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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
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January 17, 1997

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MEMORANDUM TO DISTRIBUTION LIST

From: Mary Nichols, Assistant Administrator for Air and Radiation and
David Gardiner, Assistant Administrator for Policy, Planning, and Evaluation

Attached are the two draft papers prepared by EPA, on emissions trading approaches and on technology and market transformation, for discussion at the Assistant Secretaries' meeting on Wednesday afternoon, January 22, which is being scheduled by David Sandalow.

Overview of Domestic Greenhouse Gas Emissions Trading Programs

Introduction

This paper describes how a domestic emissions trading program could be used to comply with an emissions target designed to meet an international agreement on greenhouse gases. Emissions trading is a tool for meeting a total quantity limit on emissions. It involves allocating or auctioning emissions allowances to sources, and allowing the trading of allowances in a market with sufficient mechanisms to ensure compliance with targeted levels. Emission trading systems can offer both static and dynamic efficiency advantages over more traditional forms of regulation. The potential for static efficiency gains exists because emitters face different abatement costs. Emissions trading allows those with high abatement costs to purchase allowances from those whose costs are lower. Total costs would therefore be lower than through traditional regulations which require all polluters to comply with a specific standard.

Dynamic efficiency gains can arise because emissions trading provides an incentive to conduct research and development in pollution abatement technologies. Under traditional regulation, firms have little incentive to investigate ways of abating pollution by more than the minimum required to comply with regulatory requirements – even though going beyond the standards would result in additional environmental benefits. This, coupled with the inability of firms to capture all the economic benefits from R&D spending, results in under-investment in abatement technology R&D. Under emissions trading, emitters continue to face an incentive to look for further cost-effective ways of achieving emissions reductions even when they are in compliance with allowance limits. This is because any “surplus” allowances created can be sold to others in the emissions allowance market or banked to meet future reduction obligations. Emissions trading can therefore lead to a more rapid rate of development of pollution control technologies than those traditional regulatory policies that do not offer incentives to go beyond compliance.

These same efficiency benefits could be achieved through a system of emission taxes. However, a system based on emissions trading differs from a tax system in two important ways. First, under a tax system, the quantity of total emissions is the result of individual polluters' decisions in response to the incentive provided by the tax. The resulting level of emissions can be greater or less than the level targeted when the tax rate is set. By setting overall quantity targets, emissions trading programs coupled with appropriate compliance procedures, offer greater certainty that national emission targets will be achieved. Second, emission tax systems always involve revenues accruing to the government (although they can be rebated). Under an allowance system, the government has greater flexibility in deciding whether to collect revenues by auctioning permits or allocating them based on historical emissions. This flexibility can affect the public acceptance of the mitigation program.

also reflect
in total
energy use

In principle, if the
entire structure (e.g. elus),
known, any quantity
target that could be set
would also be attained by
a tax system
forecasting
is difficult

of some combination of the two

② can
appropriately
calculated
per tax

US Experience with Emissions Trading

The US has had more experience with emissions trading than any other country in the world. Specific programs include:

- **Sulfur Dioxide (SO₂) Allowance Trading:** The Clean Air Act Amendments of 1990 imposed an overall 50% emission reduction requirement for SO₂ emissions from electric utility boilers. The portion of the program concerning trading works by allocating emission allowances to electric utilities based on a formula reflecting historical emissions. In addition, a small portion of allowances are auctioned every year to facilitate price discovery and new entrants. Allowances are specifically excluded from being defined as property rights, may be traded to any party anywhere within the continental U.S., and may be "banked" for use in future years. Participants need to conduct regular monitoring of emissions and make an annual accounting of their emissions. Penalties are imposed if emissions exceed the number of allowances held by a source.

There is now a functioning market in SO₂ allowances involving both bilateral exchanges between companies, and brokered exchanges through third parties. This market, along with other factors, has helped to dramatically reduce the cost of the abatement program. When first enacted, it was ^{claimed} generally believed that emission allowances would sell in the range of \$500-600 per ton. Current spot prices are in the range of \$80-90. In addition, 1995 emissions were 40% below legally required levels for that year.

- **Water Effluent Trading:** The US generally has regulated surface water quality through a system of discharge limits for large sources of water pollution. In addition, states have standards for ambient water quality which are often not attained even after large dischargers apply "best technology." The reason is that small ("nonpoint") sources (such as runoff from farms) contribute significantly to water pollution. A number of state and local governments are employing trading systems for watersheds that either permit trading among large dischargers, or allow large dischargers to fulfill their requirements by controlling nonpoint sources. These include the Fox River in Wisconsin, the Dillon Reservoir in Colorado, and the Tar-Pamlico River in North Carolina. The latter two programs are designed to manage future economic growth. Thus, the quantity of effluent allowances allocated exceeds current discharge levels. Once growth consumes this excess, trading is expected to reduce compliance costs.
- **Inter-refinery Lead Trading:** EPA operated a lead trading program from 1983 to 1987 as it phased out lead from gasoline. Lead trading allowed refiners and importers to trade lead reduction credits in order to meet limits for the lead content of gasoline. The quantity of allowances to which a firm was entitled was determined by the amount of leaded fuel produced by the firm and the contemporaneous EPA standard. Those who bettered the standard could sell their credits to others. Some 10 billion

The bill that was actually adopted was not as onerous as many in industry had feared

Even when the Speaker outlined the program became known the forecast price was

grams of lead were traded during the course of the program at prices ranging from 0.75 to 5 cents per gram. Allowing the trading of lead credits reduced the costs of the program by approximately 20 percent.

- *Criteria Air Pollutant Trading:* EPA first began incorporating aspects of emissions trading in its air program in 1974, when it allowed a modified source to use "credits" earned by another source within the same plant to avoid additional regulatory requirements. Since then, emission trading has substantially expanded. Trades have numbered in the thousands and have been estimated by Hahn and Hester (1986) to have achieved savings between \$525 million and \$12 billion.
- *Market Mechanisms for Chlorofluorocarbon (CFC) Phaseout:* Under the 1987 Montreal Protocol to limit stratospheric ozone depletion, the U.S. required the phase out of the production of CFCs by 1996. As part of its program, the U.S. adopted a tradeable permit regime covering CFC manufacturers and importers. These were allocated allowances based on each firm's 1986 market share. As the market for CFCs declined, the system allowed firms to allocate production between different production facilities according to the least-cost pattern of supply. It also gave CFC users the flexibility to switch between different CFC compounds, within the overall limit on allowances. This program helped reduce the costs of the phaseout. In 1988, EPA estimated that the cost to *halve* CFC use would be \$3.55 per kilogram. By 1993, it became clear that all uses could be *eliminated* by 1996 at a cost of \$2.45 per kilogram.

Emission Trading of Greenhouse Gases

These examples show that emission trading and banking have been used to meet established reduction requirements. Emissions trading, coupled with sufficient compliance mechanisms, may similarly be used to meet an established target for greenhouse gas emissions.

An emissions trading program, like any program designed to limit greenhouse gases, must contain certain elements. First and foremost, an agreed upon emissions budget grounded in science must be selected. (This, itself, may influence the rate of technological innovation). A central authority must be given the responsibility for verifying compliance and must be provided sufficient information to do so. Finally, there must be real consequences for noncompliance with allowance limitations or reporting requirements, such as penalties or subtraction of allowances.

A program would have to establish permit lifetimes, monitoring and enforcement provisions, as well as rules for permit banking, borrowing, and trading. Consideration should also be given to transaction costs, which should be kept as low as possible.

However, particularly difficult issues involve who is required to hold a permit and how permits should be allocated.

Who is required to Hold a Permit

Sources of greenhouse gases include not only those emitting carbon dioxide, but other gases such as methane, nitrous oxides, hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF₆). Gases differ both in their atmospheric lifetimes and in their ability to trap heat in the atmosphere. In addition, carbon is not only emitted through the combustion of fossil fuels, but is also absorbed by "sinks" such as trees and soils.

The decision for determining who should be required to hold a permit should consider the following:

- *Coverage:* While it may not be necessary to ensure that every ton of greenhouse gas is accounted for within an emission trading regime, the scope of coverage of the trading program should be sufficient to ensure compliance with targets set in accordance with an international agreement.
- *Administrative and Compliance feasibility:* The number of sources involved in the trading program should be small enough to be administratively feasible and large enough to ensure market competition. In addition, monitoring and verification of permit compliance must be possible for those included in the program.
- *Potential to Diffuse Low Greenhouse Gas Technologies:* Alternative points of intervention should be evaluated for their ability to provide incentives for research, development, adoption and diffusion of low greenhouse gas technologies.
- *Market Impacts:* Any program that limits emissions will affect the bottom line of firms. The permit program will have economic impacts that vary depending on program design. For example, a program that requires electricity consumers to hold permits based on the national average carbon content of electricity generation will have different competitive effects from one in which individual electric generators must hold permits based on the carbon content of the fuel they consume. In addition, exempting certain sizes or categories of sources from permit requirements because of administrative or equity concerns (e.g., small boilers or home heating oil) has competitive implications within the energy market.
- *Wealth transfers:* Allocating permits redistributes wealth within the economy. The amount of redistribution can be large depending on the permit price (which is determined by the emissions target and the cost of fossil fuel substitutes). While one option would be to auction permits with revenues accruing to the government, another would be to award permits to sources based on historical rates of emissions. In the latter case, wealth would be transferred to whomever is allocated permits.

Carbon Sources

Carbon dioxide currently accounts for about 85% of U.S. greenhouse gas emissions. The term "emission trading" implies the creation of a market of emission allowances (or permits) among *emitters* of greenhouse gases through a limitation on those emissions. In the case of carbon dioxide, however, direct emitters number in the hundreds of millions since they include sources such as automobiles and residential gas water heaters.

However, since virtually all of the carbon contained in fossil fuel extracted from the ground (with the possible exception of certain feedstocks) is eventually released to the atmosphere, a trading program need not focus uniquely on direct emitters, but can target other points in the energy market. These include fuel extraction, processing, refining, distribution, and secondary conversion (e.g., coal to electricity). In addition, these points could vary by fuel type. For example, an emission trading program could focus on the point of final combustion for coal, but on refining for oil, or distribution for natural gas.

Given the wide variety of options available for including energy sources in a trading program, a few alternative programs are described below for illustration:

A Program Targeting Primary Fuel Producers

There are various levels within the primary fuel producing sector – extraction, processing, refining, and distribution – where a permit program could be implemented. One option would be to require permits at the point of first sale (a permit is surrendered with the first inter- or intra- company transaction). Such a system would include transactions between a coal company and an electric utility, between a natural gas producer and its marketing arm, between a natural gas producer and a broker, or between an oil extraction company and its refinery operations. Fuel importers would also require permits to import fuel. This would capture the carbon from fuel consumed in the refining process. The number of market actors under this program design would be under 5000 and virtually all carbon in the energy sector would be included in the program.

A Program of Emission Trading at the Sectoral Level

An emissions trading program could also be applied at the point of combustion, allowing trading among affected sources. This system would be most comparable to the current SO₂ emission allowance trading system.

Targeting the six largest industrial CO₂ emitting sectors (electric utilities, cement, primary metals, pulp and paper, petroleum refining and chemicals) in a sectoral trading program could encompass as many as 20,000 market participants and 90 percent of industrial CO₂ emissions. Mobile source emissions could be indirectly included in the system by allocating transportation equipment manufacturers permits for emissions associated with their automobile fleets or by including refiners in the program. Residential and commercial emissions could be similarly addressed by focusing upstream in the energy system.

Other Greenhouse Gases and Sinks

The remaining 15% of greenhouse gas emissions (on a carbon-equivalent basis) are accounted for by other gases. Most important among these is methane, which by itself accounts for 11% of national emissions. Since gases differ in their lifetimes and in their potential to trap heat in the atmosphere, an "exchange rate" or trading ratio must be established to convert all gases into common units for inclusion in a trading program. Such ratios have been developed by climate researchers and could be applied here. These should be consistent with the rules established in the international protocol.

Several, although not all, of the many sources of non-carbon greenhouse gases could likely be included in a trading system. For example, methane emitting coal mines, landfills, livestock manure management facilities and potentially natural gas distribution systems may meet the criteria described above for inclusion in a greenhouse gas trading program. These sources account for 7% of national greenhouse gas emissions. Similarly, emissions of some sources of other gases could potentially be included (e.g., magnesium production).

Forests in the United States currently remove an amount of carbon equal to 8% of national emissions from the atmosphere. However, translating the potential of sinks into monitorable, verifiable, and cost effective emission reductions is hampered by the lack of a comprehensive national accounting system for sinks. Thus, while it may be possible to observe and monitor the planting of trees and preservation of forests in a given area, it is difficult to know how such actions affect national emissions. Preservation of one stand of forests may simply lead to destruction of another in a different location. Overcoming the difficulties associated with monitoring and verification is therefore especially important for the inclusion of sinks to be included in a trading program.

Allocating Permits

In an emission trading system, some mechanism must be provided for allocating permits to sources. There are a number of options available for so doing. These include allocating permits on the basis of baseline/historical emissions (where permits are given to those currently emitting) or through an auction (where revenues accrue to the government). These two mechanisms could also be combined: some portion of permits could be allocated on the basis of historical emissions while the rest are auctioned.

A reserve of allowances or a portion of auction revenues could be set aside to encourage more rapid development and diffusion of low greenhouse gas emitting technologies. For example, manufacturers of energy consuming equipment could compete for the set aside based on the degree to which they produce equipment more efficient than the average in use or than required by current mandatory efficiency standards. Such a program could yield reductions in energy demand and help buffer the consumer from the impact of higher energy costs.

Allocation Based On Baseline/Historical Emissions

Under this approach, sources are given a number of permits based on baseline fuel production or emissions and an allocation formula. Various allocation formulae can be devised, weighted to greater or lesser degrees in favor of sources with high historical emissions. Emissions allowances are endowed to facility operators for no cost and would be transferable. As discussed earlier, this mechanism results in potentially significant wealth accruing to those receiving permits.

Such an allocation mechanism could also create entry barriers. In a capital intensive sector like primary fuel production, where entry barriers are already substantial, new entrants would be further disadvantaged if they had to purchase permits.

The problem could be mitigated by withholding a number of permits for purchase by new entrants or by auctioning a portion on the open market. Such an auction would also facilitate price discovery in a new market. Although new firms will still be disadvantaged (as they will pay for all of their permits), they would be able to enter the market. The pool of permits would need to be withheld from existing sources to ensure compliance with targeted national emission levels.

It may be desirable to allow credit for early emissions reductions (those achieved prior to the start of the program, but after the baseline period) -- in particular for those that reduced greenhouse gas emissions as part of government sponsored voluntary programs. If credits for past actions are given, the total credits allowed would need to be deducted from the overall permit allocation in order not to exceed national greenhouse gas emissions target.

Auction

Alternatively, an auction could be used to allocate permits. In this case, permit holders would pay the market clearing price for every unit of greenhouse gas released. Auctions ensure that permits are available for trade, and would serve to inform potential traders about current price levels. All participants have equal access to permits, placing new entrants on the same footing as existing emitters. Given that an auction could produce substantial revenues, some decision would have to be made with respect to what to do with the proceeds.

Conclusion

Past experience with emission trading programs indicates that they can help significantly reduce the costs of meeting environmental objectives. This is due in part to the incentives they provide for developing and diffusing new environmental technologies. Thus, final compliance costs for the programs that have incorporated emissions trading have, in general, been dramatically lower than ex ante expectations. With careful attention to design, a system of emissions trading could be instituted for greenhouse gas emissions. Such a program would provide similar incentives to research, develop, and

diffuse low greenhouse gas technologies and result in achieving targeted emission levels at the lowest possible cost.

Role of Technology and Market Transformation in a National Policy to Limit Greenhouse Gas Emissions

Technology has a critical role to play in addressing climate change. Energy-efficient technologies provide a sizable opportunity to limit emissions of greenhouse gases while simultaneously enhancing economic productivity. However, to capitalize on this opportunity, the U.S. needs to overcome market failures that have directed the country along a less energy-efficient path to date. This paper discusses the types of things we are doing and can do to transform technology markets and capture the full economic benefits of increased energy efficiency.

Market transformation policies would be a cornerstone to a national policy to limit greenhouse gas emissions, and would be complementary to other policies designed to implement whatever targets and timetables the U.S. adopts under the climate change negotiations. Even highly efficient forms of regulation, such as cap and trade, do not address fundamental failures in today's energy markets. These failures systematically restrain the potential of cost-effective, energy-efficient technologies to fairly low levels.

Policies that can unharness the full potential of energy-efficient technologies are important because they allow a smooth and potentially painless transition to meeting a carbon constraint. In addition, energy efficiency enhances the economy by generating productivity investments. Shifting capital from wasted energy expenditures to new investments will drive economic growth, employment and consumer income. Several major studies have demonstrated the economic advantages of improved energy efficiency. Most recently, the Energy Information Administration released an energy efficiency report based on the *Annual Energy Outlook 1996*. The study suggests that a reduction in U.S. energy consumption of 12 percent (in the year 2015) would increase GDP by 0.5 percent. Further improvements in productivity and competitiveness can occur due to the substantial ancillary benefits of advanced technologies and processes in the industrial sector.¹

Additional studies have documented the large potential for emissions reductions through improved energy efficiency. Studies by the National Academy of Sciences, Office of Technology Assessment, and American Council for an Energy-Efficient Economy have all demonstrated that the technological potential exists to cut energy consumption by 20% or more at a net economic benefit.² However, there is clear evidence that this potential will not be realized in the current market system because of a number of institutional, organizational, and other barriers that work against the diffusion of energy efficient technologies.

Some energy efficiency improvement occurs naturally over time. Additional improvements will result from a clear policy signal on climate change and energy.³ But the existing market failures are extensive and will restrain the energy efficiency response unless they are removed. Failure to fix these barriers would result in a higher cost to the national policy than is necessary. Some programs are already underway to fix these failures. An additional set of new initiatives will be needed to more fully tap the potential of current and future technologies.

The remainder of the paper provides an overview of market failures, current programs underway to remove them, and the potential for additional efforts.

Market Failures Constrain the Markets for Energy-Efficient Technologies

The existence or availability of a financially attractive technology by itself does not mean the technology will be purchased and used in sizable quantities. For high rates of technological diffusion, a number of other key factors have to be in place:

- ▶ Potential buyers of products need to know of the technology;
- ▶ Potential buyers of products need clear, reliable information on the performance and economic benefits of the technology;
- ▶ Potential buyers must be the ones to see the benefits of lower energy bills; and
- ▶ Service providers and users of the technologies must have expertise to appropriately design for, install, and operate the technology.

In most cases, these factors are not in place. The attached table provides an example list of market failures in the buildings sector.

The benefits of removing the barriers to the diffusion of efficient products extend beyond those products. There is a substantial ripple effect that further increases the potential for energy-efficient technologies. First, overcoming barriers to diffusion of today's technologies improves the incentives to manufacturers and spurs new, private R&D and innovation. This leads to new technologies that expand the potential for future energy savings. Second, as sales and production experience increases for efficient technologies, both the fixed and variable costs of production fall, reducing the cost of the technology to the end-user. This "learning by doing" increases the cost-effectiveness of energy efficient technologies and expands the potential for greenhouse gas reductions.

Current Programs Are Overcoming Many Barriers to Energy Efficiency

A number of successful, market transformation programs are currently underway. The Climate Change Action Plan (CCAP) programs, as well as other DOE programs, are overcoming many of the existing market failures in all sectors of the economy (see box for examples). Despite harmful budget cuts, these programs are making a substantial contribution to controlling growth in greenhouse gas emissions.

The CCAP programs were designed to maximize reductions by the year 2000, a relatively short period of time to achieve fundamental market transformation. With continued support beyond the year 2000, these programs will significantly restrain growth in U.S. greenhouse gases through 2010 and beyond. Previous interagency

Examples of Current Programs Overcoming Barriers

- ◆ Information: The ENERGY STAR® Consumer Labeling Program allows manufacturers to label qualifying, efficient products. Consumers are provided with unbiased information on their environmental and economic benefits. Through 1996, this young program has seen thousands of products labeled, billions of dollars invested in ENERGY STAR® products, and hundreds of millions of dollars in consumer savings.
- ◆ No R&D Incentive: The Partnership for a New Generation of Vehicles (PNGV) is a joint R&D effort with U.S.-based automakers to develop new automotive technology that can triple the fuel efficiency.

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analysis indicates that around 1/3 of total emissions growth through 2010 will be avoided by the CCAP (a revised assessment of the impact of the CCAP programs relative to baseline growth is expected to be completed by the end of January).

These programs will need to be continued as part of a rational greenhouse gas policy in order to capture the economic potential of energy efficiency technologies. But the focus on the year 2000 limited the options that were included in the CCAP. With a longer term goal, there are significant opportunities to overcome additional barriers throughout the economy.

Further Efforts Are Needed to Remove Additional Barriers

There are additional areas of market imperfection that the Climate Change Action Plan programs and other efforts are not yet fully addressing. Many arise from split incentive problems, which occur when the manufacturer or purchaser of a technology does not receive the energy bill savings. Others are related to the ubiquitous problems of imperfect information. Following are some example areas where further efficiency improvements can be gained through government interventions to overcome market failures:

Low Private Sector R&D

Failure: In a properly working market, purchasers of technologies would recognize and fully value future energy bill savings, and they would be willing to pay accordingly for efficient technologies. Manufacturers would then have considerable incentive for additional R&D and production of efficient technologies. Because purchasers underestimate the value of energy savings, manufacturers underinvest in R&D.

Solution: Incentives may be provided to manufacturers in a number of ways in order to internalize the energy saving benefits in manufacturers' investment decisions. For example, under a domestic trading system with a cap on greenhouse gas emissions, a reserve of allowances or a portion of auction revenues could be set aside to reward new R&D investment and production of efficient equipment. The incentives could potentially be used in all sectors of the economy, but might be particularly valuable in commercializing highly efficient technologies in the transportation sector.

Lack of Financing

Failure: Because energy efficiency investments are often low risk and generate a consistent stream of savings, one would expect a robust financial market to fund these investments. But energy financing often is done entirely by the investor, and capital access is a key constraint on efficiency investments.

Solution: The federal government has been particularly successful in the past at jump-starting financial markets by chartering federal institutions. For example, since Sallie Mae was chartered by the federal government in 1972 to increase access to student loans, loan volumes have increased from \$1 billion a year to over \$25 billion a year. Both Fannie Mae (home mortgages) and Sallie Mae demonstrated that profitable financing markets were being restrained by existing institutions. They have evolved

into highly profitable, publicly traded companies that are now candidates for privatization (Fannie Mae's profit in 1996 exceeded \$2 billion). Lessons from Sallie Mae and Fannie Mae should be explored to determine if a similar institutional intervention could invigorate a profitable secondary market for energy efficiency financing.

► *Landlord/Tenant Split Incentives*

Failure: When building owners purchase building equipment but tenants pay the energy bills, the smart economic choice for the owner is to minimize first costs, which minimizes energy efficiency. Highly profitable cost savings are being lost to society because of these institutional arrangements.

Solution: Several interventions could be considered, including leasing reform and providing reliable energy information to potential tenants.

► *Builder/Buyer Split Incentives*

Failure: Because the designers and builders of new buildings do not subsequently operate the buildings and pay the energy bills, new buildings do not incorporate cost-effective, efficient designs and technologies.

Solution: Establish an energy performance rating system for commercial buildings (new and old) that can form the foundation for energy performance to be factored into the asset value of the building. Provide better information to prospective buyers and energy efficiency education and/or certification for designers and contractors.

► *Non-Rationality in the Industrial Sector*

Failure: Many companies recognize energy efficiency investments as a key to corporate competitiveness. For example, Dow Chemical has established a goal of improving energy efficiency at a rate of 2 percent per year, per product manufactured. But many other companies do not focus nearly as aggressively on their energy bills for a variety of reasons. Evidence suggests that the trend of improvements in overall industrial energy intensity has stalled.

Solution: Sector-wide compacts could put the entire industrial sector on a sustainable energy pathway. Rather than individual companies, entire industries could pledge improvements in energy intensity and benefit from the synergies of cooperative approaches to efficiency improvements.

► *Additional Information Barriers*

Failure: The CCAP programs are working in many areas of the economy on informational failures, but they persist in other areas. For example, consumers and businesses have no reliable information on the source of their electricity.

Solution: In a competitive power market, accurate information on efficiency and renewables of power providers would give the consumer the ability to place a value on environmental protection. Information in other areas might also be helpful to achieve long-term greenhouse gas reductions.

- *Barriers to Renewable Technologies* [Placeholder for DOE input on renewable portfolio]

1. Many industrial efficiency improvements also offer important productivity benefits. As an example, in 1990 a North Carolina textile firm installed a radio frequency dryer to replace a gas dryer which was used to dry cashmere wool. The project reduced the energy required for drying by almost half, and reduced fibre loss from over drying by more than 5 percent. The energy savings was about \$0.05 per pound of cashmere, while the savings in lost raw fiber, at \$30 per pound, was more than \$1.50 per pound. While the so-called "cashmere effect" at first may seem to be an extreme example of larger productivity benefits, it is not a case in isolation. Indeed, many other examples can be cited. For instance, the average total annual savings from efficiency projects from the Louisiana Division of Dow Chemicals were 3 to 13 times as large as the energy savings alone. Based on this example and other industrial experiences looking at groups of projects, the average total savings can be assumed to be as high as 4 to 6 times as large as the energy savings for projects that are implemented.

2. The Office of Technology Assessment (1991) study indicates a potential of over 400 MMTCE of reductions possible through 2010 or 2015 with a net savings to the economy. The National Academy of Sciences (1991) study shows as much as 450 MMTCE potential for emissions reductions at a cost savings. *America's Energy Choices* (1990), a study by the American Council for an Energy-Efficient Economy (ACEEE), the Union of Concerned Scientists and others, concluded that energy use could be cut by over 500 MMTCE in its least aggressive "Market Case," in which only cost-effective investments are made.

3. Under the 1987 Montreal Protocol to limit stratospheric ozone depletion, the U.S. required the phase out of the production of CFCs by 1996. Early analyses suggested that the cost to halve CFC use would be \$2.50 per kilogram. By 1990, it became clear that all uses could be eliminated by 1996 at a cost of \$2.45 per kilogram. The technological innovations that have reduced the cost were made possible by a tradeable permit regime, but were spurred by the clear policy signal of the Montreal Protocol, and by government efforts working with manufacturers.

Historical Forces Leading to Institutional and Organizational Failure in the Buildings Market

Type of Failure	Nature of Failure	Examples of Failure
Imperfect Competition		
Natural Monopoly	Economies of scale	Electric utilities
Market Power (Monopoly and Oligopoly)	Bargaining power; interdependent conduct	Uniqueness of building location; few development firms in one area
Anti-Competitive Conduct	Collusion; predation	Manipulation of permit process to the detriment of competitors
Information Availability		
Information Costs	Transaction costs	High cost of customized audit (cheaper if done en masse); collecting product info; finding credible information sources
Asymmetric Information	Unequal bargaining	Developer's superior knowledge of building
Misinformation	Misinformed exchange	Belief: "no efficiency increase is possible"
Lack of Information	Uninformed exchange	No knowledge of efficient technologies
Economic Non-Rationality		
Bounded Rationality, Satisficing	Using rules of thumb to reduce transaction costs; not maximizing profits	Ignore costs that are < 5% of rent; use a two year payback; seek acceptable profits
Other Non-Rationality	Cultural reasons for taking actions that affect business practice	Preferring energy production to cost-cutting because it is more congruent with management culture
Risk Aversion	Resistance to change	Avoid changes in suppliers and technologies; avoid new technologies
Side Effects	Negative externalities from power production	Pollution from power generation; dependence on imported oil; risks of nuclear energy
Split Incentives	Utility costs not paid by purchaser and user of equipment.	Landlord-tenant problem; builder-buyer problem
Public Goods		
R&D	Non-excludability, zero marginal costs	Too little R&D performed
Expertise and Training	Non-excludability, zero marginal costs	Too little training on efficient design, installation and maintenance; too little information dissemination
Cash Flow Constraints	Lack of access to capital	Small business tenants on the edge; developer's reluctance to take on more debt
Regulatory Distortions		
Regulatory Bias	More profits for energy production than for efficient use	Utility reluctance to install conservation even when cheaper than new supply
Average Cost Pricing	Price signals do not reflect cost, leading to inefficient usage	Utility regulation in the US
Building Codes	Obsolete codes inhibit innovation and efficiency; # of inconsistent codes inhibits achieving economies of scale	Local US building codes contain requirements that interfere with efficient construction; thousands of building codes in the US



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*This actually good.
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**AGGREGATE ECONOMIC IMPACTS
OF CLIMATE CHANGE
IN THE UNITED STATES**

Climate Change White Paper

Prepared by the U.S. Environmental Protection Agency

Draft: January 16, 1997

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EXECUTIVE SUMMARY

Atmospheric scientists widely agree that continuing emissions of greenhouse gases resulting from human activities will warm the earth's atmosphere. In turn, warming will be accompanied by rising sea level and by changes in precipitation and other climate variables, such as the pattern and intensity of storms. These climatic and related changes will affect both natural and human systems. As government and the private sector adapt or respond to the effects of climate change, production costs, prices of goods and services, and output levels in different industries may change. Further, economic impacts in individual industries, or in particular geographic areas such as coasts or wetlands, will produce changes in other markets and in other locations. Thus, the economic effects of climate change will also filter up to the national economy.

This paper summarizes results from a study that evaluates the risks to US economic performance and economic welfare from a selected set of climate change impact categories. The study is confined to a subset of market impacts, i.e., impacts that affect the supply or demand for goods and services that are traded in markets. The categories of market impacts included in the evaluation are changes in the costs of producing agricultural, forest, and fisheries commodities, heating and cooling indoor spaces, protecting coasts against sea level rise, maintaining air quality, and repairing storm and flood damages.

Using an integrated model of the US economy, the study investigates the relationship between sectoral impacts and overall impacts on the US economy, and differs from previous studies in several key respects. The analysis does not focus solely on the economic consequences once equilibrium climate is reached, but includes impacts as the climate changes over time. The potential effects of a changing climate on economic activity over a time horizon stretching from 1990 to 2080 are assessed for each year. Projected effects of climate change take into account population and economic growth over this time horizon, technological change, and the consequences of these factors for the structure and scale of the US economy.

The analysis also applies a general equilibrium framework to take into account potentially important market interactions among different economic sectors as producers and consumers respond and adapt to changing economic conditions. Climate change impacts are measured using a consistent methodology that integrates the combined effects of all impacts on a household. Because of uncertainties about climate change and its impacts, the analysis assesses the consequences of several climate change scenarios, rather than a single scenario.

The results presented in this paper suggest that, in aggregate, the market impacts of climate change could be either adverse or beneficial for the US economy and economic welfare over a time horizon reaching from the present to the end of the next century. Whether climate change will have beneficial or adverse aggregate economic impacts depends critically on the character and rate of climate change that occurs and on how sensitive economic activity is to these changes. Among the scenarios evaluated here, only two produce clear benefits—those that assume either a low doubling temperature (1.5°C) or low vulnerability of economic activity to climatic change. In contrast, if the doubling temperature is high (4.5°C), if economic activities are very vulnerable to climate change, or if emissions

increase rapidly and produce a rapid rate of temperature change, then climate will have a harmful economic effect.

How significant are the results? In percent terms, the macroeconomic impacts range from a loss of as much as two percent of national income in the year 2080 to a gain as high as one percent of national income in the same year. (A one percent change in national income in the current economy equals roughly \$50 billion). In dollar terms, the impacts on households can be substantial. For the most adverse scenario considered, economic welfare of a representative household, measured as a change in the present discounted value of the cost of living, falls by \$12,500. In the most beneficial scenario, economic welfare rises by almost \$8,000. Aggregated across all households of the US, the projected changes in the present discounted value of social welfare range from a loss of \$1 trillion to a gain of \$600 billion. These changes, while large in absolute terms, represent less than 1 percent of the present discounted value of the aggregate expenditures projected for the US economy over the period 1990 to 2080.

These national market impacts must be viewed in a larger context that includes information about other aspects of the potential impacts and risks of climate change. First, the market and non-market impacts that are omitted from the analysis represent substantial risks of negative effects that could prove to be even more important for the environment and human welfare than the included impacts. Second, aggregating impacts to a national scale—i.e., reporting the net sum of gains and losses—masks important differences in impacts across different geographic areas of the US and economic sectors or industries. Further, the scenarios considered here look only at gradual climate change and neglect the impacts that may be associated with greater climate variability or with sudden changes in climate. Last, the modeling approach does not fully capture transitional costs, or costs that occur when markets do not smoothly and completely adapt to the pressures of climate change.

Thus, while the possibility of beneficial market impacts exists under moderate rates of warming, there is a significant probability of adverse consequences, particularly when non-market and omitted market impacts are considered. The results also indicate that uncertainties regarding the character and rate of climatic change over coming decades and the vulnerability of economic activity to these changes yield considerable uncertainties regarding the economic consequences. Reducing this uncertainty will require not only advances in climate science and the prediction of future climate at global and regional scales, but also advances in knowledge about the sensitivity of natural and human systems to climate change and about the capacity of these systems to adapt to projected changes.

1. INTRODUCTION

Atmospheric scientists widely agree that continuing emissions of greenhouse gases resulting from human activities will warm the earth's atmosphere. In turn, warming will be accompanied by changes in precipitation and in other climate variables, such as the pattern and intensity of storms. Scientists also project that changing climate will alter the earth's environment by, for example, increasing sea level, shifting the natural ranges of vegetation and animal species, and reducing the quality and availability of water in rivers, lakes, and streams.

The physical changes resulting from warming may have important economic consequences for the US and other countries. As government and the private sector adapt or respond to the effects of climate change, production costs, prices of goods and services, and output levels in different industries may change. Sea level rise, for example, will threaten coastal lands, resulting in expenditures on coastal defense or in some cases losses of physical structures and property. In combination with precipitation changes, rising sea level may also alter the supplies of water for drinking and irrigation, or require new capital investment to maintain existing services. Temperature rise and precipitation changes may together affect productivity and yields in commercial agriculture, with consequences for management practices, for irrigation needs, and for the prices and supplies of food.

These economic effects of climate change will also filter up to the national economy. Impacts in individual industries, or in particular geographic areas such as coasts or wetlands, will produce changes in other markets and in other locations. For example, as warming alters energy needs for heating and cooling, resulting changes in energy prices may have ripple effects throughout the energy-using sectors of the economy. Together, the combined impacts of climate change across a multitude of markets, locations, and sectors will alter aggregate output and prices. Moreover, as prices, output, wages, and investment change throughout the economy, the cost of living and the purchasing power of households will change, altering the economic well-being of individual households.

This paper examines the potential for economic impacts in the US under several alternative future scenarios of potential climate change. Although considerable research has focused on the potential physical effects of climate and their economic consequences for individual sectors in the US, little attention has thus far been paid to developing a consistent picture of the national impact of these changes. Studies that have attempted to estimate national-level impacts typically sum costs or damages estimated across individual sectors to arrive at an aggregate measure of impacts. In so doing, these studies are forced to rely on sector-level estimates that embody diverse definitions of costs (i.e., damages) and so are not fully comparable with each other. Sector-level studies that are conducted independently also fail to capture the critical market interactions that influence the aggregate effects of climate change that occur when a number of sectors are affected jointly. Moreover, most of the available national studies focus on providing a *single point estimate* of US impacts for one climate change scenario, and so mask the range of possible negative and positive outcomes associated with warming.

Using an integrated model of the US economy, the study presented in this paper seeks to go beyond existing research to present a richer picture of the potential impacts of climate change on the US. Four critical facets of economic impacts are evaluated: (1) macroeconomic impacts (i.e., changes in national income, consumption, and investment), (2) sectoral impacts (i.e., changes in prices and quantities at the industry level), (3) impacts on the economic welfare of households, and (4) impacts on aggregate economic welfare. These impacts are evaluated for several alternative specifications of climate change and of the vulnerability of the US economy to such changes.

It is important to recognize that the estimates of economic impacts presented in this paper are conditional projections of the future and not predictions. That is, the results are dependent on a variety of assumptions that must be made regarding future emissions and concentrations of greenhouse gases, future climate, the physical and biological effects of changes in climate, and the sensitivity of economic activities and sectors to these changes. In addition, assumptions must be made about population growth, income growth, technological change, and a variety of economic variables. If the assumptions prove to be wrong, then the projections which are conditional upon them will also prove to be wrong. Nonetheless, the exercise is a useful one to aid systematic thinking about the possible consequences of climate change for different hypotheses about future events.

The remainder of the introduction highlights important features of the study methodology and discusses possible interpretations of the results. Following the introduction, section 2 describes the study methodology, section 3 presents the economic impacts estimated by the study and places the results in the context of previous estimates of national impacts, and section 4 concludes with a summary and discussion of the limitations of the study.¹

1.1. Scope of the Study: Categories of Impacts

Climate change will affect both natural and human systems. Many of these impacts will be transmitted through the market place in the form of changed factor productivities, capital and equipment needs, and damage to physical structures. The analysis addresses a number of potential market impacts of climate change, including productivity of commercial agriculture, forestry, and fisheries; storm and flood damage; energy for heating and cooling; and additional investments required to protect against sea level rise or to meet air quality standards for ground level ozone. However, the sectors included in the study are by no means a complete catalog of the potential impacts of climate change in the US (see Table 1). Climate change may have substantial market impacts in a number of categories omitted from the current analysis, such as human health, water resources, and recreation and tourism. Climate change may also have significant "non-market" impacts—such as those on recreational fishing or species diversity—that are not captured in changing market conditions, but which are nonetheless important.

Including these omitted market and non-market impacts would likely increase the losses, or decrease the benefits, estimated for climate change. In the area of human health,

¹ The methodology and results of the new study are described in greater detail in USEPA (forthcoming, 1997). Contributors to the study include Daniel Gaynor, Richard Goettle, Dale Jorgenson, Neil Leary, Daniel Slesnick, Frances Sussman, and Peter Wilcoxon.

for example, current research suggests that temperature rise and precipitation changes may encourage the spread of infectious disease by extending the ranges of parasites and mosquitoes that transmit diseases such as malaria and encephalitis; higher temperatures may also result in increased mortality due to heat-related stresses, particularly among the elderly and the poor. Increased illness and mortality will result in medical treatment costs, reduced worker productivity, and other market impacts, as well as in psychological stresses and other damages that are not reflected in the market place and are difficult to measure or value in dollar terms. Impacts on water resources may also be significant nationally, affecting the expenditures necessary to maintain water quality standards, changing the supply of water available for irrigation and drinking water, and affecting the cost of meeting demands for instream water uses such as aquatic habitat, hydropower, and navigation.

Climate change may also have significant non-market impacts. A critical component of these impacts may be those on ecosystems, most of which have not been—or are difficult to—translate into economic terms. Although considerable research has focused on the effects of climate change on ranges of vegetation and animal species (some of which is reflected in the commercial agriculture and forestry studies), little is known about how the services ecosystems provide to human society would be altered by warming. Even less is known about the economic value of these services. Wetlands, for example, provide important environmental services, such as purifying water, recycling nutrients, and providing habitat for waterfowl and spawning ground for fish and shellfish. While the recreation benefits associated with wetlands could, to some extent, be valued using conventional economic techniques and considerable time and effort, the environmental services they provide are difficult to quantify.

Moreover, many ecosystems that are unique within the US may be particularly vulnerable to climate change because of current physical or geographic constraints. For example, the Florida Everglades are already threatened by water availability constraints, and so may be especially sensitive to changing climate and associated changes in the hydrologic cycle. Moreover, the ability of Wilderness Areas, National Parks and other largely “unmanaged” ecosystems to migrate in response to climate change will be limited by their boundaries and by surrounding land uses, suggesting that their adaptive capacity will be less than is projected for commercially managed agricultural and timber lands. Thus, there is considerable concern that US ecosystems could be severely affected by climate change and that, in some cases, impacts could be irreversible. Because it is difficult to quantify and value the effects of climate change on these ecosystems (as well as to measure other non-market impacts), some of the national damage studies discussed in Section 3.7 employ extremely rough assumptions about the magnitude of these impacts.

1.2. *Projecting Macroeconomic and Welfare Impacts*

The study presented in this paper provides a broader perspective on the relationship between sectoral impacts and overall impacts on the US economy than is found in previous work. The current study focuses on three critical aspects of this relationship: (1) the impact of potential climate change on indicators of economic performance, (2) the impact of changes in the macroeconomy on the economic welfare of typical households and of the country as a whole, and (3) the sensitivity of these results to alternative, reasonable assumptions about

future rates of emissions of greenhouse gases, the probable rate of climate change in response to these emissions, and the vulnerability of individual sectors to climate change.

Estimating Macroeconomic Impacts. Climate change may alter economic performance both in aggregate—as measured by changes in national income, consumption, and investment—and in individual sectors—as measured by changes in prices of goods and services and the quantity of output. To estimate these potential economic impacts, the study integrates the results of sector-level studies of the potential impacts of climate change and available climate projections into a general equilibrium model of the US economy.

The general equilibrium approach is critical because economic impacts are influenced by interactions between economic sectors and by the ways in which markets respond and adapt to a changing climate. If, for example, climate change alters the growth rates and yields of commercial forests and timber prices fall or rise as a result, producers can alter their use of timber and other inputs in production, and thus lessen the economic impacts of climate change. Moreover, changes in the productivity of commercial forests will affect prices and output in related industries, such as housing, that use timber inputs. Both performance of the national economy and prices and outputs in multiple sectors and markets will be influenced by these interactions. Although many such interactions and possible adaptive measures are inherently captured by the general equilibrium approach, they are not included in previous studies that rely on a simple sum of the impacts estimated in individual sector studies.

The intertemporal aspects of the approach used in this study are also important. Most studies of climate change impacts are static in nature, i.e., they focus on the impacts of climate change in a world where carbon dioxide concentrations are doubled and the climate system has adjusted to a new equilibrium with higher temperatures and other changes in climatic variables. In contrast, the economic impacts presented here have been developed from a dynamic analysis that simulates the effects of climate change over a time horizon from 1990 to 2080. Thus, the analysis provides a total impact measure that sums the effects that occur as, gradually, the earth's atmosphere warms, sea level rises, and other changes occur.

Estimating Changes in Economic Welfare. Economic impacts can be stated in terms of changes in prices, output, or other economic variables in individual markets and sectors, or for the economy as a whole. Such economic changes will, through changes in wages, prices, and the availability of goods and services, be translated into changes in purchasing power and cost of living for individual households. Most economic analyses, thus, try to go beyond the raw information of market changes to look at the impacts on consumers and producers in the market, by means of measures such as consumer and producer surplus. The measure of well-being, or welfare, used in the current study is described in more detail in the methodology section, and is similar to these surplus measures.

A model of household activity and welfare for the US is used to interpret and translate the general equilibrium results into welfare change estimates. This model allows several insights not available from previous studies. First, existing cost estimates for the different impact categories are often based on very different methodologies; in some cases, costs are stated in terms of economic welfare measures (such as consumer and producer surplus) and

in others simply in terms of additional expenditures (e.g., to protect coastlines). In contrast, climate impacts in the current study are estimated using a consistent methodology that combines the effects across all markets and sectors into a single measure of the impact on the welfare of the final consumer—in this case, the household. Second, the impacts across households are aggregated to arrive at a summary measure of total impacts on US welfare. In contrast to previous studies, this welfare measure is a consistent and comparable estimate of the aggregate impacts of changes across multiple sectors.

Sensitivity Analysis. The third important feature of the study is its attempt to evaluate economic impacts for a range of assumptions about climate and the vulnerability of economic activities to climate changes. Considerable uncertainty surrounds estimates of future warming and other changes in climate that will occur and their effects on individual US sectors. One of the critical challenges in climate change policy, thus, is to adequately understand and, in turn, address this uncertainty in analyzing alternative policies to mitigate or adapt to potential climate change. This study, therefore, seeks to inform the debate by projecting aggregate economic impacts for a range of plausible assumptions, so that policy makers can understand the magnitude of both positive and negative impacts and their dependence on changes in climate and in the vulnerability of US economic activity to potential climate change.

1.3. Results: Discussion and Interpretation

The results presented in this paper suggest that whether climate change will have a beneficial or adverse impact on macroeconomic performance and economic welfare in the US over the coming decades depends critically on the amount of climate change that occurs and on how sensitive economic activity is to warming and associated changes in climate. Among the scenarios evaluated here, only two produce clear benefits—those that assume either a low doubling temperature (1.5°C) or low vulnerability of economic activity to climatic change. In contrast, if the doubling temperature is high (4.5°C), if economic activities are very vulnerable to climate change, or if emissions increase rapidly and produce a rapid rate of temperature change, then climate will have a harmful economic effect. Although beneficial impacts are projected for some scenarios, there is considerable uncertainty surrounding the range of possible outcomes, and there is a strong indication that adverse impacts will exceed those projected, as described below.

How significant are the results? In percent terms, the macroeconomic impacts range from beneficial, with a gain as high as one percent of national income in the year 2080, to adverse, with a loss of as much as two percent of national income in the same year. (A one percent change in national income in the current economy equals roughly \$50 billion). In dollar terms, the impacts on households can be substantial. In the most beneficial scenario, economic welfare of a representative household, measured from estimated changes in lifetime expenditures required to maintain a reference level of material well being, rises by almost \$8,000. In other words, the projected effects of climate change on the supplies and demands of marketed goods and services in this scenario is equivalent to an increase of \$8,000 in the household's wealth. For the most adverse scenario considered, the welfare change is equivalent to a loss in lifetime wealth of about \$12,500.

While these changes are themselves substantial and alter the purchasing power of households and the ability of the economy to undertake alternative investments (e.g., in climate mitigation), they are only a portion of the overall impacts. The market and non-market impacts that are omitted from the analysis represent substantial risks that could prove to be even more important for the environment and human welfare than the included impacts. For this reason, while the study described in this paper sheds light on some of the possible effects of climate change on economic activity and the cost of living, it is not a comprehensive assessment of the full range of risks posed by climate change to the United States.

Several features or limitations lead the study to tend to understate or mask the severity of climate change impacts on the US. First, the study treats the impacts of climate change as uniform across the US and across similar households. Thus, the study does not capture the economic and distributional impacts of regional differences in climate impacts or of differences in how households are likely to be affected, depending on their sources of income. In particular, even in the scenarios that have net beneficial impacts on the US, households located in some regions of the US, or employed in individual sectors that are more vulnerable to climate change, will be adversely affected, perhaps significantly. Averaging and aggregating impacts across the US, and offsetting losses to some by gains to others, masks the variability of effects.

Second, the general equilibrium model assumes that all households and firms have perfect information about current and future markets and can seamlessly and instantaneously adjust to climate change. This includes perfect information about how climate will change in the future, the biophysical effects of climate change, the implications of these effects for production processes (e.g., crop yields), and the price and other market effects that will result from human responses to the consequences of climate change. In reality, firms and households will have imperfect information about the factors relevant to economic decisions. Thus, they will only gradually acquire information about climate effects and the effectiveness and cost of possible adaptive responses. There will also be transitional losses of employment and economic growth in some areas and industries as employment opportunities and production shift from one region to another, or from one sector or industry to another. The costs of such dislocations and transitions in response to a changing climate are not captured in the results.

Third, the impact scenarios are constructed assuming smooth and gradual changes in normal or average climate and that the physical, biological, and ecological effects of these changes are also smooth and gradual. Not taken into account are the consequences of changes in climate variability that are likely to accompany global warming. Changes in climate variability, such as changes in the reliability of rainfall or in maximum and minimum temperatures, may be as or more important than changes in normal or average climate.² Also not taken into consideration are the consequences of abrupt, large, and unanticipated changes in the climate, or in physical, biological, and environmental systems in response to climate change. Such surprises are possible but are largely unstudied. Such

² The study does include the consequences of hypothetical changes in the damages caused by hurricanes and floods.

changes would make adaptive measures more uncertain and less effective and, hence, increase the economic losses associated with climate change.

Finally, the estimates of changes in economic welfare from the study can mask the severity of projected impacts for the future. The annual losses and gains are discounted to a single present value welfare change for each household type for each scenario. This procedure gives greater weight to impacts that are projected to occur in the relatively near term and lesser weight to impacts projected for the more distant future. Thus, although impacts grow in severity over time in a number of the scenarios (so that the greatest losses are projected to occur at the end of the model simulations), the losses in the latter decades of the simulations carry very little weight in the present value assessments of economic welfare impacts. For example, discounting using an interest rate of 3 percent reduces an impact that equals \$10,000 in the year 2080 to only \$800, approximately, in present value today, or less than 10 percent of the 2080 impact. In comparison, a \$10,000 impact in 2020 would have a present value of about \$4,900 today.

Discounting is a widely practiced procedure that provides useful summary information about a series of benefits and/or costs that are spread out over time. However, this is not the only information that may be relevant to public decisions that have long term consequences, particularly when the decisions may have significant impacts on future generations. A useful complement to present value estimates of welfare changes are estimates of the time path of undiscounted welfare changes. As a proxy for this, the study presented in this paper provides information on the time path of changes in aggregate consumption. The percentage changes in consumption in each time period can give a first order approximation of the corresponding percentage changes in economic welfare.

2. METHODOLOGY

To assess the potential effects of climate change on aggregate economic performance, household welfare, and social welfare, the study employed a series of steps, illustrated in Figure 1. First, eight separate future impact scenarios were constructed by combining available projections of changes in climate variables (including temperature and sea level rise) with the results of existing studies of the potential impacts of climate change in a number of US sectors. Next, an intertemporal, general equilibrium model of the US economy was used to simulate the values of key macroeconomic and sector level variables over time, for the baseline (no climate impacts) and each of the climate scenarios. Last, the economic results were then combined with a model of household decision making and welfare, to estimate household and aggregate welfare changes in the US. Each of these steps is described in additional detail below.

2.1. Scenario Development

The first step in the analysis was to develop climate impact scenarios that describe the time path of impacts in a number of different impact categories. Each scenario is a time path of impacts in seven different impact categories: agriculture, forestry, fisheries, energy for heating and cooling, air quality protection, sea level rise defense, and damages from hurricanes and floods. Each of the eight scenarios that were developed represents a plausible

view of the potential impacts of climate change, given current information on emissions, likely climatic changes, and sectoral responses to these changes.³

For the most part, the potential impacts of climate change have historically been evaluated using static scenarios of equilibrium climate change corresponding to an equivalent doubling of carbon dioxide in the atmosphere. Analyzing the effects of climate change over time, however, requires transient scenarios, i.e., scenarios in which sectoral impacts vary over time to reflect the gradual increase in greenhouse gas concentrations in the atmosphere.

The scenarios were developed in several steps. First, alternative trajectories of relevant climatic variables—carbon dioxide concentrations, temperature change, and sea level rise—were constructed based on IPCC projections. Second, impact functions were developed for each of the seven sectors (agriculture, forestry, fisheries, energy for heating and cooling, air quality protection, sea level rise defense, and damages from hurricanes and floods) based on available studies and literature. Each function represents the impact on costs of production in the sector as a function of temperature change, sea level rise, and carbon dioxide concentrations (the latter was included because of its potentially significant impacts on productivity in the forest and agriculture sectors). The climate projections and impact functions were combined to produce eight sets of trajectories (each set representing a scenario) of impacts for all seven sectors.

Because of the considerable uncertainty surrounding any assessment of the potential impacts of climate change in the US, the scenarios developed for this analysis represent a range of plausible optimistic and pessimistic assumptions regarding the possible impacts of continuing emissions of greenhouse gases on the US economy. As discussed below, three sources of uncertainty are reflected in the range of the scenarios: (1) the level of future emissions and concentrations of greenhouse gases, (2) the sensitivity of the earth's climate to changes in atmospheric concentrations of these gases (e.g., the rate of temperature change), and (3) the vulnerability of economic sectors and activities to climatic changes and sea level rise.

2.1.1. Emissions and Concentrations

Emissions and, hence, concentrations, of greenhouse gases in the future will depend critically on a number of important variables that are difficult to project, such as population, economic growth, fossil energy reserves, and technological development. Thus, even assuming that countries take no further action to control emissions, available emissions projections diverge dramatically after the first couple of decades following the year 2000, although projections are much closer in the nearer term. By the year 2100, published projections can differ by a factor of 50; for example, projections of energy related emissions of carbon dioxide in the year 2100 range from 1.2 billion to 60 billion metric tons globally of carbon per year (IPCC, 1994).

³ The projected temperature change and sea level rise used in this study were based on the IPCC (1992) estimates, which have been updated in the new IPCC Second Assessment (IPCC 1996). The implications of these newer data are discussed throughout this paper, as appropriate.

The carbon dioxide (CO₂) concentrations used in the scenarios are based on concentrations projected by the IPCC using the IS92 greenhouse gas emissions scenarios (IPCC, 1992), which bracket much of the range of the published projections. For the year 2100, IS92 projections of global carbon dioxide emissions range from 4.6 billion metric tons to 35.8 billion metric tons. Six of the eight climate change scenarios developed for the EPA analysis of the macroeconomic impacts of climate change are based upon the IS92a projection of greenhouse gas emissions. The IS92a emission scenario falls near the center of the range of IPCC emission projections and projects that carbon dioxide emissions will grow to 20.3 billion metric tons by the year 2100.

In order to assess the implications of emissions that exceed a middle case projection, two additional climate change scenarios were developed for the EPA study from the IS92e projection of the IPCC. The IS92e projection is the highest of the IPCC emission projections and projects carbon dioxide emissions of 35.8 billion metric tons in the year 2100. Other studies of potential future greenhouse gas emissions indicate that the range of possible emissions also extends above the range represented by the IPCC projections, and a number of projections substantially exceed the IS92e projection (IPCC, 1994).

Both emission projections assume no changes in current climate policies (IPCC, 1994). They also incorporate identical, intermediate assumptions for world population growth. The emission scenarios differ, however, in their assumptions about rates and regional patterns of economic growth, energy supplies, and other factors. Primarily because of higher economic growth, projected emissions for the IS92e scenario are higher than for IS92a. In both scenarios, rising population and incomes result in significant growth in emissions of greenhouse gases, despite allowances for technological change that increase energy efficiency and increase the share of non-fossil sources in the supply of primary energy.

With growing emissions of greenhouse gases, the atmospheric concentrations of these gases are also expected to grow. In the case of carbon dioxide, the IPCC (1992) estimated that the IS92a emission projection would increase the atmospheric concentration from a current level of 350 ppm to approximately 800 ppm by 2100. For the IS92e emission projection, the concentration of carbon dioxide would climb to approximately 1050 ppm.⁴ The concentration paths for CO₂ used in the study are illustrated in Figure 2(a). These paths are critical for the impact functions for the forestry and agriculture sectors, as described below.

2.1.2. Global Temperature Change and Sea Level Rise

Based on the concentration projections, the IPCC (1992) estimates realized (actual) warming patterns from the present to the year 2100. Doubling temperature, which is the equilibrium change in the annual global mean temperature that would result from a doubling of carbon dioxide in the atmosphere from preindustrial levels, is a key indication of the climatic effects of changes in greenhouse gas concentrations. The higher the doubling

⁴Estimated CO₂ concentrations do not include potential feedbacks in the carbon cycle and, thus, may be overestimated. Newer IPCC estimates of concentrations in the year 2100 corresponding to the IS92 emission scenarios are approximately 10 percent lower than the estimates used here. See IPCC (1996).

temperature, the greater the warming that would be caused by a given increase in the concentrations of greenhouse gases.

The IPCC estimates that the doubling temperature lies between 1.5°C and 4.5°C, with a best estimate of 2.5°C. For each doubling temperature and emissions path, the IPCC has projected time paths of temperature change, which are the basis of the scenarios in this study. The concentration paths associated with these three doubling temperature values are used to construct scenarios for this study. Depending on the emission projection and the assumed value for the doubling temperature, the transient paths of realized warming range from 0.15°C per decade to 0.50°C per decade across the different scenarios, as illustrated in Figure 2(b).⁵

Increases in global mean temperature are expected to increase global sea level. For the "business-as-usual" emission projection (which falls between the IS92a and IS92e projections), IPCC (1990) estimated that sea level would rise by 3 centimeters, 6 centimeters, and 10 centimeters per decade for doubling temperatures of 1.5°C, 2.5°C, and 4.5°C, respectively. The analysis in this paper does not adjust rates of sea level rise for differences in warming projected for the newer IS92a and IS92e scenarios. Consequently, the rates of sea level rise assumed in the present scenarios (illustrated in Figure 2(c)) may be biased upward.⁶

2.1.3. Sectoral Vulnerability to Climate Change

The impacts literature shows a wide range of results for many of the different categories of potential impacts of climate change. To reflect this uncertainty, the scenarios are varied to represent three different levels of vulnerability to climate change: low, moderate and high. The levels are intended to embody the range of impacts found in the literature, which derive from different underlying projections of global and regional climate change, the environmental and physical effects of changes in climate, and the capacity of social and economic systems to adapt to these changes.

The sector impact functions are constructed based on the available literature on climate impacts in each sector.⁷ In general, impacts are modeled as changes in unit production costs (for most sectors) or as additional expenditures (as in the case of air quality

⁵ Estimates of mean global warming corresponding to the IS92 emission scenarios have been revised in IPCC (1996), and projections of temperature change are lower than in IPCC (1992). For example, the new projection for the IS92a emission scenario, assuming a doubling temperature of 2.5°C, is about 2°C by 2100. The previous projection from IPCC (1992) was approximately 2.5°C. The reduced estimates of warming result from changes in carbon cycle modeling, which yield lower estimates of future CO₂ concentrations, and from including the effects of aerosol emissions, which are expected to reduce the globally averaged greenhouse effect.

⁶ IPCC (1996) estimates that, for an assumed doubling temperature of 2.5°C and mid-value ice melt parameters, sea level would rise 49 and 55 cm by the year 2100 for the IS92a and IS92e emission scenarios respectively. In comparison, for a 2.5°C doubling temperature, the EPA study assumes that sea level would rise 66 cm for both emission projections.

⁷ The principal studies relied upon in developing the impact functions are Adams et al. (1993), Callaway et al. (1994), Titus et al. (1991), Linder and Inglis (1989), Rosenthal et al. (1994), Smith and Tirpak (1989), US Army Corps of Engineers (1993), and Bigford (1991).

protection and coastal defenses). The impact functions model sectoral damages as a function of one or more of the following variables: global mean temperature change, global mean sea level rise, and the atmospheric concentration of CO₂. In the agriculture sector, for example, unit production costs depend on global mean temperature and CO₂ levels. In contrast, expenditures on measures to protect coastal areas depend only on sea level rise. CO₂ concentrations are critical to only two of the sectors: agriculture and forestry. In these sectors, increased CO₂ concentrations can, by increasing photosynthetic rates and water use efficiency, mitigate or offset the detrimental effects of higher temperatures on plant growth and yields.

Because most impact studies have focused on the effects of climate change from a doubling of CO₂, untested assumptions must be used to extrapolate beyond and interpolate between available estimates of impacts in order to construct the impact functions. To account for uncertainties regarding the impacts of different changes in temperature, sea level rise, and CO₂ concentration, three different sets of impact functions are constructed. They differ in the benchmark damages assumed for 4°C warming, 1 meter sea level rise, and 550 ppm CO₂ and in the assumptions used to extrapolate and interpolate damages for other values of these variables. The impact functions are used to generate transient projections of sectoral damages for low, moderate and high vulnerability cases for given trajectories of temperature change, sea level rise, and CO₂.

The quality of the data available to construct the impact functions varies considerably across the sector categories. For some categories, such as agriculture, a number of careful studies have been done on the potential effects of climate change. The results show a relatively wide range of possible effects, but nonetheless there is considerable information upon which to draw to construct and parameterize the impact functions. For others, such as fisheries and damages from hurricanes and floods, there is a basis for anticipating that they will be influenced by climate change but there exists very little information about the character and magnitude of possible effects. Impacts for these categories have been included to be as comprehensive as possible in evaluating the potential sensitivity of the US economy to climate change.

2.1.4. Discussion of the Scenarios

Figure 3 summarizes the key assumptions incorporated into each climate change scenario and the corresponding CO₂ concentration, warming, and sea level rise projected for the year 2080. Scenarios 1, 2, and 3 are based on IPCC's (1992) mid-range projection of future greenhouse gas emissions, IS92a, and IPCC's best estimate of the doubling temperature, 2.5°C. Consequently, the scenarios are identical in their hypothesized time paths of greenhouse gas concentrations, global mean temperature change, and global mean sea level rise. The scenarios differ, however, in the degree to which economic sectors and activities are hypothesized to respond to climate change.

Scenarios 4 through 8 are designed to examine the implications of variations in assumptions regarding the doubling temperature and greenhouse gas emissions. Scenario 4 examines the implications of a low doubling temperature, 1.5°C, coupled with the IS92a emission projection for the medium economic sensitivity case. Scenarios 5 and 6 examine the

implications of a high doubling temperature, 4.5°C, coupled with the IS92a emission projection for the medium and high economic sensitivity cases. Scenarios 7 and 8 incorporate a relatively high emission projection, IS92e.⁸

2.2. Model of the US Economy

The model used for the analysis is the Jorgenson-Wilcoxon-Slesnick (JWS) model, an intertemporal, general equilibrium model of the US economy. This model has been used previously to simulate economic activity for a number of policy scenarios and issues, including the impacts of carbon taxes, environmental regulation, and natural gas regulation. The model is well-suited to these types of policy analyses because of the detail included in the industry and household sectors, the long time frame over which it simulates economic conditions, and its flexibility. In addition, because of the general equilibrium structure, the model captures intersectoral market effects and adaptive responses that producers and consumers make to mitigate the adverse impacts of climate change.

The model consists of four major sectors: domestic producers, households, government, and the rest of the world. Production and consumption are broken down across 35 commodities. Each of the four key sectors is simulated based on historically observed behavior. Given a set of assumptions regarding factors outside the control of the model (such as projected US population growth, current account balances, and foreign incomes and prices) the JWS model simulates market interactions among the four sectors, over the period 1990 to 2080. The JWS model projects national income, consumption and investment, as well as prices and output at a detailed industry level.

2.3. Household Model and Economic Welfare Measurement

Sectoral changes will ultimately be mirrored in the larger economy, affecting not only output, wages, and prices, but also the purchasing power and economic welfare of US households. To estimate these impacts, the study employs a framework for measuring the welfare of individual households and combining these measures into an overall measure of social welfare.

Economists have devised a number of welfare measures to quantify the economic impact of changes in cost of living and purchasing power, as illustrated by the following example. Suppose that, as a result of climate change, prices of some goods rise, and so consumers are worse off. The most obvious measure of the change in consumer welfare is the increase in traditional cost of living measures such as the consumer price index, which indicates the additional income that would be required for consumers to purchase the commodities that are now more expensive. This measure, however, somewhat overstates the extent of damage done by the price rise, since consumers can substitute some commodities for higher priced commodities and otherwise adapt to the price change.

⁸ Although the scenarios were intended to span a plausible range of impacts of climate change, the choice of scenarios focused (as indicated by Figure 3) on exploring the potential consequences of the "downside" scenarios—scenarios involving greater vulnerability and/or greater climate changes. This choice of scenarios should be kept in mind in interpreting the range of results, as well as the preponderance of adverse climate impacts.

The welfare construct used in the study in this paper is similarly a measure of the change in the cost of living. Specifically, in cases where climate change results in reduced economic welfare (i.e., in higher prices), the welfare loss for households is measured by the increase in expenditures that would be required for the household to maintain the level of material well being that would be attainable in the absence of a change in climate. The expenditure change is conceptually equivalent to the amount of wealth that households would be willing to give up to avoid the price changes projected to result from climate change. (In this context, wealth is defined as the present discounted value of the household's lifetime expenditures.) This measure implicitly takes into account the substitutions households can make among commodities in response to price changes; as in the case of producers, these adaptive measures and interactions among the markets for diverse commodities are implicitly captured by the structure of the general equilibrium model.

To aggregate these household welfare changes into a national estimate, a "social welfare function" is used. The social welfare function in the JWS model has two components: the level of average household welfare and an adjustment to account for differences between individual and average household welfare. The second component incorporates an ethical judgment that social welfare is greater the more equitably welfare is distributed across households. Changes in social welfare are reported for two variants of the social welfare function: egalitarian and utilitarian. In this context, the egalitarian social welfare function presumes a greater aversion to inequality than does the utilitarian function.

3. RESULTS AND INTERPRETATION: PROJECTED CHANGES IN ECONOMIC PERFORMANCE AND WELFARE

For each climate change scenario, the study estimates impacts on aggregate measures of economic activity, on prices and output in individual sectors, on individual household welfare, and on aggregate welfare. The results described below suggest that climate change may result in a range of beneficial to adverse consequences, depending on assumptions made about future greenhouse gas emissions and concentrations, the sensitivity of global climate to greenhouse gas concentrations, and the degree of vulnerability of different economic sectors to climatic changes.

3.1. National Income, Consumption, and Investment

Simulations of the combined, general equilibrium effects of the direct impacts of climate change on real national income are displayed in Figure 4. In the final year of the simulations, 2080, the effects range from a 2.0 percent decrease in national income to a 1.2 percent increase relative to the baseline. To provide some perspective, a 2 percent loss in national income at current output and prices in the US would roughly correspond to a \$100 billion income loss. Impacts on consumption and investment are portrayed in Figures 4(b) and 4(c), respectively.

The projected economic impacts of climate change follow three general patterns. One pattern projects that climate change would provide a stimulus to US economic performance through the year 2080. Scenarios 1 and 4 follow this pattern. In these scenarios, combining low and intermediate assumptions about the doubling temperature and vulnerability results

in decreased costs for agriculture, forestry and non-electric heating and cooling. These cost decreases dominate relatively modest cost increases for other economic activities in these scenarios. The cost decreases lead to decreases in the aggregate prices of consumption and investment goods. The price decreases provide a stimulus to economic activity, raising real national income in the US.

A second pattern suggests that climate change will have negligible effects on US economic performance over the time horizon 1990 to 2080. This pattern is represented by scenarios 2 and 7 in Figure 4. Both these scenarios combine intermediate assumptions about the doubling temperature and vulnerability. Consequently, agriculture and forestry do not benefit from the cost decreases that were projected for scenarios 1 and 4. Because the negative consequences of climate change roughly balance the positive influence of CO₂ fertilization, costs in these sectors are nearly unchanged. Aggregate prices of consumption and investment goods are also nearly unchanged for scenarios 2 and 7. The effect of the small price changes is to first raise consumption and national income slightly, and then reduce them slightly relative to the baseline scenario.

A third pattern of projected impacts finds that climate change would reduce economic performance by the US. This pattern is illustrated by scenarios 3, 5, 6 and 8 in Figure 4. These scenarios combine a high doubling temperature with intermediate or high vulnerability, or an intermediate doubling temperature with high vulnerability. In each of these cases there are substantial cost increases in agriculture and forestry. In addition, cost increases for fisheries, electric heating and cooling, air quality protection, coastal protection, and storm damages are greater than for other scenarios and cost decreases for non-electric heating are modest relative to other scenarios. As a consequence of these cost changes, the aggregate prices of consumer and investment goods rise, indicating that marketed goods and services increase in scarcity relative to the baseline scenario. These price increases place a drag on economic growth and diminish US economic performance.

3.2. Sectoral Price and Output Effects

The potential costs and damages resulting from climate change will affect prices and quantities in a number of sectors. The projected changes in commodity prices for the 35 sectors included in the JWS model are displayed in Figure 5. The largest sector impacts are projected for agriculture, which in the JWS model is a composite of agriculture, forestry, and fisheries. In scenario 3, the price of agricultural goods increases 30 percent by 2080. Lesser but significant price increases are projected for sectors, such as food, textiles, lumber, and furniture, that use agricultural, forest and fishery inputs relatively intensively. As a result of the price increases, quantities consumed of these commodities also decrease in 2080, as illustrated in Figure 6. In contrast, for scenario 1 (moderate warming and low vulnerability), agricultural prices in the year 2080 fall by over 25 percent and quantities rise by over 35 percent. Similarly, prices and quantities in other sectors are nearly the mirror image of impacts in scenario 3.

These price and quantity changes may result in significant reallocations of resources across different sectors of the economy. Labor and capital may, for example, move from sectors that are adversely affected by climate change to sectors that are less affected. These

reallocations are adaptive measures that lessen the potential long-term impacts of climate change, or exploit gains made possible by climate change in some sectors. Reallocating resources is not, however, costless, but imposes dislocation and transition costs (such as short-term unemployment) on workers and firms that move from one sector to another, or from one region to another. Because adjustment occurs relatively rapidly in the JWS model, the negative impacts that occur during an adjustment period are only partially captured by the model.

3.3. *Household Welfare*

Household welfare changes across the scenarios range from losses (in present value) of thousands of dollars per household to gains of thousands of dollars. Figure 7 displays the welfare changes for a reference household for all eight climate change scenarios.⁹ Because of the effects of discounting, the present value of welfare changes over the time period largely reflects cost of living changes in the near term. For example, a \$10,000 impact discounted at a rate of 3 percent would equal \$7,400, \$4,100, \$1,700, and \$700 when discounted for 10, 30, 60, or 90 years in the future.¹⁰ Annual consumption, which changes relative to the baseline projection in every period from 1990 to 2080 as a result of climate change, is a rough indicator of the yearly welfare changes that occur in the scenarios. For example, while the present value welfare change for the reference household is 0.5 percent of household wealth in scenario 3, consumption is projected to decline by 0.3 percent by 2020, 0.7 percent by 2050, and 1.1 percent by 2080 for that scenario. Thus, for scenarios with adverse consequences, damages to future generations are projected to exceed those of current generations, when measured in their own time period.

In scenarios 3, 5, 6 and 8, the higher projected prices for nearly all goods and services raise the cost of living relative to the baseline scenario in every year of the 1990 to 2080 simulation period. The projected rise in the cost of living increases with time at an increasing rate for each of these scenarios. The present value welfare change due to the rising cost of living for a reference household of four persons ranges from a loss of \$2,600 to a loss of \$12,300. The meaning of these welfare changes is that the projected increases in the future cost of living are equivalent to reductions in the household's present wealth of \$2,600 to \$12,300.¹¹ These welfare changes represent 1 percent or less of a reference household's total wealth.

Results from other scenarios, however, suggest that the impacts included in the analysis may yield a net gain in household welfare. Scenarios 2 and 7, which yielded slight

⁹ The reference household in the JWS model is an urban household located in the Northeast with four members, is headed by a white male aged 35 to 44 years, and has a level of wealth equal to the average for all households.

¹⁰ The discount rate applied in the analysis is endogenously determined within the JWS model. The discount rate varies over time but can be approximated by a constant real rate of 3.4 percent over the 1990 to 2080 simulation period.

¹¹ Household wealth is defined here as the present discounted value of the lifetime expenditures of the household on goods and services. The discount rate applied in the analysis is endogenously determined within the JWS model. The discount rate varies over time but can be approximated by a constant real rate of 3.4 percent over the 1990 to 2080 simulation period.

changes in prices and national income, yield relatively small present value gains in welfare of \$200 to \$700 for the reference household. Because of discounting, reductions in the cost of living projected for the early decades of the next century dominate increases in the cost of living for the later decades and household welfare is estimated to increase. Considerable increases in household welfare are estimated for scenarios 1 and 4. Falling prices in these scenarios reduce the cost of living in all years of the model simulations with the result that welfare of the reference household increases \$2,000 to \$7,900 in present value.

The distribution of estimated welfare changes over different household types indicate that, if climate change has negative welfare consequences, poorer households may be more heavily burdened by climate change than are wealthier households. Although the absolute welfare loss increases with wealth in scenarios 3, 5, 6 and 8, poorer households suffer larger percentage welfare losses than do wealthier households. The relationship between household wealth and the percentage welfare loss is displayed for scenario 3 in Figure 8. A four person household with a high level of wealth is projected to suffer a welfare loss under the assumptions of scenario 3 that is equal to 0.40 percent of its wealth. The percentage loss to a household of low wealth is 0.55 percent. The burden borne by the poorer household is one-third greater as a percentage of wealth than is the burden borne by the wealthier household.¹²

For scenarios in which climate change is projected to cause welfare to increase, the pattern of gains is progressive in a relative sense in its distribution across households. Although the welfare gains increase with the level of household wealth, the gains are lower as a percentage of household wealth for high income households than for low income households.

3.4. Social Welfare Change

Social welfare change is a function of the household welfare changes. Aggregating the projected changes in household welfare by means of a social welfare function yields the changes in social welfare reported in Table 2. Changes in social welfare are reported for two variants of the social welfare function: egalitarian and utilitarian. Results from these two variants of the social welfare function provide illustrations of the aggregate consequences of climate change on the welfare of households in the United States. The rankings of scenarios by social welfare change from most beneficial to most detrimental are invariant across the two forms of the social welfare function.

Consistent with the projected changes in household welfare, social welfare is projected to decline in scenarios 3, 5, 6 and 8. The egalitarian social welfare function yields social welfare losses in the US ranging from \$150 billion to \$750 billion in present value terms. The losses calculated from the utilitarian social welfare function range from \$190 billion to \$950 billion. In both cases the greatest losses arise in scenario 8, which incorporates high assumptions for vulnerability, the doubling temperature, and emissions.

¹² Low, medium and high wealth refer to wealth levels that are equal to one-half the average, average, and twice the average wealth level of all US households.

Social welfare increases are obtained for scenarios 1, 2, 4 and 7. The egalitarian social welfare function yields an increase in social welfare from \$20 billion to \$480 billion. The utilitarian social welfare function yields an increase in social welfare from \$25 billion to \$620 billion. In both cases the greatest gains are obtained in scenario 1.

3.5. *Sensitivity of Results to Differences in the Scenarios*

The scenarios constructed for analysis incorporate three sources of uncertainty: the vulnerability of economic sectors and activities to climate change, the sensitivity of the earth's climate to accumulations of greenhouse gases, and future emissions and concentrations of greenhouse gases. Each of these sources of uncertainty contributes to the uncertain effects of unconstrained emissions of greenhouse gases on US economic performance and economic welfare. The sensitivity of projected household welfare changes for the reference household to varying assumptions regarding vulnerability and the doubling temperature is illustrated in Figure 9 for the IS92a scenarios. The sensitivity of household welfare changes to varying assumptions about emissions is illustrated in Figure 10.

The pattern of welfare changes depicted in Figure 9 reveals a high degree of sensitivity to assumptions regarding vulnerability. Depending on the vulnerability of economic sectors and activities, climate change may result in net gains or net losses over the 1990 to 2080 time horizon. For a doubling temperature equal to 2.5°C, varying the degree of vulnerability results in projected welfare changes that vary from a net gain of \$7,900 to a net loss of \$5,200. The projected changes in household welfare are also highly sensitive to the doubling temperature, as shown in Figure 9. For the case of medium vulnerability, changes in household welfare range from gains to losses depending on the doubling temperature.

Of the three sources of uncertainty considered, uncertainty about the vulnerability of economic sectors and activities to climate change has the greatest influence on the economic performance and welfare impacts of climate change. Holding constant assumptions regarding greenhouse gas emissions and the doubling temperature, varying the level of vulnerability over a range that is consistent with previous sectoral impact studies results in widely divergent changes in household welfare. A given climate change scenario could generate either economic gains or losses, depending upon how vulnerable are economic activities to changes in climate.

3.6. *The Role of the Agriculture Sector*

The results of the eight scenarios suggest that the effects of climate change on agriculture play a prominent role in shaping the macroeconomic and welfare effects of the set of included market impacts. Scenarios that have negative impacts on national income and economic welfare (scenarios 3, 5, 6, and 8) correspond to cases in which agricultural costs increase relative to the baseline. In scenarios 2 and 7, the net effects of warming and CO₂ fertilization on agricultural costs are nearly neutral, resulting in negligible changes in national income and welfare. In scenarios 1 and 4, the decline in agricultural and forestry production costs and in non-electric heating and cooling provide a stimulus to the economy that results in increased national income and welfare.

To evaluate the importance of agriculture in shaping the national impacts of climate change, two additional scenarios were examined. The results for these scenarios, which incorporate only the direct effects of warming and CO₂ fertilization on agricultural costs, are displayed in Table 3. A comparison of the results of these and the original eight scenarios suggests that agricultural impacts are, indeed, a significant determinant of the simulation results. When agricultural impacts are large and negative, national income in 2080 declines by 1 percent or more and household welfare declines by thousands of dollars. If CO₂ fertilization has substantial benefits, then national income and household welfare increase.

3.7. Studies of the Aggregate Costs of Climate Change

A number of previous studies have attempted to estimate the aggregate costs of climate change to the United States in monetary terms. Cost estimates from four of these studies are presented in Table 4. These cost estimates provide additional information that is useful for weighing the potential severity of the consequences of climate change. Note, however, that the cost estimates in Table 4 are not directly comparable to the results of the EPA study that are the central focus of this paper.

The estimates of the previous studies are not directly comparable to results from the EPA study for a number of reasons. The principal differences that make direct comparison of results problematic are (i) the use of equilibrium scenarios of climate change versus transient scenarios, (ii) the reporting of annual cost versus the present discounted value of a stream of costs over time, (iii) the inclusion of monetary valuations of non-market impacts as well as market impacts, and (iv) the use of welfare change as a measure of cost versus other measures of cost.

The studies included in Table 4 estimate the annual cost of a change from present climate to a projected equilibrium climate corresponding to a doubling of carbon dioxide concentration in the atmosphere (2xCO₂). The categories of impacts for which costs are estimated include non-market as well as market impacts. The costs are estimated by imposing the projected future climate on the current population, economy and technology of the US. For many categories of impacts, costs are measured by estimated changes in economic welfare, but other measures are also employed. In contrast, the EPA study extrapolates from the results of sectoral studies of equilibrium 2xCO₂ climate change impacts to estimate costs at different points in time as greenhouse gas concentrations change, taking into account projected changes in population, income growth, technology, and structural changes in the economy. Costs are measured by estimated changes in economic welfare and are reported as a present discounted value of projected costs from the present through the year 2080. Only market impacts are included in the cost estimates of the EPA study.

Three of the studies represented in Table 4 are in close agreement as to the aggregate annual cost of an equilibrium change in climate from a doubling of carbon dioxide in the atmosphere. Nordhaus (1994), Cline (1992) and Fankhauser (1993) obtain estimates of costs ranging from 1.0 to 1.3 percent of US Gross National Product (GNP). These estimates are illustrative of the rough magnitude of the aggregate costs of 2xCO₂ climate change for the categories of impacts susceptible to being monetized given current information. But the high degree of agreement across these frequently cited studies should not be interpreted as an

indicator that there is little uncertainty regarding the costs of climate change. The cost estimates are point estimates for which no confidence bounds have been attached and for which no sensitivity analyses have been performed for alternative assumptions regarding projections of future climate, biological and physical effects of climate change, human responses, and valuation of effects. The EPA study discussed in this paper indicates that uncertainties about these factors lead to considerable uncertainty regarding the costs of climate change.

The "benchmark" estimates of the costs of 2.5 or 3.0°C mean global warming from these studies mask substantial uncertainties regarding the costs of market and non-market impacts of climate change. Clearly, the 1.0 to 1.3 percent of GNP range does not represent a range that bounds a large portion of the distribution of potential costs of 2xCO₂ climate change. An interval that would bound a substantial portion of the distribution is undoubtedly much wider. Unfortunately, the current state of knowledge is insufficient to support credible estimates of the probability distribution of the costs of 2xCO₂ climate change. It is not even clear that the distribution would be centered at or near the 1.0 to 1.3 range. An indication of the potential magnitude of the uncertainties regarding aggregate costs is given by the ten-fold difference between the lowest and highest cost estimates of Titus (1992) for scenarios of 4.0 to 4.2°C.

Closer examination of Table 4 reveals that, while estimates of aggregate costs are often in close agreement, there are significant differences in the cost estimates for individual categories of climate change impacts. That they sum to nearly the same aggregate cost is partly coincidental. For example, agricultural impacts represent the largest cost in Cline's estimates and one of the largest in Fankhauser's estimates. In contrast, Nordhaus estimates very modest costs for agriculture and Titus estimates a range of agricultural impacts that span from significant costs to net benefits. Substantial differences in cost estimates are also obtained for forestry, energy, air quality, water resources, and human health. The varied estimates of costs by category is further evidence that the costs of climate change are highly uncertain.

The impact categories that overlap the categories included in the EPA study account for 20 to 70 percent of the costs estimated in the studies included in Table 4. As a percentage of GNP, the cost estimates from Nordhaus, Fankhauser, and Cline for this subset of impact categories are approximately 0.25, 0.50, and 0.75 respectively. For the lowest and highest cost estimates from Titus, these categories represent 0.1 and 4.0 percent of GNP. For a very crude comparison to the EPA study, these estimates can be compared to the EPA study's projected GNP changes for the year 2080. In 2080, mean global warming projected for the EPA scenarios ranges from 1.3 to 4.5°C, which is very nearly the range of equilibrium warming that has been estimated for a doubling of CO₂ in the atmosphere. The projected changes in GNP due to the market impacts of climate change range from -2.0 to +1.2 percent of baseline GNP. Keeping in mind that GNP changes are related to but do not measure welfare change costs, and the other limitations noted above regarding comparisons of results to the EPA study, the EPA results overlap much of the range of costs estimated by previous studies.

An important difference between the EPA results and the results of these other studies is that the estimated range of economic impacts includes the possibility of net benefits as well as net costs. As noted previously, this is driven primarily by estimates of potential net benefits for US agriculture for some sets of scenario assumptions. Titus also allows for net benefits in agriculture, but because of higher estimated costs for air quality maintenance, his aggregated effects of market impacts yield a net cost from climate change.

4. CONCLUSION

Climate change poses a variety of risks to the US. This paper summarizes results from a study that evaluates the risks to US economic performance and economic welfare from a selected set of climate change impact categories. The study is confined to a subset of market impacts, i.e., impacts that affect the supply or demand for goods and services that are traded in markets. The categories of market impacts included in the evaluation are changes in the costs of producing agricultural, forest, and fisheries commodities, heating and cooling indoor spaces, protecting coasts against sea level rise, maintaining air quality, and repairing storm and flood damages. Although this list represents many of the potentially important economic vulnerabilities to climate change, it omits other significant market impact categories such as water resources and labor productivity and medical expenditure effects of changes in human health. Moreover, it omits non-market impacts, notably impacts on ecosystems such as wetlands and national parks or preserves that provide species habitat and other benefits.

Across a set of scenarios that reflect a range of plausible assumptions about future climate changes and the vulnerability of economic activity to climate change, projected changes in national income range from -2.0 percent to +1.2 percent in the US by the year 2080. The present discounted value of aggregate economic welfare changes over the period 1990 to 2080 that would accompany these changes in national income are estimated to range from a loss of \$1 trillion to a gain of \$600 billion. For individual households, the changes are equivalent to gains or losses that range from several hundred to a few thousand dollars.

These national market impacts must be viewed in a larger context that includes information about other aspects of the potential impacts and risks of climate change. First, the market and non-market impacts that are omitted from the analysis represent substantial risks of negative effects that could prove to be even more important for the environment and human welfare than the included impacts. Second, aggregating impacts to a national scale—i.e., reporting the net sum of gains and losses—masks important differences in impacts across different geographic areas of the US and economic sectors or industries. Further, the scenarios considered here look only at gradual climate change and neglect the impacts that may be associated with greater climate variability or with sudden changes in climate. Last, the modeling approach does not capture transitional costs, or costs that occur when markets do not smoothly and completely adapt to the pressures of climate change.

In this context, the results suggest that, while the possibility of beneficial market impacts exists under moderate rates of warming, there is a significant probability of adverse consequences, particularly when non-market and omitted market impacts are considered. The results also indicate that uncertainties regarding the character and rate of climatic change over coming decades and the vulnerability of economic activity to these changes yield

considerable uncertainties regarding the economic consequences. Reducing this uncertainty will require not only advances in climate science and the prediction of future climate at global and regional scales, but also advances in knowledge about the sensitivity of natural and human systems to climate change and about the capacity of these systems to adapt to projected changes.

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Table 1
Market Impacts of Climate Change

Market Impacts Included in the Analysis

- Agricultural Productivity Changes
- Forestry Productivity Changes
- Fisheries Productivity Changes
- Indoor Heating and Cooling Productivity Changes
- Protecting Developed Coasts from Sea Level Rise
- Maintaining Air Quality Standards for Ground-level Ozone
- Storm and Flood Damages

Market Impacts Omitted from the Analysis

- Water Supply Changes in Domestic, Commercial, Industrial Uses
- Water Transportation Productivity Changes
- Hydropower Generation Productivity Changes
- Construction Sector Productivity Changes
- Marketed Recreation/Tourism Opportunity Changes
- Land and Asset Losses from Sea Level Rise
- Genetic Resource Base for New Pharmaceuticals, Chemicals, and Materials
- Maintaining Water Quality
- Medical Service Demand Changes
- Labor Productivity Changes due to Health Impacts
- Reallocating and Relocating Displaced Workers
- Reallocating and Relocating Capital
- Land Value Changes Due to Changes in Human Amenities of Climate

Table 2
Social Welfare Change

Scenario Number	Emission Projection	Doubling Temperature	Sensitivity to Climate Change	Social Welfare Change (Present value, billions of 1990 dollars)	
				Egalitarian	Utilitarian
1	IS92a	2.5°C	Low	485	615
2	IS92a	2.5°C	Medium	20	25
3	IS92a	2.5°C	High	-315	-400
4	IS92a	1.5°C	Medium	125	155
5	IS92a	4.5°C	Medium	-150	-185
6	IS92a	4.5°C	High	-600	-760
7	IS92e	2.5°C	Medium	50	60
8	IS92e	4.5°C	High	-745	-945

Table 3
The Role of Agriculture

Scenario Number	Emission Projection	Doubling Temperature	Sensitivity to Climate Change	Direct Impacts Included	National Income, 2080 (% income)	Reference Household Welfare Change (1990 dollars)
AG1	IS92a	2.5°C	Medium	Agriculture	-0.05	40
2	IS92a	2.5°C	Medium	All	-0.10	200
AG2	IS92a	4.5°C	High	Agriculture	-1.10	-7,850
6	IS92a	4.5°C	High	All	-1.65	-9,900

Table 4
Annual Effects of Equilibrium Climate Change for Doubling of CO₂:
Results from Previous Studies^a
(Billions of 1990 dollars)

	Nordhaus (1994)	Cline (1992)	Fankhauser (1993)	Titus (1992)
Equilibrium Warming for 2 x CO ₂	3.0°C	2.5°C	2.5°C	4.0 to 4.2°C
Damage Category				
Agriculture	-1.1	-17.5	-8.3	-14.0 to 7.6
Forestry		-3.3	+2.0	-113.2 to 0.3
Sea Level Rise ^b	-12.1	-7.0	-8.9	-1.7 to -19.1
Energy	-0.6	-9.9	-7.7	-3.5 to -17.6
Other ^c	-43.0			
Storms		-0.8	-0.2	
Air Quality		-3.5	-7.2	-9.5 to -75.4
Water Resources		-7.0	-15.5	-21.3 to -87.2
Leisure Activities		-1.7		
Urban Infrastructure		-0.1		
Human Health		-5.8	-18.7	-2.5 to -31.8
Migration		-0.5	-0.6	
Species Loss		-4.0	-7.2	
Total	-56.8	-61.1	-72.3	-30.6 to -358.1
Percent of GNP	-1.0	-1.1	-1.3	-0.5 to -6.3

^a Estimates of damages are based on 1990 scale of economic activity in the U.S.

^b Cline (1992), Fankhauser (1993), and Titus (1992) include the value of wetland losses in their estimates of costs for sea level rise. Nordhaus (1994) excludes wetland values from costs related to sea level rise but implicitly includes them in "other" costs.

^c Nordhaus (1994) does not explicitly estimate costs included in "other." These costs are assumed by Nordhaus to be 0.75 percent of GNP.

Figure 1. Overview of the Study Methodology

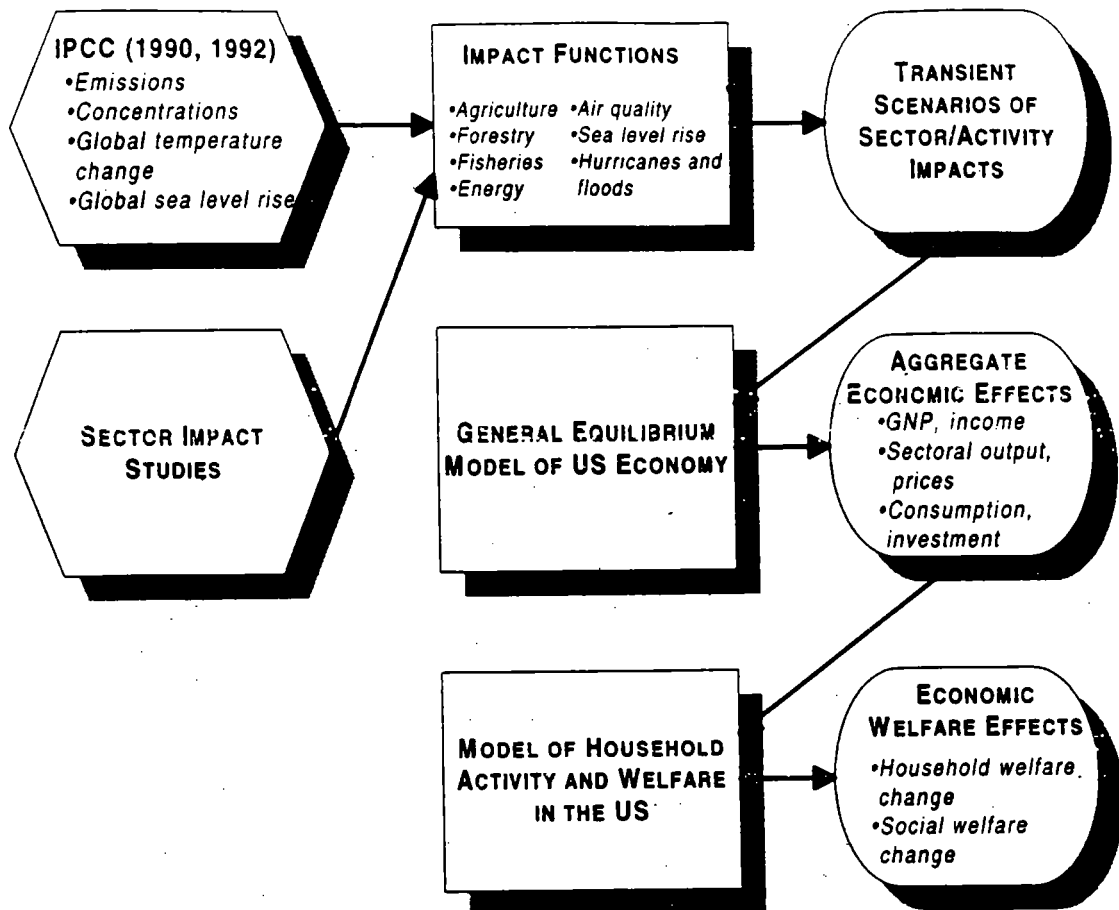
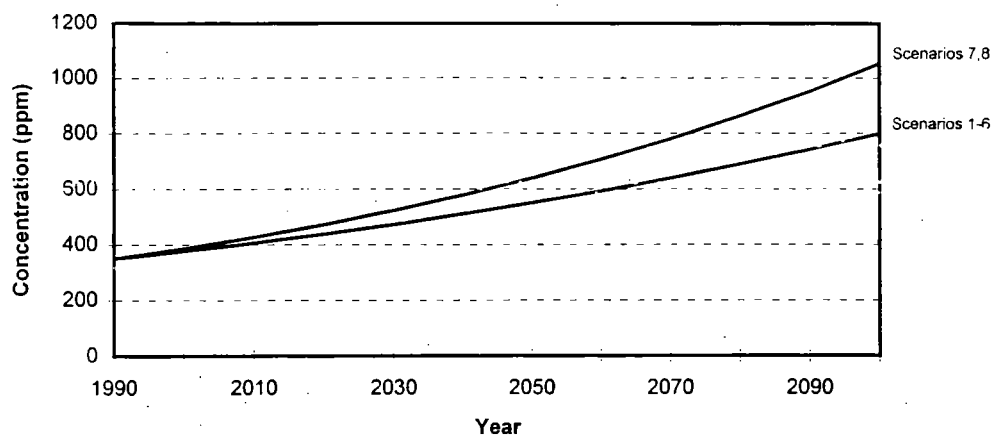
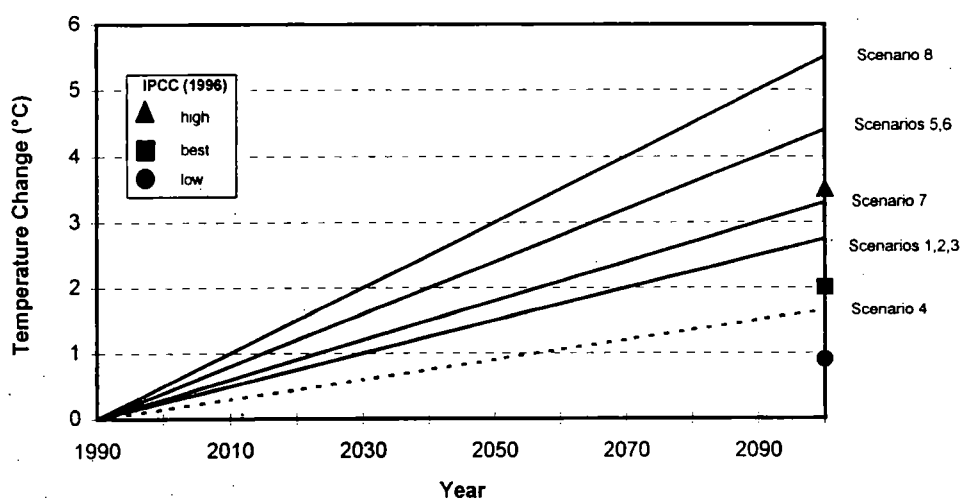


Figure 2. Scenario Assumptions: CO₂ Concentrations, and Climate

(a) CO₂ Concentration



(b) Global Mean Warming



(c) Sea Level Rise

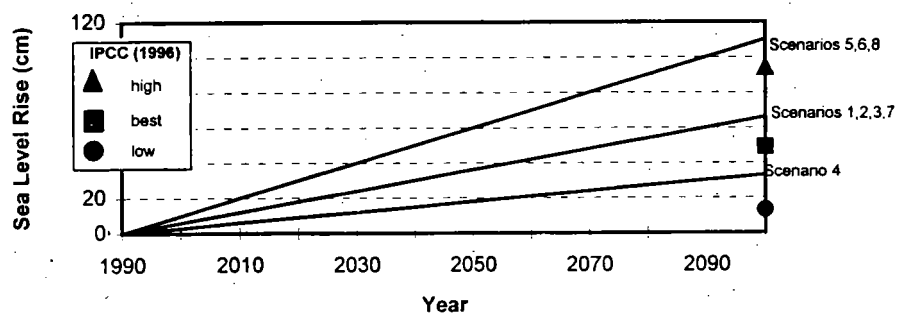


Figure 3. Scenario Assumptions

(a) IS92a (mid-range emission projection)

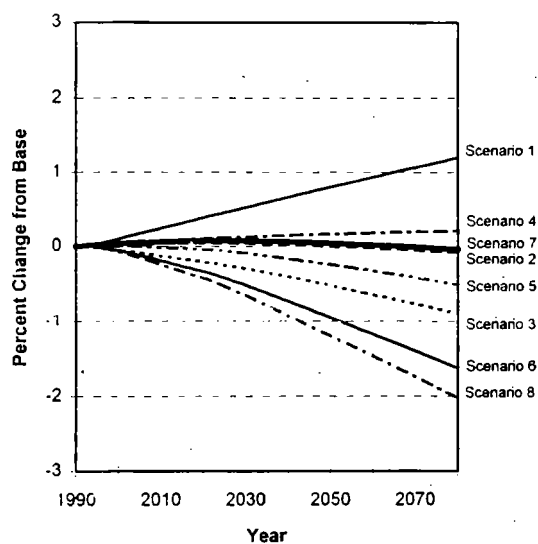
	Vulnerability		
	low	moderate	high
low (1.5°C)		scenario 4	
medium (2.5°C)	scenario 1	scenario 2	scenario 3
high (4.5°C)		scenario 5	scenario 6

(b) IS92e (high-range emission projection)

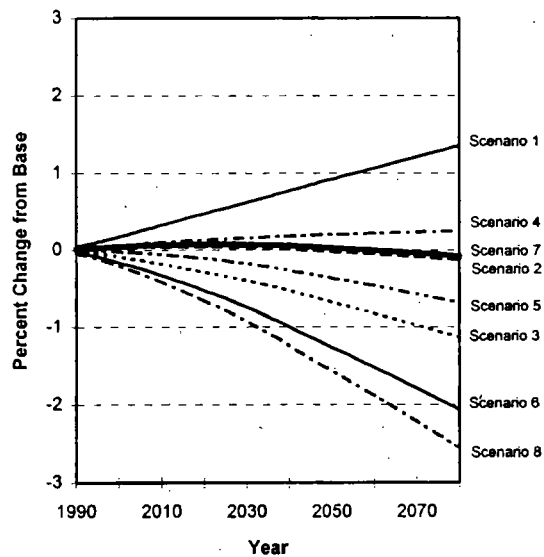
	Vulnerability		
	low	moderate	high
low (1.5°C)			
medium (2.5°C)		scenario 7	
high (4.5°C)			scenario 8

Figure 4. Changes in National Income, Consumption and Investment under Different Scenarios

(a) National Income Changes



(b) Consumption Changes



(c) Investment Changes

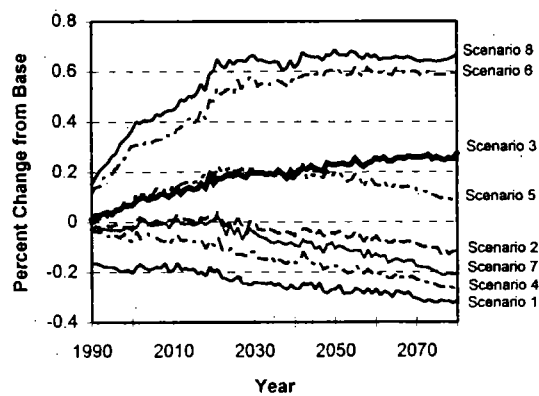


Figure 5. Sectoral Price Changes, 2080, Scenario 3

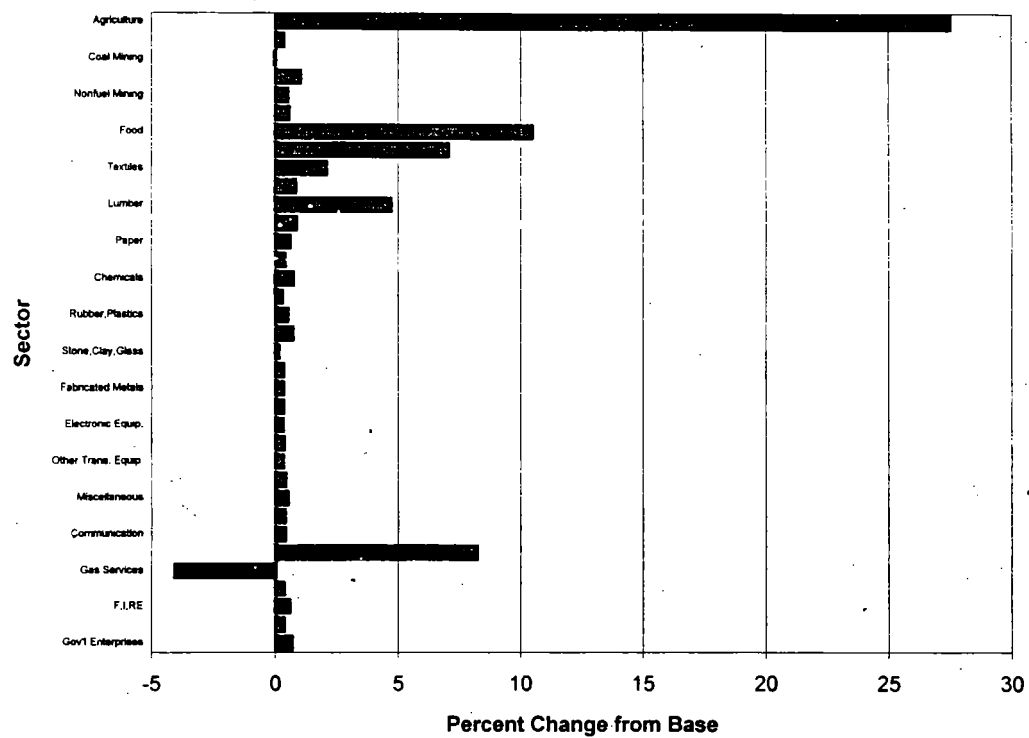


Figure 6. Sectoral Quantity Changes, 2080, Scenario 3

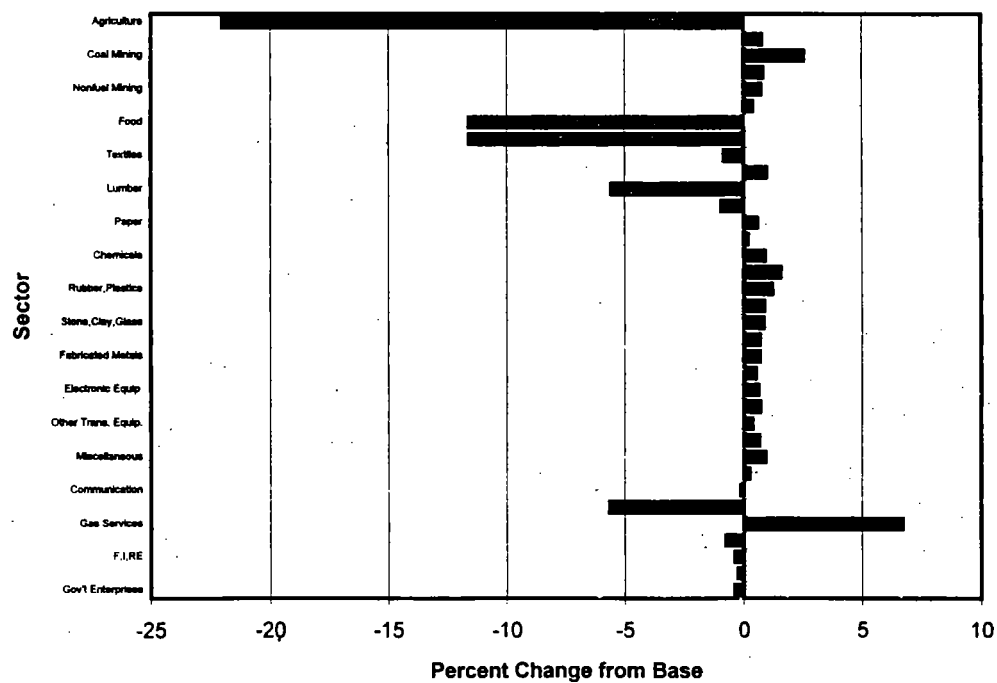


**Figure 7. Household Welfare Changes,
Reference Household
(Present Value, 1990 \$)**

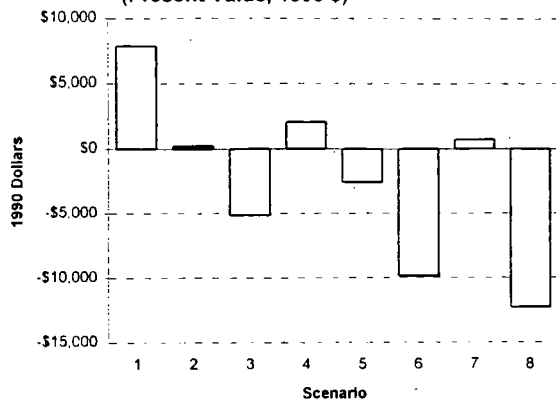


**Figure 8. Percentage Change in Household
Welfare By Level of Household
Wealth, Scenario 3**

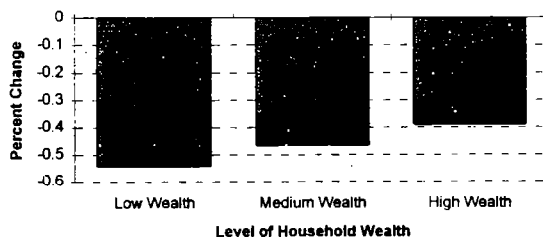


**Figure 9. Sensitivity of Household Welfare
Changes to Economic Vulnerability
and Doubling Temperature,
Reference Household (1990 \$)**

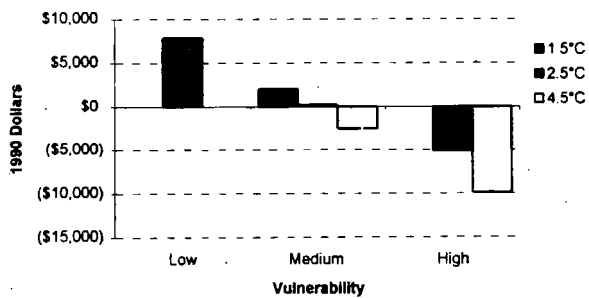
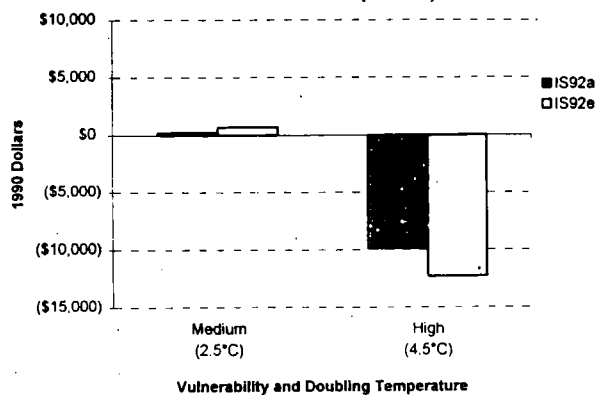


**Figure 10. Sensitivity of Household
Welfare Changes to Emissions,
Reference Household (1990 \$)**



MEMORANDUM

COUNCIL OF ECONOMIC ADVISERS

Date: 13 Jan. 96

To: Jeff Frankel
Alicia Munnell

From: Jason Shogren

RE: Revised Draft Climate Text (Revision #5) from Eileen Claussen

Two points:

1. **2 or more Budget Periods.** Article 2 #3a-c now introduces the possibility of more than 2 budget periods. Period length is open. No language on Jeff's proposal of 5 year averages for targets and meeting 4 of 6 targets for compliance.

The text does state that the emission level in a subsequent period must be *equal to or less than* the emission level in the previous period. Does this rule out by definition the optimal non-monotonic emissions path as suggested by the IPPC work? and how does borrowing fit into this?

2. **Borrowing.** The short paper on borrowing lists three options: (1) right to borrow, (2) debt carryover, and (3) continue to explore.

Right to borrow—a strict borrowing scheme that allows a party to borrow only from the subsequent budget period up to [10 percent] tonnes to be paid back at a [20 percent] interest rate.

Q? Why are we raising the transaction costs of borrowing so high when the models suggest that the optimal emission paths are non-monotonic, peaking around 2050 +/- 25 years? If budget years are 5 to 10 years in length, a party will need to borrow a lot initially given the declining emissions path in the text and the increasing optimal emissions suggested by the IPPC. Or will the target be set from the IPPC report as well—first increasing, then decreasing emissions? If this is the case, borrowing should not be needed except for emergencies.

Debt carryover—borrowing as a penalty. This does not make sense because anyone who did not meet the goal in period one is not likely to meet a stricter goal in period 2, especially in the initial stages.

Continue to explore—leave open for discussion at a future date. It was my understanding that the vagueness of such language was why borrowing did not go over in the last meeting between the countries.

Recommendation—first define the budget period length and target (decreasing or optimal path), add borrowing without the high transaction costs (perhaps with a cap and collateral).

THE WHITE HOUSE
WASHINGTON

January 10, 1997

MEMORANDUM FOR DISTRIBUTION

FROM: Kristen Panerali
National Economic Council

SUBJECT: Climate Change Deputies Meeting Agenda

Attached please find the agenda for the joint NEC-CEQ Deputies meeting on climate change for Tuesday, January 14 at 4:30 pm in 231 OEOB.

Deputies plus one are invited to attend. If you have not done so yet, please call Kristen Panerali at 456-5353 with your clearance information.

Distribution:

Charles Curtis, DoE
Morton Downey, DOT
Ev Ehrlic, Commerce
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Jack Lew, OMB
Cynthia Metzler, Labor
Richard Rominger, USDA
Alicia Munnell, CEA
Nancy Soderberg, NSC
Larry Summers, Treasury
Tim Wirth, State

CLIMATE CHANGE AGENDA
January 14, 1996, 4:30 p.m., 231 OEOB

- I. Introduction
- II. Submission of draft protocol language
- III. Review of modeling effort
- IV. Development of domestic implementation policies

**United States Department of State**

*Assistant Secretary of State for Oceans and
International Environmental and Scientific Affairs*

Washington, D.C. 20520

January 13, 1997

W. Amy
JAF
JS
IWM

TO: *Distribution
FROM: OES - Eileen B. Claussen JR fr
SUBJECT: Revised Draft Climate Text

Attached for your information is the revised draft climate text, and a short paper on borrowing (which includes options for consideration by the Deputies). The paper has been sent to the NEC for distribution to the Deputies.

Attachments:
As stated.

REV. 5, 1/13/97, 8 am

U.S. DRAFT PROTOCOL FRAMEWORK
(submitted without prejudice to ultimate form of agreement)

The Parties to this Protocol,

Have agreed as follows:

Article 1
Definitions

For purposes of this Protocol:

1. "The Convention" means the United Nations Framework Convention on Climate Change done at New York on 9 May 1992.
2. "Party" means Party to this Protocol.
3. "Greenhouse gas" means any greenhouse gas for which a global warming potential is set forth in Annex C of this Protocol.
4. "Tonne of carbon equivalent" means one metric tonne of carbon, or a quantity of one or more other greenhouse gases equivalent to one metric tonne based on the global warming potentials set forth in Annex C of this Protocol.
5. "Net anthropogenic emissions" of greenhouse gases is the calculated difference between emissions by sources and removals by sinks.
6. [other definitions to be developed or cross-referenced to the Convention as necessary]

Article 2
Emissions Budgets

1. Each Annex A and Annex B Party shall ensure that its net anthropogenic emissions of greenhouse gases do not exceed its emissions budget for any applicable budget period, as specified in this Article.
2. For each Annex A and Annex B Party, its emissions budget shall be denominated in tonnes of carbon equivalent emissions allowed and shall equal:
 - (a) the tonnes of carbon equivalent emissions it is allowed under paragraph 3 or 4 below, plus

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- (b) any tonnes of carbon equivalent emissions allowed that are carried over from a prior budget period under paragraph 5 below, plus
 - (c) any tonnes of carbon equivalent emissions allowed that are acquired from another Party under Article 6 (International Emissions Trading) or Article 7 (Joint Implementation), minus
 - (d) any tonnes of carbon equivalent emissions allowed that are transferred to another Party under Article 6 (International Emissions Trading).
3. (a) For the first budget period, [20__ through 20__], each Annex A Party shall have a number of tonnes of carbon equivalent allowed equal to [a percentage of] its net anthropogenic emissions of tonnes of carbon equivalent in 1990, multiplied by [the number of years in this budget period].
- (b) For the second budget period, [20__ through 20__], each Annex A Party shall have a number of tonnes of carbon equivalent emissions allowed equal to [a percentage equal to or less than the percentage in subparagraph 3(a)] of its net anthropogenic emissions of tonnes of carbon equivalent in 1990, multiplied by [the number of years in this budget period].
- (c) [possible subsequent budget period(s)]
4. For the budget period [20__ through 20__], each Annex B Party (see Annex B for States included) shall have a number of tonnes of carbon equivalent emissions allowed equal to [options for Annex B Parties include: budget periods, baseyears, and/or percentages different from those applicable to Annex A Parties].
5. At the end of a budget period applicable to a Party, any amount by which the Party's emissions of tonnes of carbon equivalent is under its emissions budget for that period may be carried over and added to its emissions budget for the next budget period.
6. [Provision requiring control of greenhouse gases not listed in Annex C.]
7. Any State not listed in Annex A may, in its instrument of ratification, acceptance, approval or accession, or at any time thereafter, notify the Depositary that it intends to be bound by obligations of Annex A Parties. It will then be an Annex A Party. The Depositary shall inform the other signatories and Parties of any such notification.

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8. Any State not listed in Annex A may, in its instrument of ratification, acceptance, approval, or accession, or at any time thereafter, notify the Depositary that it intends to be bound by obligations of Annex B Parties. It will then be an Annex B Party. The Depositary shall inform the other signatories and Parties of any such notification.

Article 3
Measurement and Reporting

1. Each Annex A and Annex B Party shall have in place by [the first year of its first budget period] a national system for the accurate measurement of anthropogenic emissions by sources, and removals by sinks, of greenhouse gases.
2. For the purposes of implementing paragraph 1 and promoting comparability, consistency, and transparency, the Parties shall, not later than their second Meeting, decide on minimum standards for the measurement of anthropogenic emissions by sources, and removals by sinks, of greenhouse gases.
3. Each Annex A and Annex B Party shall put in place, if it has not already done so, national compliance and enforcement programs relevant to its implementation of the obligations under this Protocol.
4. Each Annex A and Annex B Party shall submit to the Secretariat, as part of its communication under Article 12 of the Convention, information on its implementation of this Protocol, including policies and measures it is taking to meet its obligations in Article 2. Such submission shall be in accordance with guidelines which the Parties adopt at their first Meeting, taking into account any relevant guidelines adopted by the Parties to the Convention. Such submission shall also contain the following information:
 - (a) once the obligation in paragraph 1 above becomes effective, a description of the national measurement system that it has in place;
 - (b) once the obligation in paragraph 1 above becomes effective, the results of its national measurement system;
 - (c) a quantitative projection of its net anthropogenic emissions of greenhouse gases through the budget periods; and

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- (d) a description of relevant national compliance and enforcement programs it has in place pursuant to paragraph 3 above, as well as a description of their effectiveness, including actions taken in cases of non-compliance with national law.
5. In addition to the information required to be submitted under paragraph 4, each Annex A and Annex B Party shall submit to the Secretariat, on an annual basis and in accordance with the guidelines referred to in paragraph 4, its current calculation corresponding to each of the subparagraphs in Article 2.2 and its remaining emissions budget for that budget period. With respect to any tonnes of carbon equivalent emissions allowed that are acquired or transferred under Articles 6 or 7, the Party shall specify the quantity, Party of origin or destination, and the relevant budget period.
 6. The first of the submissions referred to in paragraph 5 shall be part of a Party's first communication that is due after the Protocol has been in force for that Party for two years. The frequency of subsequent submissions shall be determined by the Parties.
 7. Information communicated by Parties under this Article shall be transmitted by the secretariat as soon as possible to the Parties and to any subsidiary bodies concerned.
 8. Without prejudice to the ability of any Party to make public its communication at any time, the secretariat shall make information communicated by Parties under this Article publicly available at the time it is submitted to the Parties.

Article 4
Review and Compliance Process

1. In addition to the review of communications conducted under Article 10.2(b) of the Convention, the Meeting of the Parties shall consider the information submitted by Annex A and Annex B Parties under Article 3 in order to assess those Parties' implementation of their obligations.
2. Reviews will be conducted by expert review teams, which will be coordinated by the secretariat and composed of experts selected from those nominated by Parties and, as appropriate, by intergovernmental organizations.

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3. Reviews will be in accordance with guidelines to be adopted by the Meeting of the Parties. These guidelines shall, inter alia, provide for how information will be made available to the public and define mechanisms by which observers and the public may provide comments, supplemental data or other information to facilitate and improve reviews. The guidelines shall be periodically reviewed by the Parties for appropriate revision.
4. Review teams will review all aspects of a Party's implementation of this Protocol, including the likelihood that a Party will achieve its emissions budgets obligations. They will prepare a report assessing a Party's implementation of its obligations, identifying any areas of apparent non-compliance, as well as potential problems in achieving obligations. Reports will be provided to a Meeting of the Parties.
5. Based on such reports, a Meeting of the Parties may make recommendations to a Party. In such case, the Party shall review its implementation, take appropriate action, and report back to the next Meeting of the Parties on its action.
6. There would also be provisions setting forth various consequences for non-compliance with obligations, as determined by a Meeting of the Parties. Consequences would correspond to the type, degree, and frequency of non-compliance. Some would be automatic, while others might be discretionary. Examples of consequences could include, e.g.:
 - (a) denial of the opportunity to sell tonnes of carbon equivalent emissions allowed through international emissions trading and/or joint implementation;
 - (b) loss of voting rights and/or other opportunities to participate in processes under the Protocol.

Article 5
Advancement of the Implementation of
Article 4.1 of the Convention

Recognizing the progress that has been made to date in implementing commitments under Article 4.1 of the Convention:

1. The Parties reaffirm their commitments under Article 4.1 of the Convention and the need to continue to advance the implementation of such commitments.

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2. Each Party shall strengthen its legal and institutional framework to advance the implementation of its commitments under Article 4.1 of the Convention.
3. Each Party shall take measures to facilitate investment in climate-friendly technologies.
4. Each Party shall report, as part of its communication under the Convention, on how it is promoting public education and participation in the development of climate change policy.
5. Each Party that is neither in Annex A nor Annex B shall identify and implement "no-regrets" measures for mitigating net anthropogenic emissions of greenhouse gases, including any identified through the review process under paragraph 7 below. In this regard, each such Party shall also:
 - (a) quantify the effects of the measures it implements;
 - (b) evaluate barriers to the adoption of potential measures; and
 - (c) report to the Secretariat, as part of its communication under the Convention, on the measures it has implemented, plans to implement, and barriers to the adoption of potential measures.
6. Each Party that is neither in Annex A nor Annex B shall submit to the Secretariat, on an annual basis, its inventory of greenhouse gas emissions. Such inventory shall be consistent with any guidelines adopted by the Parties.
7. The Parties shall establish a process for reviewing communications received under the Convention from the Parties identified in paragraphs 5 and 6. The process shall be designed to:
 - (a) enable the review of the effects of individual measures described in paragraph 5;
 - (b) assist such Parties in identifying and implementing "no-regrets" measures for mitigating net anthropogenic emissions of greenhouse gases;
 - (c) seek to identify key sectors and technological options within them;

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- (d) consider possibilities for promoting voluntary arrangements with industry aimed at identifying and encouraging implementation of "no regrets" measures; and
- (e) explore various means through which such Parties could obtain both the know-how and the technology needed to implement options identified.

Article 6
International Emissions Trading

1. An Annex A or Annex B Party that is in compliance with its obligations under Article 3 (Measurement and Reporting) and that has in place a national mechanism for certification and verification of trades, may transfer to, or receive from, any Annex A or Annex B Party, any of its tonnes of carbon equivalent emissions allowed for a budget period, for the purpose of meeting its obligations under Article 2.
2. A Party may authorize any domestic entity (e.g., government agencies, private firms, non-governmental organizations, individuals) to participate in actions leading to transfer and receipt under paragraph 1 of tonnes of carbon equivalent emissions allowed.
3. A Meeting of the Parties may further elaborate guidelines to facilitate the reporting of emissions trading information.

Article 7
Joint Implementation

1. Any Party that is neither in Annex A nor B may generate tonnes of carbon equivalent emissions allowed through projects that meet the criteria set forth in paragraph 2.
2. In addition to any criteria adopted by the Parties to this Protocol, the following criteria shall apply to projects:
 - (a) Projects must be compatible with and supportive of national environment and development priorities and strategies, as well as contribute to cost-effectiveness in achieving global benefits;
 - (b) Projects must provide a reduction in emissions that is additional to any that would otherwise occur.

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3. [Additional provisions to be added on calculation, measurement, monitoring, verification, review, reporting]
4. Any Party that generates tonnes of carbon equivalent emissions allowed consistent with this Article may:
 - (a) hold such tonnes of carbon equivalent emissions allowed; or
 - (b) transfer any portion thereof to any Party.
5. An Annex A or Annex B Party may acquire tonnes of carbon equivalent emissions allowed under this Article for the purpose of meeting its obligations under Article 2, provided it is in compliance with its obligations under Article 3 (Measurement and Reporting).
6. Any Party that is neither in Annex A nor Annex B that generates or acquires tonnes of carbon equivalent emissions allowed under this Article shall notify the Secretariat annually of the quantity, origin, and destination of such tonnes.

Article 8
Science

The Parties shall periodically review this Protocol, and guidelines established thereunder, in light of evolving scientific knowledge related to climate change.

Article 9
Progress Toward Long-Term Goal

The Parties shall cooperate in the establishment of a long-term goal with respect to atmospheric concentrations of greenhouse gases.

Article 10
Meetings of the Parties

1. The Parties shall hold meetings at regular intervals. The secretariat shall convene the first meeting of the Parties not later than one year after the date of the entry into force of this Protocol and in conjunction with a meeting of the Conference of the Parties to the Convention.

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2. Subsequent meetings of the Parties shall be held, unless the Parties decide otherwise, in conjunction with meetings of the Conference of the Parties to the Convention. Extraordinary meetings of the Parties shall be held at such other times as may be deemed necessary by a meeting of the Parties, or at the written request of a Party, provided that within six months of such a request being communicated to them by the secretariat, it is supported by at least one third of the Parties.
3. The Parties, at their first meeting, shall:
 - (a) adopt, by consensus, rules of procedure for their meetings;
 - (b) [other].
4. The functions of the meetings of the Parties shall be to:
 - (a) review the implementation of this Protocol, including the information submitted in accordance with Article 3;
 - (b) periodically review the adequacy of this Protocol;
 - (c) [other].
5. The United Nations, its specialized agencies and the International Atomic Energy Agency, as well as any State not party to this Protocol, may be represented at meetings of the Parties as observers. Any body or agency, whether national or international, governmental or non-governmental, qualified in fields relating to climate change which has informed the secretariat of its wish to be represented at a meeting of the Parties as an observer may be admitted unless at least one third of the Parties present object. The admission and participation of observers shall be subject to the rules of procedure adopted by the Parties.

Article 11
Secretariat

1. In accordance with Article 8.2(g) of the Convention, the secretariat of this Protocol shall be the secretariat of the Convention.
2. The functions of the secretariat shall be:
 - (a) ...

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Article 12
Subsidiary Body for Scientific and Technological Advice

1. The Subsidiary Body for Scientific and Technological Advice of the Convention shall serve as the Subsidiary Body for Scientific and Technological Advice of the Protocol.
2. When the Subsidiary Body for Scientific and Technological Advice exercises its functions with regard to matters concerning the Protocol, decisions shall be taken only by those of its members that are, at the same time, Parties to the Protocol.
3. When the Subsidiary Body for Scientific and Technological Advice exercises its functions with regard to matters concerning the Protocol, any member of the bureau of the Subsidiary Body for Scientific and Technological Advice representing a Party to the Convention, but, at the same time, not a Party to the Protocol, shall be substituted by an additional member to be elected by and from the Parties to the Protocol.

Article 13
Subsidiary Body for Implementation

1. The Subsidiary Body for Implementation of the Convention shall serve as the Subsidiary Body for Implementation of the Protocol.
2. When the Subsidiary Body for Implementation exercises its functions with regard to matters concerning the Protocol, decisions shall be taken only by those of its members that are, at the same time, Parties to the Protocol.
3. When the Subsidiary Body for Implementation exercises its functions with regard to matters concerning the Protocol, any member of the bureau of the Subsidiary Body for Implementation representing a Party to the Convention, but, at the same time, not a Party to the Protocol, shall be substituted by an additional member to be elected by and from the Parties to the Protocol.

Article 14
Multilateral Consultative Process

[The Parties, at their first Meeting or as soon as practicable thereafter, shall consider the establishment of a multilateral consultative process to promote effective implementation of the Convention.]

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Article 15
Dispute Settlement

[silence, with the result that Article 14 of the Convention would apply to this Protocol.]

[in addition, mandatory, binding dispute settlement [with specific consequences flowing from a violation] among Annex A and Annex B Parties, as well as against other Parties as appropriate (e.g., host countries under Article 7)]

Note: this process would be without prejudice to the review and compliance process under Article 4

Article 16
Evolution

The Parties shall adopt, by [2005], legally binding provisions so that all Parties have quantitative greenhouse gas emissions obligations and so that there is a mechanism for automatic application of progressive greenhouse gas emissions obligations to Parties, based upon agreed criteria.

Views on Certain Final Clauses

Adoption and Amendments of Annexes

Depending upon what type of material is eventually included in annexes, it may not be appropriate to restrict the content of all annexes to "lists, forms and any other material of a descriptive nature that is of a scientific, technical, procedural or administrative character." For any substantive annex, it may not be appropriate to provide for tacit adoption/amendment.

Signature

This provision should state that only Parties to the Convention may be Parties to the Protocol.

Entry into Force

To ensure effective implementation, as well as to minimize the potential "free rider" problem, this provision may need to stipulate an entry into force trigger that requires ratification by States that account for a particular percentage of global emissions of greenhouse gases.

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Annex A

This Annex would include the same States as those listed in Annex I of the Convention, plus those that join subsequently pursuant to Article 2.

Annex B

This Annex would include those States not listed in Annex A that indicate before adoption of the protocol that they want to be included in this Annex, plus those that join subsequently pursuant to Article 2.

Annex C

This Annex would list greenhouse gases not covered by the Montreal Protocol, with the exception of gases, or particular sources and sinks, for which there is insufficient knowledge of the GWP or inability to accurately measure emissions or removals. GWPs would be those developed by the IPCC.

BORROWING

Currently, the draft text provides no language on "borrowing", although the December paper tabled by the United States at the AGBM session suggested we would be exploring the potential for borrowing as well as banking. While the Assistant Secretary-level discussion agreed that at least in some form the issue of borrowing might be included, no agreement was reached as to the form that a borrowing regime would take -- nor, consequently, for what text should be inserted. Three possibilities for inclusion of borrowing in the text, covering the range of alternatives discussed, are suggested below:

Option 1: Right to Borrow

Allow an Annex A or B Party to borrow from the second budget period to meet its obligations in the first budget period (and from the third period for the second, if there is a third period specified in the Protocol). Borrowing would be limited in amount, and borrowed emissions would be repaid with interest in the subsequent period. Note that reporting and review of borrowed emissions, and the possible development of additional guidelines would already be covered by language in the existing articles. Non-compliance would be affected as follows: a Party would be in non-compliance if it exceeded its allowed borrowing quota; if it borrowed within allowed limits, whether it ultimately complied (i.e., repaid the tonnes) would not be known until the end of the subsequent budget period.

Option 2: Debt Carryover

Restrict borrowing to a "debt carryover" so that it would not be used as a planning device, but only as a safety valve in case budget obligations were not met. Unlike Option 1, a Party exceeding its emissions budget would be in non-compliance. This option could be additional to that described in Option 1 above; there would be a right to borrow up to a certain percentage; beyond that, exceedences would be penalized.

Option 3: Continue to Explore

Insert general language indicating that the United States is still interested in exploring allowing Parties to borrow against future emissions budgets in order to increase their current emissions budgets. Borrowing would require a credible accounting and repayment mechanism, and could entail additional restrictions (e.g., to limit the proportion of emissions reductions postponed). A borrowing regime might also be used to provide funds to assist developing countries (e.g., requiring Parties wishing to borrow to escrow a portion of the funds that might be required to purchase emissions in case of default, and using the funds to provide loan guarantees or grants to developing countries).

TEXTUAL OPTIONS

Right to Borrow

Language to this effect could be inserted in Article 2 as a new paragraph 2(b-bis), and a new paragraph 5 bis:

Article 2(b-bis): "Up to [10 percent] of the tonnes of carbon equivalent emissions allowed under paragraphs 3 or 4 below such as may be borrowed from the subsequent budget period under paragraph 5 bis below."

Article 2(5 bis): "At the end of a budget period applicable to a Party, any amount of tonnes of carbon equivalent emissions allowed that is borrowed from the subsequent budget period shall be subtracted at a rate of [1.2:1] from the subsequent budget period."

Debt Carryover

The notion of treating borrowing as a penalty rather than a right could be inserted into Article 4.6 as follows:

Article 6(a): If an Annex A or Annex B Party exceeds its emissions budget in a particular budget period, it would have an additional emissions obligation (i.e., tonnes not achieved plus additional tonnes) for the following budget period."

Continue to Expore

Text similar to that in the description above would be inserted into Article 2 as paragraph 2(5bis).

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DOS	Alan Larson	75713

January 3rd, 1997

Dear Colleague,

As you may know, representatives of the world's nations will convene in Kyoto in December, 1997 to negotiate an international agreement addressing the threat of global climate change due to greenhouse gas emissions. This presents a significant opportunity for the United States to exercise a leadership role in ensuring our long-term well-being. Conversely, a failure on the part of the U.S. government to put forward a well-reasoned position would be a major environmental, economic, and diplomatic setback.

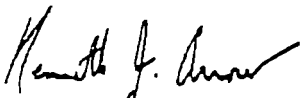
As the climate debate unfolds, it is imperative that public policy be guided by sound economics rather than misleading claims put forward by special interest groups. For this reason, we invite you to join us in endorsing the attached non-partisan consensus statement on the economics of climate change.

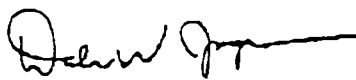
Once this statement has been signed by a large number of economists, it will be widely disseminated to leaders in the public and private sectors, and to the general media. This effort is being coordinated by Redefining Progress, a non-partisan, non-profit public policy organization.

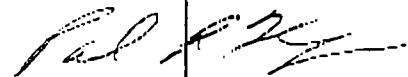
Attached please find an endorsement form for your consideration. This letter and endorsement form are being sent to the membership of the American Economic Association. Please feel free to circulate it to your colleagues in case they are not on the AEA mailing list.

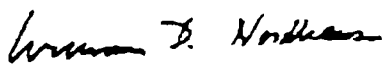
We thank you for your prompt attention to this critical issue.

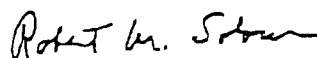
Sincerely,


Kenneth F. Arrow


Dale W. Jorgenson


Paul R. Krugman


William D. Nordhaus


Robert M. Solow

ECONOMISTS' STATEMENT ON

We the undersigned agree that:

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

II. 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.

ENDORSEMENT FORM

NAME _____ SIGNATURE _____

TITLE/AFFILIATION _____ DATE _____

DO YOU HOLD A PHD IN ECONOMICS ☐ YES ☐ NO IF NO, DEGREE _____

ADDRESS _____

CITY _____ STATE _____ ZIP _____

PHONE _____ FAX _____ E-MAIL _____

WOULD YOU LIKE TO RECEIVE MORE INFORMATION ON REDEFINING PROGRESS ☐ YES ☐ NO

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United States Department of State

Assistant Secretary of State for Oceans and
International Environmental and Scientific Affairs

Washington, D.C. 20520

January 2, 1997

TO: Distribution

FROM: Eileen B. Claussen

SUBJECT: Papers for January 7 Climate Meeting

Attached please find copies of the papers on international trading and borrowing as promised in my December 20 memo. As noted, we will discuss these, as well as the draft text, at our meeting on January 7, 1997.

Attachments:
As Stated

cc: *AW*
TF
KP
MM

AM
Fax
315 6447

Domestic Policy Thurs.

mtg.
Fri 10:00 Commerce Dep.
72 4830

Predecisional Document

DRAFT

January 2, 1987

PROPOSAL FOR AN INTERNATIONAL GREENHOUSE GAS TRADING SYSTEM

The Ministerial Declaration in Geneva at the Second Conference of the Parties to the Framework Convention on Climate Change (FCCC) called for quantified, legally binding objectives within specified timeframes. In December 1996, the U.S. circulated a non-paper that outlines its ideas on implementing the Geneva Declaration. This proposal includes a multi-year medium-term emissions target; inclusion of all greenhouse gases (GHGs) and sinks; development of a system for international trading of emissions allowances and joint implementation credits; and consideration of emissions saving and borrowing. In this paper a multi-year emissions target is referred to as a budget.

Building on the December 1996 proposal, this paper will describe how an international GHG emission trading system might be established and implemented. A complementary domestic regime would have to be developed. While the proposed trading system is designed to use existing institutions and processes as much as possible, and to provide participants with flexibility in implementation, it also includes additional reporting and compliance mechanisms as appropriate.

The proposed international GHG trading system described below is designed to address the following key questions necessary for such a system to be successful:

- How are the tradable units defined?
- Who are the participants in the trading system?
- How are units traded?
- How is trading activity reported?
- What compliance mechanisms are available?

Background Assumptions

In order to adequately characterize the proposed trading system, it is assumed that:

Form of the target(s). Legally binding budgets would apply only to Annex I countries that become Parties to the agreement currently being negotiated by the Ad-Hoc Group on the Berlin Mandate (The Agreement). The budgets would cover a period of 3-10 years, would be expressed in terms of net GHG emissions (all sources

Predecisional Document

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January 2, 1997

and sinks), and would be derived by applying a uniform limit or reduction percentage to each country's emissions in a base year or years, e.g., 1990 or 1987-1993. Parties maintain reviews of climate and environmental sciences, technology development and availability, economic impacts of budgetary compliance, and other relevant information through the FCCC Secretariat and IPCC. Based on these reviews, and to provide predictability of future obligations, the budget for subsequent periods would be established well before -- e.g., no later than four or five years -- its beginning.

Reporting and compliance provisions. Among the legal instruments agreed to would be reporting, measurement, verification and compliance provisions that address net GHG emissions for all Parties to the Agreement, and which would provide the fundamental informational basis for the international trading system. The current requirement for reporting annual inventories would incorporate reporting on trading activity.

Joint implementation. The current joint implementation (JI) pilot program, Activities Implemented Jointly, would end in 2000. A JI regime providing for emissions credits, granted by an international project reviewing body, would be established in the Agreement.

Elements of the International GHG Trading System

Within the context outlined above, the Agreement would establish an international GHG trading system. Parties with budgets could engage in international emissions trading as full or partial fulfillment of that obligation. Key elements of the proposed GHG trading system are described below:

Tradable Units. The tradable unit would be known as a "unit of carbon equivalent" (UCE). Certificates for UCEs would represent a metric ton of carbon equivalent, based on 100-year global warming potential, and would be identified by country-of-origin, year of issuance, and a serial number. This tonne could be associated with either a source or a sink of any greenhouse gas (other than water vapor). UCEs would be used to meet current budgets, held for future use, or traded. Joint implementation (JI) credits would be treated within the trading system as equivalent to UCEs on a tonne-for-tonne basis, and the partners in JI projects would decide among themselves as to sharing of UCEs associated with each project.

UCE Budgets. The number of UCEs initially available to each Party is equivalent to the budget of net GHG emissions established for each Party to cover the multi-year period. For example, assuming a budget based on the 1990 level for a 3 to 10

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1 year period, the U.S. would be allocated approximately 4500 million UCEs (3 times
2 1500 MMT for 3 years) to 15,000 million UCEs (10 times 1500 MMT for 10 years),
3 respectively. Procedures and guidelines for participation of non-Annex 1 parties
4 will be developed.

5
6 Each Party would choose its own mechanisms for meeting its national emissions
7 budget (e.g., policies and measures, taxes, national allowances/credit trading
8 systems applied to specific sectors, technology standards, etc.). For example:

- 9 ~~A nationwide tradable permits~~
- 10 1. Parties could adopt national allowance trading systems that would issue to
11 covered sources UCEs authorizing sources to emit greenhouse gases in amounts
12 equal to the number of UCEs they held; or,
13
 - 14 2. Parties could adopt other policies and measures through which domestic entities
15 could earn UCEs whenever their emissions reductions exceeded the reduction
16 required by, or expected from, them. However, hybrid approaches that combine
17 either allowance-based systems or policies and measures systems must provide
18 appropriate accounting between systems and sectors.
19

20 Irrespective of the policy framework chosen for its implementation of national
21 obligations, all Parties must provide annual reports. All international transactions
22 (i.e., sales and purchases of UCEs) must be registered domestically, i.e., accounted
23 for, or debited from national budgets, in order to be legally recognized and binding
24 upon the exporting Party. Similarly, sources could obtain UCEs from foreign
25 Parties provided that the transaction was duly registered by the exporting Party.
26

27 Trading of UCEs. The Parties would jointly establish guidelines to ensure that the
28 transaction process is sufficiently transparent. UCEs would be traded in much the
29 same way that commodities and financial instruments are currently traded.
30 Private exchanges and financial intermediaries would be expected to buy and sell
31 UCEs.
32

33 The market would provide information to potential buyers and sellers as to the
34 availability and cost of UCEs. Parties and domestic entities would consider
35 purchasing UCEs if their cost was less than the cost per tonne of alternative
36 policies and measures. Speculators might purchase UCEs in anticipation of a
37 possible rise in their value. Markets for trading in "UCE futures", contracts by
38 Parties or domestic entities to deliver UCEs in a future year, might also develop.
39 However, those future UCEs could not be used for compliance prior to that future
40 year.
41

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1 No new international organization would need to be created but domestic
2 regulatory authorities would be responsible for ensuring adequate internal
3 measurement and verification, accounting, reporting and compliance disciplines, at
4 a minimum consistent with provisions established under the Convention and its
5 protocols.

6
7 Reporting of UCE transactions. The FCCC requires that all Parties periodically
8 report information, including an annual inventory of net GHG emissions, necessary
9 for demonstrating progress toward the Convention's objectives. National
10 Communications, Compilation and Synthesis reports, and In-Depth Reviews would
11 now incorporate information regarding trading activity.

12
13 While existing FCCC provisions provide an adequate basis for determining the
14 tonnages to be associated with both individual policies and measures, and their
15 associated aggregate emissions reduction effects, the Parties would also agree
16 jointly to develop a standard annual reporting form, and require each Party to
17 provide a full accounting of UCEs held, borrowed, traded, and created through JI.
18 Parties would save UCEs not needed for meeting budgets, then use them or trade
19 them in the future. All reports would be publicly available.

20
21 Annually, Parties will identify UCEs to be retired sufficient to cover net GHG
22 emissions for that year. These UCEs could be from their own allocation, or UCEs
23 purchased, saved, and/or created through JI projects. Each year's emissions would
24 result in a subtraction of UCEs from the balance of the total budget. Therefore, in
25 each annual report, the Party would identify the serial numbers of UCEs retired, in
26 order to demonstrate compliance with budgets, as well as the remaining balance of
27 UCEs. At the point that a Party fails to have sufficient UCEs to cover its annual
28 emissions, the compliance mechanisms discussed below take effect.

29
30 Constituent elements of annual budgets must be detailed enough to provide
31 confidence in each Party's reporting of overall performance. Reliable measurement
32 and reporting of emissions will be critical to a successful GHG trading program,
33 with quality emissions data at the source-specific level, for all sources and gases,
34 being the "gold standard" that allows a Party to define credibly the quantity being
35 traded.

36
37 Since each Party would be ultimately be responsible for the actions of their MS
38 respective domestic entities to the extent that such actions have an impact on the
39 Party meeting its budgets, Parties would also agree to each require their domestic
40 entities to assume appropriate reporting responsibilities.

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1 Compliance. The trading system is designed to foster and facilitate compliance
2 with Parties' emissions budgets. Compliance mechanisms would include rules
3 governing purchases of UCEs, devaluation of UCE tonnages to reflect the degree of
4 non-compliance, fines, and/or trading restrictions (a party would not permitted to
5 sell UCEs until corrective measures are taken). Rules governing the purchases of
6 UCEs could be developed to ensure that limited overages in one period could be
7 debited from the next. To indemnify promised emissions reductions, parties might
8 also be also be required to put up a bond before trading UCEs.

9
10 As in the case of reporting, Parties would agree to establish a compliance regime for
11 their domestic entities since each Party would be ultimately responsible for the
12 actions of ~~their~~ their respective domestic entities to the extent that such actions have an
13 impact on a Party meeting its budgets.
14
15

ITS

Borrowing Against Future Targets: An Option Paper
(rev 1/2/97)

In defining the form of the target for next steps under the FCCC, the United States in its December "non-paper" urged consideration of both banking and borrowing. The former may require additional consideration of specific mechanisms for accounting, but it has so far met with little resistance. The concept of borrowing, on the other hand, has been harshly criticized, and will need to be significantly and persuasively elaborated in order to meet with general approval, and to be considered for incorporation into agreements on next steps under the Convention. This paper seeks to provide a brief explanation of how a borrowing regime might work, and to discuss the possible advantages and disadvantages of implementing such a regime in the agreement.

Borrowing Defined

The concept of borrowing is familiar to all who are involved in any financial transactions -- it involves taking a loan against future earnings in order to pay current obligations. In the case of the climate, current obligations would equate to current levels of allowable emissions (or emissions in a given target year); future earnings would equate to emissions reduced above and beyond the target set for a future year.

Also in a manner similar to financial transactions, costs could be associated with emissions borrowing. These include risks of the borrower defaulting on the loan; opportunity costs to the lender of not making a more profitable investment elsewhere; and institutional problems associated with the transaction. Unlike most financial transactions, however, some additional risks may be associated with an emissions borrowing regime, including impacts to the environment from delayed reductions.

Notwithstanding the differences between financial borrowing and emissions borrowing, some of the solutions applied in the financial arena seem applicable in both cases. For example:

- A high risk loan is often accompanied by a higher interest rate to the borrower; the analogous situation could call for the borrower to pay more in the way of future reductions for any emissions used in the current period.
 - Financial transactions are also often accompanied by requirements that the borrower put up collateral; in the case of emissions borrowing, a bond might be posted to ensure that funds would be available to "buy" emissions should the borrower default on the loan, or another entity might guarantee the shortfall.
- Y. L. 4842
S. 3*

Borrowing D R A F T (1/2/97)

P 2

- Financial transactions are also often limited in terms of the amount that can be borrowed -- either as a fixed total, or as a percentage of future earnings; emissions borrowing might have a similar limit (for example, a country or firm might be prohibited from borrowing more than 10 percent of its total emission reduction obligation).
- Finally, defaulting borrowers are usually assessed a penalty; a similar penalty might be applied toward a defaulting emissions borrower -- either in the form of a monetized fine, or in the form of an additional reduction obligation.

Advantages and Drawbacks

A financial world without borrowing would be difficult to imagine. It is rare that a firm has internal capital resources adequate to fully finance its future growth. Similarly, responding to any significant climate change mitigation strategy without a parallel option for borrowing can also be expected to impose considerable economic constraints on the system: it clearly reduces flexibility in terms of planning; and it may require the premature retirement of capital stock in order to meet strict deadlines.

However, the climate system and mitigation responses are not fully analogous to financial markets. Political considerations, cost to the environment of inaction, and the lack of an established institution infrastructure all make the prospect of borrowing more complex when emissions are considered.

Political Considerations: A number of contentious issues surround the climate change debate, including the level of the target, emissions trading and JI, and involving developing countries. Adding another complex issue to the already volatile mix may generate unwanted controversy. Political support for a borrowing regime may also be limited.

Currently, while the business community could be expected to favor a borrowing provision, most would not likely support a target WITH such a provision any more than a target without borrowing -- even though it will be the target, not the borrowing provision that will raise ire. However, some "groups" (e.g., EEI) have already indicated their interest in such a provision, and may provide some limited support.

Borrowing D R A F T (1/2/97)

P 3

The NGO community overall can be expected to object to the delay in action, and accuse proponents of a borrowing regime of seeking to derail the process. Many have already argued against emissions trading on the grounds that it will reduce the incentive for immediate domestic reductions and that it spreads the obligation to Parties with no commitments (e.g., developing countries); a borrowing regime would likely be more objectionable. However, it should be noted that EDF, a proponent of trading, also supports the notion of borrowing.

Finally, the broad international community can also be anticipated to be unsympathetic. Developing countries will see this as another attempt by Annex I Parties to renege on their commitments, and other OECD countries, particularly the EU, have already expressed skepticism. Support may come from JUSCANZ, particularly Australia and New Zealand, and possibly Canada. If a borrowing regime is to be included in the U.S. program, it will be critical to develop a strategy for overcoming some of this international opposition.

Environmental Impacts: It would be difficult if not impossible to determine the precise environmental/climate impacts of any specific delay in emissions reductions. However, it is clear that the relatively small levels of reductions being contemplated (e.g., even a 20% reduction below 1990 levels by Annex I Parties) will have only a minimal impact on long-term climate change. Delaying some subset of these reductions would thus likely be of marginal additional consequence, if the effects of such a delay were even detectable. Conversely, a possible advantage of a borrowing regime is that the target itself might be set higher -- ultimately providing an added environmental benefit rather than reducing the effectiveness of the existing benefit. There is perhaps more evidence to support the claim that any delay will reduce the incentive to develop new technologies to combat climate change; however, this must be balanced against the desire to maximize flexibility and minimize the costs of taking action.

Institutional Infrastructure: There are several components to this issue. First, unlike in the model of a financial system, it is not clear how the lending process would be structured; currently no banks, venture capital or government loan agencies exist to institute an international borrowing regime. Secondly, the analogy of "future earnings" against which borrowing occurs may not apply -- at this time most proposals (including the current version of the U.S. draft protocol) for the new legal instrument include only a single target, not multiple targets for multiple periods. Finally, there is no legal infrastructure which might facilitate compliance. For standard financial procedures, a well established judicial and criminal system operates to insure appropriate practice, at

Borrowing D R A F T (1/2/97)

P 4

both the national and interantional levels. Creating such a structure in the climate context might prove difficult.

Possible Solutions

Some solutions to these barriers do exist. The current convention (and likely subsequent agreements) place the obligation to reduce on governments. Inasmuch as governments seek to comply, they will also need to create internal processes to determine the level of emissions reductions needed -- and could in the process establish accounting procedures to assess borrowing. It is also unlikely that the first target set would be adequate to fully address the climate problem; in this case, subsequent targets are almost certain -- and could even be made explicit in the agreement (e.g., a Kyoto Mandate on the agreement to agree). In a similar manner, while no legal structure may exist to insure compliance, this is a problem with the all aspects of legally binding next steps -- and the resolution to this problem in the instrument could be applied to any borrowing regime.

Options for the Future

In light of these issues, the following options might be considered with respect to a borrowing regime::

- Do not allow borrowing;
- Do not allow borrowing at this time, but leave open the option for including a borrowing regime in the next phase;
- Allow restricted borrowing by:
 - (a) limiting the amount that can be borrowed;
 - (b) discounting the borrowed reductions (e.g., so that a ton borrowed must be paid back with more than one ton of reductions);
 - (c) limiting the countries that can borrow;
 - (d) allowing borrowing only up to the amount that has been "banked" by another country;
- Allow unrestricted borrowing.

It is clear that for any choice except the first, considerably more work would be required to operationalize the concept. A task force would need to be created and a draft proposal would need to be tabled (probably by the March 1997 AGBM) in order to have any chance of a successful outcome.

Borrowing D R A F T (1/2/97) P 5

Linkages and Tactics

The linkage between the borrowing and the trading concepts might also be appropriately considered in making any decision on this matter. We have already determined that including the flexibility provided by trading will be a high priority for inclusion in the agreement. However, our assumption is that trading WILL draw in trading partners -- and absent information on the price and transaction costs of a trading system, we cannot be certain this will indeed occur. Conversely, a borrowing regime could be implemented unilaterally, and would provides flexibility even in the absence of a trading regime.

It should also be noted that including a proposal for a borrowing regime may be desirable for tactical reasons. We may choose to include the concept in our text, and be prepared to give it up in exchange for something we want more later in the process.

SEEGC 9960

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