelihood of drought increases. New results reinforce the view that variability associated with the enhanced hydrological cycle translates into prospects for more severe droughts and/or floods in some places and less severe droughts and/or floods in other places.

Mid-latitude storms

In the few analyses available, there is little agreement between models on the changes in storminess that might occur in a warmer world. Conclusions regarding extreme storm events are obviously even more uncertain.

Hurricanes/Tropical cyclones

The formation of tropical cyclones depends not only on sea surface temperature (SST), but also on a number of atmospheric factors. Although some models now represent tropical storms with some realism for present day climate, the state of the science does not allow assessment of future changes.

El Niño-Southern Oscillation

Several global coupled models indicate that the ENSO-like SST variability they simulate continues with increased

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urban infrastructure, and ecological damages such as forest loss and species loss). Although the quantification of these effects is quite demanding, researchers have developed estimates that prompt substantial concern. The IPCC reports that a doubling of carbon dioxide levels would lead to about 6,000 to 10,000 additional deaths per year from higher summer temperatures, even after netting out the effects of warmer winters and assuming acclimatization. Other researchers have predicted sea level increases of about 20 inches by 2100, with substantially greater increases in subsequent years.

IPCC (or OSTP)

REPLACE w/ FOLLOWING PAGE

Despite the difficulties, respected researchers have developed estimates of the monetary damages expected from an average worldwide temperature increase. For example, Cline estimated that a temperature change of 4.5 degrees Fahrenheit would impose annual damages of more than $70 billion per year on the U.S. economy in today's terms. These damages include $22 billion in lost agricultural production, $13 billion in additional electricity costs, and $8 billion in new costs to maintain the existing supply of fresh water. (Cline's original estimates are quoted in 1990 dollars. The figures given above translated those numbers into 1997 dollars using the annual GDP price index.) William Nordhaus of Yale University has likewise computed estimates of the dollar loss attributable to a doubling of greenhouse gas concentrations. Although he uses methods that differ from Cline's in several respects, he finds that the Cline estimate is in the center of three estimates for the U.S., and that the high estimate is only 30 percent greater than the low estimate. It must be noted, however, that this similarity among aggregate estimates masks the true uncertainty associated with forecasts of the damages from given increases in global warming -- the estimates are all fundamentally based on extrapolations from current and past experience, and may not fully incorporate effects that will unfortunately become apparent only with future experience.

Cline Nordhaus

One key difficulty in interpreting and applying these estimates of monetary damages is uncertainty over the extent that they should be discounted because they occur in the distant future. Since the benefits of stemming future climate change accrue over not only decades but centuries, small changes in the discount rate can produce substantial changes in the results. But the precise discount rate that should be used to evaluate questions as important as the future climate of the planet remains a subject of intense debate. It is safe to say that there is, as yet, no professional consensus on the issue. Indeed there can be no technical answer to the ethical question how we should value the welfare of future generations.

NF

A similar difficulty with such estimates is that they may not fully reflect potential non-linearities in the relationships between greenhouse gas concentrations and temperature, between temperature and economic damages, or in the various other complicated relationships governing interactions between greenhouse gas emissions, the climate, and the economy. Current estimates of damages do not, and cannot, accurately reflect the value of reducing the small and unknown possibility of large-scale and potentially irreversible discrete events with potentially catastrophic consequences.

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IPCC p 87

Two such possibilities serve as illustrations. Warming of Northern tundra may release very large amounts of methane from the subarctic permafrost, thereby leading to potentially devastating acceleration of an otherwise controllable global warming process. We do not know at what point, if any, such unstable activity would be triggered. Second, evidence

IPCC (or OSTP)

NEW VERSION

Despite the difficulties, respected researchers have developed estimates of the monetary damages expected from an average worldwide temperature increase. For example, 1 Cline estimated that a temperature change of 4.5 degrees Fahrenheit would impose annual about damages of about 1.1 percent of GDP per year on the U.S. economy. That amounts to $87 89 2 Changed billion in today's terms. (Cline's original estimate is quoted in 1990 dollars. The figure given above translates this number into 1997 terms by scaling it to current GDP.) William Nordhaus of Yale University has likewise computed estimates of the dollar loss attributable to a doubling of greenhouse gas concentrations. Although he uses methods that differ from Cline's in several respects, Nordhuas estimates that a slightly larger temperature change of 5.4 degrees Fahrenheit 3 would impose losses equal to about 1 percent of GDP. A third independent estimate reported by 4 Nordhaus is close to Cline's. It must be noted, however, that this similarity among aggregated estimates masks the true uncertainty associated with forecasts of the damages from given increases in global warming -- the estimates are all fundamentally based on extrapolations from current and past experience, and may not fully incorporate effects that will unfortunately become apparent only with future experience.

CLIMATE CHANGE 1995

Economic and Social Dimensions of Climate Change

Contribution of Working Group III to the Second Assessment Report of the Intergovernmental Panel on Climate Change

and Bentham (1993) estimate that the higher temperatures predicted for 2050 (about 2.5°C) could result in some 9,000 fewer winter deaths per year.

Most economic studies use Kalkstein (1989) as a basis. Kalkstein has used statistical methods to analyze the mortality impact of changed weather conditions under $2xCO_2$ for 15 major U.S. cities (U.S. EPA, 1989; Kalkstein, 1989). Even after accounting for induced acclimatization (based on mortality statistics for control cities with comparable present climate conditions), he finds that increased summer deaths substantially exceed decreased winter deaths. Cline (1992a) and Fankhauser (1995) weight these results by population and extrapolate that benchmark warming would increase mortality by about 27-40 persons per million population, depending on the warming scenario. Without acclimatization this figure would be about six times higher. For the United States the more conservative figure including acclimatization translates (8) into 6,600 to 9,800 additional deaths annually for the present (9) U.S. population. ALSO SEE PINK ON NEXT PAGE

BUT A Mortality effects could be particularly damaging in the more vulnerable countries of the developing world, where mitigating technologies like air conditioning will be less readily available. In Shanghai, for example, death rates from heat stress are currently over twice those in New York City (Haines and Parry, 1993). Health problems associated with hot spells are also significant in Bangladesh (Asaduzzaman, personal communication, 1994) and Pakistan (Asian Development Bank, 1994). Using uniform mortality rates, Fankhauser estimates that about 115,000 additional casualties per year could occur in non-OECD countries, compared to some 23,000 additional annual deaths in the OECD (for 2.5°C warming; see Table 6.5). Tol (1994b), using the same estimates but without scaling to 2.5°C warming, arrives at a figure of 215,000 additional casualties worldwide.

Expressing the value of this loss in monetary terms is controversial (see Box 6.1). Cline (1992a) uses lifetime earnings to place statistical life valuation at a conservative \$595,000 and reaches a corresponding estimate of \$5.8 billion in annual U.S. losses from benchmark warming. Using higher values, Titus (1992) obtains annual damages of \$9.4 billion for the U.S. Fankhauser uses value-of-statistical-life estimates of \$0.1 to 1.5 million, depending on regional income levels, and obtains mortality damages of \$10 billion in the U.S., \$34 billion for the OECD, and \$49 billion worldwide. If an identical value of \$1 million for all lives were used worldwide, this latter figure would rise to almost \$140 billion. Tol (1995) assesses a statistical life at \$250,000 + 175 x (annual income per capita). With worldwide mortality costs of \$188 billion, health damages account for more than half his aggregate estimate of warming damages.

In addition to direct heat-related health effects, there could be indirect losses from increased vector-borne diseases like malaria or yellow fever, as their insect vectors adjust to new climate conditions and their risk areas shift (Haines and Parry, 1993). WHO (1990), for example, suggests that the so far disease-free highlands of Ethiopia, Indonesia, and Kenya might be invaded by vectors. A study for Indonesia predicts a fourfold increase in the incidence of dengue fever and a 20-25% increase in malaria cases (Asian Development Bank, 199[illegible] the latter half of the next century. Global simulations by M[illegible] suoka *et al.* (1994) indicate a 10-30% increase in the num[illegible] of people at risk from malaria under $2xCO_2$ conditi[illegible] Hohmeyer and Gärtner (1992) estimate that an extra 200 [illegible] lion people could be exposed to malaria worldwide. Mar[illegible] *et al.* (1994) expect several million additional malaria c[illegible] by the year 2100. Vector-borne diseases may also spread [illegible] developed countries. Simulations dealing with a possibl[illegible] crease of malaria in the U.S. are, however, inconclusive (U.[illegible] EPA, 1989).

The increased occurrence of flooding could lead to higher incidence of diseases associated with poor sanita[illegible] standards, particularly in developing countries. For Indone[illegible] it has been estimated that, by the year 2070, cases of diarrho[illegible] could rise to over 900 per 10,000 inhabitants, compared [illegible] 300 cases per 10,000 people in 1989 (Asian Developme[illegible] Bank, 1994).

The emerging picture of health impacts thus indicates th[illegible] the indirect effects could by far exceed the direct losses.

6.2.9 *Air pollution*

A warmer climate could aggravate some urban pollution pro[illegible] lems. In the U.S., tropospheric ozone is the most severe prob[illegible] lem in terms of the number of persons living in areas with [illegible] quality indexes that violate national standards (75 million per[illegible] sons in 1986). Total suspended particulates (TSP) and carbo[illegible] monoxide are also important (41 million each). TSP is also implicated in widespread health damage in the developin[illegible] world and the economies in transition.

Numerous studies confirm that ozone concentrations ris[illegible] with temperature (see, e.g., IPCC, 1990b). The U.S. EPA, af[illegible] ter summarizing various U.S. estimates, concluded that a 4°C rise in temperature (about what could be expected for the U.S. under 2.5°C global mean warming) could cause an increase i[illegible] peak ozone concentrations of 10%. The result would be t[illegible] double the number of cities in violation of the air quality stan[illegible] dards from 68 to 136, causing most midsize and some smal[illegible] cities in the Midwest, South, and East to be added to the list o[illegible] those presently in violation.

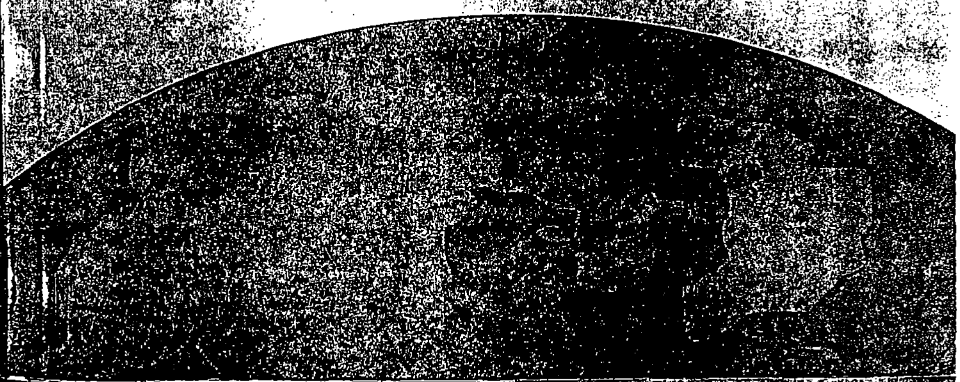
Applying its past models relating ozone concentrations t[illegible] emissions of volatile organic compounds (VOCs), the U.S EPA estimates that it would be necessary to reduce VO[illegible] emissions in the U.S. by 700,000 tonnes from a year-2000 ex[illegible] pected base of 6 million tonnes to offset the effects of 2xCO[illegible] warming on ozone formation. At an estimated cost of \$5,0[illegible] per tonne, the agency calculates that the resulting costs wou[illegible] amount to \$3.5 billion annually (U.S. EPA, 1989). Cline (1992[illegible] uses this figure as an estimate of U.S. air pollution damage [illegible] be expected from benchmark warming. In comparison, [illegible] pollution control expenditure in 1987 was \$27 billion (U. EPA, 1990).

Titus (1992) estimates U.S. tropospheric ozone dama[illegible] from benchmark warming at \$27.2 billion annually. This is [illegible] most an order of magnitude higher than Cline, although b[illegible] figures are based on the U.S. EPA (1989) estimate. The diff[illegible] ence appears to be that Titus projects a high baseline of V[illegible]

INSTITUTE FOR INTERNATIONAL ECONOMICS

THE ECONOMICS OF GLOBAL WARMING

WILLIAM R. CLINE



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were willing to pay just 0.25 percent of personal
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· countries would depend on location and income
ies, the effect would probably be favorable (i.e.,
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nost certainly would do so under very-long-term
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ɪption that amenity is an income-elastic service.

·d 1.1 million of the 1.7 million deaths annually
ɜntially sensitive to weather (cerebrovascular,
:umonia and influenza; EPA 1989a, 221). Heat
:her increase the incidence of stroke and heart
he occurrence of respiratory diseases (emphy-
warmer summers are expected to increase the
ıssed ... ·v).
Kal ... ɪas carried out a statistical analysis
·les ... ing temperature and humidity). He
·r conditions under carbon-dioxide-equivalent
in number of deaths for 15 major US cities.
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eed decreased winter deaths. For the un-
rise from 1,156 at present to 7,402 under
nd 2,198 with acclimatization. Winter deaths
hout acclimatization and 159 with acclima-

tization (the latter result is spurious, because in winter the population should be able to do at least as well with acclimatization as without).

The Kalkstein estimates may be reinterpreted by enforcing as the postwarming summer deaths the *minimum* of the following: present level, postwarming without acclimatization, and postwarming with acclimatization. Similarly, postwarming winter deaths may be set as the *maximum* of present, future with acclimatization, and future without acclimatization. When this screening is performed, and when the resulting net death rates per 1,000 population of the individual cities are weighted proportionately to city population, the overall result is that benchmark warming would increase mortality by [redacted]. Applied to the present US population base, this result indicates that global warming under carbon-dioxide- equivalent doubling would cause some 9,800 additional deaths annually. (7)

and see next page

Life valuation methods for public policy often take as a point of departure the lifetime earnings of an individual, under the assumption that earnings are what the society is willing to pay the individual (and thus the person's "marginal product"). Average nonagricultural wages in the United States amounted to $17,994 in 1990 (*Economic Report of the President*, February 1991, 336). If a working life span is set at 45 years and a 1.5 percent discount rate is applied, the value of average lifetime wages is $595,000. If this rate is applied to the estimated increase in deaths, annual mortality costs from global warming would amount to $5.8 billion for the United States.

The value of damage could be much greater on the basis of some of the higher life-valuation estimates in the literature (Cropper and Oates 1990). On the basis of the statistical relationship of wages to risk of death by occupation and industry, estimates of the "value of a statistical life" have been placed in the range of $2 million and even up to $6 million. Contingent valuation studies that ask workers what wage differentials would be required for more dangerous work generate results in the same range ($2 million to $3 million). On the other hand, studies that measure actual behavior in hazard avoidance (e.g., the purchase of smoke detectors) place the value of a statistical life at a much lower range of $500,000 to $600,000. Moreover, for environmental risks that are longer term and have a lower probability of death (e.g., exposure to hazardous waste), the value of a statistical life is even lower ($200,000 to $400,000), in part because the risk is some 20 years or more in the future.

One issue in valuing a life in the range of $2 million to $3 million is that the implied value of the entire US population would be more than 100 times the size of GDP. Since each worker's productive life is only some 45 years, this implied aggregate amount would be at least twice what American society could afford to pay for its own survival. This seeming anomaly can be resolved, however, if it is considered that for events that would only cause the death of a small fraction of the population, people might well be prepared to pay a higher per-death

Resident Population: Total

thous

1900	___	77584	79163	80632	82166
1905	83822	85450	87008	88710	90490
1910	92407	93863	95335	97225	99111
1915	100546	101961	103268	103208	104514
1920	106461	108538	110049	111947	114109
1925	115829	117397	119035	120509	121767
1930	123077	124040	124840	125579	126374
1935	127250	128053	128825	129825	130880
1940	131954	133121	133920	134245	132885
1945	132481	140054	143446	146093	148665
1950	151868	153982	156393	158956	161884
1955	165069	168088	171187	174149	177135
1960	179979	182992	185771	188483	191141
1965	193526	195576	197457	199399	201385
1970	203984	206827	209284	211357	213342
1975	215465	217563	219760	222095	224567
1980	227225	229466	231664	233792	235825
1985	237924	240133	242289	244499	246819
1990	249402	252138	255039	257800	260350
1995	262755	265185	___	___	___

from Cline (prev page)

from Cline (prev page)

(265,185) × (0.03971) = 10,528 deaths ≈ 11,000 deaths

$\frac{6,600}{255,039}$ × 265,185 ~~255,039~~

= 6,862 deaths ≈ 7,000 deaths

rate in 1992

1996 pop

IPCC, Science

global mean surface air temperature relative to 1990 of about 2°C by 2100. This estimate is approximately one third lower than the "best estimate" in 1990. This is due primarily to lower emission scenarios (particularly for CO_2 and the CFCs), the inclusion of the cooling effect of sulphate aerosols, and improvements in the treatment of the carbon cycle. Combining the lowest IPCC emission scenario (IS92c) with a "low" value of climate sensitivity and including the effects of future changes in aerosol concentrations leads to a projected increase of about 1°C by 2100. The corresponding projection for the highest IPCC scenario (IS92e) combined with a "high" value of climate sensitivity gives a warming of about 3.5°C. In all cases the average rate of warming would probably be greater than any seen in the last 10,000 years, but the actual annual to decadal changes would include considerable natural variability. Regional temperature changes could differ substantially from the global mean value. Because of the thermal inertia of the oceans, only 50-90% of the eventual equilibrium temperature change would have been realised by 2100 and temperature would continue to increase beyond 2100, even if concentrations of greenhouse gases were stabilised by that time.

(10)

- Average sea level is expected to rise as a result of thermal expansion of the oceans and melting of glaciers and ice-sheets. For the IS92a scenario, assuming the "best estimate" values of climate sensitivity and of ice melt sensitivity to warming, and including the effects of future changes in aerosol, models project an increase in sea level of about 50 cm from the present to 2100. This estimate is approximately 25% lower than the "best estimate" in 1990 due to the lower temperature projection, but also reflecting improvements in the climate and ice melt models. Combining the lowest emission scenario (IS92c) with the "low" climate and ice melt sensitivities and including aerosol effects gives a projected sea level rise of about 15 cm from the present to 2100. The corresponding projection for the highest emission scenario (IS92e) combined with "high" climate and ice-melt sensitivities gives a sea level rise of about 95 cm from the present to 2100. Sea level would continue to rise at a similar rate in future centuries beyond 2100, even if concentrations of greenhouse gases were stabilised by that time, and would continue to do so even beyond the time of stabilisation of global mean temperature. R sea level changes may differ from the glob value owing to land movement and ocean changes.

- Confidence is higher in the hemisphe continental scale projections of coupled atm ocean climate models than in the r projections, where confidence remains low. more confidence in temperature projectio hydrological changes.

- All model simulations, whether they were with increased concentrations of greenhou and aerosols or with increased concentrat greenhouse gases alone, show the following greater surface warming of the land than of t winter; a maximum surface warming in high latitudes in winter, little surface warming Arctic in summer; an enhanced globa hydrological cycle, and increased precipita soil moisture in high latitudes in winter. A changes are associated with identifiable mechanisms.

- In addition, most simulations show a reducti strength of the north Atlantic therm circulation and a widespread reduction in range of temperature. These features too explained in terms of identifiable p mechanisms.

- The direct and indirect effects of anthro aerosols have an important effect on the pro Generally, the magnitudes of the tempera precipitation changes are smaller when effects are represented, especially in northe latitudes. Note that the cooling effect of ae not a simple offset to the warming e greenhouse gases, but significantly affects the continental scale patterns of climate chan noticeably in the summer hemisphere. For models that consider only the effects of gre gases generally project an increase in prec and soil moisture in the Asian summer n region, whereas models that include, in a some of the effects of aerosols suggest that precipitation may decrease. The spatial and distribution of aerosols greatly influence projections, which are therefore more uncert accompany or are the result of temperature changes—precipitation, water levels, extremes of droughts or freezes, and thresholds like the freezing point or the level of dikes and levees—will drive the socioeconomic impacts. Mean temperature is chosen because it is a useful *index* of climate change that is highly correlated with or determines the more important variables. Moreover, it must be emphasized that impact studies are in their infancy and that studies of low-income regions are virtually nonexistent.

Existing research uses a wide variety of approaches including time-series analysis, engineering studies, and historical analogs. Climate change is likely to have different effects on different sectors and in different countries. In general, those sectors of the economy that depend heavily on unmanaged ecosystems—that is, are heavily dependent upon naturally occurring rainfall, runoff, or temperature—will be most sensitive to climate change. Agriculture, forestry, outdoor recreation, and coastal activities fall in this category. Countries like Japan or the United States are relatively insulated from climate change while developing countries like India are more vulnerable.

At present, there are few estimates of the impacts, and these generally concentrate on advanced industrial countries. The estimates used here are presented as extremely tentative, order-of-magnitude figures; we expect that these will be improved considerably in the coming years as researchers focus more attention on the impacts of climate change.

(1) plus see following page

Current analyses generally estimate the impact of climate change on a country or region at a particular time; studies typically focus on the impacts of a CO_2 doubling or on a 2.5 or 3°C rise in temperature. This section draws upon impact estimates, but additionally presents a technique for estimating the impact of climate changes over time as a function of the composition of output and of the impacts of climate change by sector. The estimates rely upon studies of impacts by sector for the United States and then apply them to different countries as a function of the projected future industrial compositions.

Impact by Sector: Methods

The basic framework is that damages in each country are a function of the sectoral composition of national output and the extent of climate change. More specifically, assume that output in sector i of country j

adaptation. For the issue of species loss, Cline takes a very costly decision (that of the spotted owl) and uses that as the basis for valuation.

Even with a generally pessimistic cast, Cline's estimates of impacts (1) are only marginally above those used here at the low end (1.1 percent F = C × 1.8 of GNP for a 2.5°C warming in Cline 1992 as opposed to 1 percent of GNP for a 3°C warming in Nordhaus 1991c); and marginally lower (3) than those used here for warming of 5°C and more.

A second study is a survey of different analyses by Fankhauser (1993). This study uses much the same methodology as those of Nordhaus and Cline but relies on additional studies and extends the analysis to the OECD countries and to the world. Fankhauser's results are also close to those used here, finding a 1.3 percent impact of a 3°C warming for the United States and a 1.5 percent impact for the world.

A third study uses a completely different approach but applies only to marketed output in the United States. This approach uses hedonic methods, examining the impact of climate variables cross sectionally on agriculture (in Mendelsohn, Nordhaus, and Shaw 1993, 1994). The results of the hedonic approach are to suggest that the impact of climate change on U.S. GNP (including only marketed sectors) is negligible.

A final estimate, more judgmental in nature, is a survey of experts conducted by the present author. Because estimating the impacts of climate change has proven extremely difficult, the present author has undertaken a survey of experts on the economic impacts of climate change on human and nonhuman systems. For scenario A, which is a 3°C warming in 2090, the "trimmed mean" of the survey is a decline of 2.9 percent of world output, while the median is 1.9 percent of gross world product (GWP). Those who have written on the impacts of global warming ("authors") as well as those who have undertaken empirical studies on the economic impacts ("researchers") have markedly lower estimates of the best guess, 1.6 and 1.8 percent, respectively. For the larger warming scenario of 6°C in 2175, the trimmed mean of experts is for an impact of 6.1 percent of global output, with the median cost of 4.5 percent. These estimates are higher than the numbers used in the DICE model for modest warming but are close to the estimates used here for the larger warming scenario. One major concern of most respondents is that the impact is thought to be considerably higher for low-income countries than for high-income countries.

A difficulty seen in many studies of climate change is that people look for problems and ignore opportunities; it is as if there exists an

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Table 4.3
Comparison of estimates of impact of global warming: Impact on incomes of CO_2 doubling (in billions of 1988 U.S. dollars and percent of total output)

	United States				Global		
	Nordhaus	Cline	Fankhauser	Other	Fankhauser	Other	DICE Model
Heavily affected sectors							
Agriculture	1	15.2	7.4	1.2[b]	39.1	12.0[b]	
Coastal areas	10.7	2.5	2.3				
Energy	0.5	9	0				
Other sectors	38.1						
Wetland and species loss	[a]	7.1	14.8				
Health and amenity	[a]	8.4	30.3				
Other	[a]	11.2	12.1				
Total							
Billions of $	50.3	53.4	66.9				
Percent of output	1.0	1.1	1.3		1.5	1.9[c]	1.33[d]

Sources: Nordhaus 1991c, Cline 1992a, Fankhauser 1993.
Notes:
a. These are included in the total for "other sectors."
b. From Reilly and Hohmann 1993, with full adaptation and CO_2 fertilization.
c. The median response for the 50th percentile of outcomes from a survey of experts (Nordhaus 1994).
d. See table 4.2.

sectors than does Nordhaus. While Cline's discussion encompasses a number of different findings, many of the extensions outside of the marketed sectors are extremely tenuous and his central estimates tend to rely on studies that may lean toward overestimating the impacts. For example, Cline's estimates of the impact of losses from storms assume that storms become more severe whereas both the IPCC and the National Academy studies concluded that the effect of warming on storm intensity is ambiguous.[5] Another example is leisure activities, where he includes losses to skiing but excludes any gains from the much larger warm weather industries such as camping. For agriculture, Cline's central estimate relies on studies that allow for little or no

5. See IPCC 1990, 155, and NAS 1992.

RANDY LUTTER

Managing the Global Commons:

The Economics of Climate Change

William D. Nordhaus

The MIT Press
Cambridge, Massachusetts
London, England

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THE REGIONAL IMPACTS OF CLIMATE CHANGE

An Assessment of Vulnerability

Intergovernmental Panel on Climate Change

EXECUTIVE SUMMARY

Main Points

- The Arctic is extremely vulnerable to projected climate change and its impacts. Over the period of this assessment, climate change is expected to contribute to major physical, ecological, sociological, and economic changes already begun in the Arctic. Because of a variety of positive feedback mechanisms, the Arctic is likely to respond to climate change rapidly and more severely than any other area on earth. The most direct and pronounced changes to the Arctic are likely to include changes in temperature and precipitation, with subsequent effects on sea ice and permafrost. Much smaller changes are likely for the Antarctic over the period of this assessment. The Antarctic is likely to respond relatively slowly to climate change.
- Substantial loss of sea ice is expected in the Arctic Ocean. If there is more open water, there will be impacts on the climate system of northern countries as temperatures moderate and precipitation increases. If warming occurs, there will be considerable thawing of permafrost—leading to changes in drainage, increased slumping, and altered landscapes over large areas.
- Polar warming probably should increase biological production but may lead to different species composition on land and in the sea. On land, there will be a tendency for poleward shifts in major biomes and associated animals. However, the Arctic Ocean geographically limits movement of the tundra, taiga, and boreal forest. In the sea, marine ecosystems will move poleward. Animals dependent on ice may be disadvantaged.
- Changes in the polar climate are likely to affect the rest of the world through increased sea levels from melting of the cryosphere, increased warming of lower latitudes from slowing of oceanic transport of heat, and increased greenhouse gas levels through carbon dioxide and methane emissions in the Arctic. 15
- Human communities in the Arctic will be affected by these physical and ecological changes. The effects will be particularly important for indigenous peoples leading traditional lifestyles.
- There will be economic benefits and costs. Benefits include new opportunities for shipping across the Arctic Ocean, lower operational costs for the oil and gas industry, lower heating costs, and easier access for tourism. Increased costs can be expected from several sources, including disruptions caused by thawing of permafrost and reduced transportation capabilities across frozen ground and water. Sea-ice changes in the Arctic have major strategic implications for trade and defense.

Document Summary

- **Regional Climate.** Cold is the overwhelming characteristic of polar regions, with nine months of snow, ice, cold, and relative darkness. In the Arctic, there are only a few weeks of thaw, when much of the ground is boggy and awash with water. There also are episodes of extreme cold and storms. In Antarctica, temperatures mostly remain below freezing.
- **Climate Trends.** Parts of the Arctic and Antarctic have warmed over the past half-century, while some parts appear to have cooled. Precipitation seems higher. Trends in the overall ice balance of the world's major ice sheets in Greenland and Antarctica are uncertain. There is conflicting information on changes in the thickness and extent of sea ice globally. Ice seems to be thinning in the Arctic but not in the Antarctic.
- **Vulnerability and Impacts.** Systems in the Arctic and Antarctic Peninsula are extremely sensitive to temperature. The primary impacts will be on the physical environment, biota and ecosystems, and human activities. The Arctic Ocean has strong sensitivity to temperature because its exposed areal extent grows and shrinks by as much as 50% within a single year. Interannual variability in sea ice similarly shows extreme sensitivity to temperature. The Arctic terrestrial system, primarily based on permafrost, also is very sensitive to temperature because much of the permafrost is currently discontinuous. Strong positive feedback mechanisms within the Arctic suggest that climate change is likely to be more severe in the Arctic than in the rest of the world.
- **Terrestrial Ecological Systems.** Climate change may occur at a rapid rate relative to forest migration ability. If there is warming, there will be a poleward migration of the northern treeline. However, geographic limitations may restrict the migration of the boreal forest. If warming occurs and the forest cover changes, there will be major impacts on biological resources (e.g., bears, caribou, small mammals, amphibians, and insects). The effects of climate change have not been deeply investigated in the Antarctic terrestrial ecosystem, but its distribution and specific composition could be altered by global warming.
- **Marine Ecological Systems.** In general, productivity should rise. Warming should increase growth and development rates of nonmammals; however, ultraviolet-B (UV-B) radiation is still increasing, which may constrain primary productivity as well as fish productivity. Additional risks include the loss of sea-ice cover, upon which several marine mammals depend for food and protection. Also,

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minal date for the planning period. The central point is that, with much greater warming over this very long horizon, economic damages could be far higher, and thus the case for preventive action is stronger than might be suggested by focusing on the usual benchmark of a doubling of carbon dioxide.

Catastrophe Scenarios

There are several possible ways in which global warming might bring catastrophic damage rather than moderate progressive decay. One possibility is that the release of carbon dioxide stored in methane clathrates submerged along continental shelves and in permafrost could cause massive positive feedback not incorporated in the GCMS. The clathrate is a crystal structure in cold water, in which ice-lattice forms cages that entrap gas molecules. Methane clathrates are stable in cold ocean sediments at depths of about 250 meters. These structures can become destabilized, however, as the result of warming or reduced pressure. MacDonald (1990a) has estimated that some 11,000 GtC is stored in ocean clathrates, and another 400 GtC in permafrost.

15

The amount of carbon in methane clathrates is thus on the same order of magnitude as that in all coal reserves (7,000 to 14,000 GtC; chapter 2). The release of a significant portion of the methane in clathrates as a consequence of global warming could cause a massive positive feedback that would contribute to still more warming.[25] Revelle (1983a, 257–59) has calculated that, for the warming associated with a doubling of carbon dioxide equivalent (e.g., 2°C to 3°C), clathrate destabilization could release enough methane to increase atmospheric concentrations by two-thirds to four-thirds, with a corresponding additional warming effect of 0.65°C to 1.8°C. In view of the scope for much higher global warming over two to three centuries (chapter 2), the amount of induced warming and thus positive feedback from this source could be expected to multiply severalfold.

Another possible source of catastrophe is the disintegration of the West Antarctic ice sheet, which would release some 2 million km^3 of ice into the sea before the remainder began to float. This phenomenon could cause mean sea

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25. Moreover, the greenhouse effect of methane (including its indirectly formed water vapor) is about 20 times as powerful as that of carbon dioxide over a time scale of 100 years and 9 times as powerful on a time scale of 500 years (IPCC 1990b, table 2.8, 64). As the molecular weight of carbon dioxide (CO_2) is 44 atomic units (hydrogen = 1) whereas that of methane (CH_4) is 16, the total potential mass of methane in the clathrate store is approximately one-third that of potential carbon dioxide emissions held in coal resources. The implication is that there is on the order of five (15/3) times as much greenhouse gas potential in methane clathrates as in fossil fuel reserves (which are mainly coal). Note, however, that clathrate destabilization would occur over a much longer time horizon.

CLIMATE CHANGE 1995

Impacts, Adaptations and Mitigation of Climate Change: Scientific-Technical Analyses

WMO

Contribution of Working Group II to the Second Assessment Report of the Intergovernmental Panel on Climate Change

UNEP

latitudes within the present-day zones of the tundra and boreal forest. With a rise in temperature of 1°C, the permafrost would be partially preserved to the east of the Pechora river. In the south of Yamal and Gydan, discontinuous permafrost would prevail. Continuous permafrost would be restricted to north of 70°N. It would remain to the east of the Yenisey at the same latitudes. The active layer of fine-grained soils could increase by 20–30 cm. With a temperature rise of 2°C, continuous permafrost would disappear in the north of Europe. From the Lower Ob to the Lower Hatanga, as well as in the Anadyr lowland, only island and discontinuous permafrost would survive. Continuous permafrost would exist only in the lowlands of the Taimyr Peninsula, Lena, lower Kolyma, and lower Indigirka basins. The stratum of seasonal thawing would increase by 40–50 cm. These changes will result in the activation of solifluction, thermokarst and thermoerosion processes, an increase in bogs, and alterations to large tracts of vegetation—which in turn will alter food sources for traditional tundra species within permafrost areas.

Other mathematical models assess permafrost dynamics during warming (MacInnes *et al.*, 1990; Burgess and Riseborough, 1990; Romanovsky, Maximova, and Seregina, 1991; Romanovsky, Garagula, and Seregina, 1991; Osterkamp and Gosink, 1991; Nixon and Taylor, 1994; Nixon *et al.*, 1995). Changes in permafrost temperatures and thaw depths under an increase in annual average air temperatures of 2 and 4°C are simulated by Vyalov *et al.* (1993). Results indicate that warming in the tundra will produce a slight increase in thawing depths, with no radical changes in permafrost conditions. Further south, more marked effects could occur—with a shift to discontinuous permafrost, formation of taliks, and degradation of ground ice. If warming is long-lasting, the permafrost line would recede northward by 500 km along 70°E longitude and by 1,200 km along 100°E longitude. Given an average thawing rate of 100 mm/yr, thawing of the upper 10 m would take a century. Lower limits of permafrost in mountain areas could rise by several hundred meters, although this is dependent on future snow depths (Hoelzle and Haeberli, 1995). Owing to the slow reaction of thermal conditions at depth, pronounced disequilibria are most likely to result over extended time periods and wide areas.

Ice-saturated permafrost forms an impervious layer to deep infiltration of water, maintaining high water tables and poorly aerated soils. Significant increases in active layer depth or loss of permafrost is expected to cause drying of upper soil layers in most regions, as well as enhanced decomposition of soil organic matter. Loss of a sizable portion of more than 50 Gt of carbon in Arctic soils and 450 Gt of carbon in soils of all tundra ecosystems could cause an appreciable positive feedback on the atmospheric rise of carbon dioxide. Marion and Oechel (1993) have examined Holocene rates of soil carbon change along a latitudinal transect across arctic Alaska and conclude that arctic areas will continue to act as a small sink for carbon.

Recent warming and drying apparently have shifted arctic ecosystems from carbon sequestration (as occurred during the Holocene and historical past) to carbon dioxide loss to the atmosphere (Oechel *et al.*, 1993). Estimates of present losses of carbon dioxide from arctic terrestrial ecosystems to the atmosphere range from 0.2 Gt of carbon (Oechel *et al.*, 1993) to much higher values in winter for the Russian Arctic (Zimov *et al.*, 1993; Kolchugina and Vinson, 1993). Malmer (1992) estimates that about 25% or less of the carbon may be released in the form of methane (CH_4). A climatic shift to warmer temperatures in the future would increase the release of CH_4 from deep peat deposits, particularly from tundra soils. It is expected that the release of CO_2 would increase, though not by more than 25% of its present level (Malmer, 1992). Wetter soils could lead to increased methane loss, and a drier tundra might become a sink for atmospheric methane (Christensen, 1991, 1993; Fukuda, 1994).

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Large amounts of natural gas—mostly methane—are stored in the form of gas hydrates, although their distribution is not well known. In the Canadian Arctic Islands and Beaufort-Mackenzie region, analysis of thermal and geophysical logs indicates that 2–4 x 10^3 Gt of methane is stored as hydrates. Decomposition is occurring presently beneath the shelves of the Arctic Ocean in response to the increase of surface temperatures accompanying the recent marine transgression. For the Beaufort Shelf, an estimated 10^5 m^3/km^2 may decompose over the next century (Judge and Majorowicz, 1992; Judge *et al.*, 1994).

There are very few data for the methane content of permafrost itself. Samples obtained near Fairbanks (Kvenvolden and Lorenson, 1993) and the Prudhoe Bay area (Moraes and Khalil, 1993; Rasmussen *et al.*, 1993) suggest substantial variability. Dallimore and Collett (1995) found high methane concentrations in ice-bonded sediments and gas releases suggest that pore-space hydrate may be found at depths as shallow as 119 m. This raises the possibility that gas hydrates could occur at much shallower depth and be more rapidly influenced by climate change than previously thought. Fukuda (1994) estimates methane emissions from melting ground ice in northern Siberia cover the range 2–10 Mt/yr.

7.4.4. River and Lake Ice

Under conditions of overall annual warming, the duration of river-ice cover would be reduced through a delay in the timing of freeze-up and an advancement of break-up (Gray and Prowse, 1993). For freeze-up, higher water and air temperatures in the autumn would combine to delay the time of first ice formation and eventual freeze-up. If there also is a reduction in the rate of autumn cooling, the interval between these two events also will increase. The frequency and magnitude of major frazil-ice growth periods could be reduced. This may alter the types of ice that constitute the freeze-up cover and has implications for hydrotechnical problems associated with particular ice forms.

Many rivers within temperate regions would tend to become ice-free or develop only intermittent or partial ice coverage. Ice

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(16)

from climate models suggests that some types of climate change may lead to changes in ocean currents, including displacement of the Gulf Stream that warms Western Europe. Evidence from ocean core samples suggests such changes of ocean currents have occurred in previous ice ages. changed

To what extent are we willing to take such chances with our planet? There is a strong argument for the Kyoto Protocol as a form of planet insurance. But what numerical weight should one assign to these catastrophic risks? In other words, what is the value of the insurance policy? Although it is difficult for an economist, or anyone, to know, reductions in the risk of such catastrophic outcomes must be considered in addition to the costs and benefits that can be reasonably quantifiable. Since human beings are typically averse to risk, such catastrophic risks are especially important in evaluating whether the benefits of a particular climate control policy justify the costs. One must have at least some sympathy with those who criticize economists on the grounds that the effects of climate change are extremely difficult to quantify in a single monetary number. NF

III. Addressing Global Climate Change in an Efficient Manner

The costs of unabated climate change may thus be difficult to quantify, but they are nonetheless real and provide the motivation for reducing greenhouse gas emissions. In taking action to reduce those emissions, economic analysis suggests that two elements are absolutely essential: NZ

- The effort must be global, to address the global externality inherent in the nature of the problem. NF
- The effort must be flexible and market-based, to ensure that we achieve our objectives in the most efficient manner possible. NF

Need for Global Action

(17) Climate change is a global problem requiring a global solution. As I mentioned earlier, no single country has an incentive to reduce emissions sufficiently to protect the global environment against climate change. [Each has an economic incentive to "free ride" on the efforts of others.] Even if the United States sharply reduced its emissions unilaterally without an international agreement limiting emissions abroad, greenhouse gas emissions from all other countries would continue to grow, and the risks posed by climate change would not be significantly reduced. It is important to emphasize that emissions of different gases anyplace in the world have very similar effects on global climate. ERP

follows from previous statement

(18) The threat of disruptive climate change has led to coordinated international efforts to reduce the risks of global warming by reducing emissions of greenhouse gases. A landmark international agreement to address global warming was the Framework Convention on Climate Change signed during the Earth Summit in Rio de Janeiro in 1992. This convention established an objective of limiting greenhouse gas concentrations and called upon industrial countries to ERP

See next page...

industrial facilities such as the Prudhoe Bay oilfields in Alaska. Sea-level rise also will allow ice-thrust events to be more damaging to the shoreline. Coastal permafrost will be thermally eroded, which will produce local slumping and coastal retreat.

Episodes of extreme cold and blizzards are major climate concerns for circumpolar countries like Russia and Canada (IPCC 1996, WG II, Section 12.4.2.5). However, the Polar regions will remain cold, so the direct effects of global warming are likely to have little effect on human health. Potential indirect effects, such as changes in infectious diseases and vector organisms, are largely unknown. UV-B radiation is increasing, which can damage the genetic (DNA) material of living cells (in an inverse relationship to organism complexity) and induce skin cancers in experimental animals. It also may affect human health: UV-B radiation is implicated in the causation of human skin cancer and lesions of the conjunctiva, cornea, and lens; it also may impair the body's immune system (IPCC 1996, WG II, Section 18.4).

3.4. Integrated Analysis of Potential Vulnerabilities and Impacts and Future Research Needs

Individual sectors and resources will not be affected in isolation but in interaction with one another. The direct effects of climate change include shifts in geographic distribution of ecosystems, changes in sea and river ice, thaw of permafrost, and changes in coastal areas. Indirect effects include feedbacks to the climate system through less ice and snow reflectivity, changes in sea ice and ocean circulation, and ecological sources and sinks of CO_2 and CH_4. Improvements are needed in modeling of future sea-ice distribution and thickness because of their importance as drivers for other physical and ecological systems, economics, and transportation. There is uncertainty about whether changes in tundra will cause it to act as a source or a sink for CO_2. This issue needs to be resolved. 16

There is a variety of positive and negative shifts in opportunities for shipping, the oil industry, fishing, mining, and tourism, as well as coastal infrastructure and the movement of populations. These impacts will lead to further interactions and potential changes in trade and strategic balance. The health consequences of these shifts will depend on human capacity to adapt.

The Arctic is more vulnerable than the Antarctic because of its sensitive and fragile ecosystems and the impacts on traditional lifestyles of indigenous peoples and because climate changes are expected to be greater. An integrated impact assessment using multiple stress models is required for the Arctic. When associated with baseline monitoring, it should be possible to distinguish natural variability from human impacts.

Further analysis should focus on particularly sensitive zones and activities, vulnerable species, marginal communities, and estimates of economic impacts. To improve biological components of regional and global models, it is important to understand how, when, and where productivity in the Southern Ocean will change with global warming (IPCC 1996, WG II, Section 8.3.2). More certainty is required regarding the future behavior of the marine-based West Antarctic Ice Sheet and ice balance of the continent. Changes have the potential to substantially alter sea level and southern hemispheric climate, but the time frame needs to be defined.

Most human and natural systems in the Arctic and the Antarctic Peninsula are extremely sensitive to temperature. Future global warming is expected to be greatest in these areas. Large reductions in sea ice, permafrost, and tundra will disrupt many natural systems and change species composition over land and in the polar oceans. These areas appear to be vulnerable to climate change, although the number of people directly affected would be relatively small. However, most are indigenous people, who lead traditional lifestyles and have few adaptive strategies that can be implemented. Antarctica is less vulnerable because the temperature changes envisioned over the next century are likely to have little impact, and few people are involved.

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IAATO, 1997: *Overview of Antarctic tourism activities: A summary of 1996–1998 and five year projection 1997– 2002*. XXI ATCM/IP75, May 1997, Christchurch, New Zealand.

IPCC, 1996. *Climate Change 1995: The Science of Climate Change. Contribution of Working Group I to the Second Assessment Report for the Intergovernmental Panel on Climate Change* [Houghton, J.J., L.G. Meiro

level to rise by five to six meters (Revelle 1983b, 442). An increase of this amount would be sufficient to inundate approximately 30 percent of the land area of Florida and Louisiana; 15 percent to 20 percent of Maryland, the District of Columbia, and Delaware; 8 percent to 10 percent of the Carolinas and New Jersey; and as much as 7 percent of Rhode Island and Washington state (Schneider and Chen 1980). Port facilities worldwide would be flooded, as would other low-lying coastal structures. Bentley (as cited in Revelle 1983b, 444) has estimated that disintegration of the West Antarctic ice sheet could occur within 300 to 500 years as a consequence of global warming. Although this prospect is not considered likely under "a typical greenhouse warming scenario" (IPCC 1990b, section 9.4.6), it would presumably become a considerably greater risk with the much larger amount of global warming that could occur over a horizon of some 250 years (see chapter 2 of this study).

Still another potential catastrophic effect is that the melting of ice could change the salinity of the North Atlantic, altering the Pacific-Atlantic salinity differential and disrupting the "deep ocean conveyor" that brings an upwelling of waters from, and the sinking of water into, the deep ocean between Iceland and Greenland. Such an event would completely alter world weather patterns and ocean currents.[26] 16

Beyond these potential catastrophe scenarios, which have already been the subject of scientific analysis and debate, there could well be serious adverse surprises from global warming from phenomena not yet suspected. The experience of ozone depletion serves as a warning about the risk of adverse surprise. Depletion of stratospheric ozone has occurred much faster than scientists had predicted, largely because their calculations failed to take into account "heterogeneous chemistry"—the influence of particle surfaces on chemical reactions as opposed to processes for homogeneously mixed gases.[27] As a result, governments have been forced to adopt steeper cutbacks of CFCS by earlier target dates.

Unavoidable Warming

Because of the buildup in atmospheric concentrations of carbon dioxide and other greenhouse gases that has already taken place, the earth is already committed to some warming now in the pipeline even if all man-made emissions were to stop virtually immediately. The IPCC estimates that total radiative forcing from 1765 through the year 2000 will have amounted to 2.95 wm^{-2}. Applying

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26. Rob Coppock of the National Academy of Sciences, speaking at a study group session at the Institute for International Economics, Washington, 29 July 1991.

27. Mack McFarland, speaking at a conference on "Assessing Climate Change Risks," sponsored by Resources for the Future, Washington, 23–24 March 1992.

Box 8-1. Ocean Conveyor Belt

The "conveyor belt" global thermohaline circulation is driven primarily by the formation and sinking of deep water (from 1500 m to the Antarctic bottom water overlying the bottom of the ocean) in the Norwegian Sea (Figure 8-1; Broecker, 1991). This circulation is thought to be responsible for the large flow of upper ocean water from the tropical Pacific to the Indian Ocean through the Indonesian Archipelago—the Indonesian Throughflow (e.g., Broecker, 1991).

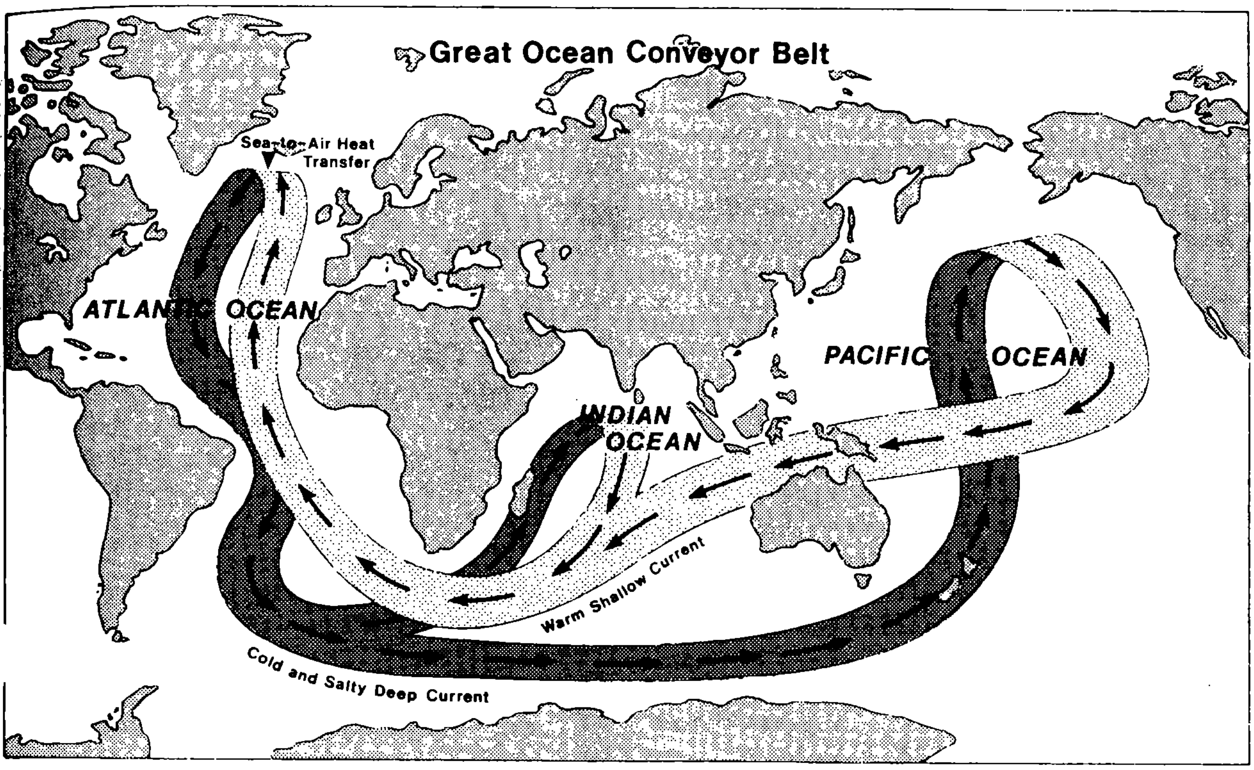

Figure 8-1: Ocean conveyor belt (after Broecker, 1991).

The global conveyor belt thermohaline circulation is controlled by two counteracting forcings operating in the North Atlantic. The *thermal forcing* (high-latitude cooling and low-latitude heating) drives a poleward surface flow, and the *haline forcing* (net high-latitude freshwater gain and low-latitude evaporation) moves in the opposite direction. In today's North Atlantic, the thermal forcing dominates. When the strength of the haline forcing increases due to excess precipitation, runoff, and/or ice melt, the conveyor belt will weaken (i.e., decrease in both poleward warm surface flow and deep-water formation) or even shut down. The variability in the strength of the conveyor belt will lead to climate change in Europe. Climatic variation in other parts of the global ocean also may be influenced by the variability of the conveyor belt (e.g., Gordon *et al.*, 1992; Lehman, 1993). Numerical simulations of global ocean circulation show that small changes in the external forcing at high latitudes can switch off the present conveyor belt and force the ocean to reach another equilibrium state, in which the Antarctic Circumpolar Front represents the sole deep-water source (e.g., Maier-Reimer *et al.*, 1993).

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The North Atlantic atmosphere-ocean-cryosphere system appears to have natural cycles of many timescales in switching the conveyor belt. In these cycles, sea ice plays a pivotal role. Periodic movement of excessive sea ice from the Arctic into the Greenland Sea appears to be responsible for the interdecadal variability of the conveyor belt (Mysak *et al.*, 1990), characterized by the freshening of the intermediate water (Dickson *et al.*, 1988). There is no evidence yet that the influx of interdecadal switching extends beyond the North Atlantic Ocean.

'eorecords show that 10,000 to 80,000 years ago there were millennial oscillations of several degrees of the sea-ace temperature in the North Atlantic (Bond *et al.*, 1993; Figure 8-2), with abrupt temperature shifts in decadal umescales (Taylor *et al.*, 1992). Interaction between the warm ocean surface current and the Scandinavian ice sheets is

preindustrial times. Of these, CO_2 is the most important: net cumulative CO_2 emissions resulting from the burning of fossil fuels and deforestation account for about two-thirds of potential warming from changes in greenhouse gas concentrations related to human activity. If growth in global emissions continues unabated, the atmospheric concentration of CO_2 will likely double, relative to its preindustrial level, midway through the next century.

The accumulation of greenhouse gases poses significant risks to the world's climate and to human well-being. Potential impacts include a rise in sea levels, greater frequency of severe weather events, shifts in agricultural growing conditions from changing weather patterns, threats to human health from increased range and incidence of diseases, changes in availability of freshwater supplies, and damage to ecosystems and biodiversity.

Climate change is a complex, long-term problem requiring global cooperation and a long-term solution. No single country has an incen-
17 tive to reduce emissions sufficiently to protect the global environment against climate change. Even if the United States sharply reduced its emissions unilaterally, greenhouse gas emissions from all other countries would continue to grow, and the risks posed by climate change would not be significantly abated. Since many of these gases remain in the atmosphere for a century or more, the climatic effects of actions taken today will primarily benefit future generations. But delaying action to reduce greenhouse gas emissions until the disruptive effects of climate change become widespread will considerably reduce the options for remedial or preventive measures.

The Framework Convention on Climate Change

The threat of disruptive climate change has led to coordinated international efforts to reduce the risks of global warming by reducing emissions of greenhouse gases. The first international agreement to address global warming was the Framework Convention on
18 Climate Change signed during the Earth Summit in Rio de Janeiro in 1992. This convention established a long-term objective of limiting greenhouse gas concentrations and encouraged the established industrial countries to return their emissions to 1990 levels by 2000. Since then it has become clear that the United States and many other participating countries will not meet this goal.

To address the lack of progress among many industrial countries toward meeting this first target, the United States and approximately 159 other nations, in negotiations held in Kyoto, Japan, last December, agreed to take substantial steps to stabilize atmospheric concentrations of greenhouse gases. The Kyoto agreement, which requires the advice and consent of the Senate, would place binding limits on industrial countries' emissions of the six principal categories of greenhouse gases: CO_2, methane, N_2O, sulfur hexafluoride, perfluorocarbons, and hydrofluorocarbons. Each industrial country's "1990

Clinton Presidential Records
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return their emissions to 1990 levels by 2000. Since then, it has become clear that the United States and many other participating countries will not meet this voluntary goal; quite the contrary, emission levels have continued to rise not fall among both developed and developing countries.

(19) [To address the lack of progress among many industrialized countries toward meeting the Rio objective, the United States and approximately 160 other nations agreed in negotiations held in Kyoto, Japan, last December, to reduce emissions of greenhouse gases. The Kyoto Protocol, which requires the advice and consent of the Senate, would place binding limits on each industrial country's combined emissions of the six principal categories of greenhouse gases: CO2, N2O, methane, sulfur hexafluoride, perfluorocarbons, and hydrofluorocarbons.] [These limits apply to the 38 so-called Annex I countries, which are the industrialized countries, defined to include Russia, Ukraine, and most Eastern European countries.] (20) ERP?

? Kyoto fixes but need "industrialized" explicitly [illegible]

(21) Under the Kyoto Protocol, each industrial country's baseline is its 1990 emissions of CO2, methane, and N2O and its choice of 1990 or 1995 levels of the other three categories of gases. The United States agreed to a target of 7 percent below this baseline by the period between 2008 and 2012. (22) Given the changes in the definition of the baseline for the three long-lived chemical compounds (HFCs, PFCs and SF6) from 1990 to 1995 combined with a change in the way sinks are accounted for in the baseline, the actual reduction required in the U.S. is no more than 2-3% more than the President originally proposed as the U.S. negotiating position. The targets for the European Union and Japan are 8 percent and 6 percent below 1990 levels, respectively. Australia, New Zealand, Norway, Russia and Ukraine all have limits somewhat less ambitious when phrased as cuts relative to their 1990 levels. In sum, over the period from 2008 to 2012, the industrial countries are expected to reduce their average emissions of greenhouse gases to about 5 percent below their 1990 levels. ERP ? Kyoto Fact Sheet (or ERP) ERP?

(23) [The President has made clear that he will not submit the Kyoto Protocol to the Senate without meaningful participation from key developing countries (who are not included in Annex I).] ERP?

(24) There are several reasons why meaningful participation from developing countries is essential. First, developing countries are projected to contribute a majority of world emissions around 2030 under a continuation of business-as-usual. (25) Without the participation of developing economies, efforts by the industrialized countries to limit emissions will therefore not provide adequate protection from climate change. ERP?

(26) Second, developing country participation is crucial because it would permit relatively low-cost emissions reductions to be internationally recognized as a substitute for more expensive emissions reductions that might otherwise be achieved domestically by U.S. companies and those in other industrialized countries. (27) Again, greenhouse gas emissions have the same basic impact on the climate regardless of where they occur. So reductions in developing countries have the same environmental benefit as reductions domestically. But these reductions are much less costly than reductions in the U.S. or in other developed nations, because of the very inefficient ERP?

again? this is the 1st explicit statement of this kind

preindustrial times. Of these, CO_2 is the most important: net cumulative CO_2 emissions resulting from the burning of fossil fuels and deforestation account for about two-thirds of potential warming from changes in greenhouse gas concentrations related to human activity. If growth in global emissions continues unabated, the atmospheric concentration of CO_2 will likely double, relative to its preindustrial level, midway through the next century.

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Climate change is a complex, long-term problem requiring global cooperation and a long-term solution. No single country has an incentive to reduce emissions sufficiently to protect the global environment against climate change. Even if the United States sharply reduced its emissions unilaterally, greenhouse gas emissions from all other countries would continue to grow, and the risks posed by climate change would not be significantly abated. Since many of these gases remain in the atmosphere for a century or more, the climatic effects of actions taken today will primarily benefit future generations. But delaying action to reduce greenhouse gas emissions until the disruptive effects of climate change become widespread will considerably reduce the options for remedial or preventive measures.

The Framework Convention on Climate Change

The threat of disruptive climate change has led to coordinated international efforts to reduce the risks of global warming by reducing emissions of greenhouse gases. The first international agreement to address global warming was the Framework Convention on Climate Change signed during the Earth Summit in Rio de Janeiro in 1992. This convention established a long-term objective of limiting greenhouse gas concentrations and encouraged the established industrial countries to return their emissions to 1990 levels by 2000. Since then it has become clear that the United States and many other participating countries will not meet this goal.

[To address the lack of progress among many industrial countries toward meeting this first target, the United States and approximately 159 other nations, in negotiations held in Kyoto, Japan, last December agreed to take substantial steps to stabilize atmospheric concentrations of greenhouse gases. The Kyoto agreement, which requires the advice and consent of the Senate, would place binding limits on industrial countries' emissions of the six principal categories of greenhouse gases: CO_2, methane, N_2O, sulfur hexafluoride, perfluorocarbons, and hydrofluorocarbons.] ~~Each industrial country's~~ 1990 the Parties serving as the meeting of the Parties to this Protocol shall, at its first session or as soon as practicable thereafter, consider ways to facilitate such cooperation, taking into account all relevant information.

2. The Parties included in Annex I shall pursue limitation or reduction of emissions of greenhouse gases not controlled by the Montreal Protocol from aviation and marine bunker fuels, working through the International Civil Aviation Organization and the International Maritime Organization, respectively.

3. The Parties included in Annex I shall strive to implement policies and measures under this Article in such a way as to minimize adverse effects, including the adverse effects of climate change, effects on international trade, and social, environmental and economic impacts on other Parties, especially developing country Parties and in particular those identified in Article 4, paragraphs 8 and 9, of the Convention, taking into account Article 3 of the Convention. The Conference of the Parties serving as the meeting of the Parties to this Protocol may take further action, as appropriate, to promote the implementation of the provisions of this paragraph.

4. The Conference of the Parties serving as the meeting of the Parties to this Protocol, if it decides that it would be beneficial to coordinate any of the policies and measures in paragraph 1(a) above, taking into account different national circumstances and potential effects, shall consider ways and means to elaborate the coordination of such policies and measures.

Article 3

1. The Parties included in Annex I shall, individually or jointly, ensure that their aggregate anthropogenic carbon dioxide equivalent emissions of the greenhouse gases listed in Annex A do not exceed their assigned amounts, calculated pursuant to their quantified emission limitation and reduction commitments inscribed in Annex B and in accordance with the provisions of this Article, with a view to reducing their overall emissions of such gases by at least 5 per cent below 1990 levels in the commitment period 2008 to 2012.

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and see next page

2. Each Party included in Annex I shall, by 2005, have made demonstrable progress in achieving its commitments under this Protocol.

3. The net changes in greenhouse gas emissions from sources and removals by sinks resulting from direct human-induced land-use change and forestry activities, limited to afforestation, reforestation and deforestation since 1990, measured as verifiable changes in carbon stocks in each commitment period, shall be used to meet the commitments under this Article of each Party included in Annex I. The greenhouse gas emissions by sources and removals by sinks associated with those activities shall be reported in a transparent and verifiable manner and reviewed in accordance with Articles 7 and 8.

4. Prior to the first session of the Conference of the Parties serving as the meeting of the Parties to this Protocol, each Party included in Annex I shall provide, for consideration by the Subsidiary Body for Scientific and Technological Advice, data to establish its level of carbon

Annex B

20

	Party	Quantified emission limitation or reduction commitment (percentage of base year or period)
1.	Australia	108
2.	Austria	92
3.	Belgium	92
4.	Bulgaria*	92
5.	Canada	94
6.	Croatia*	95
7.	Czech Republic*	92
8.	Denmark	92
9.	Estonia*	92
	European Community	92
10.	Finland	92
11.	France	92
12.	Germany	92
13.	Greece	92
14.	Hungary*	94
15.	Iceland	110
16.	Ireland	92
17.	Italy	92
18.	Japan	94
19.	Latvia*	92
20.	Liechtenstein	92
21.	Lithuania*	92
22.	Luxembourg	92
23.	Monaco	92
24.	Netherlands	92
25.	New Zealand	100
26.	Norway	101
27.	Poland*	94
28.	Portugal	92
29.	Romania*	92
30.	Russian Federation*	100
31.	Slovakia*	92
32.	Slovenia*	92
33.	Spain	92
34.	Sweden	92
35.	Switzerland	92
36.	Ukraine*	100
37.	United Kingdom of Great Britain and Northern Ireland	92
38.	United States of America	93

* Countries that are undergoing the process of transition to a market economy.

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preindustrial times. Of these, CO_2 is the most important: net cumulative CO_2 emissions resulting from the burning of fossil fuels and deforestation account for about two-thirds of potential warming from changes in greenhouse gas concentrations related to human activity. If growth in global emissions continues unabated, the atmospheric concentration of CO_2 will likely double, relative to its preindustrial level, midway through the next century.

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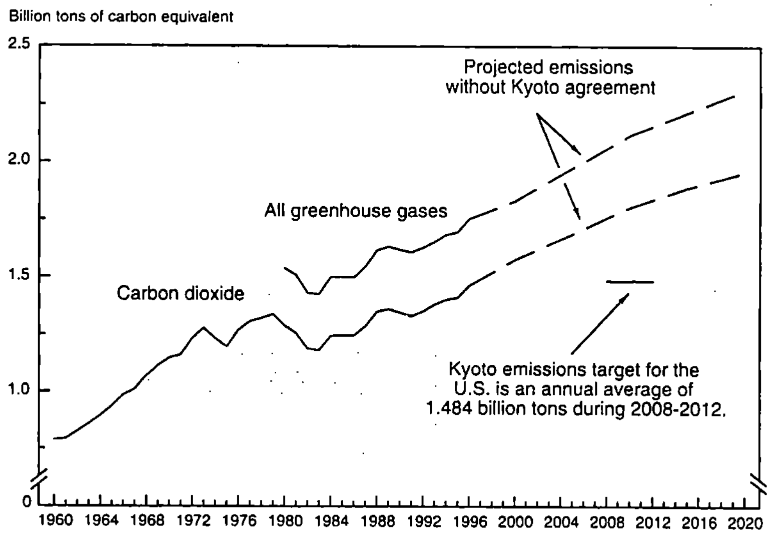
baseline" is actually based on its 1990 emissions of CO_2, methane, and N_2O and its choice of 1990 or 1995 levels of the other three categories of gases. The United States agreed to a target of 7 percent below 1990 levels over 2008-2012. To meet that target, net U.S. emissions of greenhouse gases—all emissions minus removals of CO_2 by certain forest activities such as planting trees—must average no more than 1,484 million metric tons of carbon equivalent per year during that period (Chart 5-4). The targets for the European Union and Japan are 8 percent and 6 percent below 1990 levels, respectively. Australia, New Zealand, Norway, Russia, and Ukraine all have less stringent limits. In sum, over the period from 2008 to 2012, the industrial countries are

Chart 5-4 **U.S. Greenhouse Gas Emissions, Actual and Projected**
The U.S. emissions target under the Kyoto agreement is about 25 percent below current projections in 2008-2012.



Notes: All greenhouse gases include carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride. Carbon equivalence is calculated assuming a global warming potential over a 100-year time horizon. Targets can be met through forest activities that remove carbon from the atmosphere and international permit purchases and credits in addition to domestic emissions reductions.
Sources: Department of Energy, United Nations Framework Convention on Climate Change, and U.S. Climate Action Report 1997.

expected to reduce their average emissions of greenhouse gases to about 5 percent below their 1990 levels.

The Kyoto agreement provides opportunities for the industrial countries to trade rights to emit greenhouse gases with each other. They may also invest in "clean development" projects in the developing world and use these projects' certified emissions reductions toward meeting their targets. Both of these mechanisms allow for emissions reductions to occur where they are least expensive. Many of the details of these provisions will be worked out in subsequent negotiations.

stabilize the amount of greenhouse gases in the atmosphere. Moreover, ~~some of the least-cost opportunities for reducing greenhouse gas emissions are in developing countries, because those countries now use energy relatively inefficiently.~~ Moreover, those that are industrializing rapidly have greater scope to build their industry around cleaner and more efficient energy technologies and fuels than do mature economies whose capital stock is already in place.

Failure to involve developing countries in an international agreement limiting greenhouse gas emissions could lead to a more rapid rate of increase in emissions in those countries than would occur without any agreement at all. This "leakage" effect of emissions reductions could come about in any of several ways. As industrial countries reduce their use of fossil fuels in response to emissions controls, future world oil and coal prices are likely to be lower than they would be otherwise. This is likely to increase energy consumption in countries not bound to limit their emissions. U.S. industries are also concerned about their international competitiveness if some countries remain outside an international agreement, since factories in those countries will face lower costs for producing goods that take relatively large amounts of energy to manufacture. Some may be concerned that energy-intensive industries might choose to relocate to countries not subject to emissions constraints, although there is little evidence to suggest that this would pose a significant problem in most industries. For example, energy costs for manufacturing industries average just 2.2 percent of total costs.

Given the projected growth of developing countries' emissions, the Administration's position is to seek meaningful participation by key developing countries in the reduction of greenhouse gas emissions as a condition for the United States taking on binding emissions reductions. The President has indicated he will not submit the Kyoto agreement for Senate ratification until there is meaningful participation by key developing countries.

23

Joint Implementation and the Clean Development Mechanism

To encourage participation by developing countries in the climate change initiative even before they formally sign on for binding emissions limits, the President has proposed a program known as joint implementation. This program would provide incentives to developing countries to reduce their emissions of CO_2 and other greenhouse gases. The Kyoto agreement embraces the President's proposal in its designation of a "clean development mechanism" (CDM): U.S. companies that undertake projects that reduce greenhouse gas emissions in developing countries could count those reductions to meet their commitments. Institutionalizing key elements of joint implementation through this mechanism would encourage firms in the United States to transfer a larger volume of cleaner and more energy-efficient technology to developing countries, especially in the electric power

8

The Kyoto Protocol on Climate Change
Fact Sheet

BACKGROUND

- At a conference held December 1-11, 1997 in Kyoto, Japan, the Parties to the UN Framework Convention on Climate Change agreed to an historic Protocol to reduce greenhouse gas emissions by harnessing the forces of the global marketplace to protect the environment.

- The Kyoto Protocol in key respects -- including emissions targets and timetables for industrialized nations and market-based measures for meeting those targets -- reflects proposals advanced by the United States. The Protocol makes a down payment on the meaningful participation of developing countries, but more needs to be done in this area. Securing meaningful developing country participation remains a core U.S. goal.

EMISSIONS TARGETS

- A central feature of the Kyoto Protocol is a set of binding emissions targets for developed nations. The specific limits vary from country to country, though those for the key industrial powers of the European Union, Japan, and the United States are similar -- 8% below 1990 emissions levels for the EU, 7% for the U.S., 6% for Japan.

- The framework for these emissions targets is based largely on U.S. proposals:

  - **Emissions targets are to be reached over a five-year budget period as proposed by the U.S., rather than by a single year.** Allowing emissions to be averaged across a budget period increases flexibility by helping to smooth out short-term fluctuations in economic performance or weather, either of which could spike emissions in a particular year.

  - **The first budget period will be the U.S. proposal of 2008-2012.** The Parties rejected proposals favored by others, including budget periods beginning as early as 2003, that were neither realistic nor achievable. Having a full decade before the start of the binding period will allow more time for U.S. companies to make the transition to greater energy efficiency and/or lower carbon technologies.

  - **The emissions targets include all six major greenhouse gases.** The EU and Japan initially favored counting only three gases -- carbon dioxide, methane, and nitrous oxide. Ensuring the inclusion of the additional gases (synthetic substitutes for ozone-depleting CFCs) that are highly potent and long-lasting in the atmosphere provides more comprehensive environmental protection and lends more certainty concerning the treatment of the additional gases.

- **Activities that absorb carbon, such as planting trees, will be offset against emissions targets.** The treatment of these so-called "sinks" was another controversial issue at Kyoto. Many countries wanted sinks to be excluded. The United States insisted that they be included in the interest of encouraging activities like afforestation and reforestation. Accounting for the role of forests is critical to a comprehensive and environmentally responsible approach to climate change. It also provides the private sector with low-cost opportunities to reduce emissions.

Is the target the United States agreed to actually 7% lower than what the President proposed in October?

No. The 7% target represents no more than a 3% real reduction below the President's initial proposal of reducing greenhouse gases to 1990 levels by 2008-2012. The remaining 4 percentage points result from certain changes in the way gases and sinks are calculated and do not reflect any increase in effort as compared to the President's original proposal.

- **Changing the baseline for the three synthetic greenhouse gases from 1990 to 1995 accounts for about 1% of the 7% reduction.** Use of these three gases has grown since 1990, so that permitting a 1995 baseline allows for a higher overall baseline than the Administration assumed last October when the President announced his goal of reaching 1990 levels by 2008-2012. Making reductions to meet a higher baseline is of course easier than making reductions to meet a lower baseline. Had the United States maintained the same level of effort assumed by the President in October, and no other factors had changed, the shift to a 1995 baseline for the three synthetic gases would, alone, have transformed the President's goal of 1990 levels into a goal equivalent to 1% below 1990 levels.

- **Altering the accounting method for carbon-absorbing activities, such as planting trees, accounts for about 3% of the 7% reduction.** The President's original goal assumed that carbon-absorbing activities would be counted, both in the 1990 base year and in the 2008-2012 budget period. Under the method agreed in Kyoto, carbon-absorbing activities in the 1990 base year are not counted (yielding a higher baseline), although certain carbon-absorbing activities will count against emission reduction commitments in the budget period. This decision with respect to the accounting method makes the U.S. target somewhat less stringent. Specifically, had the U.S. maintained the same level of effort assumed by the President in October, and no other factors had changed, the shift in the accounting method for carbon-absorbing activities would, alone, have transformed the President's goal of 1990 levels into a goal equivalent to at least 3% below 1990 levels. 22

INTERNATIONAL EMISSIONS TRADING

- The United States prevailed in securing acceptance of emissions trading among nations with emissions targets. This free market approach, pioneered in the U.S., will allow countries to seek out the most cost-effective emissions reductions.

- Under an emissions trading regime, countries or companies can purchase less expensive emissions permits from countries that have more permits than they need (because they have met their targets with room to spare). Structured effectively, emissions trading can provide a powerful economic incentive to cut emissions while also allowing important flexibility for taking cost-effective actions.

- The Kyoto Protocol enshrines emissions trading. Rules and guidelines -- in particular for verification, reporting, and accountability -- are to be worked out at the next meeting of the Parties at Buenos Aires in November 1998.

- The inclusion of emissions trading in the Kyoto Protocol reflects an important decision to address climate change through the flexibility of market mechanisms. Led by the United States, the Conference rejected proposals to require all Parties with targets to impose specific mandatory measures, such as energy taxes.

- The United States also reached a conceptual agreement with a number of countries, including Australia, Canada, Japan, New Zealand, Russia and Ukraine, to pursue an umbrella group to trade emissions permits. Such a trading group could further contribute to cost-effective solutions to this problem.

JOINT IMPLEMENTATION AMONG DEVELOPED COUNTRIES

- Countries with emissions targets may get credit towards their targets through project-based emission reductions in other such countries. The private sector may participate.

- Additional details may be agreed upon by the Parties at future meetings.

CLEAN DEVELOPMENT MECHANISM

- Another important free market component of the Kyoto Protocol is the so-called "Clean Development Mechanism" (CDM). The CDM embraces the U.S. proposal for "joint implementation for credit" in *developing* countries.

- With the Clean Development Mechanism, developed countries will be able to use certified emissions reductions from project activities in developing countries to contribute to their compliance with greenhouse gas reduction targets.

- This Clean Development Mechanism will allow companies in the developed world to enter into cooperative projects to reduce emissions in the developing world -- such as the construction of high-tech, environmentally sound power plants -- for the benefit of both parties. The companies will be able to reduce emissions at lower costs than they could at home, while developing countries will be able to receive the kind of technology that can allow them to grow more sustainably. The CDM will certify and score projects. The CDM can also allow developing countries to bring projects forward in circumstances where there is no immediate developed country partner.

- Under the Clean Development Mechanism, companies can choose to make investments in projects or to buy emissions reductions. In addition, Parties will ensure that a small portion of proceeds be used to help particularly vulnerable developing countries, such as island states, adapt to the environmental consequences of climate change.

- Importantly, certified emissions reductions achieved starting in the year 2000 can count toward compliance with the first budget period. This means that private companies in the developed world will be able to benefit from taking early action.

DEVELOPING COUNTRIES

- Various Protocol provisions, taken together, represent a down payment on developing country participation in efforts to reduce greenhouse gas emissions:

  - Developing countries will be engaged through the Clean Development Mechanism, noted above.

  - The Protocol advances the implementation by *all* Parties of Article 4.1 commitments under the 1992 Framework Convention on Climate Change. For example, the Protocol identifies various sectors (including the energy, transport, and industry sectors as well as agriculture, forestry, and waste management) in which actions should be considered in developing national programs to combat climate change and provides for more specific reporting on actions taken.

  - While the Conference rejected a proposal to create a new category of nations that would voluntarily assume binding emissions targets, developing countries may, as a prerequisite for engaging in emissions trading, still do so through amendment to the annex of the Protocol that lists countries with targets.

- Securing meaningful participation from key developing countries remains a priority for the United States. The Administration has stated that without such participation, it will not submit the Kyoto Protocol to the Senate for advice and consent to ratification.

MILITARY EMISSIONS

- The Kyoto Protocol achieves the objectives identified by the Department of Defense where international agreement was necessary to protect U.S. military operations.

  - Emissions from "bunker" fuels (for international maritime or aviation use) are exempted from emissions limits.

- Emissions from multilateral operations pursuant to the United Nations Charter are exempted from emissions limits. This includes not only multilateral operations expressly authorized by the UN Security Council (such as Desert Storm, Bosnia, Somalia) but also multilateral operations not expressly authorized that are nonetheless pursuant to the UN Charter, such as Grenada.

- Countries may decide, among themselves, how to account for emissions relating to multilateral operations (for example, U.S. training in another NATO country). This provision avoids the need to use emissions trading to allocate such emissions.

COMPLIANCE AND ENFORCEMENT

- The Protocol contains several provisions intended to promote compliance. These include requirements related to measurement of greenhouse gases, reporting, and review of implementation.

- The Protocol also contains certain consequences for failure to meet obligations. For example, as a result of a U.S.-proposed provision, a Party not in compliance with its measurement and reporting requirements cannot receive credit for joint implementation projects.

- Effective procedures and a mechanism to determine and address non-compliance are to be decided at a later meeting. For both environmental and competitiveness reasons, the United States will be working on proposals to strengthen the compliance and enforcement regime under the Protocol.

ENTRY INTO FORCE

- The Kyoto Protocol will be open for signature in March 1998. To enter into force, it must be ratified by at least 55 countries, accounting for at least 55 percent of the total 1990 carbon dioxide emissions of developed countries. U.S. ratification will require the advice and consent of the Senate.

ing regime among industrial countries, but leaves the details to be agreed upon later. Since it is easier to reduce emissions in some countries than others, and given that greenhouse gas emissions have equivalent climate effects regardless of their location, allowing global trading would achieve climate change objectives at lower cost. Such a global approach would ideally allow trading among all sources of greenhouse gases in participating countries and could incorporate opportunities to *remove* greenhouse gases from the atmosphere, for example by issuing emissions credits (which could then be sold to other firms) for reforestation projects.

International trading could take place among firms that have been allocated permits through domestic trading programs. For countries that have no domestically tradable permits because they have opted for a command-and-control or a tax approach to controlling emissions, it may still be possible instead to arrange exchanges on a government-to-firm or government-to-government basis.

The setting of binding targets among all countries, together with international trade in permits, could in principle result in a global market price for permits for greenhouse gas emissions. For example, the permit price could be expressed in terms of dollars per ton of carbon equivalent emitted. Firms in all countries would reduce their emissions until the cost of further reductions exceeded this price, at which point they would buy additional permits. Large differences in both the patterns of energy use and the efficiency of energy technologies among countries imply that the cost savings from international permit trading would be large compared with a system without international trading. Put differently, even in comparison with a system with full domestic trading of emissions permits, international trading could substantially lower costs. Some models predict that the incremental cost of reducing CO_2 emissions may be as little as one-seventh of the cost of reductions from domestic trading alone. The gains from international trade in permits would be particularly large if developing countries were to participate.

The Importance of Developing-Country Participation

Negotiations leading up to the Kyoto agreement sought binding limits on greenhouse gas emissions among industrial nations. Developing countries have resisted committing themselves to binding
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limits on their emissions because of concern that to do so would severely constrain their economic growth, and because by far the greater part of accumulated greenhouse gases in the atmosphere is the result of past economic activity in the industrial countries (Chart 5-5). However, current forecasts project that greenhouse gas emissions from developing countries will surpass those from industrial countries around 2030, and even sooner if industrial countries are
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plus see next page

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...cont stabilize the amount of greenhouse gases in the atmosphere. Moreover, some of the least cost opportunities for reducing greenhouse gas emissions are in developing countries, because those countries now use energy relatively inefficiently. Moreover, those that are industrializing rapidly have greater scope to build their industry around cleaner and more efficient energy technologies and fuels than do mature economies whose capital stock is already in place.

Failure to involve developing countries in an international agreement limiting greenhouse gas emissions could lead to a more rapid rate of increase in emissions in those countries than would occur without any agreement at all. This "leakage" effect of emissions reductions could come about in any of several ways. As industrial countries reduce their use of fossil fuels in response to emissions controls, future world oil and coal prices are likely to be lower than they would be otherwise. This is likely to increase energy consumption in countries not bound to limit their emissions. U.S. industries are also concerned about their international competitiveness if some countries remain outside an international agreement, since factories in those countries will face lower costs for producing goods that take relatively large amounts of energy to manufacture. Some may be concerned that energy-intensive industries might choose to relocate to countries not subject to emissions constraints, although there is little evidence to suggest that this would pose a significant problem in most industries. For example, energy costs for manufacturing industries average just 2.2 percent of total costs.

Given the projected growth of developing countries' emissions, the Administration's position is to seek meaningful participation by key developing countries in the reduction of greenhouse gas emissions as a condition for the United States taking on binding emissions reductions. The President has indicated he will not submit the Kyoto agreement for Senate ratification until there is meaningful participation by key developing countries.

Joint Implementation and the Clean Development Mechanism

To encourage participation by developing countries in the climate change initiative even before they formally sign on for binding emissions limits, the President has proposed a program known as joint implementation. This program would provide incentives to developing countries to reduce their emissions of CO_2 and other greenhouse gases. The Kyoto agreement embraces the President's proposal in its designation of a "clean development mechanism" (CDM): U.S. companies that undertake projects that reduce greenhouse gas emissions in developing countries could count those reductions to meet their commitments. Institutionalizing key elements of joint implementation through this mechanism would encourage firms in the United States to transfer a larger volume of cleaner and more energy-efficient technology to developing countries, especially in the electric power

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and carbon-intensive uses of energy in these countries today. It thus makes sense, from both an environmental and an economic perspective, to incorporate emissions reductions in developing countries into the international system.

Third, principles of basic fairness suggest all countries should do their part, depending, in part, on their ability to contribute to the solution. Thus even poor countries should participate, although the lack of resources in such countries may limit the extent of their participation. NF

Some have expressed fears that the Kyoto Protocol might adversely affect the competitive position of American industry. Evaluating how the Kyoto Protocol could affect competitiveness of a few specific manufacturing industries -- especially those that are ~~especially~~ (1) energy-intensive, such as aluminum, paper, (Not so) and chemicals -- is complex. The answer depends, in part, on the impact of the agreement on energy prices, which we will shortly address. In general it is difficult to undergo a structural change in the economy without having the effect of expanding some sectors and contracting others. But to provide some perspective on this issue, consider the following facts. First, on average, energy constitutes only 2.2 percent of total costs (2) – ERP to U.S. industry. Second, energy prices already vary significantly across countries. (3) According to – Stat Abs the *1997 Statistical Abstract,* for example, in 1996 premium gasoline cost $1.28 per gallon in the United States -- but only 8 cents per gallon in Venezuela. Similarly, gas prices were $3.71 (4) per gallon in Switzerland and $4.41 per gallon in France. Electricity prices also vary significantly: in the U.S. they were 5 cents per kilowatt hour, a fraction of prices in Switzerland of 13 cents per kilowatt hour. (5) – Zac Yet U.S. industry is not moving en masse to Venezuela, nor is Swiss industry moving to the United States. Third, roughly two-thirds of all emissions are not in manufacturing at all, but in transportation and buildings. (6) – AEO98 Table A19 I therefore believe we need developing country participation because the problem is global and cost-effective solutions are essential, than to avoid adverse effects on competitiveness.

Flexibility and Market Mechanisms

A global solution is thus critical to the global problem of climate change. Globalizing the solution is not, however, enough by itself. We must also ensure that our efforts achieve their objectives in the most efficient manner possible. The nature of the climate change problem suggests three basic methods to lower costs of achieving given levels of environmental protection. They can be characterized in terms of three categories of flexibility: (1) "when" flexibility; (2) "what" flexibility; and (3) "where" flexibility, which may be the most important of all. Such methods have long been championed by economists interested in increasing the efficiency of protection. Indeed, 2,600 economists from academia, industry and government alike urged such approaches in a letter they signed last year advocating action on climate change:

> "Economic studies have found that there are many potential policies to reduce greenhouse gas emissions for which the total benefits outweigh the total costs... The most efficient approach to slowing climate change is through market-based policies." Economists' Statement (7)

1. "When flexibility" (timing)

(MILLIONS $, 1995)							
Industry	SIC	Capital	Labor	Materials	Energy	Total	Energy/Total
Food and Kindred Products	20	11929	50802	268168.3	5545	336445	0.016
Tobacco Products	21	411	2031.7	8251.9	116.6	10811	0.011
Textile Mill Products	22	2878.5	16481	47455.1	2275.6	69090	0.033
Apparel and Other Textile Products	23	1193.9	19023	38937	921.7	60076	0.015
Lumber and Wood Products	24	2974.1	20520	64417.3	1792.5	89704	0.020
Furniture and Fixtures	25	1231.6	14628	27411.8	564.6	43836	0.013
Paper and Allied industries	26	8218.8	28000	94404.6	5955	136578	0.044
Printing and Publishing	27	5617.1	53800	63007.5	1563	123988	0.013
Chemicals and Allied Products	28	17627	44826	167061.3	10046	239561	0.042
Petroleum and Coal Products	29	6213.3	6758.6	120053.1	3689.2	136714	0.027
Rubber and Misc. Plastics	30	6651.5	34599	73121.1	3113.7	117485	0.027
Leather	31	125.6	2009.8	4921.6	90.4	7147.4	0.013
Stone, Clay, and Glass Products	32	3365.3	18965	34092.9	3543.2	59966	0.059
Primary Metal Industries	33	6717.6	33622	111909.3	8036.7	160285	0.050
Fabricated Metal Products	34	7106	56030	103460.5	3115.3	169712	0.018
Industrial Machinery and Equipment	35	9998.4	83786	181275.1	2794.9	277855	0.010
Electronic and Other Electric Equipment	36	17247	63945	128822.3	2505.5	212520	0.012
Transportation Equipment	37	13109	84433	286306.5	2952.2	386800	0.008
Instruments and Related Products	38	4367.1	39841	47988.5	1125.5	93322	0.012
Misc. Manufacturing	39	1252.8	11774	21553.3	488.9	35069	0.014
All Industries		128235	685876	1892619	60236	3E+06	0.022

(1)

(MILLIONS $, 1995)								
Industry	SIC	Capital	Labor	Materials	Energy	Total	Energy/Total	
Primary Aluminum	3334	151.6	1004	3897.9	1373.8	6427.3	0.214	1
Inorganic Chemicals	281	1707.2	4629.5	10531.7	2687.8	19556	0.137	1
Cement, Hydraulic	3241	282.2	863	2232.6	870.8	4248.6	0.205	
Blast Furnace and Basic Steel Products	331	3269.2	13943	45927.6	3884.4	67024	0.058	
Source: 1995 Annual Survey of Manufacturers, Bureau of the Census		tab2: new capital expenditures	tab3: total compensation	tab2: cost of materials	tab4: cost of purchased fuels and electric energy			

Glass	321 + 322 ~~+324~~	~~1155.3~~ 841	~~[illegible]~~ 3412.9	4405.8	846.9	9506.6	~~[illegible]~~
	+ 323	+314.3	+2,072.5	+3,798.	+161.8	6346.6	6.36%
		1,155.3	54854	8203.8	1008.7	15853.2	

stabilize the amount of greenhouse gases in the atmosphere. Moreover, some of the least cost opportunities for reducing greenhouse gas emissions are in developing countries, because those countries now use energy relatively inefficiently. Moreover, those that are industrializing rapidly have greater scope to build their industry around cleaner and more efficient energy technologies and fuels than do mature economies whose capital stock is already in place.

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No. 1371. World Production of Major Mineral Commodities: 1990 to 1995

COUNTRY	Unit	1990	1993	1994	1995	Leading producers, 1994
MINERAL FUELS [1]						
Coal	Mil. short tons	5,356	4,958	5,041	5,091	China, United States, Russia
Dry natural gas	Tril. cu. ft.	73.6	76.3	76.7	78.3	Russia, United States, Canada
Natural gas plant liquids [2]	Mil. barrels [3]	1,691	1,887	1,928	1,998	United States, Saudi Arabia, Canada
Petroleum, crude	Mil. barrels [3]	22,107	21,990	22,266	22,793	Saudi Arabia, United States, Russia
Petroleum, refined	Mil. barrels [3]	23,791	(NA)	24,512	(NA)	United States, Japan, Russia
NONMETALLIC MINERALS						
Cement, hydraulic	Mil. metric tons	1,148	1,300	1,370	1,390	China, Japan, United States
Diamond, gem and industrial	1,000 carats	110,919	105,000	111,000	(NA)	Australia, Russia, Congo (Kinshasa)
Nitrogen in ammonia	Mil. metric tons	97.1	92.0	92.0	96.0	China, United States, India
Phosphate rock	Mil. metric tons	162	120	128	137	United States, China, Morocco
Potash, marketable	Mil. metric tons	27.8	21.0	22.5	26.2	Canada, Germany, Belarus
Salt	Mil. metric tons	184	190	180	185	United States, China, Germany
Sulfur, elemental basis	Mil. metric tons	58.1	52.0	51.0	52.0	United States, Canada, China
METALS						
Aluminum [4]	Mil. metric tons	19.3	20.0	19.1	19.3	United States, Russia, Canada
Bauxite, gross weight	Mil. metric tons	108.6	110.0	107.0	109.0	Australia, Guinea, Jamaica
Chromite, gross weight [2]	1,000 metric tons	12,968	10,001	9,570	10,600	South Africa, Kazakstan, India
Copper, metal content [5]	1,000 metric tons	9,017	9,400	9,430	9,800	Chile, United States, Canada
Gold, metal content	Metric tons	2,133	2,300	2,300	2,200	South Africa, United States, Australia
Iron ore, gross weight [6]	Mil. metric tons	982	1,000	1,000	1,000	China, Brazil, Russia
Lead, metal content [5]	1,000 metric tons	3,353	2,900	2,800	2,800	Australia, United States, China
Manganese ore, gross weight	Mil. metric tons	25.3	21.8	21.2	21.0	China, Ukraine, South Africa
Nickel, metal content [5]	1,000 metric tons	965	900	906	920	Russia, Canada, New Caledonia
Steel, crude	Mil. metric tons	771	730	726	760	European Union, Japan, China
Tin, metal content [5]	1,000 metric tons	222	180	184	180	China, Indonesia, Brazil
Zinc, metal content [5]	1,000 metric tons	7,184	6,900	6,810	7,070	Australia, Canada, China

NA Not available. [1] 1995 data preliminary. [2] Excludes China. [3] 42-gallon barrels. [4] Unalloyed ingot metal. [5] Mine output. [6] Includes iron ore concentrates and iron ore agglomerates.

Source: Mineral fuels, Energy Information Administration, *International Energy Annual*; nonmetallic minerals and metals, through 1994, U.S. Bureau of Mines, thereafter, U.S. Geological Survey, *Minerals Yearbook; Annual Reports;* and *Mineral Commodity Summaries, 1996.*

No. 1372. Selected Petroleum Product Prices, by Country: 1996

[Data are averages for the available time period (daily, monthly, quarterly, year) that is closest to January 1, 1996. Includes taxes]

#4

COUNTRY	AUTOMOTIVE FUELS (U.S. dollars per gallon)		RESIDENTIAL (U.S. dollars per gallon)			INDUSTRIAL (U.S. dollars per barrel)	
	Premium gasoline	Diesel fuel	Light fuel oil	Kerosene	Liquified petroleum gases	Light fuel oil	Heavy fuel oil
United States	**1.28**	**1.15**	**0.95**	**0.72**	**0.64**	**26.46**	**19.70**
Argentina	3.04	1.00	0.55	1.09	1.74	(NA)	(NA)
Australia	2.07	1.95	(NA)	(NA)	(NA)	(NA)	(NA)
Belgium	4.26	3.20	0.99	(NA)	(NA)	34.33	20.93
Brazil	[1]2.15	1.41	0.75	1.49	0.78	(NA)	(NA)
Canada	1.80	1.43	1.03	(NA)	(NA)	27.53	15.90
Chile	2.02	1.35	0.58	1.08	1.35	(NA)	(NA)
France	4.41	3.10	1.59	(NA)	(NA)	46.73	26.07
Germany	4.32	3.02	1.19	(NA)	(NA)	43.55	22.94
Greece	3.15	2.41	1.63	(NA)	(NA)	58.01	31.88
India [2]	[1]2.25	0.92	(NA)	(NA)	(NA)	30.77	24.51
Ireland	3.58	3.37	1.53	(NA)	(NA)	46.47	27.45
Italy	4.24	3.40	3.24	(NA)	(NA)	114.41	27.76
Japan	[1]3.77	2.51	1.44	1.57	(NA)	42.57	24.25
Korea, South [2]	2.93	1.13	(NA)	(NA)	(NA)	(NA)	21.86
Mexico	1.25	0.92	0.41	0.92	0.39	35.58	11.17
Netherlands	5.31	3.67	1.39	(NA)	(NA)	(NA)	27.74
Norway	5.05	4.39	1.99	(NA)	(NA)	62.29	52.61
Peru	1.82	1.00	0.52	0.85	0.84	(NA)	(NA)
Philippines [2]	1.38	1.08	(NA)	1.08	0.81	(NA)	17.12
Russia [2]	[1]1.25	0.83	0.30	(NA)	(NA)	(NA)	(NA)
Saudi Arabia [2]	[1]0.60	0.37	0.13	0.44	(NA)	0.37	(NA)
Spain	3.32	2.66	1.28	(NA)	(NA)	46.29	28.83
Sweden	4.38	3.58	2.26	(NA)	(NA)	37.05	30.05
Switzerland	3.71	3.80	0.94	(NA)	(NA)	31.72	26.63
Turkey	2.39	1.63	1.84	(NA)	(NA)	(NA)	26.45
United Kingdom	3.47	3.26	0.92	(NA)	(NA)	31.39	22.23
Venezuela	0.08	0.04	0.03	0.03	0.04	3.85	3.81

#3

NA Not available. [1] Regular gasoline. [2] Data for 1995.

Source: Energy Information Administration, *International Energy Annual.*

	1995 Electricity for Industry (AVG Price per Kwh in Native Currency)	19 Exchange Rate	1995 Electricity for Industry (AVG Price per Kwh in US$)	#5 #3
Switzerland	0.1479	1.182	0.13	
Mexico	0.1972	6.421	0.03	
Venezuela	10.7	176.8	0.06	
France	0.3002	4.991	0.06	
Germany	0.1442	1.433	0.10	
United States	0.0469	1	0.05	

Source: International Energy Agency, Energy Prices and Taxes, Second Quarter 1996

Table A19. Carbon Emissions by Sector and Source
(Million Metric Tons per Year)

Sector and Source	Reference							Annual Growth 1996-2020 (percent)
	1995	1996	2000	2005	2010	2015	2020	
Residential								
Petroleum	25.8	27.3	25.8	25.0	24.8	24.5	24.2	-0.5%
Natural Gas	71.7	77.4	77.0	78.7	81.1	83.8	85.9	0.4%
Coal	1.4	1.4	1.4	1.4	1.3	1.3	1.3	-0.3%
Electricity	170.1	179.9	201.3	215.9	230.9	248.8	267.5	1.7%
Total	**269.0**	**286.0**	**305.6**	**321.0**	**338.1**	**358.5**	**379.0**	**1.2%**
Commercial								
Petroleum	15.0	15.3	12.8	12.8	12.8	12.7	12.4	-0.9%
Natural Gas	44.8	47.4	49.9	52.1	54.0	55.4	55.5	0.7%
Coal	2.1	2.1	2.2	2.3	2.4	2.5	2.5	0.8%
Electricity	155.7	164.8	182.2	193.1	205.1	217.8	225.5	1.3%
Total	**217.6**	**229.6**	**247.1**	**260.4**	**274.4**	**288.4**	**296.0**	**1.1%**
Industrial[1]								
Petroleum	97.4	104.8	103.3	109.7	115.6	119.3	120.3	0.6%
Natural Gas[2]	139.5	142.8	155.5	158.5	165.8	167.1	167.5	0.7%
Coal	62.1	59.3	60.7	62.3	62.8	61.7	60.7	0.1%
Electricity	165.2	169.2	187.3	203.6	219.1	230.6	240.6	1.5%
Total	**464.2**	**476.1**	**506.7**	**534.1**	**563.3**	**578.7**	**589.2**	**0.9%**
Transportation								
Petroleum	447.5	457.9	502.4	552.8	601.0	632.3	658.6	1.5%
Natural Gas[3]	10.4	10.5	12.2	14.4	17.2	18.6	19.8	2.7%
Other[4]	0.0	0.0	0.1	0.5	1.5	2.2	2.7	N/A
Electricity	2.7	2.8	3.2	5.5	7.8	9.5	11.0	5.8%
Total	**460.6**	**471.2**	**517.9**	**573.3**	**627.5**	**662.7**	**692.1**	**1.6%**
Total Carbon Emissions[5]								
Petroleum	585.7	605.3	644.4	700.4	754.2	788.9	815.5	1.2%
Natural Gas	266.4	278.1	294.6	303.7	318.1	324.9	328.7	0.7%
Coal	65.6	62.8	64.3	66.0	66.6	65.6	64.5	0.1%
Other[4]	0.0	0.0	0.1	0.5	1.5	2.2	2.7	N/A
Electricity	493.7	516.7	574.0	618.1	662.9	706.8	744.7	1.5%
Total	**1411.4**	**1462.9**	**1577.3**	**1688.8**	**1803.2**	**1888.3**	**1956.2**	**1.2%**
Electric Generators[6]								
Petroleum	13.8	15.5	11.4	7.7	7.4	6.8	6.6	-3.5%
Natural Gas	47.2	40.3	59.6	82.0	106.3	125.4	145.0	5.5%
Coal	432.7	460.9	503.0	528.4	549.3	574.5	593.1	1.1%
Total	**493.7**	**516.7**	**574.0**	**618.1**	**662.9**	**706.8**	**744.7**	**1.5%**
Total Carbon Emissions[7]								
Petroleum	599.5	620.8	655.8	708.1	761.5	795.7	822.1	1.2%
Natural Gas	313.6	318.4	354.2	385.7	424.4	450.3	473.7	1.7%
Coal	498.3	523.7	567.3	594.4	615.9	640.1	657.7	1.0%
Other[4]	0.0	0.0	0.1	0.5	1.5	2.2	2.7	N/A
Total	**1411.4**	**1462.9**	**1577.3**	**1688.8**	**1803.2**	**1888.3**	**1956.2**	**1.2%**
Carbon Emissions (tons per person)	**5.4**	**5.5**	**5.7**	**5.9**	**6.0**	**6.1**	**6.0**	**0.4%**

[1]Includes consumption by cogenerators.
[2]Includes lease and plant fuel.
[3]Includes pipeline fuel natural gas and compressed natural gas used as vehicle fuel.
[4]Includes methanol and liquid hydrogen.
[5]Measured for delivered energy consumption.
[6]Includes all electric power generators except cogenerators, which produce electricity and other useful thermal energy.
[7]Measured for total energy consumption, with emissions for electric power generators distributed to the primary fuels.
N/A = Not applicable
Note: Totals may not equal sum of components due to independent rounding.

#6 $\frac{286 + 229.6 + 471.2}{1462.9} = .67$

Sources: Carbon coefficients from Energy Information Administration, (EIA) *Emissions of Greenhouse Gases in the United States 1996*, DOE/EIA-0573(96) (Washington, DC, October 1997). 1995 consumption estimates derived from EIA, *State Energy Data Report 1994*, Online. ftp://ftp.eia.doe.gov/pub/state.data/021494.pdf (August 26, 1997). 1996 consumption estimates based on: EIA, *Short Term Energy Outlook, August 1997*, Online. http://www.eia.doe.gov/emeu/steo/pub/upd/aug97/index.html (August 21, 1997).
Projections: EIA, AEO98 National Energy Modeling System run AEO98B.D100197A.

ECONOMISTS' STATEMENT ON CLIMATE CHANGE

Endorsed by Over 2500 Economists
including eight Nobel Laureates

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. Economic 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.

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First is "when flexibility" or timing. Since climate change is a long-term problem, the exact timing of emissions reductions, within some range, is not of primary importance. Thus the freedom to delay or accelerate reductions within an agreed upon time frame -- while ensuring credibility of emissions reductions -- lowers costs.

As a result of U.S. leadership, the Kyoto Protocol incorporates this principle of "when flexibility" in four ways:

- First, the initial emissions reductions are less severe, and the period over which they occur ends much later than what had been proposed by many other countries. By adopting a gradual and credible path of reductions in the early years, we can greatly reduce costs such as those from prematurely scrapping coal-fired electricity plants, 8 while attaining the same ultimate environmental goals. ERP?

- Second, under the Kyoto Protocol, the emissions target is not specified in terms of a specific year, but rather in terms of an average over a five-year period (2008-2012). Averaging over five years, instead of requiring countries to meet a specific target each year, can lower costs, especially given an uncertain future. 9 The averaging can smooth out the effects of short-term events such as fluctuations in the business cycle and energy demand, or hard winters and hot summers that would increase energy use and emissions. ERP?

- Third, there is allowance for "banking" emission reductions within the 2008-2012 commitment period, for use in a subsequent commitment period [although the emission targets of the subsequent periods have not yet been specified]. 10 ERP

- Fourth, CDM credits achieved between 2000 and 2008 may be banked until 2008 to 2012. 11 ERP?

2. "What flexibility" (gases and sinks)

The second type of flexibility is "what flexibility", along two dimensions. The first is the inclusion in the agreement of all six greenhouse gases.[12] Emissions of different kinds of gases, not just carbon dioxide, contribute to the greenhouse effect. Since the IPCC has developed conversion factors for all greenhouse gases by estimating their global warming potentials, 13 reductions in emissions of one pollutant can be used to substitute for increases in emissions of another by an amount that has equivalent environmental effects. Again at U.S. urging, all six gases are included, while Japan and the EU had insisted until the end on covering only three. 14 Thus the U.S. succeeded in having the Kyoto Protocol stipulate that countries with binding targets are to reduce their *total* greenhouse gas emissions by certain percentages, but does not require specific reductions for specific gases. Since a molecule of sulfur hexafluoride is 23,900 times more potent over 100 years than a molecule of CO2, it may be cheaper to achieve the same 15 environmental benefit by eliminating one molecular unit of SF6 than nearly 24,000 units of CO2.

ERP
IPCC WG-I p.121
ERP? or Kyoto update (from me)
IPCC WG I p.121

limate change proposal,
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Timing Flexibility in Meeting Emissions Reductions

Flexibility about *when* emissions reductions take place can further lower the cost of reducing greenhouse gas emissions. A system that allows participants to borrow emissions permits from the future or to save unused permits for future use would take advantage of differences in cost abatement opportunities across time.

Three features of the Kyoto agreement contribute to timing flexibility. First, the target for emissions reductions is based on a 5-year commitment period. For example, the target set for the United States of a 7-percent reduction in emissions below 1990 levels is specified as an annual average over 2008-2012. By averaging over 5 years instead of requiring the United States to meet the 7-percent target each year, the agreement provides flexibility in the timing of reductions that can lower costs, especially given an uncertain future. Averaging can smooth out the effects of short-term events such as fluctuations in the business cycle and energy demand. It can also lessen the impact of a year with a hard winter, when energy demand, and thus emissions, would increase. Further, if firms anticipate that a new technology will soon be available that lowers the cost of reducing emissions, they could emit more greenhouse gases in the early years of the period and less after the technology becomes available. Another advantage of this approach is that it may avoid forcing a costly rapid turnover of capital stock for electricity generation.

9

#8 9

The Kyoto agreement allows countries to bank unused emissions rights from one commitment period for use in the next. Should investments in research and development yield some pleasant surprises in the form of cleaner and more efficient technologies, banking will encourage the early adoption of these technologies in order to save unused emissions permits for future periods when the costs of emissions abatement may be higher. 10

In addition to banking across commitment periods, countries may bank certified emissions reductions obtained through the "clean development mechanism" discussed below. Countries may use emissions reductions achieved through this mechanism over the 2000-2007 period to assist in complying with their targets in the first commitment period. This provides an incentive for firms in industrial countries to begin investing in energy-efficient technologies in developing countries before 2008. 11

International Trading in Greenhouse Gas Emissions

Building on the benefits of the domestic trading program just described, the Administration proposed in Kyoto an international trading program for greenhouse gas emissions permits. The Kyoto agreement established the right of countries assigned emissions targets to meet their commitments by trading among themselves. This establishment of the right to trade provides the foundation for a trad-

preindustrial times. Of these, CO_2 is the most important: net cumulative CO_2 emissions resulting from the burning of fossil fuels and deforestation account for about two-thirds of potential warming from changes in greenhouse gas concentrations related to human activity. If growth in global emissions continues unabated, the atmospheric concentration of CO_2 will likely double, relative to its preindustrial level, midway through the next century.

The accumulation of greenhouse gases poses significant risks to the world's climate and to human well-being. Potential impacts include a rise in sea levels, greater frequency of severe weather events, shifts in agricultural growing conditions from changing weather patterns, threats to human health from increased range and incidence of diseases, changes in availability of freshwater supplies, and damage to ecosystems and biodiversity.

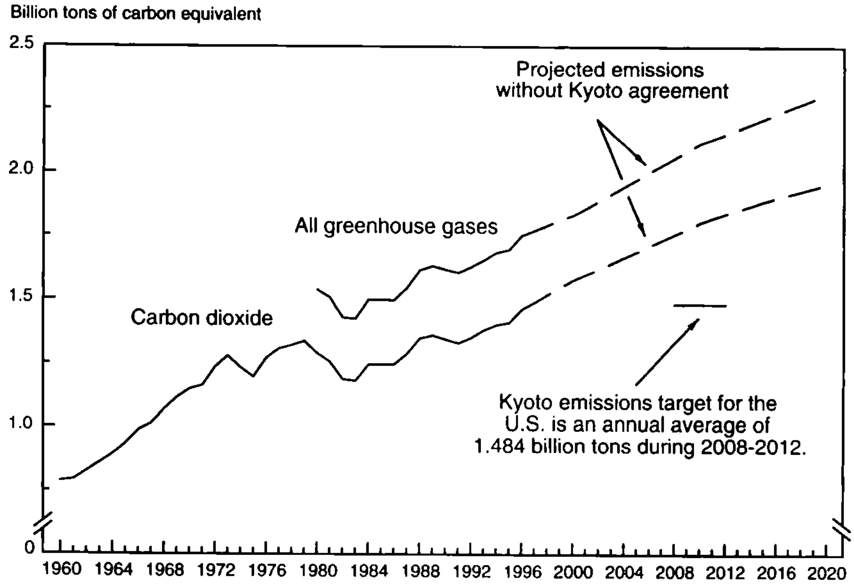
Climate change is a complex, long-term problem requiring global cooperation and a long-term solution. No single country has an incentive to reduce emissions sufficiently to protect the global environment against climate change. Even if the United States sharply reduced its emissions unilaterally, greenhouse gas emissions from all other countries would continue to grow, and the risks posed by climate change would not be significantly abated. Since many of these gases remain in the atmosphere for a century or more, the climatic effects of actions taken today will primarily benefit future generations. But delaying action to reduce greenhouse gas emissions until the disruptive effects of climate change become widespread will considerably reduce the options for remedial or preventive measures.

The Framework Convention on Climate Change

The threat of disruptive climate change has led to coordinated international efforts to reduce the risks of global warming by reducing emissions of greenhouse gases. The first international agreement to address global warming was the Framework Convention on Climate Change signed during the Earth Summit in Rio de Janeiro in 1992. This convention established a long-term objective of limiting greenhouse gas concentrations and encouraged the established industrial countries to return their emissions to 1990 levels by 2000. Since then it has become clear that the United States and many other participating countries will not meet this goal.

To address the lack of progress among many industrial countries toward meeting this first target, the United States and approximately 159 other nations, in negotiations held in Kyoto, Japan, last December, agreed to take substantial steps to stabilize atmospheric concentrations of greenhouse gases. The Kyoto agreement, which requires the advice and consent of the Senate, would place binding limits on industrial countries' emissions of the six principal categories of greenhouse gases: CO_2, methane, N_2O, sulfur hexafluoride, perfluorocarbons, and hydrofluorocarbons. Each industrial country's "1990 12 baseline" is actually based on its 1990 emissions of CO_2, methane, and N_2O and its choice of 1990 or 1995 levels of the other three categories of gases. The United States agreed to a target of 7 percent below 1990 levels over 2008-2012. To meet that target, net U.S. emissions of greenhouse gases—all emissions minus removals of CO_2 by certain forest activities such as planting trees—must average no more than 1,484 million metric tons of carbon equivalent per year during that period (Chart 5-4). The targets for the European Union and Japan are 8 percent and 6 percent below 1990 levels, respectively. Australia, New Zealand, Norway, Russia, and Ukraine all have less stringent limits. In sum, over the period from 2008 to 2012, the industrial countries are

Chart 5-4 **U.S. Greenhouse Gas Emissions, Actual and Projected**
The U.S. emissions target under the Kyoto agreement is about 25 percent below current projections in 2008-2012.



Notes: All greenhouse gases include carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride. Carbon equivalence is calculated assuming a global warming potential over a 100-year time horizon. Targets can be met through forest activities that remove carbon from the atmosphere and international permit purchases and credits in addition to domestic emissions reductions.
Sources: Department of Energy, United Nations Framework Convention on Climate Change, and U.S. Climate Action Report 1997.

expected to reduce their average emissions of greenhouse gases to about 5 percent below their 1990 levels.

The Kyoto agreement provides opportunities for the industrial countries to trade rights to emit greenhouse gases with each other. They may also invest in "clean development" projects in the developing world and use these projects' certified emissions reductions toward meeting their targets. Both of these mechanisms allow for emissions reductions to occur where they are least expensive. Many of the details of these provisions will be worked out in subsequent negotiations.

Table 2.9: *Global Warming Potential (mass basis) referenced to the updated decay response for the adopted carbon cycle model (see Section 2.1) and future CO_2 atmospheric concentrations held constant at current levels. Typical uncertainties are about ±35%.*

Species	**Chemical formula**	**Lifetime and reference**	**Global Warming Potential (Time Horizon)**		
			20 years	**100 years**	**500 years**
CO_2	CO_2	Bern model, revised	1	1	1
HFC-23	CHF_3	264 (a)	9100	11,700	9800
HFC-32	CH_2F_2	5.6 (a)	2100	650	200
HFC-41	CH_3F	3.7 (a)	490	150	45
HFC-43-10mee	$C_5H_2F_{10}$	17.1 (a)	3000	1,300	400
HFC-125	C_2HF_5	32.6 (a)	4600	2,800	920
HFC-134	$C_2H_2F_4$	10.6 (a)	2900	1,000	310
HFC-134a	CH_2FCF_3	14.6 (a)	3400	1,300	420
HFC-152a	$C_2H_4F_2$	1.5 (a)	460	140	42
HFC-143	$C_2H_3F_3$	3.8 (a)	1000	300	94
HFC-143a	$C_2H_3F_3$	48.3 (a)	5000	3800	1400
HFC-227ea	C_3HF_7	36.5 (a)	4300	2900	950
HFC-236fa	$C_3H_2F_6$	209 (a)	5100	6300	4700
HFC-245ca	$C_3H_3F_5$	6.6 (a)	1800	560	170
Chloroform	$CHCl_3$	0.51 (a)	14	4	1
Methylene chloride	CH_2Cl_2	0.46 (a)	31	9	3
Sulphur hexafluoride	SF_6	3200 (b)	16300	23900	34900
Perfluoromethane	CF_4	50000 (b)	4400	6500	10000
Perfluoroethane	C_2F_6	10000 (b)	6200	9200	14000
Perfluoropropane	C_3F_8	2600 (b)	4800	7000	10100
Perfluorobutane	C_4F_{10}	2600 (b)	4800	7000	10100
Perfluoropentane	C_5F_{12}	4100 (b)	5100	7500	11000
Perfluorohexane	C_6F_{14}	3200 (b)	5000	7400	10700
Perfluorocyclobutane	$c\text{-}C_4F_8$	3200 (b)	6000	8700	12700
Methane**	CH_4	12.2±3 (a)	56	21	6.5
Nitrous oxide	N_2O	120 (c)	280	310	170
Trifluoroiodomethane	CF_3I	<0.005 (c)	<3	<1	<1

**The GWP for methane includes indirect effects of tropospheric ozone production and stratospheric water vapour production, as in IPCC (1994). The updated adjustment time for methane is taken from the discussion in Section 2.2 of this report.

(a) Based upon the revised CH_3Cl_3 lifetime from Prinn et al. (1995b) and updated chemical kinetic data where appropriate from JPL(1994), see Section 2.2 and Table 2.2. Also includes updated information relating to radiative forcing per molecule from Section 2.4 based upon Pinnock et al. (1995), where appropriate.

(b) See Section 2.4 and Roehl et al. (1995) for discussion of radiative forcing per molecule for these gases. Lifetimes as in IPCC (1994).

(c) As in IPCC (1994).

Final Draft of Kyoto Protocol to U.N. Climate Change Convention
Issued Dec. 10, 1997

CONFERENCE OF THE PARTIES

Third session

Kyoto, 1-10 December 1997

Agenda item 5

FCCC/CP/1997/CRP.6

10 December 1997

ENGLISH ONLY

KYOTO PROTOCOL TO THE UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE

Final draft by the Chairman of the Committee of the Whole

The Parties to this Protocol,

Being Parties to the United Nations Framework convention on Climate Change, hereinafter referred to as "the Convention",

In pursuit of the ultimate objective of the Convention as stated in its Article 2,

Recalling the provisions of the Convention,

Being guided by Article 3 of the Convention,

Pursuant to the Berlin Mandate adopted by decision 1/CP.1 of the Conference of the Parties to the Convention at its first session,

Have agreed as follows:

Article 1

For the purposes of this Protocol, the definitions contained in Article 1 of the convention shall apply. In addition:

policies and measures in paragraph 1(a) above, taking into account different national circumstances and potential effects, shall consider ways and means to elaborate the coordination of such policies and measures.

7,7 Article 3

1. The Parties included in Annex I shall, individually or jointly, ensure that their aggregate anthropogenic carbon dioxide equivalent emissions of the greenhouse gases listed in Annex A do not exceed their assigned amounts, calculated pursuant tO their quantified emission limitation and reduction commitments inscribed in Annex B and in accordance with the provisions of this Article, with a view to reducing their overall emissions of such gases by six per cent below 1990 levels in the commitment period 2008 to 2012. 14

2. Each Party included in Annex I shall, by 2005, have made demonstrable progress in achieving its commitments under this Protocol.

3. The net changes in greenhouse gas emissions from sources and removals by sinks resulting from direct human-induced land-use change and forestry activities, limited to afforestation, reforestation, and deforestation since 1990, measured as verifiable changes in stocks in each commitment period shall be used to meet the commitments in this Article of each Party included in Annex I. The greenhouse gas emissions from sources and removals by sinks associated with those activities shall be reported in a transparent and verifiable manner and reviewed in accordance with Articles 7 and 8.

4. Prior to the first session of the Conference of the Parties serving as the meeting of the Parties to this Protocol, each Party included in Annex I shall provide for consideration by the Subsidiary Body for Scientific and Technological Advice data to establish its level of carbon stocks in 1990 and to enable an estimate to be made of its changes in carbon stocks in subsequent years. The Conference of the Parties serving as the meeting of the Parties to this Protocol shall, at its first session or as soon as practicable thereafter, decide upon modalities, rules and guidelines as to how and which additional human-induced activities related to changes in greenhouse gas emissions and removals in the agricultural soil and land-use change and forestry categories, shall be added to, or subtracted from, the assigned amount for Parties included in Annex I, taking into account uncertainties, transparency in reporting, verifiability, the methodological work of the Intergovernmental Panel on Climate Change, the advice provided by the Subsidiary Body for Scientific and Technological Advice in accordance with Article 5 and the decisions of the Conference of the Parties. Such a decision shall apply in the second and subsequent commitment periods.

sinks

does this exclude the 1st period?

5. The Parties included in Annex I undergoing the process of transition to a

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PRELIMINARY AND INCOMPLETE DRAFT #10 (Mar 2): CLOSE HOLD

TESTIMONY OF DR. JANET YELLEN
CHAIR, COUNCIL OF ECONOMIC ADVISERS
BEFORE THE HOUSE COMMERCE COMMITTEE
ON THE ECONOMICS OF THE KYOTO PROTOCOL
MARCH 4, 1998

Thank you, Mr. Chairman. The President has said that we can work to avert the grave dangers of climate change, while at the same time maintaining the strength of our economy. I agree and am pleased to have this opportunity to appear before the Committee to elaborate on the Administration's views on these issues.

The international agreement that was reached in Kyoto this past December is a crucial step forward in addressing global climate change. But it is only one step in a journey. Since the international effort to reduce greenhouse gas emissions is still in some respects a work-in-progress, it is not yet possible to provide a full authoritative analysis of it. Many of the specifics in several crucial areas are not completely resolved in the diplomatic arena, forcing analysts to make a variety of assumptions about the ultimate form of the international regime. In my testimony today, I will attempt to identify key elements of the agreement and the Administration's policy, such as international emissions trading, meaningful developing country participation, inclusion of land-use activities that absorb carbon ("sinks") and six categories of gases, as well as domestic initiatives, that together can ensure that reductions in global greenhouse gas emissions are consistent with continued strong economic growth. I will explain the reasoning underlying our conclusion that, under these conditions, economic impacts are likely to be modest.

The Administration is strongly committed to ensuring that these key elements are reflected in our domestic and international climate change policies. We are firmly committed to meaningful developing country participation, the use of sinks to offset emissions requirements, and emissions trading both domestically and internationally. And as you know, the President's FY 1999 budget includes a $6.3 billion package of tax cuts and R&D investments over the next 5 years; this package makes good sense in terms of energy policy and will jumpstart our efforts. A final component of the President's climate change policy is his support for electricity restructuring in a manner that will offer approximately $20 billion in cost savings to electricity consumers, while reducing greenhouse gas emissions.

I. Basic Economic Rationale of the Kyoto Treaty

To begin our analysis, it may be worth stepping back and examining the larger question of the basic rationale, from an economist's perspective, for the Kyoto Protocol.

The earth's surface appears to be warming from the accumulation of greenhouse gases from myriad sources worldwide. None of these emitters presently pays the cost to others of warming's adverse effects -- a classic externality in the language of economists. As a result of these distorted incentives, disruption of the Earth's climate is likely to proceed at an excessive pace and if left uncontrolled may pose substantial costs in terms of harm to commerce and the environment alike. The fundamental economic logic of the Kyoto Protocol is thus that without such an international agreement, individual nations will not have the proper incentives to address the threats from global climate change.

II. Costs of Climate Change

In evaluating efforts to mitigate global warming, the first step is to consider the costs of inaction. These costs --and they are significant-- provide the primary motivation for actions to reduce greenhouse gas emissions.

The Intergovernmental Panel on Climate Change (IPCC) jointly established by the World Meteorological Organization and the United Nations Environment Programme, concluded in 1995 that "the balance of evidence suggests that there is a discernible human influence on global climate." Current concentrations of carbon dioxide, methane, nitrous oxide, and the other so-called greenhouse gases have reached levels well above those of preindustrial times. Of these, carbon dioxide (CO_2) is the most important: net cumulative CO_2 emissions resulting from the burning of fossil fuels and deforestation account for about two-thirds of potential warming from changes in greenhouse gas concentrations related to human activity.

Climatic Impact

If growth in global emissions continues unabated, the atmospheric concentration of CO_2 will likely double relative to its preindustrial level by midway through the next century and continue to rise thereafter. As a result of the increased concentration of CO_2, the IPCC estimates that global temperatures will increase by between 2 to 6 degrees Fahrenheit in the next 100 years, with a best guess of about 3.5 degrees Fahrenheit. While scientists believe that human activities are leading to a gradual warming of the *average* temperature of the earth, the change in temperature in a given region at a given time may differ substantially from this average. Indeed, models predict warming will be greater in high latitudes than in the tropics, and greater over land than ocean. ~~Many models predict greater surface warming of the land than of the sea in winter, and increased precipitation and soil moisture in high latitudes in winter.~~

Potential consequences associated with this shift in climate include a rise in sea levels, greater frequency of severe weather events, shifts in agricultural growing conditions from changing weather patterns, threats to human health from increased range and incidence of diseases, changes in availability of freshwater supplies, and damage to ecosystems and biodiversity.

Economic and Monetary Damages

The derivation of quantitative or monetary estimates of the damages from such a change in the climate is extremely difficult given the capacity of today's models. Estimates of the economic damages from climate change fall into the following broad areas: agriculture, sea-level rise, air conditioning and heating, water supply, human life and health, air pollution, and other costs (hurricanes, relocation costs, human amenity, construction, leisure activities, urban infrastructure, and ecological damages such as forest loss and species loss). Although the quantification of these effects is quite demanding, researchers have developed estimates that prompt substantial concern. The IPCC reports that a doubling of carbon dioxide levels would lead to approximately 10,000 estimated additional deaths per year for the current U.S. population from higher summer temperatures, even after netting out the effects of warmer winters and assuming acclimatization. Other researchers have predicted sea level increases of about 20 inches by 2100, with greater increases in subsequent years.

Despite the difficulties, respected researchers have developed estimates of the monetary damages expected from an average worldwide temperature increase. For example, William Cline, then of the Institute for International Economics, estimated that a temperature change of 4.5 degrees Fahrenheit would impose annual damages of about 1.1 percent of GDP per year on the U.S. economy. That amounts to $89 billion in today's terms. (Cline's original estimate is quoted in 1990 dollars. The figure given above translates this number into 1997 terms by scaling it to current GDP.) William Nordhaus of Yale University has likewise computed estimates of the dollar loss attributable to a doubling of greenhouse gas concentrations. Although he uses methods that differ from Cline's in several respects, Nordhuas estimates that a slightly larger temperature change of 5.4 degrees Fahrenheit would impose losses equal to about 1 percent of GDP. A third independent estimate reported by Nordhaus is close to Cline's. It must be noted, however, that this similarity among aggregated estimates masks the true uncertainty associated with forecasts of the damages from given increases in global warming -- the estimates are all fundamentally based on extrapolations from current and past experience, and may not fully incorporate effects that will unfortunately become apparent only with future experience.

One key difficulty in interpreting and monetizing these estimates of damages is uncertainty over the extent that they should be discounted because they occur in the distant future. Since the benefits of stemming future climate change accrue over not only decades but centuries, small changes in the discount rate can produce substantial changes in the results. But the precise discount rate that should be used to evaluate questions as important as the future climate of the planet remains a subject of intense debate. It is safe to say that there is, as yet, no professional consensus on the issue. Indeed there can be no technical answer to the ethical question how we should value the welfare of future generations.

A similar difficulty with such estimates is that they do not include potential non-linearities in the relationships between greenhouse gas concentrations and temperature, between temperature and economic damages, or in the various other complicated relationships governing interactions between greenhouse gas emissions, the climate, and the economy. Current estimates of damages do not, and cannot, accurately reflect the value of reducing the unknown risk of large-scale and potentially irreversible discrete events with potentially catastrophic consequences.

Two such possibilities serve as illustrations. Warming of Northern tundra may release huge amounts of methane from the permafrost, thereby leading to accelerated warming. We do not know at what point, if any, such potentially unstable activity would be triggered. Second, evidence from climate models suggests that some types of climate change may lead to changes in ocean currents, including weakening of the Gulf Stream that warms Western Europe. Scientific evidence suggests that abrupt seawater temperature shifts have occurred over periods as short as decades.

strange opinion exists -tob, see 3

To what extent are we willing to take such chances with our planet? There is a strong argument for the Kyoto Protocol as a form of planet insurance. But what numerical weight should one assign to these catastrophic risks? In other words, what is the value of the insurance policy? Although it is difficult for an economist, or anyone, to know, reductions in the risk of such catastrophic outcomes must be considered in addition to the costs and benefits that can be reasonably quantified. Since human beings are typically averse to risk, such catastrophic risks are especially important in evaluating whether the benefits of a particular climate control policy justify the costs. One must have at least some sympathy with those who criticize economists on the grounds that the effects of climate change are extremely difficult to quantify in a single monetary number.

III. Addressing Global Climate Change in an Efficient Manner

The costs of unabated climate change may thus be difficult to quantify, but they are nonetheless real and provide the motivation for reducing greenhouse gas emissions. In taking action to reduce those emissions, economic analysis suggests that two elements are absolutely essential:

- The effort must be <u>global</u>, to address the global externality inherent in the nature of the problem.

- The effort must be <u>flexible and market-based</u>, to ensure that we achieve our objectives in the most efficient manner possible.

Need for Global Action

Climate change is a global problem requiring a global solution. As I mentioned earlier, no single country has an incentive to reduce emissions sufficiently to protect the global environment against climate change. Each has an economic incentive to "free ride" on the efforts of others. Even if the United States sharply reduced its emissions unilaterally without an international agreement limiting emissions abroad, greenhouse gas emissions from all other countries would continue to grow, and the risks posed by climate change would not be significantly reduced. It is important to emphasize that emissions of different gases anyplace in the world have very similar effects on global climate.

The threat of disruptive climate change has led to coordinated international efforts to reduce the risks of global warming by reducing emissions of greenhouse gases. A landmark international agreement to address global warming was the Framework Convention on Climate Change signed during the Earth Summit in Rio de Janeiro in 1992. This convention established an objective of limiting greenhouse gas concentrations and called upon industrial countries to return their emissions to 1990 levels by 2000. Since then, it has become clear that the United States and many other participating countries will not meet this voluntary goal; quite the contrary, emission levels have continued to rise not fall among both developed and developing countries.

To address the lack of progress among many industrialized countries toward meeting the Rio objective, the United States and approximately 160 other nations agreed in negotiations held in Kyoto, Japan, last December, to reduce emissions of greenhouse gases. The Kyoto Protocol, which requires the advice and consent of the Senate, would place binding limits on each industrial country's combined emissions of the six principal categories of greenhouse gases: carbon dioxide (CO_2), nitrous oxide (N_2O), methane, sulfur hexafluoride, perfluorocarbons, and hydrofluorocarbons. These limits apply to the 38 so-called Annex I countries, which are the industrialized countries, defined to include Russia, Ukraine, and most Eastern European countries. ?

Under the Kyoto Protocol, each industrial country's baseline is its 1990 emissions of CO_2, methane, and N_2O and its choice of 1990 or 1995 levels of the other three categories of gases. The United States agreed to a target of 7 percent below this baseline by the period between 2008 and 2012. Given the changes in the definition of the baseline for the three long-lived chemical compounds (HFCs, PFCs and SF6) from 1990 to 1995 combined with a change in the way sinks are accounted for in the baseline, the actual reduction required in the U.S. is no more than 2-3% more than the President originally proposed as the U.S. negotiating position. The targets for the European Union and Japan are 8 percent and 6 percent below 1990 levels, respectively. Australia, New Zealand, Norway, Russia, and Ukraine all have limits somewhat less ambitious when phrased as cuts relative to their 1990 levels. In sum, over the period from 2008 to 2012, the industrial countries are expected to reduce their average emissions of greenhouse gases to about 5 percent below their 1990 levels.

The President has made clear that he will not submit the Kyoto Protocol to the Senate without meaningful participation from key developing countries (who are not included in Annex I).

There are several reasons why meaningful participation from developing countries is essential. First, developing countries are projected to contribute a majority of world emissions around 2030 under a continuation of business-as-usual. Without the participation of developing economies, efforts by the industrialized countries to limit emissions will therefore not provide adequate protection from climate change.

It is well known

Second, developing country participation is crucial because it would permit relatively low-cost emissions reductions to be internationally recognized as a substitute for more expensive emissions reductions that might otherwise be achieved domestically by U.S. companies and those in other industrialized countries. Greenhouse gas emissions have the same basic impact on the climate regardless of where they occur. So reductions in developing countries have the same environmental benefit as reductions domestically. But these reductions are much less costly than reductions in the U.S. or in other developed nations, because of the very inefficient and carbon-intensive uses of energy in these countries today. It thus makes sense, from both an environmental and an economic perspective, to incorporate emissions reductions in developing countries into the international system.

Third, principles of basic fairness suggest all countries should do their part, depending, in part, on their ability to contribute to the solution. Thus even poor countries should participate, although the lack of resources in such countries may limit the extent of their participation.

Some have expressed fears that the Kyoto Protocol might adversely affect the competitive position of American industry. Evaluating how the Kyoto Protocol could affect competitiveness of a few specific manufacturing industries -- especially those that are especially energy-intensive, such as aluminum, ~~paper~~ cement, and chemicals -- is complex. The answer depends, in part, on the impact of the agreement on energy prices, which we will shortly address. In general it is difficult to undergo a structural change in the economy without having the effect of expanding some sectors and contracting others. But to provide some perspective on this issue, consider the following facts. First, on average, energy constitutes only 2.2 percent of total costs to U.S. industry. Second, energy prices already vary significantly across countries. According to the *1997 Statistical Abstract,* for example, in 1996 premium gasoline cost $1.28 per gallon in the United States -- but only 8 cents per gallon in Venezuela. Similarly, gas prices were $3.71 per in 1995

gallon in Switzerland and $4.41 per gallon in France. Electricity prices also vary significantly: in the U.S. they were 5 cents per kilowatt hour, a fraction of prices in Switzerland of 13 cents per kilowatt hour. Yet U.S. industry is not moving en masse to Venezuela, nor is Swiss industry moving to the United States. Third, roughly two-thirds of all emissions are not in manufacturing at all, but in transportation and buildings, sectors which, by their very nature, are severely limited in their ability to relocate to other countries. We therefore believe we need developing country participation because the problem is global and cost-effective solutions are essential, than to avoid adverse effects on competitiveness.

Flexibility and Market Mechanisms

A global solution is thus critical to the global problem of climate change. Globalizing the solution is not, however, enough by itself. We must also ensure that our efforts to reduce global greenhouse gas emissions reductions in the most efficient manner possible. The nature of the climate change problem suggests three basic methods to lower costs of achieving given levels of environmental protection. They can be characterized in terms of three categories of flexibility: (1) "when" flexibility; (2) "what" flexibility; and (3) "where" flexibility, which may be the most important of all. Such methods have long been championed by economists interested in increasing the efficiency of protection. Indeed, 2,600 economists from academia, industry, and government alike urged such approaches in a letter they signed last year advocating action on climate change:

over 2,500

> "Economic studies have found that there are many potential policies to reduce greenhouse gas emissions for which the total benefits outweigh the total costs...The most efficient approach to slowing climate change is through market-based policies."

1. "When flexibility" (timing)

First is "when flexibility" or timing. Since climate change is a long-term problem, the exact timing of emissions reductions is, within some range, not of primary importance. Thus the freedom to delay or accelerate reductions within an agreed upon time frame -- while ensuring credibility of emissions reductions -- lowers costs.

As a result of U.S. leadership, the Kyoto Protocol incorporates this principle of "when flexibility" in four ways:

- First, the initial emissions reductions are less severe, and the period over which they occur ends much later than what had been proposed by many other countries. By adopting a gradual and credible path of reductions in the early years, we can greatly reduce costs such as those from prematurely scrapping coal-fired electricity plants, while attaining the same ultimate environmental goals.

- Second, under the Kyoto Protocol, the emissions target is not specified in terms of a specific year, but rather in terms of an average over a five-year period (2008-2012). Averaging over five years, instead of requiring countries to meet a specific target each year, can lower costs, especially given an uncertain future. The averaging can smooth out the effects of short-term events such as fluctuations in the business cycle and energy demand, or hard winters and hot summers that would increase energy use and emissions.

- Third, there is allowance for "banking" emission reductions within the 2008-2012 commitment period, for use in a subsequent commitment period [although the emission targets of the subsequent periods have not yet been specified].

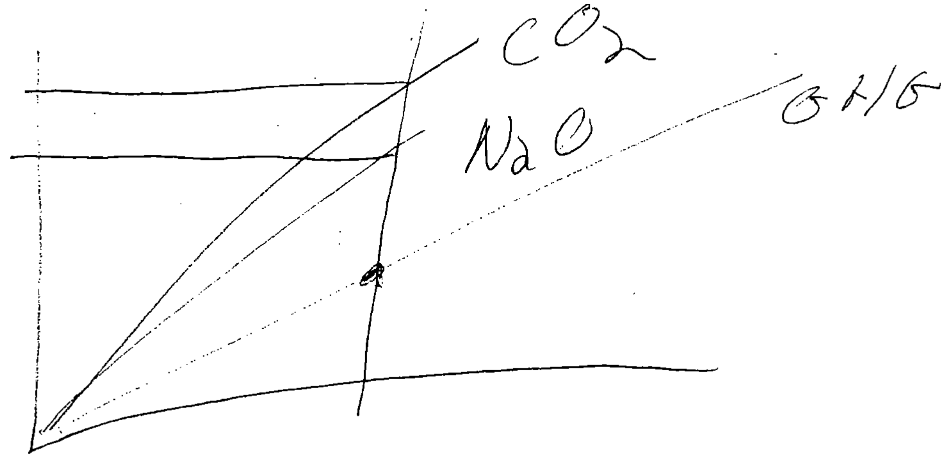
- Fourth, CDM credits achieved between 2000 and 2008 may be banked until 2008 to 2012.

2. "What flexibility" (gases and sinks)

The second type of flexibility is "what flexibility", along two dimensions. The first is the inclusion in the agreement of all six greenhouse gases. Emissions of different kinds of gases, not just carbon dioxide, contribute to the greenhouse effect. Since the IPCC has developed conversion factors for all greenhouse gases by estimating their global warming potentials, reductions in emissions of one gas can be used to substitute for increases in emissions of another by an amount that has equivalent environmental effects. Again at U.S. urging, all six gases are included, while Japan and the EU had insisted until the end on covering only three. Thus the U.S. succeeded in having the Kyoto Protocol stipulate that countries with binding targets are to 20%? [redacted] reduce their *total* greenhouse gas emissions by certain percentages, but does not require specific reductions for specific gases. Since a molecule of sulfur hexafluoride is 23,900 times more potent over 100 years than a molecule of CO_2, it may be cheaper to achieve the same environmental benefit by eliminating one molecular unit of SF_6 than nearly 24,000 units of CO_2.

Some initial analysis indicates that a strategy ~~of~~ reducing non-CO_2 greenhouse ? ~~gases~~ emissions by a greater percent than ~~reductions of~~ CO_2 emissions could ~~reduce~~ lower prices by as much as 10 percent. Thus allowing countries flexibility in what gases they reduce -- essentially trading emissions reductions across gases -- can help lower significantly the costs of meeting their targets.

The second source of "what flexibility" is the treatment of sinks, i.e., land use activities that promote the removal of carbon from the atmosphere through the growth of plants. At the urging of the U.S. delegation, sinks can be used to offset emissions targets. Promoting such sinks through afforestation and reforestation may reduce atmospheric concentrations of CO_2



CO_2
$NaCl$
CH_4

at much lower costs than reducing emissions of greenhouse gases.

3. "Where flexibility" (international)

The third type of flexibility, and perhaps the most important, is "where flexibility" (international). As I have already emphasized, emissions have the same environmental consequences regardless of where in the world they occur. Therefore, the least-cost approach to controlling climate change is to reduce emissions wherever such reductions are cheapest. The Kyoto Protocol, because of U.S. insistence and persistence, includes three important cost-saving provisions of this nature.

- First, it provides the opportunity for countries that take on binding targets to trade rights to emit greenhouse gases with each other. This market in emissions permits could ensure that emissions reductions occur where they are least expensive within the industrial countries. In particular, U.S. companies could purchase emissions reductions in other participating countries when doing so would reduce their costs -- thus lowering costs without affecting the level of environmental protection. While currently only industrialized countries have emissions caps, this mechanism also offers an incentive for developing countries to take on emissions targets.

- Second, the agreement provides for Joint Implementation by Annex I countries. Thus if some countries do not develop programs to trade permits internationally, U.S. firms could nonetheless implement projects in those countries for which they could receive emissions reductions credits in the U.S.

- Third, the agreement allows industrial countries to invest in "clean development" projects in the developing world and use these projects' certified emissions reductions toward meeting their targets. Many such clean development projects may be quite cheap in terms of the cost per ton of emissions avoided, as has been illustrated by the Joint Implementation pilot program that is already in place in the U.S.

Details of how these provisions will operate will be discussed in future negotiations such as the one in Buenos Aires later this year. Nonetheless, effective international trading of emission credits, Joint Implementation, and the Clean Development Mechanism can lead to substantial reductions in costs relative to alternative policies that do not exploit the power of market incentives. To illustrate briefly the ability of U.S. industry to perform beyond expectations when given appropriate economic incentives, consider further EPA's highly acclaimed sulfur dioxide (SO_2) program, which relies, among other things, on a system of tradeable permits to reduce emissions of SO_2 from electric utilities. The SO_2 program has been successful in several ways: a large number of utilities participate, SO_2 emissions and ambient concentrations have fallen and the costs of reducing emissions are considerably lower than originally forecast.

As has been frequently noted, the average cost of SO_2 emissions reductions has recently been significantly lower than was originally forecast, in part due to the role of incentives in fostering innovation. Emission permit prices, currently at approximately $100 per ton of SO_2, are well below earlier estimates of around $250 to $400 per ton.

Trading programs may not always bring cost savings as large as those achieved by the SO_2 program; trading programs will not always be accompanied by the discovery of much cheaper control strategies. However, the SO_2 experience demonstrates clearly how programs like international permit trading, Joint Implementation, and the Clean Development Mechanism will lead firms to find cheaper ways of reducing emissions that can lead to unexpectedly low costs.

IV. Difficulties of Economic Analysis of the Kyoto Protocol

Now that we have a Protocol -- even if it is not yet fully complete nor ready for the President's submission to the Senate -- it is possible to examine it in somewhat more detail from an economic perspective. But, once again the inherent limitations of any such estimates deserve emphasis. Such limitations should not be surprising to you: economists have a difficult enough time projecting the behavior of the economy over the next quarter or year, let alone over the next two decades. The scale of the forecasting exercise is therefore daunting, and any specific results should be treated with substantial caution.

The difficulties associated with economic analysis of climate change fall into three broad categories. First are the uncertainties that still remain over the terms of the ultimate treaty, necessitating assumptions on which the analysis is predicated. Second are the inherent limitations of available models to analyze even short-term costs and benefits. And finally is a topic discussed earlier: the impossibility of putting a single monetary number on the long-term benefits of climate change mitigation, although there will clearly be economic benefits of emission reductions.

Uncertainties in the International Effort to Combat Climate Change

The Kyoto Protocol was an historic accomplishment, delineating the broad terms of the international effort to address climate change. But although we know a lot more than we did before Kyoto about how that international system can work, and that informs our analysis, there is still much that we do not know.

First, some provisions raise complex implementation issues. At issue here is the treatment of so-called sinks -- activities that affect the rate at which carbon is removed from the atmosphere and "sequestered," e.g., by the planting of trees.

Second, the details of a number of items -- primarily concerning international trading, the Clean Development Mechanism, and developing countries -- are the subject of further discussions including future negotiations in Buenos Aires next fall, because they had not been definitively settled by the end of the Kyoto talks.

Finally, and most importantly, we have not yet negotiated international agreements to limit emissions beyond the 2012 window. The emission cuts agreed upon at Kyoto are only a first step on a long journey. The first step that we propose to take over the next 15 years is critical. But the reason it is critical is *not* that, by itself, it will solve the climate change problem -- emissions during any given decade are small compared to the cumulative concentrations in the atmosphere. Rather, the first step is critical because we can not take the second and third steps until we have taken the first. At the same time, any analysis is complicated by the lack of knowledge over what the subsequent steps will be.

Inherent Limitations of Models

In addition to these uncertainties about the details of the international effort to address climate change, are the inherent limitations of the models used to evaluate that effort. Even within a given model, answers depend critically on the precise nature of the question asked. For example, the costs of emissions reductions depend critically on the extent of global participation and international trading that a treaty is assumed to feature. But in addition to the dependence of the results from a given model on the precise assumptions, different models can give different answers even when all the assumptions are specified to be the same -- a concrete illustration of the range of uncertainty to which we must assign the predictions of any one individual model.

One area in which the uncertainty is particularly large is the pace of technological progress --especially the diffusion of existing energy-efficient technologies, but also the development of new technologies -- and the extent to which the pace will accelerate in response to government programs. Models and experts on climate change policy tend to have a wider range of disagreement on the scope for speeding the diffusion of existing energy-efficient technologies than on any other single issue.

Furthermore, each model has strengths and weaknesses; each has questions to which it is better or worse suited to answer. Some, for example, model the energy sector in detail. Some allow for the fact that a coal-fired power plant cannot costlessly be converted to one that runs on natural gas. Some show the effects of hypothetical tax cuts made possible by the new revenues earned through the auction of emissions permits. Some are capable of showing recessions and booms. Others include a long-term "carbon cycle" model that can keep track of the accumulation of greenhouse gas concentrations in the atmosphere and their climatological effects. Some break down the rest of the world into regions and so can model international trade. No one model does everything, and therefore we must not rely blindly on the results of any one model or set of models. Professional judgement and economic intuition, along with diplomatic assessments, are also crucial.

Benefits of Averting Climate Change

As discussed above, it is evident that the benefits of averting climate change are potentially immense. But we have chosen not to try to quantify them in monetary terms, in light of the difficulties we have enumerated. These include the uncertainty of these benefits, their timing and therefore the extreme sensitivity of the results to the chosen discount rate, and the dependence of benefits on emissions paths after the 2008 to 2012 budget period specified in Kyoto.

V. Assessing the Kyoto Protocol

In order to evaluate the likely net economic impact of the Kyoto Protocol, *excluding the benefits of mitigating climate change itself*, we have drawn upon a variety of tools to assess the various possible costs and non-climate benefits of the Administration's emissions reduction policy. To give away the punch line, our conclusion is as follows: the net costs of our policies to reduce emissions are likely to be small, assuming those reductions are undertaken in an efficient manner and we are successful in securing meaningful developing country participation as well as effective international trading, and the Clean Development Mechanism in future negotiations. That potential small net premium, even excluding the benefits of mitigating climate change, in effect, purchases a partial insurance policy against a serious environmental threat.

Because the results from any model must be treated with caution, the Administration has employed a broad set of economic tools to assess the Kyoto Protocol. We have drawn on the insights of a wide range of models of the energy sector and economy over the next 25 years, including but not limited to the results of the Stanford Energy Modeling Forum exercises, the IPCC's review of the economic and social dimensions of climate change, the work of the OECD on Economic Dimensions and Policy Responses to Global Warming, and the staff-level Interagency Analytical Team analysis produced last year. Other tools include simple relevant statistics, "meta-analyses" such as work by the World Resources Institute, models, and basic economic reasoning. Drawing on this broad array of analytical tools is crucial to an intelligent evaluation of the policy alternatives.

To our knowledge, no model -- whether used inside the government or not -- has yet been set up to analyze the implications of the Kyoto Protocol, since this agreement is only a few months old and remains unfinished. In particular, no model is currently designed to assess Kyoto's treatment of sinks, or all six greenhouse gases. Some model-builders outside the government tend to take as long as several years to incorporate changes in policy parameters into their models.

Our thinking has been informed, however, by simulations conducted with the Second Generation Model of Battelle Laboratories, one of the leading models in the field. The SGM is one of the models best positioned to analyze the role of international trade in emission permits, which we consider to be a critical element of the Kyoto Treaty. However, the SGM does not cover all six gases included in the Kyoto Protocol or include a role for sinks. We have used the SGM model as one input into our overall assessment of the Kyoto treaty, but have attempted to supplement its results with additional analysis to account for such special features of the agreement as the inclusion of six gases, a possible trading arrangement that could include a subset of the Annex I countries and the Clean Development Mechanism. We will share with you today some preliminary results of this analysis. To the extent possible, we have compared results obtained with the SGM model with those of other modelling efforts.

Mindful of the limitations of any single model, we are eager to see features of the Kyoto Protocol assessed by other models to obtain a better feel for the range of possible effects. This work is just beginning and much of it will continue to go on outside the government. For example, the Energy Modeling Forum, based at Stanford University, is a long-running model comparison exercise involving many of the leading climate models. EMF is currently studying how features of the Kyoto legal language can be translated into terms recognizable to economic modelers. We expect that the group will conduct a full scale analysis of the Kyoto Protocol. The Energy Modeling Forum believes that its members will need at least until mid-year to update their results.

VI. Assessing the Potential Costs of Emissions Reductions

I said in Congressional testimony last July that we can do this smart or we can do this dumb. I was referring to the point that the costs of cutting emissions can be much reduced if flexible, market-based mechanisms are used. Our economic analysis highlighted the importance of such flexible, market-based mechanisms -- which are therefore reflected, at the President's insistence, in the Kyoto Protocol and our ongoing diplomatic strategy.

Within the Kyoto Protocol, this means an insistence on international trading, Joint Implementation, the Clean Development Mechanism, and, ultimately, on meaningful developing country participation. Domestically, this means that we implement any emissions reductions through a market-based system of *tradeable* emissions permits, which ensures that we achieve reductions wherever they are least expensive. But this also means taking serious and responsible steps in the short run to prepare us to meet our obligations in the longer term.

The first such step is the inclusion in this year's budget of an aggressive, $6.3 billion program of tax cuts and R&D investments -- $1.3 billion more than the $5 billion package the

President promised in his October 22 speech on this issue. The goal is both to stimulate the development of new energy-saving and carbon-saving technologies and to encourage the dissemination of those that exist already. The proposed package contains $3.6 billion over the next 5 years in tax cuts for energy efficient purchases and renewable energy, including tax credits of $3,000 to $4,000 for consumers who purchase highly fuel efficient vehicles, a 15 percent credit (up to $2,000) for purchases of rooftop solar equipment, a 20 percent credit (subject to a cap) for purchasing energy-efficient building equipment, a credit up to $2,000 for purchasing energy-efficient new homes, an extension of the wind and biomass tax credit, and a 10 percent investment credit for the purchase of combined heat and power systems. The package also contains $2.7 billion over the next 5 years in additional research and development investments -- covering the four major carbon-emitting sectors of the economy (buildings, industry, transportation, and electricity), plus carbon removal and sequestration, Federal facilities, and cross-cutting analyses and research. One example of the R&D effort is the Partnership for a New Generation of Vehicles (PNGV). PNGV is a government-industry effort to develop attractive, affordable cars that meet all applicable safety and environmental standards and get up to three times the fuel efficiency of today's cars. In FY99, the combined proposal for PNGV is $277 million, up from $227 million appropriated in FY98. Similar government-industry efforts are proposed to develop more efficient diesel engines for both light trucks and heavy trucks.

A second responsible step entails industry-by-industry consultations to prepare emission reduction plans in key industrial sectors. The Administration will work in partnership with industry to identify ways in which the Federal government might remove regulatory hurdles that discourage energy efficiency. In addition, DOE will spearhead a comprehensive effort to improve the energy efficiency of the Federal government's own operations and purchases.

The third step is the promotion of an environmentally-responsible electricity restructuring bill, which the President identified as part of his domestic climate change package in his address to the National Geographic Society on October 22. An electricity sector freed from government regulation would be a more efficient energy sector. Costs to consumers would fall. In addition, stronger incentives for improved generation efficiency in conjunction with appropriate market based provisions could achieve modest reductions in emissions. A reasonable overall estimate of the contribution of federal electricity restructuring to the rest of the President's program to address climate change is that it would make further progress to the same emission reduction goals at a cost saving of roughly $20 billion per year. These steps should be taken regardless of Kyoto, because they make sense in terms of energy efficiency. But they have the added benefit of preparing us for Kyoto.

Estimated Reduction in Costs from Annex I Trading

In the language of the treaty, "Annex I," is the set of countries that have agreed to take on binding limitations in emissions of greenhouse gases. Even without meaningful developing country participation -- which, again, the President has emphasized is essential before the treaty would be submitted for ratification -- costs could be reduced substantially by emission trading among the Annex I countries. To provide some indication of the possible efficiency improvements, Russia and Ukraine consume six times as much energy per dollar of output as does the United States. Such large international differences in energy efficiency suggest that adoption of existing U.S. technology would yield very large emissions reductions in these countries.

Estimates derived from the SGM model confirm that emissions trading among Annex I countries can reduce the cost to the United States of achieving its targets for 2008-2012 emissions by about half relative to a situation in which such trading was not available. This concept of costs is meant to capture aggregate resource costs to the US economy, including the cost to domestic firms of purchasing emission permits from other countries where emission reductions may be cheaper than in the United States. Although these estimates reflect idealized international trading in efficient markets, the overall conclusion is clear. The dramatic reduction in costs potentially available from Annex I trading within the SGM model -- cutting the costs involved by half -- highlights why the President insisted that international trading be part of the Kyoto Protocol; and why its achievement by our negotiators in Kyoto was such an important accomplishment.

Estimated reduction in costs from umbrella trading

One possibility that emerged in Kyoto, which none of us foresaw, was the idea developed there by the U.S. delegation, that the United States might undertake trading with a subset of Annex I countries, dubbed the "umbrella". Countries that have expressed interest in the umbrella include the United States, Australia, Canada, New Zealand and Russia, with strong indications of interest from some others. This subset of Annex I countries shares a common interest in promoting market-based mechanisms, most specifically, fully flexible rules for international trading of emissions permits.

It is too early to state the precise form the umbrella will take. But we can envision a number of potential benefits. The umbrella could, for example greatly reduce costs to the U.S. Results that we have derived from various SGM simulations of efficient international trading suggest that, relative to the situation in which there is no trading at all, the umbrella can reduce costs by an estimated 60-75 percent, depending on whether the former Warsaw Pact countries fall within the umbrella. The Kyoto Protocol classifies these countries outside of the EU bubble for the first budget period 2008-2012. ok

Estimated reduction in costs from developing country participation

The next consideration is participation by developing countries. The President has said that he will not submit the treaty for ratification without meaningful participation by key developing countries. Such participation would further reduce the costs involved.

The substantial potential gains from meaningful developing country participation are highlighted by the significant benefits that will likely accrue from the limited role that the developing countries have already agreed to: the Clean Development Mechanism (CDM), modeled after the U.S. joint implementation concept. The CDM cannot realistically be expected to yield all the gains of binding targets for developing countries, but it might shave costs by roughly another 20 to 25 percent from the reduced costs that result from trading among Annex I countries.

Another possibility is that we persuade some of the key developing countries that are the largest emitters to commit to targets, and allow us to buy emission reductions from those paths. Simulations with the SGM model suggest that full participation by non Annex I countries could cut roughly 55 percent off the reduced costs that result from Annex I trading. The actual cost reduction would depend on the extent of developing country participation that is ultimately obtained, as well as the effectiveness of international trading arrangements. The more developing countries that take on modest binding targets and trade in international permit markets, the lower will be costs.

These cost-saving opportunities are fundamental tenets of the U.S. position. The promise of Kyoto cannot be achieved without effective emissions trading. Moreover, if we do not get meaningful participation by key developing countries, we won't submit the treaty for ratification to the Senate. So, while our analysis may be predicated on some ambitious conditions concerning trading and developing country participation, it is exactly those conditions that form the foundation of the U.S. position in international negotiations including those at Buenos Aires.

Accounting for Carbon Sinks

The preceding discussion has emphasized the importance of trading arrangements and the CDM. In reaching an overall economic assessment, it is also important to factor in the potential role of carbon sinks. Again, the U.S. delegation obtained a novel concept, that carbon absorbing activities called sinks could be used to offset emissions. The arrangements concerning carbon sinks in the Kyoto Protocol have received less attention than they merit. The Kyoto Protocol specifies that removals of CO_2 by sinks count toward meeting the target. The Kyoto Protocol counts the net emissions effects of three sink activities --afforestation, reforestation, and deforestation. Very preliminary estimates of the implications for the United States of the Kyoto provision on sinks indicate that carbon sinks could comprise a significant portion of the total required emissions reductions. Decreasing the required emissions reduction by, for example, 10% would likely result in cost-savings greater than 10%.

Furthermore, ~~due to~~ economic principles ~~of MC~~ MB, inform us that

Even this estimate of the effect of sinks is conservative in one respect: it is based on an assumption for sink activity in the U.S. over the 2008-2012 period, and no assumed benefits from sinks elsewhere in the world. Very preliminary estimates suggest that incorporating the gains from sinks *throughout the world* can substantially reduce the costs of meeting the Kyoto target, on top of the gains from trading among Annex I countries. (Furthermore, no model has yet even tried to take into account that government policies can help increase the activities qualifying as allowable sinks, like some tree-planting.) Because the quantitative uncertainty is so large, we do not yet have an estimate with which we are comfortable. But we expect that complete modelling of the Kyoto provision pertaining to sinks will likely have favorable and potentially large effects on projected costs.

Accounting for the role of improvements in energy efficiency

Another issue in analyzing the Kyoto protocol concerns future improvements in energy efficiency due to innovation and diffusion of existing technology. The parameter that figures most prominently in analysis of energy efficiency is the rate of improvement in the so-called Autonomous Energy Efficiency Index (AEEI), that is the rate at which the total use of energy falls relative to GDP. A plausible assumption on the AEEI is an improvement of 1.0 percent per year. Reflecting a conservative interpretation of the 15-year impact of various climate change initiatives, this is only a small increase above the 0.9 percent number in the Energy Information Administration's Annual Energy Outlook. That assumption is not the most optimistic outcome that might occur. Some authorities in the field of energy policy forecast more rapid technological progress. Experts at five national laboratories managed by the Department of Energy, using an engineering approach rather than an economic paradigm, found that a third of the emissions reductions necessary to return to 1990 levels by 2010 could be achieved through the adoption of existing energy-efficient technologies at no net resource cost, or even some savings. The National Academy of Sciences reached qualitatively similar conclusions in a 1992 report.

The President's FY 1999 budget, as I have noted, includes a \$6.3 billion package of tax cuts and R&D investments intended to spur the discovery and adoption of new technologies. If the Administration is successful in this effort, the rate of improvement in energy efficiency could rise and such improvements would lower the cost of meeting our Kyoto target. For example, published results based on SGM model simulations with different assumed rates of AEEI suggest that an increase in the AEEI of 25 percent could lead to declines in the permit price of approximately 40 percent.

Our justification for incorporating into our assessment a small assumed impact of Administration technology policies is somewhat analogous to the Administration's rationale for employing mainstream economic assumptions in our budget forecasts: in the presence of uncertainty, we are conservative in our estimates of the speed with which the economy will grow, tax receipts will rise, and the budget will improve. That way, any revisions or surprises that occur are likely to be in the pleasant direction. In this instance, we prudently and conservatively assume that there will be substantial delays between investments in new technology or the diffusion of existing technology, and the returns to such investments.

CUT?

Moreover, at the recent automobile show in Detroit, General Motors announced that it has developed a hybrid-based vehicle that can achieve fuel efficiency of 80 miles per gallon, and that this car could be in commercial production within a few years. Ford also exhibited a prototype of a light-weight highly fuel efficient sedan that could be in commercial production by the middle of the next decade. These announcements followed an earlier breakthrough announced by DOE and its partners of a fuel cell that could run on gasoline and double current fuel economy while reducing conventional air pollution emissions by 90 percent. These technological advances have been made possible through the efforts of the Partnership for a New Generation of Vehicles between the Administration and the U.S. auto companies and their suppliers.

Such progress may be replicated in other sectors. VCRs and TVs, while switched off, consume about $1 billion worth of electricity annually. EPA has established a partnership with major manufacturers that has a goal of achieving up to a 70 percent reduction in energy use while switched off, without sacrificing product quality, usefulness, or increasing costs. This partnership offers promise of substantial improvements in energy efficiency.

for TVs + VCRs

Non-Climate Benefits

A final factor that should be included in any comprehensive assessment of the economic implications of the Kyoto protocol are the benefits of the agreement. The literature has emphasized that any relative price shifts that prove necessary to reduce emissions should produce non-climate benefits in three areas: air pollution unrelated to climate change, traffic congestion, and highway accidents. These benefits are hard to quantify precisely but are potentially significant: our rough estimates suggest that these three benefits could offset 15-25% of any resource cost of the climate change policy. ?

Synthesis

A comprehensive evaluation of the economic impact of the Kyoto Protocol must integrate all of the factors described above: reliance on flexible market-based mechanisms domestically; international trading and Joint Implementation among Annex I countries; the Clean Development Mechanism; meaningful developing country participation; the potential cost-mitigating role of including six gases and carbon sinks; the benefits of electricity restructuring; and emissions reductions achieved as a consequence of other proposed Administration climate change initiatives. Assuming that effective mechanisms for international trading, Joint

Implementation and the Clean Development Mechanism are established, and assuming also that the U.S. achieves meaningful developing country participation, our overall assessment is that the economic cost to the United States in aggregate and to typical households of attaining the targets and timetables specified in the Kyoto Protocol, will be modest.

This conclusion that the impact will be modest is not entirely dependent upon, but is fully consistent with, formal model results. I have previously emphasized the limitations of relying on any single model in assessing the economic impact of the Kyoto Protocol, and continue to view any such results as just one input into an overall analysis. But it is worth emphasizing that model results reflecting the details of the Kyoto Protocol are consistent with our conclusion. For example, under the assumptions of either trading under the umbrella or within Annex I, the CDM and permit trading with developing countries, estimates derived using the SGM model, which adjust for the inclusion of six gases and assume little banking of credits beyond 2012, suggest that the resource costs of attaining the Kyoto targets for emission reductions might amount to $7 to $12 billion per year in 2008 to 2012. This implies that overall costs, excluding not only climate and non-climate benefits, but also such cost mitigating factors as sinks and payoffs from the President's electricity restructuring and climate change initiatives, would reach roughly one tenth of one percent of projected GDP in 2010.

A more tangible measure of costs is the estimated effects on energy prices. Excluding the impact of electricity restructuring and the ancillary benefits of mitigation and better forest management, the SGM-based estimate, corresponding to the gross resource cost estimate cited above, is an emissions price in the range of $14 to $23 per ton of carbon equivalent. This translates into an increase in energy prices between 2008 and 2012 at the household level of between 3 and 5 percent, an increase in fuel oil prices of about 5 to 9 percent, natural gas prices of 3 to 5 percent, gasoline prices of 3 to 4 percent (or around 4 to 6 cents per gallon), and electricity prices of 3 to 4 percent. This increase in energy prices at ~~the household~~ level would raise the average household's energy bill by between $70 and $110 per year in 2010, although such predictions may not be observable because they would be small relative to other energy price changes, and nearly fully offset by electricity price declines from Federal electricity restructuring. In particular, this increase in energy prices is small relative to the average of *year to year* real energy price changes experienced by U.S. consumers since 1960: such *annual* changes have averaged 3.8 percent. In addition, by 2008-2012, the projected 10 percent decline in electricity prices from the restructuring that is part of our climate change agenda is projected to lead to expenditure reductions of about $90 per year for the average household.

As highlighted earlier, there are substantial but unavoidable uncertainties surrounding estimates like these. For example, the estimate just discussed is predicated, among other things, on the developing country participation that we are insisting upon as a condition for our ratifying the Kyoto Protocol, but which is not yet part of that Protocol, and on effective international trading. Moreover, other models will yield other answers and much work remains to be done by the modeling community to test the robustness of these results. Preliminary comparisons of the SGM model to the few other models that have attempted to evaluate the Kyoto accord, suggest that its predictions concerning the impact of the Kyoto Protocol on carbon permit prices are neither the most conservative nor the most optimistic of the models that have been developed. The predictions of the SGM model are robust in the sense that virtually all energy models reveal the potency of effective, flexible, domestic and international trading mechanisms to reduce substantially the cost and energy price impact of meeting the Kyoto targets.

Of course, the most important factor that has been left out of the above assessment is the benefit of mitigating climate change itself. A full cost-benefit analysis would include mitigation in the benefits column. The only reason we have not done so, explained repeatedly above, is the difficulty in coming up with a number to capture the monetary benefits. But nobody should lose sight of our ultimate objective -- keeping our planet the hospitable home that we enjoy today.

Effects on employment and aggregate output

So far we have said nothing about job losses resulting from climate change policy. Although there may be job gains in some sectors and job losses in others, we do not anticipate any significant aggregate employment effect if we achieve the conditions we have discussed. The effects on energy prices described above will occur only 10 to 14 years in the future. Not only are these effects small relative to historical variations in energy prices, and offset by other policies like electricity restructuring, they would occur sufficiently far in the future to enable monetary policy to keep the economy operating at its potential. In energy-intensive sectors some employment reduction could occur, although given the very small predicted change in energy prices, impacts in most such sectors are apt to be minimal. Furthermore, a large number of jobs will be created in other sectors -- many of them high-tech jobs paying high wages. The President is firmly committed to assisting any workers who are adversely affected during the transition to a climate-friendly economy.

PARA CUT ?

VII. Conclusion

In conclusion, the Kyoto Protocol and the President's general approach to climate change reflect the insight of economic analysis. The Kyoto Protocol includes key provisions on international trading and Clean Development projects. The President's approach relies on market incentives -- first, with a system of tax cuts and R&D investments, and then later with a market-based system of tradeable permits -- to ensure that our objectives are achieved as efficiently as possible.

Our overall conclusion is that the economic impact of the Protocol will be modest under the conditions we have identified. The purpose of this testimony has been to explain the reasoning underlying this conclusion, which draws insights from not only the forecasts of individual models, any one of which has its own strengths and limitations, but also a broad variety of additional analyses.

I look forward to continuing to work with members of this Committee, as well as other interested parties, in further analyzing the Kyoto Protocol and evaluating the net effects of reducing greenhouse gas emissions. It is my hope that economic analysis will continue to play a key role in designing policies in this area.

I welcome your questions.

CO_2
target: 1333   16 → Joe will write up

2010: 1838

Δ: 505

→ 173

target: 1580

20: 2115

Δ: 535

→ 139.4

20%

Some initial analysis indicates that a strategy of reducing non-CO2 greenhouse gases by *more* than 3 percent below their 1990/1995 baseline levels while reducing CO2 by *less* than 3 percent below its 1990 level could reduce greenhouse gas emission permit prices by more than 10 percent. [Double check number] Thus allowing countries flexibility in what gases they reduce -- essentially trading emissions reductions across gases -- can help lower significantly the costs of meeting their targets. Joe's analysis 16

The second source of "what flexibility" is the treatment of sinks, i.e., land use activities that promote the removal of carbon from the atmosphere through the growth of plants. At the urging of the U.S. delegation, sinks can be used to offset emissions targets. Promoting such sinks through afforestation and reforestation may reduce atmospheric concentrations of CO2 at much lower costs than reducing emissions of greenhouse gases. 18 ERP Article 3 of Protocol

3. "Where flexibility" (international)

The third type of flexibility, and perhaps the most important, is "where flexibility" (international). As I have already emphasized, emissions have the same environmental 19 consequences regardless of where in the world they occur. Therefore, the least-cost approach to controlling climate change is to reduce emissions wherever such reductions are cheapest. The Kyoto Protocol, because of U.S. insistence and persistence, includes three important cost-saving provisions of this nature. ERP

- First, it provides for countries that take on binding targets, at present the industrial countries, to trade rights to emit greenhouse gases with each other. This market in emissions permits could ensure that emission reductions occur where they are least expensive within the industrial countries. In particular, U.S. companies could purchase emissions reductions in other participating countries when doing so would reduce their costs -- thus lowering costs without affecting the level of environmental protection. 20 Kyoto: Article 16b.3

- Not #2 21 Second, the agreement provides for joint implementation by Annex I countries. Thus if one industrial country did not develop a program to trade permits internationally, U.S. firms could nonetheless implement projects abroad for which they could receive emissions reductions credits in the U.S. Article 6

- Third, the agreement allows industrial countries to invest in "clean development" projects in the developing world and use these projects' certified emissions reductions toward meeting their targets. Many such clean-development projects may be quite cheap in terms of the cost per ton of emissions avoided, as has been illustrated by the joint implementation pilot program that is already in place in the U.S. 22 Also see fact #2 Article 12

Details of how these provisions will operate will be discussed in future negotiations such as the one in Buenos Aires later this year. Nonetheless, effective international trading of emission credits, joint implementation and the Clean Development Mechanism can lead to substantial reductions in costs relative to alternative policies that do not exploit the power of 23 ERP see fact #2

-- It should be noted that COP 3 Decision L.9 requests the Subsidiary Body for Implementation, at its 8th session, to determine actions necessary to implement the corresponding provision in the Framework Convention (i.e., Article 4(8) and (9) relating to the specific needs of developing country Parties particularly affected by either climate change or by response measures to climate change) and further requests COP 4 to take a decision on actions.

o Finally, the Article provides for the COP/MOP, if it decides it would be beneficial to coordinate any policies and measures (i.e., on a strictly voluntary basis), then it is to consider ways to elaborate such coordination.

Article 3 (Annex I Target)

o Paragraph 1 contains two important features:

-- First, it sets forth the obligation of Annex I Parties to ensure that their emissions do not exceed their commitments, as set forth in Annex B (which contains the relevant percentage for each Party) and the rest of Article 3 (which contains time periods, base years, accounting rules, etc.). In order to make clear that the obligation, even though written in the plural ("The Parties included in Annex I shall..."), is not a collective obligation under which each Party would be responsible for another, the phrase "individually or jointly" was included.

-- Second, the end of the sentence containing the obligation states "with a view to reducing their overall emissions of such gases by at least 5 per cent below 1990 levels in the commitment period 2008 to 2012." There are three reasons why this phrase was written in non-legally binding terms:

o The point of the statement is more political than legal, i.e., it was considered that it more make it more palatable to have certain Annex I Parties increasing their emissions over 1990 levels (such as Australia) if it were pointed out that, as a group, the Annex I Parties will actually be reducing below 1990 levels.

o The figure of 5% below 1990 levels does not take account of the ability of Annex I Parties to increase their allowed emissions through the Clean Development Mechanism, described below. In other words, emissions trading and joint implementation among Annex I Parties would not change the 5% figure; however, additional emissions allowances through the CDM from outside of Annex I could theoretically even put the Annex I Parties over 1990 levels.

- o If legally binding, the provision might imply a collective responsibility to meet the group target, which would not have been acceptable to us.

o It should also be noted, with respect to paragraph 1, that there has been a lack of clarity under the Convention as to which emissions count against a Party. In part to address this issue, and in part to address the U.S. national security issue, COP 3 adopted Decision L.5, which provides, inter alia:

-- that emissions based upon fuel sold to ships or aircraft engaged in international transport are not included in national totals; and

-- that emissions resulting from multilateral operations pursuant to the UN Charter are not included in national totals; and

-- that other emissions related to the operations noted above (such as from training in a foreign country) are to be included in the national totals of one or more of the Parties involved, but it leaves to those Parties to figure out which. (In this way, it allows Parties to reallocate emissions without going through emissions trading.)

o Paragraph 2, in order to respond to calls for an obligation before the 2008-2012 commitment period, calls for each Annex I Party to have made "demonstrable progress" in achieving its commitments. The U.S. took the position that, for example, having in place the necessary implementing legislation would fulful this obligation.

o Paragraph 3 relates to sinks, specifically their treatment during the commitment period. (One must look to paragraph 7 of this Article to see that sinks are not included in the baseline.) The significant features include:

-- that net changes in the specified categories are to be used in meeting the target commitment; in other words, a Party does not get to count only the positive.

-- that the net changes in the specified categories must be counted; in other words, counting sinks is not optional.

-- that the categories are currently limited to afforestation, reforestation, and deforestation, and, further, that these activities only count since 1990; in other words, the net changes in emissions from trees planted before 1990 would not count.

17

19

ing regime among industrial countries, but leaves the details to be agreed upon later. Since it is easier to reduce emissions in some countries than others, and given that greenhouse gas emissions have equivalent climate effects regardless of their location, allowing global trading would achieve climate change objectives at lower cost. Such a global approach would ideally allow trading among all sources of greenhouse gases in participating countries and could incorporate opportunities to *remove* greenhouse gases from the atmosphere, for example by issuing emissions credits (which could then be sold to other firms) for reforestation projects.

International trading could take place among firms that have been allocated permits through domestic trading programs. For countries that have no domestically tradable permits because they have opted for a command-and-control or a tax approach to controlling emissions, it may still be possible instead to arrange exchanges on a government-to-firm or government-to-government basis.

The setting of binding targets among all countries, together with international trade in permits, could in principle result in a global market price for permits for greenhouse gas emissions. For example, the permit price could be expressed in terms of dollars per ton of carbon equivalent emitted. Firms in all countries would reduce their emissions until the cost of further reductions exceeded this price, at which point they would buy additional permits. Large differences in both the patterns of energy use and the efficiency of energy technologies among countries imply that the cost savings from international permit trading would be large compared with a system without international trading. Put differently, even in comparison with a system with full domestic trading of emissions permits, international trading could substantially lower costs. Some models predict that the incremental cost of reducing CO_2 emissions may be as little as one-seventh of the cost of reductions from domestic trading alone. The gains from international trade in permits would be particularly large if developing countries were to participate.

The Importance of Developing-Country Participation

Negotiations leading up to the Kyoto agreement sought binding limits on greenhouse gas emissions among industrial nations. Developing countries have resisted committing themselves to binding limits on their emissions because of concern that to do so would severely constrain their economic growth, and because by far the greater part of accumulated greenhouse gases in the atmosphere is the result of past economic activity in the industrial countries (Chart 5-5). However, current forecasts project that greenhouse gas emissions from developing countries will surpass those from industrial countries around 2030, and even sooner if industrial countries are successful in limiting their emissions (Chart 5-6). Thus, eventual curbs on emissions from developing countries are essential in order to

Article 15 (Subsidiary Bodies)

- This Article provides for the Convention's subsidiary bodies, namely the Subsidiary Body for Scientific and Technological Advice and the Subsidiary Body for Implementation, to serve as the subsidiary bodies under the Protocol.

Article 16 (Multilateral Consultative Process)

- Article 13 of the Convention provides for the COP to

  > "consider the establishment of a multilateral consultative process, available to Parties on their request, for the resolution of questions regarding the implementation of the Convention."

- The intent was to create a forum for implementation questions that, in contrast to traditional dispute-settlement, was: multilateral; friendly; [illegible]d able to take up issues that were necessarily alleged tr[illegible]ty violations.

- Numerous, inconclusive discussions have taken place under the Convention concerning the establishment of such a process.

- This Article of the Protocol presupposes the existence of a process under the Convention. It provides for the COP/MOP to consider the application to the Protocol of such a process, making modifications as appropriate.

Article 16 bis (Emissions Trading) #20

- This Article establishes emissions trading for purposes of meeting target commitments.

- Its significant features include:

  - It provides for the COP (as opposed to the COP/MOP, so that decisions can be made in advance of the Protocol's entry into force) to define the relevant rules for trading. (The rules are on the agenda for COP 4.)

  - There is a free-standing sentence providing for the ability to participate in emissions trading; unlike the penultimate version of the text, it is not explicitly preconditioned on the establishment of rules.

-- In contrast to proposals to put a percentage limit on the amount of the target that Party could satisfy through trading (either through a number or by providing that domestic actions had to be the "main" means of meeting the target), the Article simply provides that trading is to be "supplemental" to domestic actions.

-- Unlike other provisions in Article 3, which refer to Parties "included in Annex I," this Article provides for trading among "Parties included in Annex B." This is a result of a technical fix that was made when Article 10 (voluntary opt-in) was still in the text; that Article provided that, if a developing country took on a target, it would be inscribed in Annex B. In order to make clear that such countries could then trade, the emissions trading article then had to say that trading was possible among "Annex B" Parties. Even in the absence of Article 10, this Article can be read to allow trading among Parties, provided they are listed with a target in Annex B. As such, a developing country could presumably propose an amendment to Annex B with its target; if it were adopted and entered into force, it would seem to be able to trade.

<u>Article 17 (Non-Compliance)</u>

o This Article provides for the COP/MOP to approve appropriate and effective procedures and mechanisms to determine and address cases of non-compliance. Pursuant to a U.S. proposal, the task includes development of an indicative list of consequences for non-compliance, taking into account the cause, type, degree and frequency of non-compliance.

o It also provides that any <u>binding</u> consequences need to be adopted through an amendment.

-- This provision was a compromise between two views. Some considered that the COP/MOP ought to be authorized to establish binding penalties through decision. Our view was that binding consequences of non-compliance should be spelled out in the Protocol itself (such as our borrowing proposal) and that it was not appropriate (or likely to be acceptable to the Senate) to establish binding penalties through decisions. The compromise provides for the option of binding penalties, but makes clear that they would need to go through the normal amendment procedure.

- If a regional economic integration organization (such as the EU) is involved, any change in the composition of the organization after adoption does not affect existing commitments. In other words, if an Eastern European country were to join the EU next week, it could not join the EU bubble; that country would only be part of the bubble for purposes of subsequent commitments.

Article 5 (Measurement)

- Under this Article, each Annex I Party must have in place, no later than 2007, a national system for the estimation of anthropogenic emissions by sources and removals by sinks of greenhouse gases.

- Guidelines for national measurement systems are to be decided by the COP/MOP and are to incorporate the IPCC methodologies, which were agreed upon at COP 3.

- Where a Party does not use the accepted methodologies, appropriate adjustments (e.g., discounting) are to be applied according to methodologies agreed by the COP/MOP.

- The COP/MOP is to regularly review methodologies and revise them as needed; importantly, revisions would only apply prospectively to subsequent commitments.

- This Article also provides that the global warming potentials (GWPs) used to calculate carbon dioxide equivalence (note that the target commitment is written in terms of carbon dioxide equivalence) are those accepted by the IPCC and agreed by COP 3. As with methodologies, the COP/MOP may revise GWPs; however, any revisions would only apply to subsequent commitments.

Article 6 (JI with Annex I) 21

- This Article is largely the joint implementation provision that the U.S. sought, except limited to Annex I Parties.

- The key elements include:

  -- Unlike under emissions trading (see Article 16 bis below) and the Clean Development Mechanism (see Article 12 below), the COP/MOP is not commanded to set rules; rather, it is authorized ("may") to further elaborate guidelines. This implies that JI could go forward without further COP/MOP action. (It should be noted, however, that the elaboration of guidelines is on the COP 4 agenda.)

-- JI applies to emission reduction units resulting not only from mitigation projects, but also from projects "enhancing anthropogenic removals by sinks."

-- Projects must have the approval of the Parties involved.

-- A project must provide a reduction that is "additional" to any that would otherwise occur.

-- A Party cannot acquire units if it is not in compliance with its measurement/reporting obligations; if a compliance issue is raised, units can continue to be exchanged; however, units may not be used to meet the target until any compliance issue is resolved.

-- As under emissions trading (<u>see</u> Article 16 <u>bis</u> below), JI is to be "supplemental" to domestic actions for meeting the target.

-- Parties may authorize legal entities (which could include the private sector) to participate.

<u>Article 7 (Reporting)</u>

o Under this Article, each Annex I Party must incorporate in its annual inventory of emissions/removals and its national communication under the Convention the additional information that is necessary to ensure compliance with the target obligation.

o The COP/MOP is to adopt guidelines for the submission of such additional information.

<u>Article 8 (Review)</u>

o This Article provides that the information submitted by Annex I Parties under the previous Article is to be reviewed by expert teams, which are to be coordinated by the Secretariat and to be composed of experts selected from those nominated by Parties and, as appropriate, by intergovernmental organizations.

o Expert teams are to prepare a report to the COP/MOP assessing implementation of all commitments (not just the target), including identifying potential problems in fulfilling commitments.

Article 11 (Financial Resources)

- This Article essentially restates the financial provisions of the Convention; it does not create new financial obligations.

- First, it provides that the operating entity of the financial mechanism of the Convention (i.e., the GEF) shall apply.

- Second, under the Convention, developed country Parties are obligated to provide new and additional financial resources to meet:

  - the agreed full costs incurred by developing country Parties in meeting certain commitments, such as reporting; and

  - the agreed full incremental costs of meeting other commitments.

  This Article makes clear which provisions of the previous Article (which advances the implementation of existing commitments under the Convention) qualify for full cost funding and which qualify for incremental cost funding.

Article 12 (Clean Development Mechanism) 22

- This Article provides for the functional equivalent of joint implementation with developing countries.

- It provides for Annex I Parties to be able to get credit towards "part" of their target (to be defined by the COP/MOP) for emissions reductions from project activities in non-Annex I countries.

- Emission reductions are to be certified by operational entities to be designated by the COP/MOP, based on:

  - voluntary participation by each involved Party;

  - real, measurable, and long-term benefits related to mitigation of climate change (which would appear to include sink projects);

  - reductions in emissions that are "additional" to any that would occur in the absence of the activity.

- The COP/MOP is to ensure that a share of proceeds from certified activities is used to cover administrative expenses, as well as assist developing country Parties (such as small island states) to adapt to climate change.

- As in Article 6 on JI, it is clear that the private sector may participate; participation may involve either investing in project activities that yield emission reductions or acquiring certified emission reductions without such an investment.

- Significantly, the Article provides for early credit in that certified reductions obtained from 2000 up to 2008 can be used to meet the target.

  - COP 3 Decision L.7 calls for COP 4 to analyze the implications of this provision.

Article 13 (COP/MOP)

- As a compromise between those wanting the Convention's Conference of the Parties (COP) to be the institution for the Protocol and those seeking a new, separate institution, Article 13 provides that the Convention COP will serve as the "meeting of the Parties" to the Protocol. While leaving ambiguous whether the COP/MOP is a new institution, the Article does make clear that decisions under the Protocol may only be taken by those that are Parties to the Protocol.

- The COP/MOP has basically the same functions with respect to the Protocol that the COP has with respect to the Convention.

- Significantly, the Article provides that the Convention's rules of procedure and financial rules will apply under the Protocol, except as otherwise decided by consensus by the COP/MOP. The implications of this provision are:

  - that, in the absence of agreed rules of procedure under the Convention (the current situation), the default decision-making rule under the Protocol would be consensus; and

  - the Convention's rules of procedure now need to be approached from the point of view that, absent consensus to the contrary, they will also apply to the Protocol.

Article 14 (Secretariat)

- This Article provides for the Convention Secretariat to serve as the Protocol Secretariat.

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market incentives. To illustrate briefly the ability of U.S. industry to perform beyond expectations when given appropriate economic incentives, consider further EPA's highly acclaimed sulfur dioxide (SO2) program, which relies, among other things, on a system of tradeable permits to reduce emissions of SO2 from electric utilities. The SO2 program has been successful in several ways: a large number of utilities participate, SO2 emissions and ambient concentrations have fallen and the costs of reducing emissions are considerably lower than originally forecast. 24 ERP

As has been frequently noted, the average cost of SO2 emissions reductions has recently been significantly lower than was originally forecast, in part due to the role of incentives in fostering innovation. Emission permit prices, currently at approximately \$100 per ton of SO2, are well below earlier estimates of around \$250 to \$350 per ton. 25 ERP

\$400

Trading programs may not always bring cost savings as large as those achieved by the SO2 program; trading programs will not always be accompanied by the discovery of much cheaper control strategies. However, the SO2 experience demonstrates clearly how programs like international permit trading, joint implementation and the Clean Development Mechanism will lead firms to find cheaper ways of reducing emissions that can lead to unexpectedly low costs. NE

IV. Difficulties of Economic Analysis of the Kyoto Protocol

Now that we have a Protocol -- even if it is not yet fully complete nor ready for the President's submission to the Senate -- it is possible to examine it in somewhat more detail from an economic perspective. But, once again the inherent limitations of any such estimates deserve emphasis. Such limitations should not be surprising to you: economists have a difficult enough time projecting the behavior of the economy over the next quarter or year, let alone over the next two decades. The scale of the forecasting exercise is therefore daunting, and any specific results should be treated with substantial caution. NE

The difficulties associated with economic analysis of climate change fall into three broad categories. First are the uncertainties that still remain over the terms of the ultimate treaty, necessitating assumptions on which the analysis is predicated. Second are the inherent limitations of available models to analyze even short-term costs and benefits. And finally is a topic discussed earlier: the impossibility of putting a single monetary number on the long-term benefits of climate change mitigation, although there will clearly be economic benefits of emission reductions. NE

Uncertainties in the International Effort to Combat Climate Change

The Kyoto Protocol was an historic accomplishment, delineating the broad terms of the international effort to address climate change. But although we know a lot more than we did before Kyoto about how that international system will work, and that informs our analysis, there is still much that we do not know. NE for their cost share of emissions reductions, leaving them better off than before the permit system was introduced.

Lessons from the Sulfur Dioxide Program

Practical experience in designing and implementing trading programs for pollution emissions permits is still limited. The highly acclaimed sulfur dioxide (SO_2) program—also called the acid rain program—administered by the Environmental Protection Agency (EPA) relies on, among other things, a system of tradable permits to reduce emissions of SO_2 from electric utilities. Trading of emissions permits began in 1992, and to date the program is the only emissions permit trading program that is national in scope. The SO_2 program is being implemented in two phases. The first phase covers the 110 most heavily polluting electric generating plants. Phase II, beginning in 2000, will impose a more stringent emissions cap and include a total of more than 2,000 units. The program has been successful in several ways: a large number of utilities engage in trading, SO_2 emissions and ambient concentrations have fallen, and the costs of reducing emissions have been considerably lower than originally forecast.

24

24

Why the early cost estimates were higher than the costs actually realized is a matter of considerable discussion. One contributing factor was a greater-than-expected decline in rail freight rates, which made low-sulfur coal from the Powder River Basin of Wyoming more competitive with locally mined, high-sulfur coal in Midwestern markets. Use of low-sulfur coal proved a less costly means of reducing SO_2 emissions than the smokestack scrubbers that utilities had anticipated using. A second factor was lower-than-predicted costs of using scrubbers, in part because of unexpectedly high utilization rates. The average cost of reducing SO_2 emissions using retrofitted smokestack scrubbers was about $270 per ton in 1995, far below early estimates of around $450 to $500 per ton.

25

One measure of the decline in cost relative to expectations is the trend in emission permit prices (Chart 5-1). Currently, at approximately $100 per ton of SO_2, permit prices are well below earlier estimates of around $250 to $400 per ton. These prices reflect the short-run marginal cost of reducing SO_2. Prices are low partly because firms, believing that permit prices would be much higher, overinvested in scrubbers. Average total control costs are likely to be higher than these short-run marginal costs.

The permit trading program also allows firms to bank unused emissions permits for future use, for example when emissions limits become more stringent in phase II. By banking, utilities can lower costs by timing their reductions according to their projections of emissions control costs and permit prices. If firms expect permit prices or control costs to go up, or if they want to take advantage of newly available control technology, they can adopt measures to reduce emissions sooner than they otherwise might.

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First, some provisions raise complex implementation issues. At issue here is the treatment of so-called sinks -- activities that affect the rate at which carbon is removed from the atmosphere and "sequestered," e.g., by the planting of trees. NE

Second, the details of a number of items -- primarily concerning international trading and developing countries -- are the subject of further discussions including future negotiations in Buenos Aires next fall, because they had not been definitively settled by the end of the last all-night session of the Kyoto talks. ERP 26

Finally, and most importantly, we have not yet negotiated international agreements to limit emissions beyond the 2012 window. The emission cuts agreed upon at Kyoto are only a first step on a long journey. The first step that we propose to take over the next 15 years is critical. But the reason it is critical is *not* that, by itself, it will solve the climate change problem -- emissions during any given decade are small compared to the cumulative concentrations in the atmosphere. Rather, the first step is critical because we can not take the second and third steps until we have taken the first. At the same time, any analysis is complicated by the lack of knowledge over what the subsequent steps will be. NE

Inherent Limitations of Models

In addition to these uncertainties about the details of the international effort to address climate change, are the inherent limitations of the models used to evaluate that effort. Even within a given model, answers depend critically on the precise nature of the question asked. For example, the costs of emissions reductions depend critically on the extent of global participation and international trading that a treaty is assumed to feature. But in addition to the dependence of the results from a given model on the precise assumptions, different models can give different answers even when all the assumptions are specified to be the same -- a concrete illustration of the range of uncertainty to which we must assign the predictions of any one individual model. NF

One area in which the uncertainty is particularly large is the pace of technological progress --especially the diffusion of existing energy-efficient technologies, but also the development of new technologies -- and the extent to which the pace will accelerate in response to government programs. Models and experts on climate change policy tend to have a wider range of disagreement on the scope for speeding the diffusion of existing energy-efficient technologies than on any other single issue. NF

Furthermore, each model has strengths and weaknesses; each has questions to which it is better or worse suited to answer. Some, for example, model the energy sector in detail. — SGM, MERGE Joe
Some allow for the fact that a coal-fired power plant cannot costlessly be converted to one that — SGM
runs on natural gas. Some show the effects of hypothetical tax cuts made possible by the new — G3, DRI
revenues earned through the auction of emissions permits. Some are capable of showing — DRI
recessions and booms. Others include a long-term "carbon cycle" model that can keep track of the accumulation of greenhouse gas concentrations in the atmosphere and their climatological — MiniCAM
effects. Some break down the rest of the world into regions and so can model international trade. — G3
No one model does everything, and therefore we must not rely blindly on the results of any one

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model or set of models. Professional judgement and economic intuition, along with diplomatic assessments, are also crucial.

Benefits of Averting Climate Change

As discussed above, it is evident that the benefits of averting climate change are potentially immense. But we have chosen not to try to quantify them in monetary terms, in light of the difficulties we have enumerated. These include the uncertainty of these benefits, their timing and therefore the extreme sensitivity of the results to the chosen discount rate, and the dependence of benefits on emissions paths after the 2008 to 2012 budget period specified in Kyoto. NF

V. Assessing the Kyoto Protocol

In order to evaluate the likely net economic impact of the Kyoto Protocol, ***excluding the benefits of mitigating climate change itself***, we have drawn upon a variety of tools to assess the various possible costs and non-climate benefits of the Administration's emissions reduction policy. To give away the punch line, our conclusion is as follows: the net costs of our policies to reduce emissions are likely to be small, assuming those reductions are undertaken in an efficient manner and we are successful in securing meaningful developing country participation as well as effective international trading and clean-development mechanisms in future negotiations. That potential small net premium, even excluding the benefits of mitigating climate change, in effect, purchases a partial insurance policy against a serious environmental threat. NF

Because the results from any model must be treated with caution, the Administration has employed a broad set of economic tools to assess the Kyoto Protocol. We have drawn on the insights of a wide range of models of the energy sector and economy over the next 25 years, including but not limited to the results of the Stanford Energy Modeling Forum exercises, the IPCC's review of the economic and social dimensions of climate change, the work of the OECD on Economic Dimensions and Policy Responses to Global Warming, and the staff-level Interagency Analytical Team analysis produced last year. Other tools include simple relevant statistics, "meta-analyses" including work by the World Resources Institute, models, and basic economic reasoning. Drawing on this broad array of analytical tools is crucial to an intelligent evaluation of the policy alternatives. NF

To our knowledge, no model -- whether used inside the government or not -- has yet been set up to analyze the implications of the Kyoto Protocol, since this agreement is only a few months old and remains unfinished. In particular, no model is currently designed to assess Kyoto's treatment of sinks, or all six greenhouse gases. Some model-builders outside the government tend to take as long as several years to incorporate changes in policy parameters into their models. LT Joe's conversation w/ John Weyant

Our thinking has been informed, however, by simulations conducted with the Second Generation Model of Battelle Laboratories, one of the leading models in the field. The SGM is

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one of the models best positioned to analyze the role of international trade in emission permits, which we consider to be a critical element of the Kyoto Treaty. However, the SGM does not cover all six gases included in the Kyoto Protocol or include a role for sinks. We have used the SGM model as one input into our overall assessment of the Kyoto treaty, but have attempted to supplement its results with additional analysis to account for such special features of the agreement as the inclusion of six gases, a possible trading arrangement that could include a subset of the Annex I countries and the Clean Development Mechanism. We will share with you today some preliminary results of this analysis. To the extent possible, we have compared results obtained with the SGM model with those of other modelling efforts.

Mindful of the limitations of any single model, we are eager to see features of the Kyoto Protocol assessed by other models to obtain a better feel for the range of possible effects. This work is just beginning and much of it will continue to go on outside the government. For example, the Energy Modeling Forum, based at Stanford University, is a long-running model comparison exercise involving many of the leading climate models. EMF is currently studying how features of the Kyoto legal language can be translated into terms recognizable to economic modelers. We expect that the group will conduct a full scale analysis of the Kyoto Protocol. The Energy Modeling Forum believes that its members will need at least until mid-year to update their results. 28 Joe's conversation w/ John Weyant

VI. Assessing the Potential Costs of Emissions Reductions

I said in Congressional testimony last July that we can do this smart or we can do this dumb. I was referring to the point that the costs of cutting emissions can be much reduced if flexible, market-based mechanisms are used. Our economic analysis highlighted the importance of such flexible, market-based mechanisms -- which are therefore reflected, at the President's insistence, in the Kyoto Protocol and our ongoing diplomatic strategy. NF

Within the Kyoto Protocol, this means an insistence on international trading, joint implementation, and, ultimately, on meaningful developing country participation. Domestically, this means that we implement any emissions reductions through a market-based system of *tradeable* emissions permits, which ensures that we achieve reductions wherever they are least expensive. But this also means taking serious and responsible steps in the short run to prepare us to meet our obligations in the longer term. NF

Not in budget

The first such step is the inclusion in this year's budget of an aggressive, $6.3 billion program of tax cuts and R&D -- $1.3 billion more than the $5 billion package the President promised in his October 22 speech on this issue. The goal is both to stimulate the development of new energy-saving and carbon-saving technologies and to encourage the dissemination of those that exist already. ~~The proposed package contains $3.6 billion over the next 5 years in tax cuts for energy-efficient purchases and renewable energy, including~~ tax credits of $3,000 to $4,000 for consumers who purchase highly fuel efficient vehicles, a 15 percent credit (up to $2,000) for purchases of rooftop solar equipment, a 20 percent credit (subject to a cap) for purchasing energy-efficient building equipment, a credit up to $2,000 for purchasing energy-efficient new homes, an extension of the wind and biomass tax credit, and a 10 percent 26 31 CETI TD 32 33 34 35 36

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Climate Change Technology Initiative (CCTI)

30 Last fall, the President announced a nine-point plan to begin addressing climate change, including a five-year, $5 billion package of tax incentives and research and development spending to spur energy efficiency and help develop low-carbon energy sources. With the historic agreement in Kyoto in December 1997 to reduce greenhouse gas emissions, the President is now proposing a $6.3 billion initiative over 5 years -- $2.7 billion in increased spending and 31 $3.6 billion in tax incentives. (See Table 1.) For FY 1999, the budget shows $473 million in increased spending on climate-change related technologies ($1.292 billion vs. $819 million in FY 1998) and $421 million in tax incentives, for a total first-year initiative of $894 million.

TABLE 1

Direct Programs & Tax Incentives	Dollars in Millions				
BY AGENCY	1997 Actual	1998 Estimate	1999 Proposed	Dollar Change: 1998 to 1999	Total Increase 1999-2003
Energy	657	729	1060	+331	+1,899
Environmental Protection Agency	86	90	205	+115	+677
Housing and Urban Development	--	--	10	+10	+10
Commerce	--	--	7	+7	+38
Agriculture	--	--	10	+10	+86
R&D Program Total	743	819	1,292	+473	+2,710
Tax Incentives	--	--	421	+421	+3,635
Climate Change Technology Total	743	819	1,713	+894	+6,345 29

TABLE 2

Direct Programs	Dollars in Millions		
BY AREA OF EFFORT	1998 Estimate	1999 Proposed	Dollar Change: 1998 to 1999
Buildings	146	264	+118
Industry	156	216	+60
Transportation	246	356	+110
Electricity	220	332	+112
Carbon Sequestration and Cross-Cutting Research	0	42	+42
Policy Analysis, Market Incentives	6	26	+20
Program Direction	45	57	+12
Climate Change Technology Direct R&D Total	819	1,292	+473

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Columns may not add due to rounding.

The principal focus of the initiative is an R&D portfolio that covers the four major carbon-emitting sectors of the economy (buildings, industry, transportation, and electricity), plus carbon removal and sequestration, Federal facilities, and crossing cutting analyses and research. (In Table 2, Federal Facilities are included under Buildings.)

BUILDINGS

- ***Accelerate the deployment of existing technologies.*** Major improvements in the energy efficiency of both residential and commercial buildings can be obtained through better labeling of highly efficient technologies and appliances (such as the easily identified Energy Star label), through demonstrations and partnerships with builders and developers, and through two related tax credits:

    - one that encourages the purchase of certain highly efficient building equipment (electric heat pumps, natural gas heat pumps, advanced central air conditioners, and fuel cells for power generation); and,

    - one that provides a credit for the purchase of highly-efficient new homes.

- ***Partnerships for Advanced Technologies in Housing (PATH).*** HUD will lead a team that includes DOE and EPA to work with the building industry to develop, demonstrate, and deploy housing technologies and practices that are inexpensive, highly efficient, and attractive to consumers. This effort will also focus on streamlining Federal, state, and local codes and regulations, education outreach, and creating local markets for PATH housing using pilot sites and demonstrations.

- ***Million Solar Roofs.*** In June of 1997, the President announced an initiative to encourage the installation of one million solar hot water and solar photovoltaic (PV) installations on buildings over the next 10 years. DOE will fund cost-reduction R&D for solar thermal and rooftop PV systems, and will establish partnerships with communities, builders, and other Federal agencies to promote the use of building-mounted solar systems.

    - In addition, a tax credit is proposed to encourage the purchase of rooftop solar thermal and PV systems.

- ***Increased R&D.*** In addition to encouraging the deployment of the best available technologies, DOE is also increasing its research on building systems modeling, to help architectural engineers, and on major components such as next-generation heat-pumps, cooling systems, furnaces, and lighting.

INDUSTRY

- *Partnerships with industry.* DOE works closely with industry on technology roadmaps and plans to reduce energy consumption and secure early reductions in greenhouse gas emissions. Industries already engaged in this effort include aluminum, steel, glass, paper and forest products, metal casting, and chemicals. These technology roadmaps form the basis for cost-shared R&D with industry teams and consortia.

    - This work will be enhanced within DOE, and complementary efforts will be undertaken by EPA, USDA, and DOC (NIST), which will lead to voluntary greenhouse gas reduction programs within industry.

- *Combined heat and power.* This is an advanced form of cogeneration that integrates power generation with the provision of useful thermal energy in a factory or building.

    - R&D will be accelerated on advanced turbines, fuel cells, and other technologies, and new approaches to capturing useful work or heat through several temperature stages (e.g. electric generation, industrial process steam, steam building heat) in factories or commercial buildings will be demonstrated. When commercially accepted, these systems will allow us to capture the waste heat the Nation now throws away.

    - A 10 percent tax credit is also proposed for investments in combined heat and power systems that have depreciation recovery periods of 15 years or longer. 26

    - Tax credits are also proposed for certain investments to remove or recycle fluorine and fluorocarbon compounds that act as highly-potent greenhouse gases.

TRANSPORTATION

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- *Partnership for a New Generation of Vehicles (PNGV).* A government-industry effort to develop an attractive, affordable car that meets all applicable safety and environmental standards and gets up to three times the fuel efficiency of today's cars, or roughly 80 miles per gallon. Five agencies participate in PNGV -- DOE is the largest player, followed by EPA, DOC, NSF, and DOT.

    - The program will lead to "concept cars" in the year 2000 and production prototypes in 2004.

    - This winter, industry and the government have announced the designs that they will pursue -- hybrid vehicles that combine a power source (a piston engine or fuel cell) with battery storage and electric motors.

- In FY99, the combined request for PNGV-related work in those agencies is $277 million, up from $227 appropriated in FY98.

- Tax credits are proposed to encourage the purchase of this type of highly-efficient vehicle, and to help make them more affordable. A $3,000 credit will be available starting January 1, 2000 for vehicles that are twice as efficient as the norm for their class, and a $4,000 credit will become available January 1, 2003 for vehicles that are three times as efficient as the norm. (The $3,000 credit would phase out by 2006, and the $4,000 credit would phase out by 2010.) 32

- ***Partnerships for Light and Heavy Trucks.*** Similar government-industry efforts are proposed to develop more efficient diesel engines for both light trucks and heavy trucks.

  - DOE has been engaged in R&D on more efficient large truck engines for several years, and that effort will be stepped up in FY99, in coordination with increased work on large diesel engines at EPA and DOD.

  - A government-industry partnership is currently being formed for R&D on smaller diesel engines suitable for light trucks and sport-utility vehicles (SUVs), which are the fastest-growing class of passenger vehicles. A clean, efficient diesel engine could improve the fuel-economy of light trucks and SUVs by 50 percent.

- ***Sustainable Transportation.*** This initiative would promote alternatives to single-occupancy vehicle travel using pilot projects in selected communities modeled after the highly successful approach adopted by the Portland, Oregon metropolitan region.

  - Tthe sustainable transportation programs in EPA and DOE will be coordinated with existing and planned DOT programs. (DOT is not funded within the Climate Change Technology Initiative, however.)

  - An amendment is proposed to current tax law to equalize treatment of parking and transit benefits. To encourage public transportation and vanpools, employers would be allowed to provide tax free transit and vanpool benefits in lieu of compensation, up to the same amount that they can provide for parking.

ELECTRICITY

- ***Renewable energy.*** Expand research partnerships for key renewable technologies such as wind, photovoltaics, geothermal, biomass, and hydropower to accelerate price reductions and improve performance. The same programs will also be supporting increased R&D in hydrogen production and storage and in superconductivity.

  - The FY99 budget proposes a $100 million increase in DOE for solar and renewable energy R&D -- a 37 percent increase over FY98.

- A 5-year extension is proposed for the tax credit for electricity produced from wind and biomass.

- The photovoltaic (solar electric) component of the Million Solar Roofs initiative (described above under "Buildings") also can be described as an electricity-sector initiative, providing "distributed generation."

- ***Electricity Restructuring.*** DOE and EPA will work with States and utilities on the restructuring of the electricity sector, to ensure that the restructuring does not create barriers to the adoption of renewable and low-carbon generating technologies.

- ***Nuclear power-plant life extension.*** DOE will initiate an R&D effort addressing the critical technology needs to allow currently-operating nuclear power plants to safely extend their opertaing lifetimes by 10 to 20 years.

  - Under current NRC licences, approximately 60 gigawatts of electric generating capacity would have to be retired between now and 2015. (Most of that comes between 2005 and 2015.)

  - Providing the technologies necessary to safely operate these plants for another 10 to 20 years will make the transition to other low-carbon energy sources, such as solar and renewable energy, much easier.

  - (NRC has indicated that they would probably not grant any plant more than one life extension.)

- ***Innovative coal combustion technologies.*** In FY99, DOE will initiate a research program on innovative new approaches to coal combustion that offer the possibility of much lower carbon emissions than existing technologies.

CARBON REMOVAL AND SEQUESTRATION.

- ***Sequestration R&D.*** Research initiatives are being funded in both basic and applied research to find ways to remove carbon dioxide (CO_2) from combustion gases and sequester (store) the carbon so that it does not enter the atmosphere.

  - DOE's basic science office will engage in biochemical and microbial research.

  - DOE's fossil energy office will conduct an applied sequestration R&D program, jointly managed with the basic science office.

  - USDA will initiate research on enhancing the carbon-sequestering capabilities of agricultural species. NIST will support complementary biotechnology work on plant metabolism and carbon use.

CROSSCUTTING ANALYSIS AND RESEARCH

- ***Emissions credits, incentives, and trading.*** EPA will lead an effort, assisted by DOE, to evaluate options for a domestic trading system and early reduction program in industry. The Federal government will work with stakeholders to understand their views and interests, and to build the institutional capacity needed to implement a carbon emissions credit and trading system.

- ***Program and science assessments.*** DOE will lead efforts to assess the implications of new research results produced by the Global Change Research Program, in order to determine what geographic and technological responses may be appropriate.

Katie McGinty's Testimony

more energy efficient products. It challenges the innovative abilities of the private sector and helps ensure that those firms that succeed in developing energy saving products will have a substantial market in which to sell those products. For consumers, it provides a double bonus. First it helps reduce the initial costs of purchasing energy saving products. Second, throughout the lifetime of the product, consumers will benefit from reduced energy costs. The President's 1999 Budget includes $3.6 billion over five years in tax credits aimed at encouraging broader use of existing energy saving technologies and spurring further innovations. It also includes $2.7 billion in new research and development investments to ensure that innovative greenhouse gas reducing products continue to flow through the pipeline and into the market-place in the coming years.

Examples of specific provisions contained in the President's budget include the following:

-- Tax credits for highly fuel efficient vehicles: This credit would be $4,000 for each vehicle that gets three times the base fuel economy for its class beginning in 2003. A credit of $3,000 would be available beginning in 2000 for vehicles that get double the base fuel economy for its class. These credits would be available to jump start these markets and would be phased out over time.

-- Tax credits for energy efficient equipment: These credits (all of which are subject to caps) would include a 20% credit (subject to a cap) for purchasing certain types of highly efficient
37 building equipment, a 15% credit for the purchase of solar rooftop systems, and a 10% credit for
36 the purchase of highly efficient combined heat and power systems. 33

33 -- Research and development support: Additional resources are provided for key areas of renewable energy and for carbon sequestration. Activities related to the Partnership for a New Generation of Vehicles include expanded research in fuel cells, batteries and ultra-clean combustion engines. Two new partnerships are proposed for heavy trucks and light trucks, including sport-utility vehicles.

These budget proposals implement one of the key commitments made by the President in his October 22nd speech at the National Geographic Society. In that speech the President also pledged: that the federal government, as the largest user of energy, would take the lead in enhancing our efforts at improving energy efficiency; that we would work closely with the private sector in developing voluntary programs to reduce emissions; that we would grant early credit for reductions that occur prior to a binding target; and that we would help shape utility restructuring in ways that contribute to reductions in greenhouse gas reductions. We are working today to make all of these commitments real.

Beyond the President's budget proposals, a number of encouraging developments have taken place in both the public and private sectors in the short time since Kyoto. Let me briefly mention four of them today.

Saturday Radio Address

January 31, 1998

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THE WHITE HOUSE

Office of the Press Secretary

For Immediate Release January 31, 1998

RADIO ADDRESS OF THE PRESIDENT
TO THE NATION

The Roosevelt Room

THE PRESIDENT: Good morning. Today I'd like to talk to you about one of the ways we are strengthening our nation for the 21st century: our bold new efforts to deal with the challenge of global **climate** through the force of the market and the power of American innovation.

The world's leading **climate** scientists have concluded, unequivocally, that if we don't reduce the emissions of greenhouse gases into the atmosphere all across the Earth, then the temperature of the Earth will heat up, seas will rise and increasingly severe floods and droughts will occur, disrupting life in low coastal areas, disrupting agricultural production and causing other difficulties for the generations of the 21st century. Fortunately, we can avert these dangers, and do it while keeping our economy going strong.

This past December, America led the world to reach an historic agreement committing nations to reduce greenhouse gas emissions through market forces, new technology and energy efficiency. We can do some things right here, right now, to show that America is doing its part. In my State of the Union address, I called for an unprecedented commitment of $6 billion for research and tax incentives to mobilize cutting-edge technology in the fight against global warming. I'd like to explain just what that means to you.

First, we want to help bring down the price of high-efficiency cars for every American. Earlier this month, Ford, GM and Chrysler unveiled prototypes of advanced-technology cars that get more than twice the mileage of today's models -- with no sacrifice in comfort, safety or performance. When cars like these begin to enter the showrooms in the year 2000, we'll give everyone who buys one a $3,000 tax credit to apply to every size car. When these cars become even more efficient, we'll increase the tax credit to $4,000. We're committed to making it not only wiser, but actually cheaper, to buy highly efficient cars.

34 Second, we'll help you turn your home into a model of energy efficiency. We'll offer tax credits that will give you a discount of 20 percent off the cost of energy-saving water heaters and air conditioners. And we'll also offer a tax credit -- worth up to $2,000 -- to help you put solar panels on your roof or to help you buy an energy-efficient home in the first place.

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Third, we will accelerate research on clean, renewable energy and energy-saving technologies. We'll help to develop energy-efficient lighting, refrigerators and other appliances that will mean lower monthly bills for you, and reduced greenhouse gas emissions. And we will work with industry to cut their energy use, so that they can also protect the environment while enhancing the bottom line.

Whenever we act to heal our environment, some always question whether it will hurt our economy. But today our economy is the strongest in a generation and our environment, the cleanest in a generation. Whether the problem has been acid rain, deadly pesticides, polluted rivers or the ozone hole, the ingenuity of the American people has always proved to carry the day -- and we'll do it once again. Working together, we will overcome the challenge of global **climate change** and create new avenues of growth for our economy. And, most important, we'll honor our deepest responsibility to pass on this home, without harm, to our children, our grandchildren and generations yet to come.

Thanks for listening.

END

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