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001. email	David Wilcox to Janet L. Yellen at 06:44:49.00. Subject: Doug Elmendorf. (2 pages)	02/05/1998	b(6)

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CREATOR: Janet L. Yellen (CN=Janet L. Yellen/OU=CEA/O=EOP [CEA])

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SUBJECT: Revised draft incorporating Joe's conclusion and my revision of Jeff's draft 9

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===== ATTACHMENT 1 =====

ATT CREATION TIME/DATE: 0 00:00:00.00

TEXT:

Unable to convert ARMS_EXT:[ATTACH.D92]MAIL46188553N.026 to ASCII,
The following is a HEX DUMP:

**TESTIMONY OF DR. JANET YELLEN
CHAIR, COUNCIL OF ECONOMIC ADVISERS
BEFORE THE SENATE FOREIGN RELATIONS COMMITTEE
ON THE ECONOMICS OF THE KYOTO AGREEMENT
FEBRUARY 11, 1998**

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

The international agreement that was reached in Kyoto this past December is a crucial first step in addressing global climate change. But it is only a first step. Since the international effort to reduce greenhouse gas emissions is more of a work-in-progress than a completely finished product, it is not yet possible to provide a full authoritative analysis of it. Many of the specifics in several crucial areas are not completely resolved in the diplomatic arena, forcing analysts to make a variety of assumptions about the ultimate form of the international regime. In my testimony today, I will attempt to identify key elements of the agreement, such as global participation and reliance on flexible, market-based measures, that ensure that reductions in global greenhouse gas emissions are consistent with continued strong economic growth. I will do my best also to provide some rough estimates of costs and benefits.

The Administration is strongly committed to ensuring that these critical elements are reflected in our domestic and international climate change policies. We are firmly committed to meaningful developing country participation, as well as emissions trading both domestically and internationally. And as you know, the President's FY 1999 budget includes a \$6.3 billion package of tax cuts and R&D over the next 5 years to jumpstart our efforts.

I. Basic Economic Rationale of the Kyoto Treaty

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

The earth's surface is warming from the accumulation of greenhouse gases from myriad sources worldwide. None of these emitters presently pays the cost to others of warming's adverse effects -- a classic externality in the language of economists. As a result of these distorted incentives, disruption of the Earth's climate is likely to proceed at an excessive pace and if left uncontrolled may pose substantial costs in terms of disruption to commerce and the environment alike. The fundamental economic logic of the Kyoto agreement is thus that

without such an international agreement, individual nations will not have the proper incentives to address the threats from global climate change.

II. Costs of Climate Change

In evaluating efforts to mitigate global warming, the first step is to consider the costs that are likely if we fail to take any action -- for these costs provide the primary motivation for reducing greenhouse gas emissions. What, then, are the costs associated with allowing global climate change?

The Intergovernmental Panel on Climate Change (IPCC) jointly established by the World Meteorological Organization and the United Nations Environment Programme, concluded in 1995 that "the balance of evidence suggests that there is a discernible human influence on global climate." Current concentrations of carbon dioxide, methane, nitrous oxide, and the other so-called greenhouse gases have reached levels well above those of preindustrial times. Of these, carbon dioxide (CO₂) is the most important: net cumulative CO₂ emissions resulting from the burning of fossil fuels and deforestation account for about two-thirds of potential warming from changes in greenhouse gas concentrations related to human activity.

Climatic Impact

If growth in global emissions continues unabated, the atmospheric concentration of CO₂ will likely double relative to its preindustrial level by midway through the next century. As a result of the increased concentration of CO₂, the IPCC estimates that global temperatures will increase by between 2.5 to 6 degrees Fahrenheit in the next 100 years, with a best guess of about 3.5 degrees Fahrenheit. While scientists believe that human activities are leading to a gradual warming of the *average* temperature of the earth, the change in temperature in a given region at a given time may differ substantially from this average. Indeed, models predict warming will be greater in high latitudes than in the tropics, and greater over land than ocean. Many models predict larger increases in evaporation than in precipitation over midlatitude land areas, which would result in drier conditions in those regions, especially during summer in North America and Europe.

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

Economic and Monetary Damages

The derivation of quantitative or monetary estimates of the damages from such climate changes is extremely difficult given the capacity of today's forecasting models. Estimates of the economic damages from climate change fall into the following broad areas: agriculture, sea-level rise, air conditioning and heating, water supply, human life and health, air pollution, and other costs (hurricanes, migration costs, human amenity, construction, leisure activities, urban infrastructure, and ecological damages such as forest loss and species loss).

A subject of great uncertainty and sensitivity is the "discount rate" that is applied to the benefits of averting future climate change. Such a discount rate is needed if the analysis is to be expressed in monetary terms, because a dollar today is not worth the same as a dollar tomorrow. And since the benefits of stemming future climate change accrue over not only decades but centuries, small changes in the discount rate can produce substantial changes in the results. But the precise discount rate that should be used to evaluate questions as important as the future climate of the planet remains a subject of intense debate. It is safe to say that there is, as of yet, no professional consensus on the issue.

A similar point concerns risk aversion. To what extent are we willing to take chances with our planet? The point applies particularly to catastrophe scenarios. Scientists have thought of many possible scenarios, most of which they are fortunately not yet prepared to pronounce as particularly likely based on current evidence, but which might be truly catastrophic for the planet if they were to occur. There is a strong argument for the Kyoto agreement as a form of planet insurance. But what numerical weight should one assign to these catastrophic risks? In other words, what is the value of the insurance policy? It is difficult for an economist, or anyone, to know.

Despite these shortcomings and potential problems, respected researchers have developed estimates of the monetary damages expected from an average worldwide temperature increase of approximately 4.5 degrees Fahrenheit (corresponding to, roughly, a doubling of pre-industrial carbon dioxide concentrations). For example, William Cline, then a Senior Fellow at the Institute for International Economics, estimated that such a temperature change would impose annual damages of more than \$70 billion per year on the U.S. economy in today's terms. These damages include \$22 billion in lost agricultural production, \$13 billion in additional electricity costs, and \$8 billion in new costs to maintain the existing supply of fresh water. (Cline's original estimates are quoted in 1990 dollars. The figures given above translated those numbers into 1997 dollars using the annual GDP price index.) William Nordhaus of Yale University has likewise computed estimates of the dollar loss attributable to a doubling of carbon dioxide concentrations. He finds that the Cline estimate is in the center of three estimates for the U.S., and that the high estimate is only 1.3 times greater than the low estimate.

It must be noted, however, that this similarity of aggregate estimates masks the true uncertainty associated with forecasts of the damages from given increases in global warming --

the estimates are all fundamentally based on extrapolations from current and past experience, and may not fully incorporate effects that will unfortunately become apparent only with future experience. In particular, the estimates may not fully reflect potential non-linearities in the relationships between carbon dioxide concentrations and temperature, between temperature and economic damages, or in the various other complicated relationships governing interactions between greenhouse gas emissions, the climate, and the economy. Current quantitative analyses do not, and cannot, accurately reflect the small and unknown possibility of large-scale and potentially irreversible discrete events with potentially catastrophic consequences.

Two such possibilities serve as illustrations. Warming of Northern tundra may release very large amounts of methane from the subarctic permafrost, thereby leading to potentially devastating acceleration of an otherwise controllable global warming process. We do not know at what point, if any, such unstable activity would be triggered. Second, evidence from climate models suggests that some types of climate change may lead to displacement of the Gulf Stream that warms Western Europe. Evidence from ocean core samples suggests that such reversals of ocean currents have occurred in previous ice ages. Reductions in the risk of such catastrophic outcomes must be considered in addition to the costs and benefits that can be reasonably quantifiable. Since human beings are typically averse to risk, such possibilities are especially important in evaluating whether the benefits of a particular climate control policy justify the costs. One must have at least some sympathy with those who criticize economists on the grounds that the effects of climate change are extremely difficult to quantify in a single monetary number.

III. Addressing Global Climate Change in an Efficient Manner

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

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

Need for Global Action

Climate change is a global problem requiring a global solution. As I mentioned earlier, no single country has an incentive to reduce emissions sufficiently to protect the global environment against climate change. Each has an economic incentive to “free ride” on the efforts of others. Even if the United States sharply reduced its emissions unilaterally, greenhouse gas emissions from all other countries would continue to grow, and the risks posed by climate change would not be significantly abated. It is important to emphasize that emissions of different gases anywhere in the world have very similar effects on global climate.

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

To address the lack of progress among many industrialized countries toward meeting the Rio objective, the United States and approximately 160 other nations agreed in negotiations held in Kyoto, Japan, last December, to take substantial steps to stabilize atmospheric concentrations of greenhouse gases. The Kyoto Agreement, which requires the advice and consent of the Senate, would place binding limits on industrial countries' emissions of the six principal categories of greenhouse gases: CO₂, N₂O, methane, sulfur hexafluoride, perfluorocarbons, and hydrofluorocarbons. **These limits apply to the 38 so-called Annex I countries, which are the industrialized countries, defined to include Russia, Ukraine, and most Eastern European countries.**

Under the Kyoto agreement, each industrial country's “1990 baseline” is actually based on its 1990 emissions of CO₂, methane, and N₂O and its choice of 1990 or 1995 levels of the other three categories of gases. The United States agreed to a target of 7 percent below 1990 levels by the period between 2008 and 2012. To meet that target, net U.S. emissions of greenhouse gases -- all emissions minus removals of CO₂ by certain forestry-related activities -- must average no more than 1,484 million metric tons of carbon equivalent per year during that period. The targets for the European Union and Japan are 8 percent and 6 percent below 1990 levels, respectively. Australia, New Zealand, Norway, Russia and Ukraine all have limits somewhat less ambitious when phrased as cuts relative to

their 1990 levels. In sum, over the period from 2008 to 2012, the industrial countries are expected to reduce their average emissions of greenhouse gases to about 5 percent below their 1990 levels.

The President has made clear that his support of the Kyoto Agreement is dependent on meaningful participation from key developing countries (who are not included in Annex I). The President has also made clear that he will not submit the treaty to the Senate without such participation.

There are several reasons why meaningful participation from developing countries is essential. First, developing countries are projected to contribute a majority of total emissions by 2030 under a continuation of business-as-usual. Without the participation of developing economies, emissions reductions by the industrialized countries will therefore not achieve necessary protection from climate change. Indeed, if developing countries do not participate in the international regime, their emissions could potentially increase by *more* than under their business-as-usual baselines. One mechanism for such an unintended consequence is as follows.

As Annex I countries comply with their targets, their demand for oil will fall, which will probably work to reduce the price of oil on world markets, and perhaps to encourage non-participating countries to use more oil and emit more carbon than they otherwise would have.

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

Third, principles of basic fairness suggest all countries should do their part, depending on their ability to contribute to the solution. Thus even poor countries should contribute, although the existence of more pressing social needs in such countries will inevitably limit the magnitude of their contributions.

So far I have not mentioned the word “competitiveness.” One of the difficulties in analyzing concerns related to competitiveness is that the term itself is used to mean many different things. I have seen at least one study that uses “loss of competitiveness” to refer to predictions of negative effects on the *aggregate* trade balance. As a professional economist, I do not accept the logic upon which that particular argument is predicated: the aggregate trade

balance is determined by macroeconomic forces -- the difference between saving and investment -- and not by our environmental policies.

On the other hand, if competitiveness refers to adverse effects on a few specific manufacturing industries -- those that are especially energy-intensive, such as aluminum, paper, and chemicals -- the situation may be more complicated. It is difficult to undergo a significant structural change in the economy without having the effect of expanding some sectors and contracting others. But to provide some perspective on this issue, consider the following facts. First, on average, energy constitutes only 2.2 percent of total costs to U.S. industry. Second, energy prices already vary significantly across countries. According to the *1997 Statistical Abstract*, for example, in 1996 premium gasoline cost \$1.28 per gallon in the United States -- but only 8 cents in Venezuela. Yet U.S. industry is not moving en masse to Venezuela. Third, roughly two-thirds of all emissions are not in manufacturing at all, but in transportation and buildings. I therefore believe it more accurate to say that we need developing country participation for the reasons I outlined above, than to say that we need it to avoid adverse effects on competitiveness.

Flexibility and Market Mechanisms

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

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

1. "When flexibility" (timing)

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

The Kyoto Protocol incorporates this principle of "when flexibility" in four ways:

- First, the cuts to be made in the first period are less severe, and the first period ends much later, than what had been proposed by many other countries, most notably the Europeans. By adopting a gradual and credible path of reductions in the early years, we can greatly reduce costs such as those from prematurely scrapping coal-fired electricity plants still in the prime of their operating lives, while attaining the same ultimate environmental goals.
- Second, under the Kyoto agreement, the emissions target is not specified in terms of a specific year, but rather in terms of an average over a five-year period (2008-2012). Averaging over five years, instead of requiring countries to meet a specific target each year, can lower costs, especially given an uncertain future. The averaging can smooth out the effects of short-term events such as fluctuations in the business cycle and energy demand, or hard winters and hot summers that would increase energy use and emissions.
- Third, there is allowance for “banking” emission reductions within the 2008-2012 commitment period, for use in a subsequent commitment period [although the emission targets of the next period have not yet been specified].

2. “What flexibility” (gases and sinks)

The second type of flexibility is “what flexibility”, along two dimensions. The first is the inclusion in the agreement of all six greenhouse gases. Emissions of different kinds of gases, not just carbon dioxide, contribute to the greenhouse effect. Since the IPCC has developed conversion factors for all greenhouse gases by estimating their global warming potentials, reductions in emissions of one pollutant can be used to substitute for increases in emissions of another by an amount that has equivalent environmental effects. The Kyoto Protocol stipulates that countries with binding targets are expected to reduce their *total* greenhouse gas emissions by certain percentages, but does not require specific reductions for specific gases. Since a molecule of sulfur hexafluoride is 23,900 times more potent over 100 years than a molecule of CO₂, it may be cheaper to achieve the same environmental benefit by eliminating one molecular unit of SF₆ than nearly 24,000 units of CO₂.

Some initial rough analysis indicates that a strategy of reducing non-CO₂ greenhouse gases by *more* than 7 percent below their 1990/1995 baseline levels while reducing CO₂ by *less* than 7 percent below its 1990 level could reduce greenhouse gas emission permit prices by more than 10 percent. [This analysis is based on the integrated SGM/non-CO₂ cost curve.] Thus allowing countries flexibility in what gases they reduce -- essentially trading emissions reductions across gases -- can help lower significantly the costs of meeting their targets.

The second source of “what flexibility” is the treatment of sinks, i.e., land use activities that promote the removal of carbon from the atmosphere through the growth of plants. Promoting such sinks through afforestation and reforestation may reduce atmospheric

concentrations of CO₂ at much lower costs than reducing emissions of greenhouse gases.

3. "Where flexibility" (international)

The third type of flexibility, and perhaps the most important, is "where flexibility" (international). As I have already emphasized, emissions have the same environmental consequences regardless of where in the world they occur. Therefore, the least-cost approach to controlling climate change is to reduce emissions wherever such reductions are cheapest. The Kyoto agreement includes two important cost-saving provisions of this nature. First, it provides for industrial countries to trade rights to emit greenhouse gases with each other. This market in emissions permits will ensure that emission reductions occur where they are least expensive within the industrial countries. In particular, U.S. companies could purchase emissions reductions in other participating countries when doing so would reduce their costs -- lowering costs without affecting the level of environmental protection.

Second, the agreement allows industrial countries to invest in "clean development" projects in the developing world and use these projects' certified emissions reductions toward meeting their targets. Many such clean-development projects may be quite cheap in terms of the cost per ton of emissions avoided, as has been illustrated by the joint implementation pilot program that is already in place in the U.S. Details of these provisions will be worked out in negotiations in Buenos Aires later this year.

IV. Difficulties of Economic Analysis of Kyoto Agreement

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

The difficulties associated with economic analysis of climate change fall into three broad categories. First is the uncertainties that still remain over the terms of the ultimate treaty. Second is the inherent limitations of available models to analyze even short-term costs and benefits. And finally is a topic I discussed earlier: the impossibility of putting a single monetary number on the long-term benefits of climate change mitigation.

Uncertainties over Certain Provisions in International Effort to Combat Climate Change

The Kyoto Agreement was an historic accomplishment, delineating the broad terms of

the international effort to address climate change. But although we know a lot more than we did before Kyoto about how that international system will work, there is still much that we don't know.

First, as is often the case in a legal document of the length and complexity of the Kyoto Protocol, there are some provisions that require further clarification and interpretation. Of particular concern here is the treatment of so-called sinks -- activities that affect the rate at which carbon is removed from the atmosphere and "sequestered," specifically by the planting of trees.

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

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

Inherent Limitations of Models

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

One area in which the uncertainty is particularly large is the pace of technological progress -- including diffusion of existing energy-efficient technologies, as well as research and development of new technologies -- and the extent to which the pace will accelerate in response to government programs. Economics does not offer a good understanding of how technological progress is determined, in part because it is the stuff of experimentation, brainstorming, genius, breakthroughs, perceptions and habits. Invention is largely determined by inspiration -- notwithstanding Edison, who assigned a 99 percent share to perspiration -- and inspiration, in my

experience, is difficult to fit into mathematical formulae or economic models. Models and experts on climate change policy tend to have a wider range of disagreement on the speed with which technology can be changed and the scope for speeding the diffusion of existing energy-efficient technologies than on any other single issue.

Furthermore, each model has strengths and weaknesses; each has questions to which it is better or worse suited to answer. Some, for example, model the energy sector in detail. Some allow for the fact that a coal-fired power plant cannot costlessly be converted to one that runs on natural gas. Some have enough policy detail to distinguish alternative ways of redistributing revenues that would result if emission permits were to be auctioned. Some are capable of showing short-term macroeconomic disequilibria. Some include a long-term “carbon cycle” model that can keep track of the accumulation of greenhouse gas concentrations in the atmosphere and their climatological effects. Some break down the rest of the world into regions and so can model international trade. No one model does everything, and therefore we must not rely blindly on the results of any one model or set of models. Professional judgement and economic intuition are also crucial.

Benefits of Averting Climate Change

As I discussed above, it is evident that the benefits of averting climate change are potentially immense. But I have chosen not to try to quantify them in monetary terms for you, in light of the difficulties I have enumerated -- including the quantitative uncertainty of these benefits, and their timing and therefore the extreme sensitivity of the results to the chosen discount rate.

Instead, what I will do is draw upon a variety of sources in an attempt to add up the various possible costs and benefits of emissions policy *excluding* climate change. To give away the punch line, my conclusion is as follows: the net costs of our policies to reduce emissions are likely to be small, if those reductions are undertaken in an efficient manner, *even before taking into account the benefits of averting climate change itself*. That small net premium excluding the benefits of mitigating climate change, in effect, purchases a partial insurance policy against a serious environmental threat.

V. Models of the Kyoto Agreement

The existence of modeling difficulties means that the results from any model must be treated with caution. We have therefore employed a broad set of economic tools to assess the Kyoto agreement.-- We have drawn on the insights of a wide range of models of the energy sector and economy over the next 25 years, including but not limited to the results of the Stanford Energy Modeling Forum exercises, the IPCC’s review of the economic and social dimensions of climate change, and the staff-level Interagency Analytical Team effort last year. Other tools include simple relevant statistics, “meta-analyses” of existing models, historical and

sectoral examples, and basic economic reasoning. Drawing on this broad array of analytical tools is crucial to an intelligent evaluation of the policy alternatives.

To my knowledge, as of December, no model -- whether used inside the government or not -- had been set up precisely to analyze the parameters of the agreement that was reached in Kyoto. Most model-builders outside the government tend to take as long as several years to incorporate changes in policy parameters into their models. And no model is currently designed to assess sinks, or all six greenhouse gases included in the treaty.

One of the leading models in the field is the Second Generation Model of Battelle Laboratories. The SGM is one of the models best positioned to analyze the role of international trade in emission permits, which we consider to be a critical element of the Kyoto Treaty. However, the SGM does not cover all six gases included in the Kyoto agreement or include a role for sinks. We have used the SGM model as a starting point for a preliminary assessment of the Kyoto treaty, but have attempted to supplement its results with additional analysis to account for such special features of the agreement as the inclusion of six gases, sinks and a possible Annex I trading that could exclude the EU. I will share with you today some preliminary results of this analysis.

Mindful of the limitations of any single model, we are eager to see features of the Kyoto agreement assessed by other models to obtain a better feel for the range of possible effects. Much of this work will continue to go on outside the government. For example, we have had discussions with the Energy Modeling Forum, based at Stanford University. The EMF is a long-running exercise involving many of the leading climate models. We have given the EMF advice on how features of the Kyoto legal language can be translated into terms recognizable to an economist. Unfortunately, the Energy Modeling Forum believes that its members will need at least until mid-year to produce reliable results.

VI. Economic Analysis

With all of that as important background, let us now turn to the task at hand. As we do so, let me emphasize once again that the figures presented below do not incorporate the benefits of starting to mitigate climate change.

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

Within the Kyoto agreement, this means an insistence on international trading, joint implementation, and, ultimately, on full developing country participation. Domestically, this

means that we implement any emissions reductions through a market-based system of *tradeable* emissions permits, which ensures that we achieve reductions wherever they are least expensive. But this also means taking serious and responsible steps in the short run to prepare us to meet our obligations in the longer term.

The first such step is the inclusion in this year's budget of an aggressive, \$6.3 billion program of tax cuts and R&D -- \$1.3 billion more than the \$5 billion package the President promised in his October 22 speech on this issue. The goal is both to stimulate the development of new energy-saving and carbon-saving technologies and to encourage the dissemination of those that exist already. The proposed package contains \$3.6 billion over the next 5 years in tax cuts for energy efficient purchases and renewable energy, including tax credits of \$3,000 to \$4,000 for consumers who purchase highly fuel efficient vehicles, a 15 percent credit (up to \$2,000) for purchases of rooftop solar equipment, a 20 percent credit (subject to a cap) for purchasing energy-efficient building equipment, a \$2,000 credit for purchasing energy-efficient new homes, an extension of the wind and biomass tax credit, and a 10 percent investment credit for the purchase of combined heat and power systems. The package also contains \$2.7 billion over the next 5 years in additional research and development spending -- covering the four major carbon-emitting sectors of the economy (buildings, industry, transportation, and electricity), plus carbon removal and sequestration, Federal facilities, and cross-cutting analyses and research. One example of the R&D effort is the Partnership for a New Generation of Vehicles (PNGV). PNGV is a government-industry effort to develop attractive, affordable cars that meet all applicable safety and environmental standards and get up to three times the fuel efficiency of today's cars. In FY99, the combined proposal for PNGV is \$277 million, up from \$227 million appropriated in FY98. Similar government-industry efforts are proposed to develop more efficient diesel engines for both light trucks and heavy trucks. [ADD SOMETHING MORE ABOUT INDUSTRY-GOVERNMENT DIALOG. PERHAPS A CONCRETE EXAMPLE OF IDENTIFYING AN INDUSTRY REGULATION THAT COULD BE REMOVED.]

The second such step is the promotion of an environmentally-responsible electricity restructuring bill, which the President identified as part of his domestic climate change package in his address to the National Geographic Society on October 22. An electricity sector freed from government regulation would be a more efficient energy sector. Costs to consumers would fall. A reasonable overall estimate of the effects of adding federal electricity restructuring to the rest of the President's program to address climate change is to achieve the same environmental goals at a cost saving of roughly \$16 billion per year.

Estimated Reduction in Costs from Annex I Trading

In the language of the treaty, "Annex I," you will recall, is the set of countries that have agreed to take on binding limitations in emissions of greenhouse gases. Even without developing country participation -- which, again, the President has emphasized as essential before the treaty could be ratified -- costs would be reduced substantially by trading among the Annex I countries. To provide some indication of the possible efficiency improvements, Russia

and the Ukraine consume six times as much energy per dollar of output as does the United States.

Estimates derived from the SGM model suggest that trading among Annex I countries is likely to reduce the cost to the United States of achieving its targets for 2008-2012 emissions by about half relative to a situation in which such trading was not available. This concept of costs is meant to capture aggregate resource costs to the US economy, including the cost to domestic firms of purchasing emission permits from Russia and other countries where emission reductions are cheaper than in the United States. The dramatic reduction in costs available from Annex I trading within the SGM model -- cutting the costs involved by half -- highlights why the President insisted that international trading be part of the Kyoto Agreement.

Estimated reduction in costs from umbrella trading

One possibility that emerged in Kyoto, which none of us foresaw, was the idea that the United States might undertake trading with a subset of Annex I countries, dubbed the "umbrella," that would exclude the European Union. The initial list of proposed participants in the umbrella includes the United States, Australia, Canada, Japan, New Zealand and Russia, with strong indications of interest from some others. The motivation for this idea was that the Europeans have been reluctant to agree to the sort of international trading that we want (preferring that they achieve their goals collectively in a group of their own, called the "EU bubble").

It is too early to say whether the umbrella concept will in fact be accepted by the parties. But it is an important concept to consider, for three reasons. First, it is conceivable that it will be formally agreed to in future negotiations. Second, even if the final treaty does not explicitly include the umbrella, but rather allows trading among all signatories (as the United States has proposed all along), it is conceivable that umbrella countries will agree, outside the treaty, to trade only among themselves. Third, the aversion toward international trading that the Europeans have expressed suggests that they might refrain from making the trades to which they would be entitled -- which would mean that the umbrella would operate in practice, if not in formal international agreement.

The significance of the umbrella idea in the present context is that it has the potential to further reduce costs to the United States. The reason is that if the Europeans do not bid against us for the relatively abundant, low-cost opportunities to reduce emissions in Russia and Eastern Europe, then the price of emissions reductions will be even lower. Results that we have derived from various SGM simulations suggest that, relative to the situation in which there is no trading at all, the umbrella arrangement would reduce costs by an estimated 60-75 per cent, depending on whether the former Warsaw Pact countries are classed with the EU, or are instead assumed to fall within the umbrella.

Estimated reduction in costs from LDC participation

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

A moderate version of developing country participation is the Clean Development Mechanism, modelled after Joint Implementation (JI). JI cannot realistically be expected to yield all the gains of binding targets for developing countries, but it might shave costs by roughly another 20 to 25 percent from the reduced costs that result from trading among Annex I countries.

Another possibility is that we persuade some of the key developing countries that are the largest emitters to commit to targets, and allow us to buy emission reductions from those paths. We estimate that this could cut roughly 55 percent off the reduced costs that result from Annex I trading. [The four countries included in this particular estimate are China, India, Brazil and Korea.] Once these savings have been attained, the estimated reductions to US costs from persuading the rest of the developing world to go along with full commitments are relatively small.

A useful rough check on our estimate of the gains from international emissions trading can be obtained from other modelling efforts, notwithstanding that they are likely to be more distant approximations to the parameters of the Kyoto Treaty. Recent results from six leading models that participated in the Stanford Energy Modeling Forum show that worldwide permit trading would reduce the estimated costs -- defined as lost consumption -- of a full, long-term, global program to stabilize atmospheric concentrations at 550 ppmv by an average of 56 percent, although the results vary from model to model.

I offer these numbers because they show the potential effectiveness of trading in reducing costs dramatically. But it is important that I repeat three caveats: First, as always, there is a wide range of uncertainty around all these estimates. Second, they apply to an idealized version of trading, one that assumes no problems of enforcement or transactions costs. Third, it seems unlikely that we will convince all of our partners to agree in Buenos Aires to the most complete and cost-effective international trading arrangements. Nonetheless, despite these caveats, the numbers do show major savings even without getting the most optimistic case. And if we don't get enough of what we want, we won't submit the treaty for ratification to the Senate.

VII. Non-Climate Benefits

The costs of undertaking greenhouse gas emission reductions must be compared to the benefits. As I have indicated, for various reasons our analysis does not quantify the benefits from averting climate change itself. But the relative price shifts that are necessary to reduce emissions should produce benefits in three areas: air pollution, traffic congestion, and highway accidents. These benefits are quantifiable.

Reductions in carbon emissions also lead to reductions in emissions of pollutants that contribute to excess concentrations of fine particulate matter and low-level ozone. Conservative estimates suggest that, at an emission permit price of \$20 per ton, such ancillary emissions reductions could be well in excess of a half million tons of pollutants per year, and entail cost savings of about \$0.9 billion per year. These cost savings be even larger if carbon emissions reduction efforts could be carefully coordinated with the implementation of the national ambient air quality standards.

Traffic congestion hurts motorists by causing delays and inconvenience. More efficient pricing -- which recognizes the externalities involved -- should lead to reductions in congestion as motorists choose other means of travel, share rides, or even forgo less important trips. . We estimate, for example, that higher fuel prices resulting from carbon permit prices of say \$20/ton would reduce travel delays associated with congestion, and that the value of such time savings to consumers would be about \$0.4 billion per year.

Vehicle use also leads to costly accidents and to highway injuries including fatalities. Assuming that accidents fall proportionately with vehicle use, more efficient pricing will also create savings from reduced accidents and resultant mortality. We estimate that the savings from reduced accidents and the value of reduced mortality risk corresponding to a \$20/ton carbon price is approximately \$0.3 to \$2.7 billion per year [depending on whether lighter cars are less crashworthy].

A variety of other benefits that are harder to quantify are likely to result from reductions in carbon emissions. With respect to transportation, reduced vehicle use will also reduce the cost of road repair and maintenance. Second, reduced coal use will lower mercury emissions. Finally, reduced energy use will also increase U.S. energy independence. Our inability to estimate these effects quantitatively does not imply that they are necessarily small or unimportant.

VIII. Preliminary Estimate of the Net Effects of the Kyoto Agreement

We can now combine the various benefits and costs delineated above to provide a preliminary assessment of the net impact of the Kyoto agreement, excluding, however, the benefits of averted damage from climate change. This assessment relies on SGM model results along with additional Administration analysis. It accounts for the impact of trading under the umbrella, and assumes full participation by four key LDCs. We find that the net resource costs of attaining our Kyoto targets for emission reductions are approximately \$7 to \$9 billion. _Thus the net costs _are \$5 billion to \$8 billion, or roughly 0.08 percent of projected GDP. **(i.e., net of ancillary non-climate benefits, predicted from a permit price of \$12-\$16 per ton, depending on which umbrella definition is used).**

A more tangible measure of costs is the estimated effects on energy prices. Excluding the impact of electricity restructuring, our SGM-based estimate is that the price of emissions would be in the range \$12 to \$16 per ton of carbon equivalent -- and that energy prices at the household level would rise by about 3 percent under the Kyoto accords. Fuel oil prices would rise by about 6 percent, natural gas prices by 4 percent, gasoline prices by 3 percent, and electricity prices by 3 percent. The 3 percent increase in energy prices at the household level would raise the average family's energy bill by about \$75 per year.

These estimates do *not* mean that households' energy expenses will in fact be higher in 2010 than today, however. In the first place, energy prices fluctuate year-by-year for all sorts of reasons. They could go either up or down. But even if we leave out unpredictable fluctuations, the energy price declines from Federal electricity restructuring would be enough to offset the impact estimated above. By 2008-2012, the projected 10 percent decline in electricity prices from the restructuring that is part of our climate change agenda will mean a net reduction in electricity prices in the U.S., even accounting for the small increases noted above.

As highlighted earlier, estimates of the type that I am presenting are fraught with uncertainty. The estimate I just discussed was predicated on the developing country participation that we will insist upon in Buenos Aires as a condition for our ratifying the Kyoto Protocol, but which is not yet part of that Protocol. At the same time, the numbers I have cited are in several respects conservative: they leave out several factors, such as the role of sinks, that could further reduce costs. But before I bring these factors into the analysis, allow me to say a few words about macroeconomics.

Effects on employment and aggregate output

So far I have said nothing about job losses resulting from climate change policy. Although there may be job gains in some sectors and job losses in others, I do not anticipate any significant aggregate effect. Some jobs could be lost in energy-intensive sectors, although given the very small predicted change in energy prices, impacts in most such sectors are apt to be minimal. Furthermore, a large number of jobs will be created in other sectors -- many of them high-tech jobs paying high wages. The President is firmly committed to assisting any workers who are adversely affected during the transition to a climate-friendly economy.

The situation might be different if a large energy shock were to hit the economy with no warning, as happened in the oil crisis of 1973-74, when the real money supply, output and employment all contracted sharply. In addition to hitting with no warning, the oil shocks of the 1970s also entailed large transfers from the U.S. and other oil-importing countries to OPEC, thus depressing real income and spending in the former. A self-imposed shift in the relative price of

carbon-intensive energy to address global climate change, on the other hand, need not entail such a transfer of purchasing power. Thus there are critical differences between the oil price shocks and the effort to reduce carbon emissions. Our reassuring conclusion regarding aggregate output might also be different if the policy were to be implemented inefficiently (by command-and-control style regulations of the sort put in place in that oil crisis) rather than efficiently (by market mechanisms of the sort that the President has proposed to use).

IX. The Foregoing Estimates Are Conservative Along Several Dimensions

I should emphasize that the estimates I have presented are conservative in the sense that they do not include the potential cost reductions resulting from the inclusion in the Kyoto treaty of carbon sinks, the potential payoffs to the President's technology or energy efficiency initiatives, or the benefits of mitigating climate change itself. The first omission, sinks, concerns a provision of the Kyoto Protocol that has received less attention than it merits. It is only *net* emissions -- emissions to the atmosphere minus sequestration -- that are to be reduced 7 percent below 1990 levels, not gross emissions. The United States plants many trees every year, and would receive credit for this activity under the Protocol. Very preliminary estimates of the implications for the United States of the Kyoto provision on sinks indicates that carbon sinks could comprise nearly 10% of total required emissions reductions. Decreasing the required emissions reduction by 10% would likely result in cost-savings greater than 10%.

The estimates I have cited so far also make little allowance for the payoff to the President's \$6.3 billion Climate Change Technology Initiative. The parameter that figures most prominently in analysis of technological progress in the energy field is the rate of improvement in the so-called Autonomous Energy Efficiency Index (AEEI), that is the rate at which the total use of energy falls relative to GDP. In the SGM model analysis that underlies our assessment, the AEEI is assumed to improve by 1.0 percent per year. Reflecting a conservative interpretation of the 15-year impact of the technology initiative, this is only a small increase above the 0.9 percent number in the Energy Information Administration's Annual Energy Outlook.

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

Clearly, this is neither the best outcome we *can* attain nor the best outcome we *expect* to attain as a consequence of our climate change strategy over the next decade. Many energy technology forecast more rapid technological progress; and engineering models suggest that

some energy improving technologies are available now at negative costs.

If the Administration is successful in speeding the discovery and adoption of new technologies, the rate of improvement in energy efficiency could rise and such improvements would lower the cost of meeting our Kyoto target. For example, published results based on SGM model simulations with different assumed rates of AEEI improvement suggest an increase in the AEEI from 1.0 to 1.25 would be reflected in about a 40% decrease in the permit price.

The preceding estimates do not fully reflect potential entrepreneurial response to appropriate incentives. An instructive example of the ability of U.S. industry to perform beyond expectations when given appropriate economic incentives is EPA's highly acclaimed sulfur dioxide (SO₂) program, which relies, among other things, on a system of tradeable permits to reduce emissions of SO₂ from electric utilities. The SO₂ program has been successful in several ways: a large number of utilities participate, SO₂ emissions and ambient concentrations have fallen and the costs of reducing emissions are considerably lower than originally forecast.

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

Trading programs may not always bring cost savings as large as those achieved by the SO₂ program; trading programs will not always be accompanied by the discovery of much cheaper control strategies. However, the SO₂ experience demonstrates clearly how programs that offer important market incentives to find cheaper ways of reducing emissions can lead to unexpectedly low prices.

Finally, and most important: the estimates I have presented are conservative in that they leave out the benefits of mitigating climate change itself. A full cost-benefit analysis would include mitigation in the benefits column. The only reason we have not done so, as I have explained repeatedly above, is the difficulty in coming up with a number to capture the monetary benefits. But I trust that nobody will lose sight of our ultimate objective -- keeping our planet the hospitable home that we enjoy today.

CONCLUSION

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

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

I welcome your questions.

RECORD TYPE: PRESIDENTIAL (NOTES MAIL)

CREATOR: Jeffrey A. Frankel (CN=Jeffrey A. Frankel/OU=CEA/O=EOP [CEA])

CREATION DATE/TIME: 5-FEB-1998 09:35:02.00

SUBJECT: Re: Doug Elmendorf

TO: Janet L. Yellen (CN=Janet L. Yellen/OU=CEA/O=EOP @ EOP [CEA])

READ:UNKNOWN

CC: Michele Jolin (CN=Michele Jolin/OU=CEA/O=EOP @ EOP [CEA])

READ:UNKNOWN

CC: Rebecca M. Blank (CN=Rebecca M. Blank/OU=CEA/O=EOP @ EOP [CEA])

READ:UNKNOWN

TEXT:

I know Elmendorf, and would be enthusiastic (assuming a macro-public finance type suits our needs; our lunch discussion yesterday suggested that it might).

JF

Janet L. Yellen

02/05/98 09:29:01 AM

Record Type: Record

To: Rebecca M. Blank/CEA/EOP, Jeffrey A. Frankel/CEA/EOP, Michele Jolin/CEA/EOP

cc:

Subject: Doug Elmendorf

----- Forwarded by Janet L. Yellen/CEA/EOP on 02/05/98
09:28 AM -----

DAVID.WILCOX @ MS01.DO.treas.sprint.com

02/05/98 05:38:00 AM

Record Type: Record

To: Janet L. Yellen

cc:

Subject: Doug Elmendorf

Date: 02/04/1998 09:56 pm (Wednesday)

From: David W. Wilcox
To: janet
Subject: Doug Elmendorf

Janet:

Doug Elmendorf asked me to put in a good word for him with you, which I am very happy to do. Doug is a really solid all-around economist. He's a generalist -- I would describe him as a macro/public finance person. He's very thoughtful, a clear writer, good empirical instincts, and quite plugged in with the public finance crowd. I would not characterize him as a "tax junkie", so I don't know whether he's your person for the tax job. Unbeknownst to him, I seriously considered Doug as a DAS to replace Gruber, and decided to go with someone more microeconomically oriented. But I think he'd make a very solid member of the CEA staff. And he's a truly delightful person. I have gotten to know Doug well since he arrived on the staff of the Federal Reserve, and he's just a first-rate person.

Give me a call or drop me a line if I can provide any other information about him.

Regards,
DWW

===== ATTACHMENT 1 =====
ATT CREATION TIME/DATE: 0 00:00:00.00

TEXT:

RFC-822-headers:

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id <011T7MATJ1G000JLXF@PMDf.EOP.GOV> for yellen_j@al.eop.gov; Thu,
05 Feb 1998 06:39:07 -0500 (EST)

Received: from storm.eop.gov (storm.eop.gov)
by PMDF.EOP.GOV (PMDf V5.0-4 #6879) id <011T7MAP8PW000BOZK@PMDf.EOP.GOV> for
yellen_j@al.eop.gov; Thu, 05 Feb 1998 06:39:00 -0500 (EST)

Received: from reston-mx1.telemail.net ([206.229.206.20])
by STORM.EOP.GOV (PMDf V5.1-7 #6879)
with SMTP id <011T7M9Y0Y6K001EZH@STORM.EOP.GOV> for yellen_j@al.eop.gov; Thu,

05 Feb 1998 06:38:24 -0500 (EST)

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; Relayed; Thu, 05 Feb 1998 05:38:28 -0500

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; Relayed; Thu, 05 Feb 1998 05:38:28 -0500

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; Relayed; Thu, 05 Feb 1998 05:38:28 -0500

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X400-Originator: DAVID.WILCOX@MS01.DO.treas.sprint.com

X400-Recipients: yellen_j@al.eop.gov

===== END ATTACHMENT 1 =====

RECORD TYPE: PRESIDENTIAL (NOTES MAIL)

CREATOR: Jeffrey A. Frankel (CN=Jeffrey A. Frankel/OU=CEA/O=EOP [CEA])

CREATION DATE/TIME: 5-FEB-1998 00:05:54.00

SUBJECT: JY testimony: current draft

TO: Janet L. Yellen (CN=Janet L. Yellen/OU=CEA/O=EOP @ EOP [CEA])

READ:UNKNOWN

CC: Michele Jolin (CN=Michele Jolin/OU=CEA/O=EOP @ EOP [CEA])

READ:UNKNOWN

CC: Randall W. Lutter (CN=Randall W. Lutter/OU=CEA/O=EOP @ EOP [CEA])

READ:UNKNOWN

CC: Adele C. Morris (CN=Adele C. Morris/OU=CEA/O=EOP @ EOP [CEA])

READ:UNKNOWN

CC: Joseph E. Aldy (CN=Joseph E. Aldy/OU=CEA/O=EOP @ EOP [CEA])

READ:UNKNOWN

Lisa D. Branch (CN=Lisa D. Branch/OU=CEA/O=EOP [CEA])

READ:UNKNOWN

TEXT:

See note below. (The version I sent outside CEA does not include the last page of this file, which gives three key Q&As -- which is mostly material that in the preceding draft had been in the text.)

JF

----- Forwarded by Jeffrey A. Frankel/CEA/EOP on 02/04/98

11:54 PM -----

Jeffrey A. Frankel

02/04/98 11:55:11 PM

Record Type: Record

To: David B Sandalow/CEQ/EOP, ORSZAG_P @ A1 @ CD @ LNGTWY, Jonathan.gruber
@ treas.sprint.com @ inet

cc:

Subject: JY testimony: current draft

It's missing a few items toward the end, marked in boldface, that Randy Lutter will fill in very shortly. Otherwise, it is almost ready for us to circulate for vetting by other agencies. (By the way, we have a plan for answering questions about percentage of reductions abroad vs. at home.)

JF

===== ATTACHMENT 1 =====

ATT CREATION TIME/DATE: 0 00:00:00.00

TEXT:

Unable to convert ARMS_EXT:[ATTACH.D44]MAIL415570539.026 to ASCII,
The following is a HEX DUMP:

**TESTIMONY OF DR. JANET YELLEN
CHAIR, COUNCIL OF ECONOMIC ADVISERS
BEFORE THE SENATE FOREIGN RELATIONS COMMITTEE
ON THE ECONOMICS OF THE KYOTO AGREEMENT
FEBRUARY 11, 1998**

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

The international agreement that was reached in Kyoto this past December is a crucial first step in addressing global climate change. But it is only a first step. Since the international effort to reduce greenhouse gas emissions is more of a work-in-progress than a completely finished product, it is not yet possible to provide a full authoritative analysis of it. Many of the specifics in several crucial areas are not completely resolved in the diplomatic arena, forcing analysts to make a variety of assumptions about the ultimate form of the international regime. In my testimony today, I will attempt to identify the key elements of the agreement that ensure that reductions in global greenhouse gas emissions are consistent with continued strong economic growth. I will do my best also to provide some rough estimates of costs and benefits.

The Administration is strongly committed to ensuring that these critical elements -- including global participation and a reliance on flexible, market-based mechanisms -- are reflected in our domestic and international climate change policies. We are firmly committed to meaningful developing country participation, as well as emissions trading both domestically and internationally. And as you know, the President's FY 1999 budget includes a \$6.3 billion package of tax cuts and R&D over the next 5 years to jumpstart our efforts.

I. Basic Economic Rationale of the Kyoto Treaty

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

The earth's surface is warming from the accumulation of greenhouse gases from myriad sources worldwide. None of these emitters presently pays the cost to others of warming's adverse effects -- a classic externality in the language of economists. As a result of these distorted incentives, disruption of the Earth's climate is likely to proceed at an excessive pace and if left uncontrolled may pose substantial costs in terms of disruption to commerce and the environment alike. The fundamental economic logic of the Kyoto agreement is thus that

without such an international agreement, individual nations will not have the proper incentives to address the threats from global climate change.

II. Costs of Climate Change

In evaluating efforts to address climate change, the first step is to consider the costs that are likely if we fail to take any action -- for these costs provide the primary motivation for reducing greenhouse gas emissions. What, then, are the costs associated with allowing global climate change?

The Intergovernmental Panel on Climate Change (IPCC) jointly established by the World Meteorological Organization and the United Nations Environment Programme, concluded in 1995 that "the balance of evidence suggests that there is a discernible human influence on global climate." Current concentrations of carbon dioxide, methane, nitrous oxide, and the other so-called greenhouse gases have reached levels well above those of preindustrial times. Of these, carbon dioxide (CO₂) is the most important: net cumulative CO₂ emissions resulting from the burning of fossil fuels and deforestation account for about two-thirds of potential warming from changes in greenhouse gas concentrations related to human activity.

Climatic Impact

If growth in global emissions continues unabated, the atmospheric concentration of CO₂ will likely double relative to its preindustrial level by midway through the next century. As a result of the increased concentration of CO₂, the IPCC estimates that global temperatures will increase by between 2.5 to 6 degrees Fahrenheit in the next 100 years, with a best guess of about 3.5 degrees Fahrenheit. While scientists believe that human activities are leading to a gradual warming of the *average* temperature of the earth, the change in temperature in a given region at a given time may differ substantially from this average. Indeed, models predict warming will be greater in high latitudes than in the tropics, and greater over land than ocean. Many models predict larger increases in evaporation than in precipitation over midlatitude land areas, which would result in drier conditions in those regions, especially during summer in North America and Europe.

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

Economic and Monetary Damages

The derivation of quantitative or monetary estimates of the damages from such climate changes is extremely difficult given the capacity of today's forecasting models. Estimates of the economic damages from climate change fall into the following broad areas: agriculture, sea-level rise, air conditioning and heating, water supply, human life and health, air pollution, and other costs (hurricanes, migration costs, human amenity, construction, leisure activities, urban infrastructure, and ecological damages such as forest loss and species loss).

A subject of great uncertainty and sensitivity is the "discount rate" that is applied to the benefits of averting future climate change. Such a discount rate is needed if the analysis is to be expressed in monetary terms, because a dollar today is not worth the same as a dollar tomorrow. And since the benefits of stemming future climate change accrue over not only decades but centuries, small changes in the discount rate can produce substantial changes in the results. But the precise discount rate that should be used to evaluate questions as important as the future climate of the planet remains a subject of intense debate. It is safe to say that there is, as of yet, no professional consensus on the issue.

A similar point concerns risk aversion. To what extent are we willing to take chances with our planet? The point applies particularly to catastrophe scenarios. Scientists have thought of many possible scenarios, most of which they are fortunately not yet prepared to pronounce as particularly likely based on current evidence, but which might be truly catastrophic for the planet if they were to occur. There is a strong argument for the Kyoto agreement as a form of planet insurance. But what numerical weight should one assign to these catastrophic risks? In other words, what is the value of the insurance policy? It is difficult for an economist, or anyone, to know.

Despite these shortcomings and potential problems, respected researchers have developed estimates of the monetary damages expected from an average worldwide temperature increase of approximately 4.5 degrees Fahrenheit (corresponding to, roughly, a doubling of pre-industrial carbon dioxide concentrations). For example, William Cline, then a Senior Fellow at the Institute for International Economics, estimated that such a temperature change would impose annual damages of more than \$70 billion per year on the U.S. economy in today's terms. These damages include \$22 billion in lost agricultural production, \$13 billion in additional electricity costs, and \$8 billion in new costs to maintain the existing supply of fresh water. (Cline's original estimates are quoted in 1990 dollars. The figures given above translated those numbers into 1997 dollars using the annual GDP price index.) William Nordhaus of Yale University has likewise computed estimates of the dollar loss attributable to a doubling of carbon dioxide concentrations. He finds that the Cline estimate is in the center of three estimates for the U.S., and that the high estimate is only 1.3 times greater than the low estimate.

It must be noted, however, that this similarity of aggregate estimates masks the true uncertainty associated with forecasts of the damages from given increases in global warming --

the estimates are all fundamentally based on extrapolations from current and past experience, and may not fully incorporate effects that will unfortunately become apparent only with future experience. In particular, the estimates may not fully reflect potential non-linearities in the relationships between carbon dioxide concentrations and temperature, between temperature and economic damages, or in the various other complicated relationships governing interactions between greenhouse gas emissions, the climate, and the economy. Current quantitative analyses do not, and cannot, accurately reflect the small and unknown possibility of large-scale and potentially irreversible discrete events with potentially catastrophic consequences.

Two such possibilities serve as illustrations. Warming of Northern tundra may release very large amounts of methane from the subarctic permafrost, thereby leading to potentially devastating acceleration of an otherwise controllable global warming process. We do not know at what point, if any, such unstable activity would be triggered. Second, evidence from climate models suggests that some types of climate change may lead to displacement of the Gulf Stream that warms Western Europe. Evidence from ocean core samples suggests that such reversals of ocean currents have occurred in previous ice ages. Reductions in the risk of such catastrophic outcomes must be considered in addition to the costs and benefits that can be reasonably quantifiable. Since human beings are typically averse to risk, such possibilities are especially important in evaluating whether the benefits of a particular climate control policy justify the costs. One must have at least some sympathy with those who criticize economists on the grounds that the effects of climate change are extremely difficult to quantify in a single monetary number.

III. Addressing Global Climate Change in an Efficient Manner

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

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

Need for Global Action

Climate change is a global problem requiring a global solution. As I mentioned earlier, no single country has an incentive to reduce emissions sufficiently to protect the global environment against climate change. Each has an economic incentive to “free ride” on the efforts of others. Even if the United States sharply reduced its emissions unilaterally, greenhouse gas emissions from all other countries would continue to grow, and the risks posed by climate change would not be significantly abated. It is important to emphasize that emissions of different gases anywhere in the world have very similar effects on global climate.

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

To address the lack of progress among many industrialized countries toward meeting the Rio objective, the United States and approximately 160 other nations agreed in negotiations held in Kyoto, Japan, last December, to take substantial steps to stabilize atmospheric concentrations of greenhouse gases. The Kyoto Agreement, which requires the advice and consent of the Senate, would place binding limits on industrial countries' emissions of the six principal categories of greenhouse gases: CO₂, N₂O, methane, sulfur hexafluoride, perfluorocarbons, and hydrofluorocarbons. **These limits apply to the 38 so-called Annex I countries, which are the industrialized countries, defined to include Russia, Ukraine, and most Eastern European countries.**

Under the Kyoto agreement, each industrial country's “1990 baseline” is actually based on its 1990 emissions of CO₂, methane, and N₂O and its choice of 1990 or 1995 levels of the other three categories of gases. The United States agreed to a target of 7 percent below 1990 levels by the period between 2008 and 2012. To meet that target, net U.S. emissions of greenhouse gases -- all emissions minus removals of CO₂ by certain forestry-related activities -- must average no more than 1,484 million metric tons of carbon equivalent per year during that period. The targets for the European Union and Japan are 8 percent and 6 percent below 1990 levels, respectively. Australia, New Zealand, Norway, Russia and Ukraine all have limits somewhat less ambitious when phrased as cuts relative to

their 1990 levels. In sum, over the period from 2008 to 2012, the industrial countries are expected to reduce their average emissions of greenhouse gases to about 5 percent below their 1990 levels.

The President has made clear that his support of the Kyoto Agreement is dependent on meaningful participation from key developing countries (who are not included in Annex I). The President has also made clear that he will not submit the treaty to the Senate without such participation.

There are several reasons why meaningful participation from developing countries is essential. First, developing countries are projected to contribute a majority of total emissions by 2030 under a continuation of business-as-usual. Without the participation of developing economies, emissions reductions by the industrialized countries will therefore not achieve necessary protection from climate change. Indeed, if developing countries do not participate in the international regime, their emissions could potentially increase by *more* than under their business-as-usual baselines. One mechanism for such an unintended consequence is as follows.

As Annex I countries comply with their targets, their demand for oil will fall, which will probably work to reduce the price of oil on world markets, and perhaps to encourage non-participating countries to use more oil and emit more carbon than they otherwise would have.

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

Third, principles of basic fairness suggest all countries should do their part, depending on their ability to contribute to the solution. Thus even poor countries should contribute, although the existence of more pressing social needs in such countries will inevitably limit the magnitude of their contributions.

So far I have not mentioned the word “competitiveness.” One of the difficulties in analyzing concerns related to competitiveness is that the term itself is used to mean many different things. I have seen at least one study that uses “loss of competitiveness” to refer to predictions of negative effects on the *aggregate* trade balance. As a professional economist, I do not accept the logic upon which that particular argument is predicated: the aggregate trade

balance is determined by macroeconomic forces -- the difference between saving and investment -- and not by our environmental policies.

On the other hand, if competitiveness refers to adverse effects on a few specific manufacturing industries -- those that are especially energy-intensive, such as aluminum, paper, and chemicals -- the situation may be more complicated. It is difficult to undergo a significant structural change in the economy without having the effect of expanding some sectors and contracting others. But to provide some perspective on this issue, consider the following facts. First, on average, energy constitutes only 2.2 percent of total costs to U.S. industry. Second, energy prices already vary significantly across countries. According to the *1997 Statistical Abstract*, for example, in 1996 premium gasoline cost \$1.28 per gallon in the United States -- but only 8 cents in Venezuela. Yet U.S. industry is not moving en masse to Venezuela. Third, roughly two-thirds of all emissions are not in manufacturing at all, but in transportation and buildings. I therefore believe it more accurate to say that we need developing country participation for the reasons I outlined above, than to say that we need it to avoid adverse effects on competitiveness.

Flexibility and Market Mechanisms

A global solution is thus critical to the global problem of climate change. Globalizing the solution is not, however, enough by itself. We must also ensure that our efforts achieve their objectives in the most efficient manner possible. The nature of the climate change problem suggests some methods to lower costs of achieving given levels of environmental protection. Such methods have long been championed by economists interested in increasing the efficiency of protection. They were the sort of thing that 2,600 economists had in mind last year when they signed a letter, urging action on climate change:

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

What are these methods and policies? They can be characterized in terms of three categories of flexibility: (1) “when” flexibility; (2) “what” flexibility; and (3) “where” flexibility, which may be the most important of all.

1. “When flexibility” (timing)

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

The Kyoto Protocol incorporates this principle of “when flexibility” in four ways:

- First, the cuts to be made in the first period are less severe, and the first period ends much later, than what had been proposed by many other countries, most notably the Europeans. By adopting a gradual and credible path of reductions in the early years, we can greatly reduce costs such as those from prematurely scrapping coal-fired electricity plants still in the prime of their operating lives, while attaining the same ultimate environmental goals.
- Second, under the Kyoto agreement, the emissions target is not specified in terms of a specific year, but rather in terms of an average over a five-year period (2008-2012). Averaging over five years, instead of requiring countries to meet a specific target each year, can lower costs, especially given an uncertain future. The averaging can smooth out the effects of short-term events such as fluctuations in the business cycle and energy demand, or hard winters and hot summers that would increase energy use and emissions.
- Third, there is allowance for “banking” emission reductions within the 2008-2012 commitment period, for use in a subsequent commitment period [although the emission targets of the next period have not yet been specified].

2. “What flexibility” (gases and sinks)

The second type of flexibility is “what flexibility”, along two dimensions. The first is the inclusion in the agreement of all six greenhouse gases. Emissions of different kinds of gases, not just carbon dioxide, contribute to the greenhouse effect. Since the IPCC has developed conversion factors for all greenhouse gases by estimating their global warming potentials, reductions in emissions of one pollutant can be used to substitute for increases in emissions of another by an amount that has equivalent environmental effects. The Kyoto Protocol stipulates that countries with binding targets are expected to reduce their *total* greenhouse gas emissions by certain percentages, but does not require specific reductions for specific gases. Since a molecule of sulfur hexafluoride is 23,900 times more potent over 100 years than a molecule of CO₂, it may be cheaper to achieve the same environmental benefit by eliminating one molecular unit of SF₆ than nearly 24,000 units of CO₂.

Some initial rough analysis indicates that a strategy of reducing non-CO₂ greenhouse gases by *more* than 7 percent below their 1990/1995 baseline levels while reducing CO₂ by *less* than 7 percent below its 1990 level could reduce greenhouse gas emission permit prices by more than 10 percent. [This analysis is based on the integrated SGM/non-CO₂ cost curve.] Thus allowing countries flexibility in what gases they reduce -- essentially trading emissions reductions across gases -- can help lower significantly the costs of meeting their targets.

The second source of “what flexibility” is the treatment of sinks, i.e., land use activities that promote the removal of carbon from the atmosphere through the growth of plants.

Promoting such sinks through afforestation and reforestation may reduce atmospheric concentrations of CO₂ at much lower costs than reducing emissions of greenhouse gases.

3. "Where flexibility" (international)

The third type of flexibility, and perhaps the most important, is "where flexibility" (international). As I have already emphasized, emissions have the same environmental consequences regardless of where in the world they occur. Therefore, the least-cost approach to controlling climate change is to reduce emissions wherever such reductions are cheapest. The Kyoto agreement includes two important cost-saving provisions of this nature. First, it provides for industrial countries to trade rights to emit greenhouse gases with each other. This market in emissions permits will ensure that emission reductions occur where they are least expensive within the industrial countries. In particular, U.S. companies could purchase emissions reductions in other participating countries when doing so would reduce their costs -- lowering costs without affecting the level of environmental protection.

Second, the agreement allows industrial countries to invest in "clean development" projects in the developing world and use these projects' certified emissions reductions toward meeting their targets. Many such clean-development projects may be quite cheap in terms of the cost per ton of emissions avoided, as has been illustrated by the joint implementation pilot program that is already in place in the U.S. Details of these provisions will be worked out in negotiations in Buenos Aires later this year.

IV. Difficulties of Economic Analysis of Kyoto Agreement

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

The difficulties associated with economic analysis of climate change fall into three broad categories. First is the uncertainties that still remain over the terms of the ultimate treaty. Second is the inherent limitations of available models to analyze even short-term costs and benefits. And finally is a topic I discussed earlier: the impossibility of putting a single monetary number on the long-term benefits of climate change mitigation.

Uncertainties over Certain Provisions in International Effort to Combat Climate Change

The Kyoto Agreement was an historic accomplishment, delineating the broad terms of

the international effort to address climate change. But although we know a lot more than we did before Kyoto about how that international system will work, there is still much that we don't know.

First, as is often the case in a legal document of the length and complexity of the Kyoto Protocol, there are some provisions that require further clarification and interpretation. Of particular concern here is the treatment of so-called sinks -- activities that affect the rate at which carbon is removed from the atmosphere and "sequestered," specifically by the planting of trees.

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

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

Inherent Limitations of Models

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

One area in which the uncertainty is particularly large is the pace of technological progress -- including diffusion of existing energy-efficient technologies, as well as research and development of new technologies -- and the extent to which the pace will accelerate in response to government programs. Economics does not offer a good understanding of how technological progress is determined, in part because it is the stuff of experimentation, brainstorming, genius, breakthroughs, perceptions and habits. Invention is largely determined by inspiration -- notwithstanding Edison, who assigned a 99 percent share to perspiration -- and inspiration, in my

experience, is difficult to fit into mathematical formulae or economic models. Models and experts on climate change policy tend to have a wider range of disagreement on the speed with which technology can be changed than on any other single issue.

Furthermore, each model has strengths and weaknesses; each has questions to which it is better or worse suited to answer. Some, for example, model the energy sector in detail. Some allow for the fact that a coal-fired power plant cannot costlessly be converted to one that runs on natural gas. Some have enough policy detail to distinguish alternative ways of redistributing revenues that would result if emission permits were to be auctioned. Some are capable of showing short-term macroeconomic disequilibria. Some include a long-term "carbon cycle" model that can keep track of the accumulation of greenhouse gas concentrations in the atmosphere and their climatological effects. Some break down the rest of the world into regions and so can model international trade. No one model does everything, and therefore we must not rely blindly on the results of any one model or set of models. Professional judgement and economic intuition are also crucial.

Benefits of Averting Climate Change

As I discussed above, it is evident that the benefits of averting climate change are potentially immense. But I have chosen not to try to quantify them in monetary terms for you, in light of the difficulties I have enumerated -- including the quantitative uncertainty of these benefits, and their timing and therefore the extreme sensitivity of the results to the chosen discount rate.

Instead, what I will do is draw upon a variety of sources in an attempt to add up the various possible costs and benefits of emissions policy *excluding* climate change. To give away the punch line, my conclusion is as follows: the net costs of our policies to reduce emissions are likely to be small, if those reductions are undertaken in an efficient manner, *even before taking into account the benefits of averting climate change itself*. That small net premium excluding the benefits of mitigating climate change, in effect, purchases a partial insurance policy against the threat.

V. Models of the Kyoto Agreement

The existence of modeling difficulties means that the results from any model must be treated with caution. We have employed a broad set of economic tools available to analyze the policy options. Such tools include models of the energy sector and economy over the next 25 years, including but not limited to the results of the Stanford Energy Modeling Forum exercises, the IPCC's review of the economic and social dimensions of climate change, and the staff-level Interagency Analytical Team effort last year. Other tools include simple relevant statistics, "meta-analyses" of existing models, historical and sectoral examples, and basic economic reasoning. Drawing on this broad array of analytical tools is crucial to an intelligent evaluation of the policy alternatives.

To my knowledge, as of December, no model -- whether used inside the government or not -- had been set up precisely to analyze the parameters of the agreement that was reached in Kyoto. Most model-builders outside the government tend to take as long as several years to incorporate changes in policy parameters into their models. And no model is currently designed to assess sinks, or all six greenhouse gases included in the treaty.

One of the leading models in the field is the Second Generation Model of Battelle Laboratories. The SGM is one of the models best positioned to analyze the role of international trade in emission permits, which we consider to be a critical element of the Kyoto Treaty. I would therefore like to share with you some preliminary analyses based on the SGM model that have been developed over the past two months to reflect what was agreed to in Kyoto. To do so, several modifications to the original SGM results are necessary. For example, the SGM does not cover all six gases included in the Kyoto agreement. We therefore integrated the SGM model results with cost analyses of the other gases by EPA.

Mindful of the limitations that any one model has, however, I am eager to see the Kyoto parameters fed into other models, to get a better feel for the range of possible effects. Much of this work will continue to go on outside the government. For example, we have had discussions with the Energy Modeling Forum, based at Stanford University. The EMF is a long-running exercise involving many of the leading climate models. We have given the EMF advice on how features of the Kyoto legal language can be translated into terms recognizable to an economist. Unfortunately, the Energy Modeling Forum believes that its members will need at least until mid-year to produce reliable results.

VI. Economic Analysis

With all of that as important background, let us now turn to the task at hand. As we do so, let me emphasize once again that the figures presented below do not incorporate the benefits of starting to mitigate climate change.

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

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

obligations in the longer term.

The first such step is the inclusion in this year's budget of an aggressive, \$6.3 billion program of tax cuts and R&D -- \$1.3 billion more than the \$5 billion package the President promised in his October 22 speech on this issue. The goal is both to stimulate the development of new energy-saving and carbon-saving technologies and to encourage the dissemination of those that exist already. The proposed package contains \$3.6 billion over the next 5 years in tax cuts for energy efficient purchases and renewable energy, including tax credits of \$3,000 to \$4,000 for consumers who purchase highly fuel efficient vehicles, a 15 percent credit (up to \$2,000) for purchases of rooftop solar equipment, a 20 percent credit (subject to a cap) for purchasing energy-efficient building equipment, a \$2,000 credit for purchasing energy-efficient new homes, an extension of the wind and biomass tax credit, and a 10 percent investment credit for the purchase of combined heat and power systems. The package also contains \$2.7 billion over the next 5 years in additional research and development spending -- covering the four major carbon-emitting sectors of the economy (buildings, industry, transportation, and electricity), plus carbon removal and sequestration, Federal facilities, and cross-cutting analyses and research. One example of the R&D effort is the Partnership for a New Generation of Vehicles (PNGV). PNGV is a government-industry effort to develop attractive, affordable cars that meet all applicable safety and environmental standards and get up to three times the fuel efficiency of today's cars. In FY99, the combined proposal for PNGV is \$277 million, up from \$227 million appropriated in FY98. Similar government-industry efforts are proposed to develop more efficient diesel engines for both light trucks and heavy trucks. [ADD SOMETHING MORE ABOUT INDUSTRY-GOVERNMENT DIALOG. PERHAPS A CONCRETE EXAMPLE OF IDENTIFYING AN INDUSTRY REGULATION THAT COULD BE REMOVED.]

The second such step is the promotion of an environmentally-responsible electricity restructuring bill, which the President identified as part of his domestic climate change package in his address to the National Geographic Society on October 22. An electricity sector freed from government regulation would be a more efficient energy sector. Costs to consumers would fall. A reasonable overall estimate of the effects of adding federal electricity restructuring to the rest of the President's program to address climate change is to achieve the same environmental goals at a cost saving of roughly \$16 billion per year.

Estimated Reduction in Costs from Annex I Trading

In the language of the treaty, "Annex I," you will recall, is the set of countries that have agreed to take on binding limitations in emissions of greenhouse gases. Even without developing country participation -- which, again, the President has emphasized as essential before the treaty could be ratified -- costs can be reduced substantially by trading among the Annex I countries. To provide some indication of the possible efficiency improvements, Russia and the Ukraine consume six times as much energy per dollar of output as does the United States.

The estimate derived from the SGM model is that, under certain base-case assumptions,

trading among Annex I countries reduces the cost to the United States of achieving its targets for 2008-2012 emissions by about half relative to a situation in which such trading was not available.

This concept of costs is meant to capture aggregate resource costs to the US economy, including the cost to domestic firms of purchasing emission permits from Russia and other countries where emission reductions are cheaper than in the United States. The dramatic reduction in costs available from Annex I trading within the SGM model -- cutting by half the costs involved -- highlights why the President insisted that international trading be part of the Kyoto Agreement.

A useful rough check on this estimate can be obtained from other model[s], notwithstanding that they are likely to be more distant approximations to the parameters of the Kyoto Treaty. The G-cubed model, for example, shows that trading among Annex I countries reduces overall costs by roughly 20 percent [CHECK]. [The G-cubed model is better designed than most to analyze trading of permits in a system where the usual international trade in goods and services is also important.] Twelve leading models that participate in the Stanford Energy Modeling Forum show that trading among industrialized countries reduces estimated costs -- defined as lost consumption -- by an average of 56 percent, although the results vary from model to model.

Estimated reduction in costs from umbrella trading

One possibility that emerged in Kyoto, which none of us foresaw, was the idea that the United States might undertake trading with a subset of Annex I countries, dubbed the "umbrella," that would exclude the European Union. The initial list of proposed participants in the umbrella includes the United States, Australia, Canada, Japan, New Zealand and Russia, with strong indications of interest from some others. The motivation for this idea was that the Europeans have been reluctant to agree to the sort of international trading that we want (preferring that they achieve their goals collectively in a group of their own, called the "EU bubble").

It is too early to say whether the umbrella concept will in fact be accepted by the parties. But it is an important concept to consider, for three reasons. First, it is conceivable that it will be formally agreed to in future negotiations. Second, even if the final treaty does not explicitly include the umbrella, but rather allows trading among all signatories (as the United States has proposed all along), it is conceivable that umbrella countries will agree, outside the treaty, to trade only among themselves. Third, the aversion toward international trading that the Europeans have expressed suggests that they might refrain from making the trades to which they would be entitled -- which would mean that the umbrella would operate in practice, if not in formal international agreement.

The significance of the umbrella idea in the present context is that it has the potential to further reduce costs to the United States. The reason is that if the Europeans are not bidding against us for the cheap emission rights that the Russians and other Eastern Europeans have to

sell, then the price will be even lower. The SGM results suggest that, relative to the situation in which there is no trading at all, the umbrella arrangement would reduce costs by an estimated 61-75 per cent, depending on whether the former Warsaw Pact countries are classed with the EU, or are instead assumed to fall within the umbrella. Thus, the umbrella arrangement raises the benefit to international trading significantly relative to full Annex I trading, reducing costs from roughly half their no-trading level to as low as one-quarter their no-trading level.

Estimated reduction in costs from LDC participation

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

A moderate version of developing country participation is the Clean Development Mechanism, modelled after Joint Implementation (JI). JI cannot realistically be expected to yield all the gains of binding targets for developing countries, but it might shave costs by roughly another 20 to 25 percent from the reduced costs that result from trading among Annex I countries.

Another possibility is that we persuade some of the key developing countries that are the largest emitters to commit to targets, and allow us to buy emission reductions from those paths. The model estimate is that this would cut roughly 55 percent off the reduced costs that result from Annex I trading. [The four countries included in this particular estimate are China, India, Brazil and Korea.] Once these savings have been attained, the estimated reductions to US costs from persuading the rest of the developing world to go along with full commitments are relatively small.

I offer these numbers because they show the potential effectiveness of trading in reducing costs dramatically. But it is important that I repeat three caveats: First, as always, there is a wide range of uncertainty around all these estimates. Second, they apply to an idealized version of trading, one that assumes no problems of enforcement or transactions costs. Third, it seems unlikely that we will get all our partners to agree in Buenos Aires to the very most optimistic or ambitious case. Nonetheless, despite these caveats, the numbers do show major savings even without getting the most optimistic case. And if we don't get enough of what we want, we won't submit the treaty for ratification to the Senate.

VII. Non-Climate Benefits

The costs of undertaking greenhouse gas emission reductions must be compared to the benefits. As I have indicated, for various reasons our analysis does not quantify the benefits from averting climate change itself. But the relative price shifts that are necessary to reduce emissions should produce benefits in three areas: air pollution, traffic congestion, and highway

accidents. These benefits are quantifiable.

Reductions in carbon emissions also lead to reductions in emissions of pollutants that contribute to excess concentrations of fine particulate matter and low-level ozone.

[FORTHCOMING, PENDING ANALYSIS FROM EPA and LUTTER.]

Traffic congestion hurts motorists by causing delays and inconvenience. More efficient pricing -- which recognizes the externalities involved -- should lead to reductions in congestion as motorists choose other means of travel, share rides, or even forgo less important trips. . We estimate that higher fuel prices resulting from carbon permit prices of \$20/ton will reduce travel delays associated with congestion, and that the value of such time savings to consumers would be about \$0.4 billion per year.

Vehicle use also leads to costly accidents and to highway injuries including fatalities. Assuming that accidents fall proportionately with vehicle use, more efficient pricing will also create savings from reduced accidents and resultant mortality. The savings from reduced accidents and the value of reduced mortality risk is approximately \$0.3 to \$2.7 billion/ year [depending on whether lighter cars are less crashworthy] given a \$20/ton carbon price.

A variety of other benefits that are harder to quantify are likely to result from reductions in carbon emissions. With respect to transportation, reduced vehicle use will also reduce the cost of road repair and maintenance. Second, reduced coal use will reduce the cost of sulfur dioxide controls, as utilities switch to energy sources other than coal. Reduced coal use will also lower mercury emissions. Finally, reduced energy use will also increase U.S. energy independence. Our inability to estimate these effects quantitatively does not imply that they are necessarily small or unimportant.

VIII. Estimated Net Effects For One Illustrative Case

We can now combine the various benefits and costs delineated above. By way of summary, it may be helpful to focus on an illustrative case. We consider the case of trading under the umbrella, together with full participation by four key LDCs. In this case, adding together the estimates derived from the SGM and other sources suggests that the resource costs of attaining our Kyoto targets for emission reductions are \$7 to \$9 billion. **Thus the net costs are \$_ billion to \$_ billion, or roughly 0.0_ percent of projected GDP** (i.e., net of ancillary non-climate benefits, predicted from a permit price of \$12-\$16 per ton, depending on which umbrella definition is used).

A more tangible measure of costs is the estimated effects on energy prices. Again excluding the impact of electricity restructuring, the SGM-based estimate is that the price of emissions would be in the range \$12 to \$16 per ton of carbon equivalent -- and that energy

prices at the household level would rise by about 3 percent under the Kyoto accords [CHECK].

Fuel oil prices would rise by about 5 percent, natural gas prices by 4 percent, gasoline prices by 3 percent, and electricity prices by 2 percent. The 3 percent increase in energy prices at the household level would raise the average family's energy bill by about \$75.

These estimates do *not* mean that households' energy expenses will in fact be higher in 2010 than today, however. In the first place, energy prices fluctuate year-by-year for all sorts of reasons. They could go either up or down. But even if we leave out unpredictable fluctuations, the energy price declines from Federal electricity restructuring would be enough to offset the impact estimated above. By 2008-2012, the projected 10 percent decline in electricity prices from the restructuring that is part of our climate change agenda will mean a net reduction in energy prices in the U.S., even accounting for the small increases noted above.

As highlighted earlier, estimates of the type that I am presenting are fraught with uncertainty. The estimate I just discussed was predicated on the developing country participation that we will insist upon in Buenos Aires as a condition for our ratifying the Kyoto Protocol, but which is not yet part of that Protocol. At the same time, the numbers I have cited are in several respects conservative: they leave out several factors, such as the role of sinks, that could further reduce costs. But before I bring these factors into the analysis, allow me to say a few words about macroeconomics.

Effects on employment and aggregate output

So far I have said nothing about job losses resulting from climate change policy. Although there may be job gains in some sectors and job losses in others, I do not anticipate any significant aggregate effect. Some jobs may be lost in energy-intensive sectors, but a large number of jobs will be created in other sectors -- many of them high-tech jobs paying high wages. The President is firmly committed to assisting any workers who are adversely affected during the transition to a climate-friendly economy.

The situation might be different if a large energy shock were to hit the economy with no warning, as happened in the oil crisis of 1973-74, when the real money supply, output and employment all contracted sharply. In addition to hitting with no warning, the oil shocks of the 1970s also entailed large transfers from the U.S. and other oil-importing countries to OPEC, thus depressing real income and spending in the former. A self-imposed shift in the relative price of carbon-intensive energy to address global climate change, on the other hand, need not entail such a transfer of purchasing power. Thus there are critical differences between the oil price shocks and the effort to reduce carbon emissions. Our reassuring conclusion regarding aggregate output might also be different if the policy were to be implemented inefficiently (by command-and-control style regulations of the sort put in place in

that oil crisis) rather than efficiently (by market mechanisms of the sort that the President has proposed to use).

Consider for a moment the ability of U.S. industry to evolve to changes when there is sufficient lead time. [SO2 EXAMPLE to be added shortly]

VIII. The Foregoing Estimates Are Conservative in That They Do Not Yet Include Several Factors

I should emphasize that the estimates I have presented are conservative in three very important ways: sinks, technology, and climate change benefits. The first omission, sinks, concerns a provision of the Kyoto Protocol that has received less attention than it merits. It is only *net* emissions -- emissions to the atmosphere minus sequestration -- that are to be reduced 7 percent below 1990 levels, not gross emissions. The United States plants many trees every year, and would receive credit for this activity under the Protocol. Very preliminary estimates of the implications for the United States of the Kyoto provision on sinks reduce the resource cost by to 17 per cent. This brings resource costs down to \$15-\$18 billion, depending on whether we count in no LDC participation at all or we count the benefits of joint implementation through the Clean Development Mechanism (as currently agreed to in the Kyoto Protocol). **These numbers translate into net costs of __ and energy prices of __.** If we get the full participation of LDCs, the costs come down further.

Even those estimates for the effect of sinks are conservative in one respect: they are based on an assumption for sink activity in the U.S. over the 2008-2012 period, and no assumed benefits from sinks elsewhere in the world. Very preliminary estimates suggest that incorporating the gains from sinks *throughout the world* can reduce the costs of meeting the Kyoto target by half or more, on top of the gains from trading among Annex I countries. (Furthermore, no model has yet even tried to take into account that government policies can help increase the amount of tree-planting, possibly through some version of the Conservation Reserve Program, for example.) But neither we nor other analysts are yet sure exactly how to interpret the legal language of the Protocol. Because the quantitative uncertainty is so large, we do not yet have an estimate with which I feel comfortable. But we do know that the effect of fully modelling the Kyoto provision on sinks is likely to be both favorable and large.

The estimates I have cited so far also make little allowance for the payoff to the President's \$6.3 billion Climate Change Technology Initiative. The parameter that figures most prominently in analysis of technological progress in the energy field is the rate of improvement in the so-called Autonomous Energy Efficiency Index (AEEI), that is the rate at which the total use of energy falls relative to GDP. In the analysis on which the numbers I have reported to you is based, the AEEI improves by 1.0 percent per year. Reflecting a conservative interpretation of

the 15-year impact of the technology initiative, this is only a small increase above the number in the Energy Information Administration's Annual Energy Outlook.

The logic with which one could justify such an assumption would be somewhat analogous to the rationale behind the macroeconomic assumptions that we feed into our budget forecasts: in the presence of uncertainty, we are conservative in our estimates of the speed with which the economy will grow, tax receipts will rise, and the budget will improve. That way, any revisions or surprises that occur are likely to be in the pleasant direction. The nature of the conservatism here would be that we assume in our modeling that, because of lags, most of the payoff from new technology research and dissemination expenditures (as opposed to those in the past) comes after 2012.

If the Administration is successful in speeding the discovery and adoption of new technologies, the rate of improvement in energy efficiency could rise. As a second example, we therefore report results assuming that the AEEI parameter is boosted to 1.25 percent. This has the effect of reducing resource costs by 26 - 27 per cent, to \$13 to \$16 billion, again depending on whether we count no LDC participation at all or count the benefits of joint implementation. **These numbers translate into net costs of __ and energy prices of __.** If we were to get the full participation of some LDCs, the costs would again come down further.

This "technology case" is far from the most optimistic outcome that might occur. Some experts in the technology of climate change policy forecast more rapid technological progress. Estimates coming from engineering models predict even higher rates of AEEI improvement, and thus even lower costs.

The third, and most important, respect in which the estimates I have presented are conservative is that they leave out the benefits of mitigating climate change itself. A full cost-benefit analysis would include mitigation in the benefits column. The only reason we have not done so, as I have explained repeatedly above, is the difficulty in coming up with a number to capture the monetary benefits. But I trust that nobody will lose sight of our ultimate objective -- keeping our planet the hospitable home that we enjoy today.

CONCLUSION

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

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

key role in designing policies in this area.

I welcome your questions.

**TESTIMONY OF DR. JANET YELLEN
CHAIR, COUNCIL OF ECONOMIC ADVISERS
BEFORE THE SENATE FOREIGN RELATIONS COMMITTEE
ON THE ECONOMICS OF THE KYOTO AGREEMENT
FEBRUARY 11, 1998**

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

The international agreement that was reached in Kyoto this past December is a crucial first step in addressing global climate change. But it is only a first step. Since the international effort to reduce greenhouse gas emissions is more of a work-in-progress than a completely finished product, it is not yet possible to provide a full authoritative analysis of it. Many of the specifics in several crucial areas are not completely resolved in the diplomatic arena, forcing analysts to make a variety of assumptions about the ultimate form of the international regime. In my testimony today, I will attempt to identify the key elements of the agreement that ensure that reductions in global greenhouse gas emissions are consistent with continued strong economic growth. I will do my best also to provide some rough estimates of costs and benefits.

The Administration is strongly committed to ensuring that these critical elements -- including global participation and a reliance on flexible, market-based mechanisms -- are reflected in our domestic and international climate change policies. We are firmly committed to meaningful developing country participation, as well as emissions trading both domestically and internationally. And as you know, the President's FY 1999 budget includes a \$6.3 billion package of tax cuts and R&D over the next 5 years to jumpstart our efforts.

I. Basic Economic Rationale of the Kyoto Treaty

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

The earth's surface is warming from the accumulation of greenhouse gases from myriad sources worldwide. None of these emitters presently pays the cost to others of warming's adverse effects -- a classic externality in the language of economists. As a result of these distorted incentives, disruption of the Earth's climate is likely to proceed at an excessive pace and if left uncontrolled may pose substantial costs in terms of disruption to commerce and the environment alike. The fundamental economic logic of the Kyoto agreement is thus that

without such an international agreement, individual nations will not have the proper incentives to address the threats from global climate change.

II. Costs of Climate Change

In evaluating efforts to address climate change, the first step is to consider the costs that are likely if we fail to take any action -- for these costs provide the primary motivation for reducing greenhouse gas emissions. What, then, are the costs associated with allowing global climate change?

The Intergovernmental Panel on Climate Change (IPCC) jointly established by the World Meteorological Organization and the United Nations Environment Programme, concluded in 1995 that "the balance of evidence suggests that there is a discernible human influence on global climate." Current concentrations of carbon dioxide, methane, nitrous oxide, and the other so-called greenhouse gases have reached levels well above those of preindustrial times. Of these, carbon dioxide (CO₂) is the most important: net cumulative CO₂ emissions resulting from the burning of fossil fuels and deforestation account for about two-thirds of potential warming from changes in greenhouse gas concentrations related to human activity.

Climatic Impact

If growth in global emissions continues unabated, the atmospheric concentration of CO₂ will likely double relative to its preindustrial level by midway through the next century. As a result of the increased concentration of CO₂, the IPCC estimates that global temperatures will increase by between 2.5 to 6 degrees Fahrenheit in the next 100 years, with a best guess of about 3.5 degrees Fahrenheit. While scientists believe that human activities are leading to a gradual warming of the *average* temperature of the earth, the change in temperature in a given region at a given time may differ substantially from this average. Indeed, models predict warming will be greater in high latitudes than in the tropics, and greater over land than ocean. Many models predict larger increases in evaporation than in precipitation over midlatitude land areas, which would result in drier conditions in those regions, especially during summer in North America and Europe.

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

Economic and Monetary Damages

The derivation of quantitative or monetary estimates of the damages from such climate changes is extremely difficult given the capacity of today's forecasting models. Estimates of the economic damages from climate change fall into the following broad areas: agriculture, sea-level rise, air conditioning and heating, water supply, human life and health, air pollution, and other costs (hurricanes, migration costs, human amenity, construction, leisure activities, urban infrastructure, and ecological damages such as forest loss and species loss).

A subject of great uncertainty and sensitivity is the "discount rate" that is applied to the benefits of averting future climate change. Such a discount rate is needed if the analysis is to be expressed in monetary terms, because a dollar today is not worth the same as a dollar tomorrow. And since the benefits of stemming future climate change accrue over not only decades but centuries, small changes in the discount rate can produce substantial changes in the results. But the precise discount rate that should be used to evaluate questions as important as the future climate of the planet remains a subject of intense debate. It is safe to say that there is, as of yet, no professional consensus on the issue.

A similar point concerns risk aversion. To what extent are we willing to take chances with our planet? The point applies particularly to catastrophe scenarios. Scientists have thought of many possible scenarios, most of which they are fortunately not yet prepared to pronounce as particularly likely based on current evidence, but which might be truly catastrophic for the planet if they were to occur. There is a strong argument for the Kyoto agreement as a form of planet insurance. But what numerical weight should one assign to these catastrophic risks? In other words, what is the value of the insurance policy? It is difficult for an economist, or anyone, to know.

Despite these shortcomings and potential problems, respected researchers have developed estimates of the monetary damages expected from an average worldwide temperature increase of approximately 4.5 degrees Fahrenheit (corresponding to, roughly, a doubling of pre-industrial carbon dioxide concentrations). For example, William Cline, then a Senior Fellow at the Institute for International Economics, estimated that such a temperature change would impose annual damages of more than \$70 billion per year on the U.S. economy in today's terms. These damages include \$22 billion in lost agricultural production, \$13 billion in additional electricity costs, and \$8 billion in new costs to maintain the existing supply of fresh water. (Cline's original estimates are quoted in 1990 dollars. The figures given above translated those numbers into 1997 dollars using the annual GDP price index.) William Nordhaus of Yale University has likewise computed estimates of the dollar loss attributable to a doubling of carbon dioxide concentrations. He finds that the Cline estimate is in the center of three estimates for the U.S., and that the high estimate is only 1.3 times greater than the low estimate.

It must be noted, however, that this similarity of aggregate estimates masks the true uncertainty associated with forecasts of the damages from given increases in global warming --

the estimates are all fundamentally based on extrapolations from current and past experience, and may not fully incorporate effects that will unfortunately become apparent only with future experience. In particular, the estimates may not fully reflect potential non-linearities in the relationships between carbon dioxide concentrations and temperature, between temperature and economic damages, or in the various other complicated relationships governing interactions between greenhouse gas emissions, the climate, and the economy. Current quantitative analyses do not, and cannot, accurately reflect the small and unknown possibility of large-scale and potentially irreversible discrete events with potentially catastrophic consequences.

Two such possibilities serve as illustrations. Warming of Northern tundra may release very large amounts of methane from the subarctic permafrost, thereby leading to potentially devastating acceleration of an otherwise controllable global warming process. We do not know at what point, if any, such unstable activity would be triggered. Second, evidence from climate models suggests that some types of climate change may lead to displacement of the Gulf Stream that warms Western Europe. Evidence from ocean core samples suggests that such reversals of ocean currents have occurred in previous ice ages. Reductions in the risk of such catastrophic outcomes must be considered in addition to the costs and benefits that can be reasonably quantifiable. Since human beings are typically averse to risk, such possibilities are especially important in evaluating whether the benefits of a particular climate control policy justify the costs. **One must have at least some sympathy with those who criticize economists on the grounds that the effects of climate change are extremely difficult to quantify in a single monetary number.**

III. Addressing Global Climate Change in an Efficient Manner

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

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

Need for Global Action

Climate change is a global problem requiring a global solution. As I mentioned earlier, no single country has an incentive to reduce emissions sufficiently to protect the global environment against climate change. Each has an economic incentive to “free ride” on the efforts of others. Even if the United States sharply reduced its emissions unilaterally, greenhouse gas emissions from all other countries would continue to grow, and the risks posed by climate change would not be significantly abated. It is important to emphasize that emissions of different gases anywhere in the world have very similar effects on global climate.

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

To address the lack of progress among many industrialized countries toward meeting the Rio objective, the United States and approximately 160 other nations agreed in negotiations held in Kyoto, Japan, last December, to take substantial steps to stabilize atmospheric concentrations of greenhouse gases. The Kyoto Agreement, which requires the advice and consent of the Senate, would place binding limits on industrial countries' emissions of the six principal categories of greenhouse gases: CO₂, N₂O, methane, sulfur hexafluoride, perfluorocarbons, and hydrofluorocarbons. **These limits apply to the 38 so-called Annex I countries, which are the industrialized countries, defined to include Russia, Ukraine, and most Eastern European countries.**

Under the Kyoto agreement, each industrial country's “1990 baseline” is actually based on its 1990 emissions of CO₂, methane, and N₂O and its choice of 1990 or 1995 levels of the other three categories of gases. The United States agreed to a target of 7 percent below 1990 levels by the period between 2008 and 2012. To meet that target, net U.S. emissions of greenhouse gases -- all emissions minus removals of CO₂ by certain forestry-related activities -- must average no more than 1,484 million metric tons of carbon equivalent per year during that period. The targets for the European Union and Japan are 8 percent and 6 percent below 1990 levels, respectively. Australia, New Zealand, Norway, Russia and Ukraine all have limits somewhat less ambitious when phrased as cuts relative to

their 1990 levels. In sum, over the period from 2008 to 2012, the industrial countries are expected to reduce their average emissions of greenhouse gases to about 5 percent below their 1990 levels.

The President has made clear that his support of the Kyoto Agreement is dependent on meaningful participation from key developing countries (who are not included in Annex I). The President has also made clear that he will not submit the treaty to the Senate without such participation.

There are several reasons why meaningful participation from developing countries is essential. First, developing countries are projected to contribute a majority of total emissions by 2030 under a continuation of business-as-usual. Without the participation of developing economies, emissions reductions by the industrialized countries will therefore not achieve necessary protection from climate change. Indeed, if developing countries do not participate in the international regime, their emissions could potentially increase by *more* than under their business-as-usual baselines. One mechanism for such an unintended consequence is as follows.

As Annex I countries comply with their targets, their demand for oil will fall, which will probably work to reduce the price of oil on world markets, and perhaps to encourage non-participating countries to use more oil and emit more carbon than they otherwise would have.

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

Third, principles of basic fairness suggest all countries should do their part, depending on their ability to contribute to the solution. Thus even poor countries should contribute, although the existence of more pressing social needs in such countries will inevitably limit the magnitude of their contributions.

So far I have not mentioned the word "competitiveness." One of the difficulties in analyzing concerns related to competitiveness is that the term itself is used to mean many different things. I have seen at least one study that uses "loss of competitiveness" to refer to predictions of negative effects on the *aggregate* trade balance. As a professional economist, I do not accept the logic upon which that particular argument is predicated: the aggregate trade

balance is determined by macroeconomic forces -- the difference between saving and investment -- and not by our environmental policies.

On the other hand, if competitiveness refers to adverse effects on a few specific manufacturing industries -- those that are especially energy-intensive, such as aluminum, paper, and chemicals -- the situation may be more complicated. It is difficult to undergo a significant structural change in the economy without having the effect of expanding some sectors and contracting others. But to provide some perspective on this issue, consider the following facts. First, on average, energy constitutes only 2.2 percent of total costs to U.S. industry. Second, energy prices already vary significantly across countries. According to the *1997 Statistical Abstract*, for example, in 1996 premium gasoline cost \$1.28 per gallon in the United States -- but only 8 cents in Venezuela. Yet U.S. industry is not moving en masse to Venezuela. Third, roughly two-thirds of all emissions are not in manufacturing at all, but in transportation and buildings. I therefore believe it more accurate to say that we need developing country participation for the reasons I outlined above, than to say that we need it to avoid adverse effects on competitiveness.

Flexibility and Market Mechanisms

A global solution is thus critical to the global problem of climate change. Globalizing the solution is not, however, enough by itself. We must also ensure that our efforts achieve their objectives in the most efficient manner possible. The nature of the climate change problem suggests some methods to lower costs of achieving given levels of environmental protection. Such methods have long been championed by economists interested in increasing the efficiency of protection. They were the sort of thing that 2,600 economists had in mind last year when they signed a letter, urging action on climate change:

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

What are these methods and policies? They can be characterized in terms of three categories of flexibility: (1) “when” flexibility; (2) “what” flexibility; and (3) “where” flexibility, which may be the most important of all.

1. “When flexibility” (timing)

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

The Kyoto Protocol incorporates this principle of “when flexibility” in four ways:

- First, the cuts to be made in the first period are less severe, and the first period ends much later, than what had been proposed by many other countries, most notably the Europeans. By adopting a gradual and credible path of reductions in the early years, we can greatly reduce costs such as those from prematurely scrapping coal-fired electricity plants still in the prime of their operating lives, while attaining the same ultimate environmental goals.
- Second, under the Kyoto agreement, the emissions target is not specified in terms of a specific year, but rather in terms of an average over a five-year period (2008-2012). Averaging over five years, instead of requiring countries to meet a specific target each year, can lower costs, especially given an uncertain future. The averaging can smooth out the effects of short-term events such as fluctuations in the business cycle and energy demand, or hard winters and hot summers that would increase energy use and emissions.
- Third, there is allowance for “banking” emission reductions within the 2008-2012 commitment period, for use in a subsequent commitment period [although the emission targets of the next period have not yet been specified].

2. “What flexibility” (gases and sinks)

The second type of flexibility is “what flexibility”, along two dimensions. The first is the inclusion in the agreement of all six greenhouse gases. Emissions of different kinds of gases, not just carbon dioxide, contribute to the greenhouse effect. Since the IPCC has developed conversion factors for all greenhouse gases by estimating their global warming potentials, reductions in emissions of one pollutant can be used to substitute for increases in emissions of another by an amount that has equivalent environmental effects. The Kyoto Protocol stipulates that countries with binding targets are expected to reduce their *total* greenhouse gas emissions by certain percentages, but does not require specific reductions for specific gases. Since a molecule of sulfur hexafluoride is 23,900 times more potent over 100 years than a molecule of CO₂, it may be cheaper to achieve the same environmental benefit by eliminating one molecular unit of SF₆ than nearly 24,000 units of CO₂.

Some initial rough analysis indicates that a strategy of reducing non-CO₂ greenhouse gases by *more* than 7 percent below their 1990/1995 baseline levels while reducing CO₂ by *less* than 7 percent below its 1990 level could reduce greenhouse gas emission permit prices by more than 10 percent. [This analysis is based on the integrated SGM/non-CO₂ cost curve.] Thus allowing countries flexibility in what gases they reduce -- essentially trading emissions reductions across gases -- can help lower significantly the costs of meeting their targets.

The second source of “what flexibility” is the treatment of sinks, i.e., land use activities that promote the removal of carbon from the atmosphere through the growth of plants.

Promoting such sinks through afforestation and reforestation may reduce atmospheric concentrations of CO₂ at much lower costs than reducing emissions of greenhouse gases.

3. "Where flexibility" (international)

The third type of flexibility, and perhaps the most important, is "where flexibility" (international). As I have already emphasized, emissions have the same environmental consequences regardless of where in the world they occur. Therefore, the least-cost approach to controlling climate change is to reduce emissions wherever such reductions are cheapest. The Kyoto agreement includes two important cost-saving provisions of this nature. First, it provides for industrial countries to trade rights to emit greenhouse gases with each other. This market in emissions permits will ensure that emission reductions occur where they are least expensive within the industrial countries. In particular, U.S. companies could purchase emissions reductions in other participating countries when doing so would reduce their costs -- lowering costs without affecting the level of environmental protection.

Second, the agreement allows industrial countries to invest in "clean development" projects in the developing world and use these projects' certified emissions reductions toward meeting their targets. Many such clean-development projects may be quite cheap in terms of the cost per ton of emissions avoided, as has been illustrated by the joint implementation pilot program that is already in place in the U.S. Details of these provisions will be worked out in negotiations in Buenos Aires later this year.

IV. Difficulties of Economic Analysis of Kyoto Agreement

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

The difficulties associated with economic analysis of climate change fall into three broad categories. First is the uncertainties that still remain over the terms of the ultimate treaty. Second is the inherent limitations of available models to analyze even short-term costs and benefits. And finally is a topic I discussed earlier: the impossibility of putting a single monetary number on the long-term benefits of climate change mitigation.

Uncertainties over Certain Provisions in International Effort to Combat Climate Change

The Kyoto Agreement was an historic accomplishment, delineating the broad terms of

the international effort to address climate change. But although we know a lot more than we did before Kyoto about how that international system will work, there is still much that we don't know.

First, as is often the case in a legal document of the length and complexity of the Kyoto Protocol, there are some provisions that require further clarification and interpretation. Of particular concern here is the treatment of so-called sinks -- activities that affect the rate at which carbon is removed from the atmosphere and "sequestered," specifically by the planting of trees.

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

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

Inherent Limitations of Models

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

One area in which the uncertainty is particularly large is the pace of technological progress -- including diffusion of existing energy-efficient technologies, as well as research and development of new technologies -- and the extent to which the pace will accelerate in response to government programs. Economics does not offer a good understanding of how technological progress is determined, in part because it is the stuff of experimentation, brainstorming, genius, breakthroughs, perceptions and habits. Invention is largely determined by inspiration -- notwithstanding Edison, who assigned a 99 percent share to perspiration -- and inspiration, in my

experience, is difficult to fit into mathematical formulae or economic models. Models and experts on climate change policy tend to have a wider range of disagreement on the speed with which technology can be changed than on any other single issue.

Furthermore, each model has strengths and weaknesses; each has questions to which it is better or worse suited to answer. Some, for example, model the energy sector in detail. Some allow for the fact that a coal-fired power plant cannot costlessly be converted to one that runs on natural gas. Some have enough policy detail to distinguish alternative ways of redistributing revenues that would result if emission permits were to be auctioned. Some are capable of showing short-term macroeconomic disequilibria. Some include a long-term "carbon cycle" model that can keep track of the accumulation of greenhouse gas concentrations in the atmosphere and their climatological effects. Some break down the rest of the world into regions and so can model international trade. No one model does everything, and therefore we must not rely blindly on the results of any one model or set of models. Professional judgement and economic intuition are also crucial.

Benefits of Averting Climate Change

As I discussed above, it is evident that the benefits of averting climate change are potentially immense. But I have chosen not to try to quantify them in monetary terms for you, in light of the difficulties I have enumerated -- including the quantitative uncertainty of these benefits, and their timing and therefore the extreme sensitivity of the results to the chosen discount rate.

Instead, what I will do is draw upon a variety of sources in an attempt to add up the various possible costs and benefits of emissions policy *excluding* climate change. To give away the punch line, my conclusion is as follows: the net costs of our policies to reduce emissions are likely to be small, if those reductions are undertaken in an efficient manner, *even before taking into account the benefits of averting climate change itself*. That small net premium excluding the benefits of mitigating climate change, in effect, purchases a partial insurance policy against the threat.

V. Models of the Kyoto Agreement

The existence of modeling difficulties means that the results from any model must be treated with caution. We have employed a broad set of economic tools available to analyze the policy options. Such tools include models of the energy sector and economy over the next 25 years, including but not limited to the results of the Stanford Energy Modeling Forum exercises, the IPCC's review of the economic and social dimensions of climate change, and the staff-level Interagency Analytical Team effort last year. Other tools include simple relevant statistics, "meta-analyses" of existing models, historical and sectoral examples, and basic economic reasoning. Drawing on this broad array of analytical tools is crucial to an intelligent evaluation of the policy alternatives.

To my knowledge, as of December, no model -- whether used inside the government or not -- had been set up precisely to analyze the parameters of the agreement that was reached in Kyoto. Most model-builders outside the government tend to take as long as several years to incorporate changes in policy parameters into their models. And no model is currently designed to assess sinks, or all six greenhouse gases included in the treaty.

One of the leading models in the field is the Second Generation Model of Battelle Laboratories. The SGM is one of the models best positioned to analyze the role of international trade in emission permits, which we consider to be a critical element of the Kyoto Treaty. I would therefore like to share with you some preliminary analyses based on the SGM model that have been developed over the past two months to reflect what was agreed to in Kyoto. To do so, several modifications to the original SGM results are necessary. For example, the SGM does not cover all six gases included in the Kyoto agreement. We therefore integrated the SGM model results with cost analyses of the other gases by EPA.

Mindful of the limitations that any one model has, however, I am eager to see the Kyoto parameters fed into other models, to get a better feel for the range of possible effects. Much of this work will continue to go on outside the government. For example, we have had discussions with the Energy Modeling Forum, based at Stanford University. The EMF is a long-running exercise involving many of the leading climate models. We have given the EMF advice on how features of the Kyoto legal language can be translated into terms recognizable to an economist. Unfortunately, the Energy Modeling Forum believes that its members will need at least until mid-year to produce reliable results.

VI. Economic Analysis

With all of that as important background, let us now turn to the task at hand. As we do so, let me emphasize once again that the figures presented below do not incorporate the benefits of starting to mitigate climate change.

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

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

obligations in the longer term.

The first such step is the inclusion in this year's budget of an aggressive, \$6.3 billion program of tax cuts and R&D -- \$1.3 billion more than the \$5 billion package the President promised in his October 22 speech on this issue. The goal is both to stimulate the development of new energy-saving and carbon-saving technologies and to encourage the dissemination of those that exist already. The proposed package contains \$3.6 billion over the next 5 years in tax cuts for energy efficient purchases and renewable energy, including tax credits of \$3,000 to \$4,000 for consumers who purchase highly fuel efficient vehicles, a 15 percent credit (up to \$2,000) for purchases of rooftop solar equipment, a 20 percent credit (subject to a cap) for purchasing energy-efficient building equipment, a \$2,000 credit for purchasing energy-efficient new homes, an extension of the wind and biomass tax credit, and a 10 percent investment credit for the purchase of combined heat and power systems. The package also contains \$2.7 billion over the next 5 years in additional research and development spending -- covering the four major carbon-emitting sectors of the economy (buildings, industry, transportation, and electricity), plus carbon removal and sequestration, Federal facilities, and cross-cutting analyses and research. One example of the R&D effort is the Partnership for a New Generation of Vehicles (PNGV). PNGV is a government-industry effort to develop attractive, affordable cars that meet all applicable safety and environmental standards and get up to three times the fuel efficiency of today's cars. In FY99, the combined proposal for PNGV is \$277 million, up from \$227 million appropriated in FY98. Similar government-industry efforts are proposed to develop more efficient diesel engines for both light trucks and heavy trucks. [ADD SOMETHING MORE ABOUT INDUSTRY-GOVERNMENT DIALOG. PERHAPS A CONCRETE EXAMPLE OF IDENTIFYING AN INDUSTRY REGULATION THAT COULD BE REMOVED.]

The second such step is the promotion of an environmentally-responsible electricity restructuring bill, which the President identified as part of his domestic climate change package in his address to the National Geographic Society on October 22. An electricity sector freed from government regulation would be a more efficient energy sector. Costs to consumers would fall. A reasonable overall estimate of the effects of adding federal electricity restructuring to the rest of the President's program to address climate change is to achieve the same environmental goals at a cost saving of roughly \$16 billion per year.

Estimated Reduction in Costs from Annex I Trading

In the language of the treaty, "Annex I," you will recall, is the set of countries that have agreed to take on binding limitations in emissions of greenhouse gases. Even without developing country participation -- which, again, the President has emphasized as essential before the treaty could be ratified -- costs can be reduced substantially by trading among the Annex I countries. To provide some indication of the possible efficiency improvements, Russia and the Ukraine consume six times as much energy per dollar of output as does the United States.

The estimate derived from the SGM model is that, under certain base-case assumptions,

trading among Annex I countries reduces the cost to the United States of achieving its targets for 2008-2012 emissions by about half relative to a situation in which such trading was not available.

This concept of costs is meant to capture aggregate resource costs to the US economy, including the cost to domestic firms of purchasing emission permits from Russia and other countries where emission reductions are cheaper than in the United States. The dramatic reduction in costs available from Annex I trading within the SGM model -- cutting by half the costs involved -- highlights why the President insisted that international trading be part of the Kyoto Agreement.

A useful rough check on this estimate can be obtained from other model[s], notwithstanding that they are likely to be more distant approximations to the parameters of the Kyoto Treaty. The G-cubed model, for example, shows that trading among Annex I countries reduces overall costs by roughly 20 percent [CHECK]. [The G-cubed model is better designed than most to analyze trading of permits in a system where the usual international trade in goods and services is also important.] Twelve leading models that participate in the Stanford Energy Modeling Forum show that trading among industrialized countries reduces estimated costs -- defined as lost consumption -- by an average of 56 percent, although the results vary from model to model.

Estimated reduction in costs from umbrella trading

One possibility that emerged in Kyoto, which none of us foresaw, was the idea that the United States might undertake trading with a subset of Annex I countries, dubbed the "umbrella," that would exclude the European Union. The initial list of proposed participants in the umbrella includes the United States, Australia, Canada, Japan, New Zealand and Russia, with strong indications of interest from some others. The motivation for this idea was that the Europeans have been reluctant to agree to the sort of international trading that we want (preferring that they achieve their goals collectively in a group of their own, called the "EU bubble").

It is too early to say whether the umbrella concept will in fact be accepted by the parties. But it is an important concept to consider, for three reasons. First, it is conceivable that it will be formally agreed to in future negotiations. Second, even if the final treaty does not explicitly include the umbrella, but rather allows trading among all signatories (as the United States has proposed all along), it is conceivable that umbrella countries will agree, outside the treaty, to trade only among themselves. Third, the aversion toward international trading that the Europeans have expressed suggests that they might refrain from making the trades to which they would be entitled -- which would mean that the umbrella would operate in practice, if not in formal international agreement.

The significance of the umbrella idea in the present context is that it has the potential to further reduce costs to the United States. The reason is that if the Europeans are not bidding against us for the cheap emission rights that the Russians and other Eastern Europeans have to

sell, then the price will be even lower. The SGM results suggest that, relative to the situation in which there is no trading at all, the umbrella arrangement would reduce costs by an estimated 61-75 per cent, depending on whether the former Warsaw Pact countries are classed with the EU, or are instead assumed to fall within the umbrella. Thus, the umbrella arrangement raises the benefit to international trading significantly relative to full Annex I trading, reducing costs from roughly half their no-trading level to as low as one-quarter their no-trading level.

Estimated reduction in costs from LDC participation

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

A moderate version of developing country participation is the Clean Development Mechanism, modelled after Joint Implementation (JI). JI cannot realistically be expected to yield all the gains of binding targets for developing countries, but it might shave costs by roughly another 20 to 25 percent from the reduced costs that result from trading among Annex I countries.

Another possibility is that we persuade some of the key developing countries that are the largest emitters to commit to targets, and allow us to buy emission reductions from those paths. The model estimate is that this would cut roughly 55 percent off the reduced costs that result from Annex I trading. [The four countries included in this particular estimate are China, India, Brazil and Korea.] Once these savings have been attained, the estimated reductions to US costs from persuading the rest of the developing world to go along with full commitments are relatively small.

I offer these numbers because they show the potential effectiveness of trading in reducing costs dramatically. But it is important that I repeat three caveats: First, as always, there is a wide range of uncertainty around all these estimates. Second, they apply to an idealized version of trading, one that assumes no problems of enforcement or transactions costs. Third, it seems unlikely that we will get all our partners to agree in Buenos Aires to the very most optimistic or ambitious case. Nonetheless, despite these caveats, the numbers do show major savings even without getting the most optimistic case. And if we don't get enough of what we want, we won't submit the treaty for ratification to the Senate.

VII. Non-Climate Benefits

The costs of undertaking greenhouse gas emission reductions must be compared to the benefits. As I have indicated, for various reasons our analysis does not quantify the benefits from averting climate change itself. But the relative price shifts that are necessary to reduce emissions should produce benefits in three areas: air pollution, traffic congestion, and highway

accidents. These benefits are quantifiable.

Reductions in carbon emissions also lead to reductions in emissions of pollutants that contribute to excess concentrations of fine particulate matter and low-level ozone.

[FORTHCOMING, PENDING ANALYSIS FROM EPA and LUTTER.]

Traffic congestion hurts motorists by causing delays and inconvenience. More efficient pricing -- which recognizes the externalities involved -- should lead to reductions in congestion as motorists choose other means of travel, share rides, or even forgo less important trips. . We estimate that higher fuel prices resulting from carbon permit prices of \$20/ton will reduce travel delays associated with congestion, and that the value of such time savings to consumers would be about \$0.4 billion per year.

Vehicle use also leads to costly accidents and to highway injuries including fatalities. Assuming that accidents fall proportionately with vehicle use, more efficient pricing will also create savings from reduced accidents and resultant mortality. The savings from reduced accidents and the value of reduced mortality risk is approximately \$0.3 to \$2.7 billion/ year [depending on whether lighter cars are less crashworthy] given a \$20/ton carbon price.

A variety of other benefits that are harder to quantify are likely to result from reductions in carbon emissions. With respect to transportation, reduced vehicle use will also reduce the cost of road repair and maintenance. Second, reduced coal use will reduce the cost of sulfur dioxide controls, as utilities switch to energy sources other than coal. Reduced coal use will also lower mercury emissions. Finally, reduced energy use will also increase U.S. energy independence. Our inability to estimate these effects quantitatively does not imply that they are necessarily small or unimportant.

VIII. Estimated Net Effects For One Illustrative Case

We can now combine the various benefits and costs delineated above. By way of summary, it may be helpful to focus on an illustrative case. We consider the case of trading under the umbrella, together with full participation by four key LDCs. In this case, adding together the estimates derived from the SGM and other sources suggests that the resource costs of attaining our Kyoto targets for emission reductions are \$7 to \$9 billion. **Thus the net costs are \$_ billion to \$_ billion, or roughly 0.0_ percent of projected GDP** (i.e., net of ancillary non-climate benefits, predicted from a permit price of \$12-\$16 per ton, depending on which umbrella definition is used).

A more tangible measure of costs is the estimated effects on energy prices. Again excluding the impact of electricity restructuring, the SGM-based estimate is that the price of emissions would be in the range \$12 to \$16 per ton of carbon equivalent -- and that energy

prices at the household level would rise by about 3 percent under the Kyoto accords [CHECK].

Fuel oil prices would rise by about 5 percent, natural gas prices by 4 percent, gasoline prices by 3 percent, and electricity prices by 2 percent. The 3 percent increase in energy prices at the household level would raise the average family's energy bill by about \$75.

These estimates do *not* mean that households' energy expenses will in fact be higher in 2010 than today, however. In the first place, energy prices fluctuate year-by-year for all sorts of reasons. They could go either up or down. But even if we leave out unpredictable fluctuations, the energy price declines from Federal electricity restructuring would be enough to offset the impact estimated above. By 2008-2012, the projected 10 percent decline in electricity prices from the restructuring that is part of our climate change agenda will mean a net reduction in energy prices in the U.S., even accounting for the small increases noted above.

As highlighted earlier, estimates of the type that I am presenting are fraught with uncertainty. The estimate I just discussed was predicated on the developing country participation that we will insist upon in Buenos Aires as a condition for our ratifying the Kyoto Protocol, but which is not yet part of that Protocol. At the same time, the numbers I have cited are in several respects conservative: they leave out several factors, such as the role of sinks, that could further reduce costs. But before I bring these factors into the analysis, allow me to say a few words about macroeconomics.

Effects on employment and aggregate output

So far I have said nothing about job losses resulting from climate change policy. Although there may be job gains in some sectors and job losses in others, I do not anticipate any significant aggregate effect. Some jobs may be lost in energy-intensive sectors, but a large number of jobs will be created in other sectors -- many of them high-tech jobs paying high wages. The President is firmly committed to assisting any workers who are adversely affected during the transition to a climate-friendly economy.

The situation might be different if a large energy shock were to hit the economy with no warning, as happened in the oil crisis of 1973-74, when the real money supply, output and employment all contracted sharply. In addition to hitting with no warning, the oil shocks of the 1970s also entailed large transfers from the U.S. and other oil-importing countries to OPEC, thus depressing real income and spending in the former. A self-imposed shift in the relative price of carbon-intensive energy to address global climate change, on the other hand, need not entail such a transfer of purchasing power. Thus there are critical differences between the oil price shocks and the effort to reduce carbon emissions. Our reassuring conclusion regarding aggregate output might also be different if the policy were to be implemented inefficiently (by command-and-control style regulations of the sort put in place in

that oil crisis) rather than efficiently (by market mechanisms of the sort that the President has proposed to use).

Consider for a moment the ability of U.S. industry to evolve to changes when there is sufficient lead time. [SO2 EXAMPLE to be added shortly]

VIII. The Foregoing Estimates Are Conservative in That They Do Not Yet Include Several Factors

I should emphasize that the estimates I have presented are conservative in three very important ways: sinks, technology, and climate change benefits. The first omission, sinks, concerns a provision of the Kyoto Protocol that has received less attention than it merits. It is only *net* emissions -- emissions to the atmosphere minus sequestration -- that are to be reduced 7 percent below 1990 levels, not gross emissions. The United States plants many trees every year, and would receive credit for this activity under the Protocol. Very preliminary estimates of the implications for the United States of the Kyoto provision on sinks reduce the resource cost by to 17 per cent. This brings resource costs down to \$15-\$18 billion, depending on whether we count in no LDC participation at all or we count the benefits of joint implementation through the Clean Development Mechanism (as currently agreed to in the Kyoto Protocol). **These numbers translate into net costs of __ and energy prices of __.** If we get the full participation of LDCs, the costs come down further.

Even those estimates for the effect of sinks are conservative in one respect: they are based on an assumption for sink activity in the U.S. over the 2008-2012 period, and no assumed benefits from sinks elsewhere in the world. Very preliminary estimates suggest that incorporating the gains from sinks *throughout the world* can reduce the costs of meeting the Kyoto target by half or more, on top of the gains from trading among Annex I countries. (Furthermore, no model has yet even tried to take into account that government policies can help increase the amount of tree-planting, possibly through some version of the Conservation Reserve Program, for example.) But neither we nor other analysts are yet sure exactly how to interpret the legal language of the Protocol. Because the quantitative uncertainty is so large, we do not yet have an estimate with which I feel comfortable. But we do know that the effect of fully modelling the Kyoto provision on sinks is likely to be both favorable and large.

The estimates I have cited so far also make little allowance for the payoff to the President's \$6.3 billion Climate Change Technology Initiative. The parameter that figures most prominently in analysis of technological progress in the energy field is the rate of improvement in the so-called Autonomous Energy Efficiency Index (AEEI), that is the rate at which the total use of energy falls relative to GDP. In the analysis on which the numbers I have reported to you is based, the AEEI improves by 1.0 percent per year. Reflecting a conservative interpretation of

the 15-year impact of the technology initiative, this is only a small increase above the number in the Energy Information Administration's Annual Energy Outlook.

The logic with which one could justify such an assumption would be somewhat analogous to the rationale behind the macroeconomic assumptions that we feed into our budget forecasts: in the presence of uncertainty, we are conservative in our estimates of the speed with which the economy will grow, tax receipts will rise, and the budget will improve. That way, any revisions or surprises that occur are likely to be in the pleasant direction. The nature of the conservatism here would be that we assume in our modeling that, because of lags, most of the payoff from new technology research and dissemination expenditures (as opposed to those in the past) comes after 2012.

If the Administration is successful in speeding the discovery and adoption of new technologies, the rate of improvement in energy efficiency could rise. As a second example, we therefore report results assuming that the AEEI parameter is boosted to 1.25 percent. This has the effect of reducing resource costs by 26 - 27 per cent, to \$13 to \$16 billion, again depending on whether we count no LDC participation at all or count the benefits of joint implementation. **These numbers translate into net costs of __ and energy prices of __.** If we were to get the full participation of some LDCs, the costs would again come down further.

This "technology case" is far from the most optimistic outcome that might occur. Some experts in the technology of climate change policy forecast more rapid technological progress. Estimates coming from engineering models predict even higher rates of AEEI improvement, and thus even lower costs.

The third, and most important, respect in which the estimates I have presented are conservative is that they leave out the benefits of mitigating climate change itself. A full cost-benefit analysis would include mitigation in the benefits column. The only reason we have not done so, as I have explained repeatedly above, is the difficulty in coming up with a number to capture the monetary benefits. But I trust that nobody will lose sight of our ultimate objective -- keeping our planet the hospitable home that we enjoy today.

CONCLUSION

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

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

key role in designing policies in this area.

I welcome your questions.

ADDENDUM. NOT FOR DISTRIBUTION *** SAVE FOR Q AND A**

Q -- Senator Brown: I have seen one study that claims large losses in output and employment from climate change policy [EPI, 8/14/97].

A: But this study is misleading in three important ways. First, it did not in my view take into account the points I have made about the ability of the economy to adjust to structural change with a 15-year warning. In particular, a number of commentators on this specific model have highlighted that this is a model best designed to predict economic impacts in the very near future, two to three years from now, and that it is not useful for long term predictions of this type. Second, the model fully assumes that we “do this dumb”, ignoring the efficiencies from international emissions trading, joint implementation, LDC participation. Third, the model ignores any of the benefits of reducing emissions noted above, as well as any benefits of averting climate change, and it does not embody any technological advance in response to our \$6.3 billion technology package, nor any benefits to the economic from our electricity restructuring proposal. These results are therefore exaggerated and present a misleading portrait of the effects of our climate change plan.

Q -- Senator Red-White-&-Blue: Your solution seems to be to buy all the reductions abroad. I can't see American taxpayers paying foreigners for the right to pollute. What share of reductions is done at home?

A: [Unspoken answer: a lot, in the base case...]
I believe the case where we rely heavily on international trading should be viewed as a safety-net case -- a backup if all else fails. Toward the end of my testimony, I discussed the cases where we make some allowances for the effects of sinks and for the payoff from the President's technology initiative. Under those assumptions, with simple Annex I trading, we can accomplish our Kyoto targets by making half our reductions at home: more precisely 52% in the sinks case and 48 percent in the technology case (or 53 % if we allow for *both* the U.S. sinks and the 1.25 AEEI). [If we allow for JI, then the percent of reductions accomplished at home falls into the 40s.]

Q -- Senator Green: What is the single trading combination that is most advantageous for the United States?

A: That would be an umbrella that excludes the EU, but that otherwise includes full worldwide participation and trading. In this case, admittedly one that is not particularly likely, the

cumulative reduction in costs relative to obtaining all reductions domestically is an estimated 88 percent. (And that's before we count accelerated technology or sinks!)

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RECORD TYPE: PRESIDENTIAL (NOTES MAIL)

CREATOR: Lisa D. Branch (CN=Lisa D. Branch/OU=CEA/O=EOP [CEA])

CREATION DATE/TIME: 5-FEB-1998 18:20:10.00

SUBJECT: Addendum to Testimony

TO: Janet L. Yellen (CN=Janet L. Yellen/OU=CEA/O=EOP @ EOP [CEA])

READ:UNKNOWN

TEXT:

Janet, I have taken three of the paragraphs that we cut from the testimony
and modified them for possible use as answers to questions in Q&A.

Jeff===== ATTACHMENT 1 =====

ATT CREATION TIME/DATE: 0 00:00:00.00

TEXT:

Unable to convert ARMS_EXT:[ATTACH.D97]MAIL47166653L.026 to ASCII,

The following is a HEX DUMP:

ADDENDUM. NOT FOR DISTRIBUTION *** SAVE FOR Q AND A**

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RECORD TYPE: PRESIDENTIAL (NOTES MAIL)

CREATOR: Janet L. Yellen (CN=Janet L. Yellen/OU=CEA/O=EOP [CEA])

CREATION DATE/TIME: 5-FEB-1998 11:36:53.00

SUBJECT: Revised climate change testimony

TO: Randall W. Lutter (CN=Randall W. Lutter/OU=CEA/O=EOP @ EOP [CEA])
READ:UNKNOWN

TO: Joseph E. Aldy (CN=Joseph E. Aldy/OU=CEA/O=EOP @ EOP [CEA])
READ:UNKNOWN

TO: Jeffrey A. Frankel (CN=Jeffrey A. Frankel/OU=CEA/O=EOP @ EOP [CEA])
READ:UNKNOWN

TEXT:

I attach a revised version of my testimony. I am perplexed about how Jeff intended for you to fill in the holes. Let's talk about it. Jeff is off at State, and we need to get this out this afternoon. ===== ATTACHMENT 1
=====

ATT CREATION TIME/DATE: 0 00:00:00.00

TEXT:

Unable to convert ARMS_EXT:[ATTACH.D18]MAIL485724531.026 to ASCII,
The following is a HEX DUMP:

**TESTIMONY OF DR. JANET YELLEN
CHAIR, COUNCIL OF ECONOMIC ADVISERS
BEFORE THE SENATE FOREIGN RELATIONS COMMITTEE
ON THE ECONOMICS OF THE KYOTO AGREEMENT
FEBRUARY 11, 1998**

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

The international agreement that was reached in Kyoto this past December is a crucial first step in addressing global climate change. But it is only a first step. Since the international effort to reduce greenhouse gas emissions is more of a work-in-progress than a completely finished product, it is not yet possible to provide a full authoritative analysis of it. Many of the specifics in several crucial areas are not completely resolved in the diplomatic arena, forcing analysts to make a variety of assumptions about the ultimate form of the international regime. In my testimony today, I will attempt to identify key elements of the agreement, such as global participation and reliance on flexible, market-based measures, that ensure that reductions in global greenhouse gas emissions are consistent with continued strong economic growth. I will do my best also to provide some rough estimates of costs and benefits.

The Administration is strongly committed to ensuring that these critical elements are reflected in our domestic and international climate change policies. We are firmly committed to meaningful developing country participation, as well as emissions trading both domestically and internationally. And as you know, the President's FY 1999 budget includes a \$6.3 billion package of tax cuts and R&D over the next 5 years to jumpstart our efforts.

I. Basic Economic Rationale of the Kyoto Treaty

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

The earth's surface is warming from the accumulation of greenhouse gases from myriad sources worldwide. None of these emitters presently pays the cost to others of warming's adverse effects -- a classic externality in the language of economists. As a result of these distorted incentives, disruption of the Earth's climate is likely to proceed at an excessive pace and if left uncontrolled may pose substantial costs in terms of disruption to commerce and the environment alike. The fundamental economic logic of the Kyoto agreement is thus that

without such an international agreement, individual nations will not have the proper incentives to address the threats from global climate change.

II. Costs of Climate Change

In evaluating efforts to mitigate global warming, the first step is to consider the costs that are likely if we fail to take any action -- for these costs provide the primary motivation for reducing greenhouse gas emissions. What, then, are the costs associated with allowing global climate change?

The Intergovernmental Panel on Climate Change (IPCC) jointly established by the World Meteorological Organization and the United Nations Environment Programme, concluded in 1995 that "the balance of evidence suggests that there is a discernible human influence on global climate." Current concentrations of carbon dioxide, methane, nitrous oxide, and the other so-called greenhouse gases have reached levels well above those of preindustrial times. Of these, carbon dioxide (CO₂) is the most important: net cumulative CO₂ emissions resulting from the burning of fossil fuels and deforestation account for about two-thirds of potential warming from changes in greenhouse gas concentrations related to human activity.

Climatic Impact

If growth in global emissions continues unabated, the atmospheric concentration of CO₂ will likely double relative to its preindustrial level by midway through the next century. As a result of the increased concentration of CO₂, the IPCC estimates that global temperatures will increase by between 2.5 to 6 degrees Fahrenheit in the next 100 years, with a best guess of about 3.5 degrees Fahrenheit. While scientists believe that human activities are leading to a gradual warming of the *average* temperature of the earth, the change in temperature in a given region at a given time may differ substantially from this average. Indeed, models predict warming will be greater in high latitudes than in the tropics, and greater over land than ocean. Many models predict larger increases in evaporation than in precipitation over midlatitude land areas, which would result in drier conditions in those regions, especially during summer in North America and Europe.

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

Economic and Monetary Damages

The derivation of quantitative or monetary estimates of the damages from such climate changes is extremely difficult given the capacity of today's forecasting models. Estimates of the economic damages from climate change fall into the following broad areas: agriculture, sea-level rise, air conditioning and heating, water supply, human life and health, air pollution, and other costs (hurricanes, migration costs, human amenity, construction, leisure activities, urban infrastructure, and ecological damages such as forest loss and species loss).

A subject of great uncertainty and sensitivity is the "discount rate" that is applied to the benefits of averting future climate change. Such a discount rate is needed if the analysis is to be expressed in monetary terms, because a dollar today is not worth the same as a dollar tomorrow. And since the benefits of stemming future climate change accrue over not only decades but centuries, small changes in the discount rate can produce substantial changes in the results. But the precise discount rate that should be used to evaluate questions as important as the future climate of the planet remains a subject of intense debate. It is safe to say that there is, as of yet, no professional consensus on the issue.

A similar point concerns risk aversion. To what extent are we willing to take chances with our planet? The point applies particularly to catastrophe scenarios. Scientists have thought of many possible scenarios, most of which they are fortunately not yet prepared to pronounce as particularly likely based on current evidence, but which might be truly catastrophic for the planet if they were to occur. There is a strong argument for the Kyoto agreement as a form of planet insurance. But what numerical weight should one assign to these catastrophic risks? In other words, what is the value of the insurance policy? It is difficult for an economist, or anyone, to know.

Despite these shortcomings and potential problems, respected researchers have developed estimates of the monetary damages expected from an average worldwide temperature increase of approximately 4.5 degrees Fahrenheit (corresponding to, roughly, a doubling of pre-industrial carbon dioxide concentrations). For example, William Cline, then a Senior Fellow at the Institute for International Economics, estimated that such a temperature change would impose annual damages of more than \$70 billion per year on the U.S. economy in today's terms. These damages include \$22 billion in lost agricultural production, \$13 billion in additional electricity costs, and \$8 billion in new costs to maintain the existing supply of fresh water. (Cline's original estimates are quoted in 1990 dollars. The figures given above translated those numbers into 1997 dollars using the annual GDP price index.) William Nordhaus of Yale University has likewise computed estimates of the dollar loss attributable to a doubling of carbon dioxide concentrations. He finds that the Cline estimate is in the center of three estimates for the U.S., and that the high estimate is only 1.3 times greater than the low estimate.

It must be noted, however, that this similarity of aggregate estimates masks the true uncertainty associated with forecasts of the damages from given increases in global warming --

the estimates are all fundamentally based on extrapolations from current and past experience, and may not fully incorporate effects that will unfortunately become apparent only with future experience. In particular, the estimates may not fully reflect potential non-linearities in the relationships between carbon dioxide concentrations and temperature, between temperature and economic damages, or in the various other complicated relationships governing interactions between greenhouse gas emissions, the climate, and the economy. Current quantitative analyses do not, and cannot, accurately reflect the small and unknown possibility of large-scale and potentially irreversible discrete events with potentially catastrophic consequences.

Two such possibilities serve as illustrations. Warming of Northern tundra may release very large amounts of methane from the subarctic permafrost, thereby leading to potentially devastating acceleration of an otherwise controllable global warming process. We do not know at what point, if any, such unstable activity would be triggered. Second, evidence from climate models suggests that some types of climate change may lead to displacement of the Gulf Stream that warms Western Europe. Evidence from ocean core samples suggests that such reversals of ocean currents have occurred in previous ice ages. Reductions in the risk of such catastrophic outcomes must be considered in addition to the costs and benefits that can be reasonably quantifiable. Since human beings are typically averse to risk, such possibilities are especially important in evaluating whether the benefits of a particular climate control policy justify the costs. One must have at least some sympathy with those who criticize economists on the grounds that the effects of climate change are extremely difficult to quantify in a single monetary number.

III. Addressing Global Climate Change in an Efficient Manner

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

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

Need for Global Action

Climate change is a global problem requiring a global solution. As I mentioned earlier, no single country has an incentive to reduce emissions sufficiently to protect the global environment against climate change. Each has an economic incentive to “free ride” on the efforts of others. Even if the United States sharply reduced its emissions unilaterally, greenhouse gas emissions from all other countries would continue to grow, and the risks posed by climate change would not be significantly abated. It is important to emphasize that emissions of different gases anywhere in the world have very similar effects on global climate.

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

To address the lack of progress among many industrialized countries toward meeting the Rio objective, the United States and approximately 160 other nations agreed in negotiations held in Kyoto, Japan, last December, to take substantial steps to stabilize atmospheric concentrations of greenhouse gases. The Kyoto Agreement, which requires the advice and consent of the Senate, would place binding limits on industrial countries' emissions of the six principal categories of greenhouse gases: CO₂, N₂O, methane, sulfur hexafluoride, perfluorocarbons, and hydrofluorocarbons. **These limits apply to the 38 so-called Annex I countries, which are the industrialized countries, defined to include Russia, Ukraine, and most Eastern European countries.**

Under the Kyoto agreement, each industrial country's “1990 baseline” is actually based on its 1990 emissions of CO₂, methane, and N₂O and its choice of 1990 or 1995 levels of the other three categories of gases. The United States agreed to a target of 7 percent below 1990 levels by the period between 2008 and 2012. To meet that target, net U.S. emissions of greenhouse gases -- all emissions minus removals of CO₂ by certain forestry-related activities -- must average no more than 1,484 million metric tons of carbon equivalent per year during that period. The targets for the European Union and Japan are 8 percent and 6 percent below 1990 levels, respectively. Australia, New Zealand, Norway, Russia and Ukraine all have limits somewhat less ambitious when phrased as cuts relative to

their 1990 levels. In sum, over the period from 2008 to 2012, the industrial countries are expected to reduce their average emissions of greenhouse gases to about 5 percent below their 1990 levels.

The President has made clear that his support of the Kyoto Agreement is dependent on meaningful participation from key developing countries (who are not included in Annex I). The President has also made clear that he will not submit the treaty to the Senate without such participation.

There are several reasons why meaningful participation from developing countries is essential. First, developing countries are projected to contribute a majority of total emissions by 2030 under a continuation of business-as-usual. Without the participation of developing economies, emissions reductions by the industrialized countries will therefore not achieve necessary protection from climate change. Indeed, if developing countries do not participate in the international regime, their emissions could potentially increase by *more* than under their business-as-usual baselines. One mechanism for such an unintended consequence is as follows.

As Annex I countries comply with their targets, their demand for oil will fall, which will probably work to reduce the price of oil on world markets, and perhaps to encourage non-participating countries to use more oil and emit more carbon than they otherwise would have.

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

Third, principles of basic fairness suggest all countries should do their part, depending on their ability to contribute to the solution. Thus even poor countries should contribute, although the existence of more pressing social needs in such countries will inevitably limit the magnitude of their contributions.

So far I have not mentioned the word "competitiveness." One of the difficulties in analyzing concerns related to competitiveness is that the term itself is used to mean many different things. I have seen at least one study that uses "loss of competitiveness" to refer to predictions of negative effects on the *aggregate* trade balance. As a professional economist, I do not accept the logic upon which that particular argument is predicated: the aggregate trade

balance is determined by macroeconomic forces -- the difference between saving and investment -- and not by our environmental policies.

On the other hand, if competitiveness refers to adverse effects on a few specific manufacturing industries -- those that are especially energy-intensive, such as aluminum, paper, and chemicals -- the situation may be more complicated. It is difficult to undergo a significant structural change in the economy without having the effect of expanding some sectors and contracting others. But to provide some perspective on this issue, consider the following facts. First, on average, energy constitutes only 2.2 percent of total costs to U.S. industry. Second, energy prices already vary significantly across countries. According to the *1997 Statistical Abstract*, for example, in 1996 premium gasoline cost \$1.28 per gallon in the United States -- but only 8 cents in Venezuela. Yet U.S. industry is not moving en masse to Venezuela. Third, roughly two-thirds of all emissions are not in manufacturing at all, but in transportation and buildings. I therefore believe it more accurate to say that we need developing country participation for the reasons I outlined above, than to say that we need it to avoid adverse effects on competitiveness.

Flexibility and Market Mechanisms

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

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

1. "When flexibility" (timing)

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

The Kyoto Protocol incorporates this principle of "when flexibility" in four ways:

- First, the cuts to be made in the first period are less severe, and the first period ends much later, than what had been proposed by many other countries, most notably the Europeans. By adopting a gradual and credible path of reductions in the early years, we can greatly reduce costs such as those from prematurely scrapping coal-fired electricity plants still in the prime of their operating lives, while attaining the same ultimate environmental goals.
- Second, under the Kyoto agreement, the emissions target is not specified in terms of a specific year, but rather in terms of an average over a five-year period (2008-2012). Averaging over five years, instead of requiring countries to meet a specific target each year, can lower costs, especially given an uncertain future. The averaging can smooth out the effects of short-term events such as fluctuations in the business cycle and energy demand, or hard winters and hot summers that would increase energy use and emissions.
- Third, there is allowance for “banking” emission reductions within the 2008-2012 commitment period, for use in a subsequent commitment period [although the emission targets of the next period have not yet been specified].

2. “What flexibility” (gases and sinks)

The second type of flexibility is “what flexibility”, along two dimensions. The first is the inclusion in the agreement of all six greenhouse gases. Emissions of different kinds of gases, not just carbon dioxide, contribute to the greenhouse effect. Since the IPCC has developed conversion factors for all greenhouse gases by estimating their global warming potentials, reductions in emissions of one pollutant can be used to substitute for increases in emissions of another by an amount that has equivalent environmental effects. The Kyoto Protocol stipulates that countries with binding targets are expected to reduce their *total* greenhouse gas emissions by certain percentages, but does not require specific reductions for specific gases. Since a molecule of sulfur hexafluoride is 23,900 times more potent over 100 years than a molecule of CO₂, it may be cheaper to achieve the same environmental benefit by eliminating one molecular unit of SF₆ than nearly 24,000 units of CO₂.

Some initial rough analysis indicates that a strategy of reducing non-CO₂ greenhouse gases by *more* than 7 percent below their 1990/1995 baseline levels while reducing CO₂ by *less* than 7 percent below its 1990 level could reduce greenhouse gas emission permit prices by more than 10 percent. [This analysis is based on the integrated SGM/non-CO₂ cost curve.] Thus allowing countries flexibility in what gases they reduce -- essentially trading emissions reductions across gases -- can help lower significantly the costs of meeting their targets.

The second source of “what flexibility” is the treatment of sinks, i.e., land use activities that promote the removal of carbon from the atmosphere through the growth of plants. Promoting such sinks through afforestation and reforestation may reduce atmospheric

concentrations of CO₂ at much lower costs than reducing emissions of greenhouse gases.

3. "Where flexibility" (international)

The third type of flexibility, and perhaps the most important, is "where flexibility" (international). As I have already emphasized, emissions have the same environmental consequences regardless of where in the world they occur. Therefore, the least-cost approach to controlling climate change is to reduce emissions wherever such reductions are cheapest. The Kyoto agreement includes two important cost-saving provisions of this nature. First, it provides for industrial countries to trade rights to emit greenhouse gases with each other. This market in emissions permits will ensure that emission reductions occur where they are least expensive within the industrial countries. In particular, U.S. companies could purchase emissions reductions in other participating countries when doing so would reduce their costs -- lowering costs without affecting the level of environmental protection.

Second, the agreement allows industrial countries to invest in "clean development" projects in the developing world and use these projects' certified emissions reductions toward meeting their targets. Many such clean-development projects may be quite cheap in terms of the cost per ton of emissions avoided, as has been illustrated by the joint implementation pilot program that is already in place in the U.S. Details of these provisions will be worked out in negotiations in Buenos Aires later this year.

IV. Difficulties of Economic Analysis of Kyoto Agreement

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

The difficulties associated with economic analysis of climate change fall into three broad categories. First is the uncertainties that still remain over the terms of the ultimate treaty. Second is the inherent limitations of available models to analyze even short-term costs and benefits. And finally is a topic I discussed earlier: the impossibility of putting a single monetary number on the long-term benefits of climate change mitigation.

Uncertainties over Certain Provisions in International Effort to Combat Climate Change

The Kyoto Agreement was an historic accomplishment, delineating the broad terms of

the international effort to address climate change. But although we know a lot more than we did before Kyoto about how that international system will work, there is still much that we don't know.

First, as is often the case in a legal document of the length and complexity of the Kyoto Protocol, there are some provisions that require further clarification and interpretation. Of particular concern here is the treatment of so-called sinks -- activities that affect the rate at which carbon is removed from the atmosphere and "sequestered," specifically by the planting of trees.

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

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

Inherent Limitations of Models

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

One area in which the uncertainty is particularly large is the pace of technological progress -- including diffusion of existing energy-efficient technologies, as well as research and development of new technologies -- and the extent to which the pace will accelerate in response to government programs. Economics does not offer a good understanding of how technological progress is determined, in part because it is the stuff of experimentation, brainstorming, genius, breakthroughs, perceptions and habits. Invention is largely determined by inspiration -- notwithstanding Edison, who assigned a 99 percent share to perspiration -- and inspiration, in my

experience, is difficult to fit into mathematical formulae or economic models. Models and experts on climate change policy tend to have a wider range of disagreement on the speed with which technology can be changed and the scope for speeding diffusion of existing energy-efficient technologies than on any other single issue.

Furthermore, each model has strengths and weaknesses; each has questions to which it is better or worse suited to answer. Some, for example, model the energy sector in detail. Some allow for the fact that a coal-fired power plant cannot costlessly be converted to one that runs on natural gas. Some have enough policy detail to distinguish alternative ways of redistributing revenues that would result if emission permits were to be auctioned. Some are capable of showing short-term macroeconomic disequilibria. Some include a long-term "carbon cycle" model that can keep track of the accumulation of greenhouse gas concentrations in the atmosphere and their climatological effects. Some break down the rest of the world into regions and so can model international trade. No one model does everything, and therefore we must not rely blindly on the results of any one model or set of models. Professional judgement and economic intuition are also crucial.

Benefits of Averting Climate Change

As I discussed above, it is evident that the benefits of averting climate change are potentially immense. But I have chosen not to try to quantify them in monetary terms for you, in light of the difficulties I have enumerated -- including the quantitative uncertainty of these benefits, and their timing and therefore the extreme sensitivity of the results to the chosen discount rate.

Instead, what I will do is draw upon a variety of sources in an attempt to add up the various possible costs and benefits of emissions policy *excluding* climate change. To give away the punch line, my conclusion is as follows: the net costs of our policies to reduce emissions are likely to be small, if those reductions are undertaken in an efficient manner, *even before taking into account the benefits of averting climate change itself*. That small net premium excluding the benefits of mitigating climate change, in effect, purchases a partial insurance policy against a serious environmental threat.

V. Models of the Kyoto Agreement

The existence of modeling difficulties means that the results from any model must be treated with caution. We have therefore employed a broad set of economic tools to assess the Kyoto agreement. We have drawn on the insights of a wide range of models of the energy sector and economy over the next 25 years, including but not limited to the results of the Stanford Energy Modeling Forum exercises, the IPCC's review of the economic and social dimensions of climate change, and the staff-level Interagency Analytical Team effort last year. Other tools include simple relevant statistics, "meta-analyses" of existing models, historical and sectoral

examples, and basic economic reasoning. Drawing on this broad array of analytical tools is crucial to an intelligent evaluation of the policy alternatives.

To my knowledge, as of December, no model -- whether used inside the government or not -- had been set up precisely to analyze the parameters of the agreement that was reached in Kyoto. Most model-builders outside the government tend to take as long as several years to incorporate changes in policy parameters into their models. And no model is currently designed to assess sinks, or all six greenhouse gases included in the treaty.

One of the leading models in the field is the Second Generation Model of Battelle Laboratories. The SGM is one of the models best positioned to analyze the role of international trade in emission permits, which we consider to be a critical element of the Kyoto Treaty. However, the SGM does not cover all six gases included in the Kyoto agreement or include a role for sinks. We have used the SGM model as a starting point for a preliminary assessment of the Kyoto treaty, but have attempted to supplement its results with additional analysis to account for such special features of the agreement as the inclusion of six gases, sinks and a possible Annex I trading that could exclude the EU. I will share with you today some preliminary results of this analysis.

Mindful of the limitations of any single model, we are eager to see features of the Kyoto agreement assessed by other modelers to obtain a better feel for the range of possible effects. Much of this work will continue to go on outside the government. For example, we have had discussions with the Energy Modeling Forum, based at Stanford University. The EMF is a long-running exercise involving many of the leading climate models. We have given the EMF advice on how features of the Kyoto legal language can be translated into terms recognizable to an economist. Unfortunately, the Energy Modeling Forum believes that its members will need at least until mid-year to produce reliable results.

VI. Economic Analysis

With all of that as important background, let us now turn to the task at hand. As we do so, let me emphasize once again that the figures presented below do not incorporate the benefits of starting to mitigate climate change.

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

Within the Kyoto agreement, this means an insistence on international trading, joint implementation, and, ultimately, on full developing country participation. Domestically, this

means that we implement any emissions reductions through a market-based system of *tradeable* emissions permits, which ensures that we achieve reductions wherever they are least expensive. But this also means taking serious and responsible steps in the short run to prepare us to meet our obligations in the longer term.

The first such step is the inclusion in this year's budget of an aggressive, \$6.3 billion program of tax cuts and R&D -- \$1.3 billion more than the \$5 billion package the President promised in his October 22 speech on this issue. The goal is both to stimulate the development of new energy-saving and carbon-saving technologies and to encourage the dissemination of those that exist already. The proposed package contains \$3.6 billion over the next 5 years in tax cuts for energy efficient purchases and renewable energy, including tax credits of \$3,000 to \$4,000 for consumers who purchase highly fuel efficient vehicles, a 15 percent credit (up to \$2,000) for purchases of rooftop solar equipment, a 20 percent credit (subject to a cap) for purchasing energy-efficient building equipment, a \$2,000 credit for purchasing energy-efficient new homes, an extension of the wind and biomass tax credit, and a 10 percent investment credit for the purchase of combined heat and power systems. The package also contains \$2.7 billion over the next 5 years in additional research and development spending -- covering the four major carbon-emitting sectors of the economy (buildings, industry, transportation, and electricity), plus carbon removal and sequestration, Federal facilities, and cross-cutting analyses and research. One example of the R&D effort is the Partnership for a New Generation of Vehicles (PNGV). PNGV is a government-industry effort to develop attractive, affordable cars that meet all applicable safety and environmental standards and get up to three times the fuel efficiency of today's cars. In FY99, the combined proposal for PNGV is \$277 million, up from \$227 million appropriated in FY98. Similar government-industry efforts are proposed to develop more efficient diesel engines for both light trucks and heavy trucks. [ADD SOMETHING MORE ABOUT INDUSTRY-GOVERNMENT DIALOG. PERHAPS A CONCRETE EXAMPLE OF IDENTIFYING AN INDUSTRY REGULATION THAT COULD BE REMOVED.]

The second such step is the promotion of an environmentally-responsible electricity restructuring bill, which the President identified as part of his domestic climate change package in his address to the National Geographic Society on October 22. An electricity sector freed from government regulation would be a more efficient energy sector. Costs to consumers would fall. A reasonable overall estimate of the effects of adding federal electricity restructuring to the rest of the President's program to address climate change is to achieve the same environmental goals at a cost saving of roughly \$16 billion per year.

Estimated Reduction in Costs from Annex I Trading

In the language of the treaty, "Annex I," you will recall, is the set of countries that have agreed to take on binding limitations in emissions of greenhouse gases. Even without developing country participation -- which, again, the President has emphasized as essential before the treaty could be ratified -- costs would be reduced substantially by trading among the Annex I countries. To provide some indication of the possible efficiency improvements, Russia

and the Ukraine consume six times as much energy per dollar of output as does the United States.

Estimates derived from the SGM model suggest that trading among Annex I countries is likely to reduce the cost to the United States of achieving its targets for 2008-2012 emissions by about half relative to a situation in which such trading was not available. This concept of costs is meant to capture aggregate resource costs to the US economy, including the cost to domestic firms of purchasing emission permits from Russia and other countries where emission reductions are cheaper than in the United States. The dramatic reduction in costs available from Annex I trading within the SGM model -- cutting the costs involved by half -- highlights why the President insisted that international trading be part of the Kyoto Agreement.

A useful rough check on this estimate can be obtained from other modelling efforts, notwithstanding that they are likely to be more distant approximations to the parameters of the Kyoto Treaty. Recent results from twelve leading models that participate in the Stanford Energy Modeling Forum show that trading among industrialized countries reduces estimated costs -- defined as lost consumption -- by an average of 56 percent, although the results vary from model to model.

Estimated reduction in costs from umbrella trading

One possibility that emerged in Kyoto, which none of us foresaw, was the idea that the United States might undertake trading with a subset of Annex I countries, dubbed the "umbrella," that would exclude the European Union. The initial list of proposed participants in the umbrella includes the United States, Australia, Canada, Japan, New Zealand and Russia, with strong indications of interest from some others. The motivation for this idea was that the Europeans have been reluctant to agree to the sort of international trading that we want (preferring that they achieve their goals collectively in a group of their own, called the "EU bubble").

It is too early to say whether the umbrella concept will in fact be accepted by the parties. But it is an important concept to consider, for three reasons. First, it is conceivable that it will be formally agreed to in future negotiations. Second, even if the final treaty does not explicitly include the umbrella, but rather allows trading among all signatories (as the United States has proposed all along), it is conceivable that umbrella countries will agree, outside the treaty, to trade only among themselves. Third, the aversion toward international trading that the Europeans have expressed suggests that they might refrain from making the trades to which they would be entitled -- which would mean that the umbrella would operate in practice, if not in formal international agreement.

The significance of the umbrella idea in the present context is that it has the potential to further reduce costs to the United States. The reason is that if the Europeans do not bid against us for the relatively abundant, low-cost opportunities to reduce emissions in Russia and Eastern

Europe, then the price of emissions reductions will be even lower. Results that we have derived from various SGM simulations suggest that, relative to the situation in which there is no trading at all, the umbrella arrangement would reduce costs by an estimated 61-75 per cent, depending on whether the former Warsaw Pact countries are classed with the EU, or are instead assumed to fall within the umbrella. Thus, the umbrella arrangement raises the benefit to international trading significantly relative to full Annex I trading, reducing costs from roughly half their no-trading level to as low as one-quarter their no-trading level.

Estimated reduction in costs from LDC participation

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

A moderate version of developing country participation is the Clean Development Mechanism, modelled after Joint Implementation (JI). JI cannot realistically be expected to yield all the gains of binding targets for developing countries, but it might shave costs by roughly another 20 to 25 percent from the reduced costs that result from trading among Annex I countries.

Another possibility is that we persuade some of the key developing countries that are the largest emitters to commit to targets, and allow us to buy emission reductions from those paths. We estimate that this could cut roughly 55 percent off the reduced costs that result from Annex I trading. [The four countries included in this particular estimate are China, India, Brazil and Korea.] Once these savings have been attained, the estimated reductions to US costs from persuading the rest of the developing world to go along with full commitments are relatively small.

I offer these numbers because they show the potential effectiveness of trading in reducing costs dramatically. But it is important that I repeat three caveats: First, as always, there is a wide range of uncertainty around all these estimates. Second, they apply to an idealized version of trading, one that assumes no problems of enforcement or transactions costs. Third, it seems unlikely that we will get all our partners to agree in Buenos Aires to the very most optimistic or ambitious case. Nonetheless, despite these caveats, the numbers do show major savings even without getting the most optimistic case. And if we don't get enough of what we want, we won't submit the treaty for ratification to the Senate.

VII. Non-Climate Benefits

The costs of undertaking greenhouse gas emission reductions must be compared to the benefits. As I have indicated, for various reasons our analysis does not quantify the benefits from averting climate change itself. But the relative price shifts that are necessary to reduce

emissions should produce benefits in three areas: air pollution, traffic congestion, and highway accidents. These benefits are quantifiable.

Reductions in carbon emissions also lead to reductions in emissions of pollutants that contribute to excess concentrations of fine particulate matter and low-level ozone.

[FORTHCOMING, PENDING ANALYSIS FROM EPA and LUTTER.]

Traffic congestion hurts motorists by causing delays and inconvenience. More efficient pricing -- which recognizes the externalities involved -- should lead to reductions in congestion as motorists choose other means of travel, share rides, or even forgo less important trips. We estimate, for example, that higher fuel prices resulting from carbon permit prices of, say \$20/ton, would reduce travel delays associated with congestion, and that the value of such time savings to consumers would be about \$0.4 billion per year.

Vehicle use also leads to costly accidents and to highway injuries including fatalities. Assuming that accidents fall proportionately with vehicle use, more efficient pricing will also create savings from reduced accidents and resultant mortality. We estimate that the savings from reduced accidents and the value of reduced mortality risk, corresponding to a \$20/ton carbon price, is approximately \$0.3 to \$2.7 billion/ year [depending on whether lighter cars are less crashworthy].

A variety of other benefits that are harder to quantify are likely to result from reductions in carbon emissions. With respect to transportation, reduced vehicle use will also reduce the cost of road repair and maintenance. Second, reduced coal use will reduce the cost of sulfur dioxide controls, as utilities switch to energy sources other than coal. Reduced coal use will also lower mercury emissions. Finally, reduced energy use will also increase U.S. energy independence. Our inability to estimate these effects quantitatively does not imply that they are necessarily small or unimportant.

VIII. Preliminary Estimate of the Net Effects of the Kyoto Agreement

We can now combine the various benefits and costs delineated above to provide a preliminary assessment of the net impact of the Kyoto agreement, excluding, however, the benefits of averted damage from climate change. This assessment relies on SGM model results along with additional Administration analysis. It accounts for the impact of trading under the umbrella, and assumes full participation by four key LDCs. We find that the net resource costs of attaining our Kyoto targets for emission reductions are \$7 to \$9 billion. **Thus the net costs are \$_ billion to \$_ billion, or roughly 0.0_ percent of projected GDP (i.e., net of ancillary non-climate benefits, predicted from a permit price of \$12-\$16 per ton, depending on which umbrella definition is used).**

A more tangible measure of costs is the estimated effects on energy prices. Excluding the impact of electricity restructuring, the SGM-based estimate is that the price of emissions would be in the range \$12 to \$16 per ton of carbon equivalent -- and that energy prices at the household level would rise by about 3 percent under the Kyoto accords [CHECK]. Fuel oil prices would rise by about 5 percent, natural gas prices by 4 percent, gasoline prices by 3 percent, and electricity prices by 2 percent. The 3 percent increase in energy prices at the household level would raise the average family's energy bill by about \$75.

These estimates do *not* mean that households' energy expenses will in fact be higher in 2010 than today, however. In the first place, energy prices fluctuate year-by-year for all sorts of reasons. They could go either up or down. But even if we leave out unpredictable fluctuations, the energy price declines from Federal electricity restructuring would be enough to offset the impact estimated above. By 2008-2012, the projected 10 percent decline in electricity prices from the restructuring that is part of our climate change agenda will mean a net reduction in energy prices in the U.S., even accounting for the small increases noted above.

As highlighted earlier, estimates of the type that I am presenting are fraught with uncertainty. The estimate I just discussed was predicated on the developing country participation that we will insist upon in Buenos Aires as a condition for our ratifying the Kyoto Protocol, but which is not yet part of that Protocol. At the same time, the numbers I have cited are in several respects conservative: they leave out several factors, such as the role of sinks, that could further reduce costs. But before I bring these factors into the analysis, allow me to say a few words about macroeconomics.

Effects on employment and aggregate output

So far I have said nothing about job losses resulting from climate change policy. Although there may be job gains in some sectors and job losses in others, I do not anticipate any significant aggregate effect. Some jobs could be lost in energy-intensive sectors, although given the very small predicted change in energy prices, impacts in most such sectors are apt to be minimal. Furthermore, a large number of jobs will be created in other sectors -- many of them high-tech jobs paying high wages. The President is firmly committed to assisting any workers who are adversely affected during the transition to a climate-friendly economy.

The situation might be different if a large energy shock were to hit the economy with no warning, as happened in the oil crisis of 1973-74, when the real money supply, output and employment all contracted sharply. In addition to hitting with no warning, the oil shocks of the 1970s also entailed large transfers from the U.S. and other oil-importing countries to OPEC, thus depressing real income and spending in the former. A self-imposed shift in the relative price of carbon-intensive energy to address global climate change, on the other hand,

need not entail such a transfer of purchasing power. Thus there are critical differences between the oil price shocks and the effort to reduce carbon emissions. Our reassuring conclusion regarding aggregate output might also be different if the policy were to be implemented inefficiently (by command-and-control style regulations of the sort put in place in that oil crisis) rather than efficiently (by market mechanisms of the sort that the President has proposed to use).

Consider for a moment the ability of U.S. industry to evolve to changes when there is sufficient lead time. [SO2 EXAMPLE to be added shortly]

VIII. The Foregoing Estimates Are Conservative along Several Dimensions

I should emphasize that the estimates I have presented are conservative in the sense that they do not include the potential cost reductions resulting from the inclusion in the Kyoto treaty of carbon sinks, the potential payoffs to the President's technology or energy efficiency policies, or the benefits of mitigating climate change itself. The first omission, sinks, concerns a provision of the Kyoto Protocol that has received less attention than it merits. It is only *net* emissions -- emissions to the atmosphere minus sequestration -- that are to be reduced 7 percent below 1990 levels, not gross emissions. The United States plants many trees every year, and would receive credit for this activity under the Protocol. Very preliminary estimates of the implications for the United States of the Kyoto provision on sinks reduce the resource cost by to 17 per cent. **This brings resource costs down to \$15-\$18 billion, depending on whether we count in no LDC participation at all or we count the benefits of joint implementation through the Clean Development Mechanism (as currently agreed to in the Kyoto Protocol).**

These numbers translate into net costs of __ and energy prices of __. If we get the full participation of LDCs, the costs come down further.

Even those estimates for the effect of sinks are conservative in one respect: they are based on an assumption for sink activity in the U.S. over the 2008-2012 period, and no assumed benefits from sinks elsewhere in the world. Very preliminary estimates suggest that incorporating the gains from sinks *throughout the world* can reduce the costs of meeting the Kyoto target by half or more, on top of the gains from trading among Annex I countries. (Furthermore, no model has yet even tried to take into account that government policies can help increase the amount of tree-planting, possibly through some version of the Conservation Reserve Program, for example.) But neither we nor other analysts are yet sure exactly how to interpret the legal language of the Protocol. Because the quantitative uncertainty is so large, we do not yet have an estimate with which I feel comfortable. But we do know that the effect of fully modelling the Kyoto provision on sinks is likely to be both favorable and large.

The estimates I have cited so far also make little allowance for the payoff to the President's \$6.3 billion Climate Change Technology Initiative. The parameter that figures most

prominently in analysis of technological progress in the energy field is the rate of improvement in the so-called Autonomous Energy Efficiency Index (AEEI), that is the rate at which the total use of energy falls relative to GDP. In the SGM model analysis that underlies our assessment, the AEEI is assumed to improve by 1.0 percent per year. Reflecting a conservative interpretation of the 15-year impact of the technology initiative, this is only a small increase above the 0.9 percent number in the Energy Information Administration's Annual Energy Outlook.

Our justification for incorporating into our assessment such a small assumed impact of Administration technology policies logic is somewhat analogous to the Administration's rationale for employing mainstream economic assumptions in our budget forecasts: in the presence of uncertainty, we are conservative in our estimates of the speed with which the economy will grow, tax receipts will rise, and the budget will improve. That way, any revisions or surprises that occur are likely to be in the pleasant direction. In this instance, we have conservatively assumed that there will be substantial lags in producing payoffs from new technology research and dissemination expenditures. Clearly, this is neither the best outcome we can attain nor the best outcome we expect to attain as a consequence of our climate change strategy over the next decade. Experts on the energy technology relating to climate change forecast more rapid technological progress; and engineering models suggest that some energy improving technologies are available now at negative net costs.

If the Administration is successful in speeding the discovery and adoption of new technologies, the rate of improvement in energy efficiency could rise and such improvements would lower the cost of meeting our Kyoto target. For example, model based analysis suggests that a 25 percent boost in the AEEI parameter has the effect of reducing resource costs by **26 - 27 per cent, to \$13 to \$16 billion, again depending on whether we count no LDC participation at all or count the benefits of joint implementation. These numbers translate into net costs of __ and energy prices of __.** If we were to get the full participation of some LDCs, the costs would again come down further.

The third, and most important, respect in which the estimates I have presented are conservative is that they leave out the benefits of mitigating climate change itself. A full cost-benefit analysis would include mitigation in the benefits column. The only reason we have not done so, as I have explained repeatedly above, is the difficulty in coming up with a number to capture the monetary benefits. But I trust that nobody will lose sight of our ultimate objective -- keeping our planet the hospitable home that we enjoy today.

CONCLUSION

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

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

I welcome your questions.

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CREATOR: Janet L. Yellen (CN=Janet L. Yellen/OU=CEA/O=EOP [CEA])

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SUBJECT: A few small revisions a la Gruber

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===== ATTACHMENT 1 =====

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TEXT:

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**TESTIMONY OF DR. JANET YELLEN
CHAIR, COUNCIL OF ECONOMIC ADVISERS
BEFORE THE SENATE FOREIGN RELATIONS COMMITTEE
ON THE ECONOMICS OF THE KYOTO AGREEMENT
FEBRUARY 11, 1998**

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

The international agreement that was reached in Kyoto this past December is a crucial first step in addressing global climate change. But it is only a first step. Since the international effort to reduce greenhouse gas emissions is more of a work-in-progress than a completely finished product, it is not yet possible to provide a full authoritative analysis of it. Many of the specifics in several crucial areas are not completely resolved in the diplomatic arena, forcing analysts to make a variety of assumptions about the ultimate form of the international regime. In my testimony today, I will attempt to identify key elements of the agreement, such as global participation and reliance on flexible, market-based measures, that ensure that reductions in global greenhouse gas emissions are consistent with continued strong economic growth. I will do my best also to provide some rough estimates of costs and benefits.

The Administration is strongly committed to ensuring that these critical elements are reflected in our domestic and international climate change policies. We are firmly committed to meaningful developing country participation, as well as emissions trading both domestically and internationally. And as you know, the President's FY 1999 budget includes a \$6.3 billion package of tax cuts and R&D over the next 5 years to jumpstart our efforts.

I. Basic Economic Rationale of the Kyoto Treaty

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

The earth's surface is warming from the accumulation of greenhouse gases from myriad sources worldwide. None of these emitters presently pays the cost to others of warming's adverse effects -- a classic externality in the language of economists. As a result of these distorted incentives, disruption of the Earth's climate is likely to proceed at an excessive pace and if left uncontrolled may pose substantial costs in terms of disruption to commerce and the environment alike. The fundamental economic logic of the Kyoto agreement is thus that

without such an international agreement, individual nations will not have the proper incentives to address the threats from global climate change.

II. Costs of Climate Change

In evaluating efforts to mitigate global warming, the first step is to consider the costs that are likely if we fail to take any action -- for these costs provide the primary motivation for reducing greenhouse gas emissions. What, then, are the costs associated with allowing global climate change?

The Intergovernmental Panel on Climate Change (IPCC) jointly established by the World Meteorological Organization and the United Nations Environment Programme, concluded in 1995 that "the balance of evidence suggests that there is a discernible human influence on global climate." Current concentrations of carbon dioxide, methane, nitrous oxide, and the other so-called greenhouse gases have reached levels well above those of preindustrial times. Of these, carbon dioxide (CO₂) is the most important: net cumulative CO₂ emissions resulting from the burning of fossil fuels and deforestation account for about two-thirds of potential warming from changes in greenhouse gas concentrations related to human activity.

Climatic Impact

If growth in global emissions continues unabated, the atmospheric concentration of CO₂ will likely double relative to its preindustrial level by midway through the next century. As a result of the increased concentration of CO₂, the IPCC estimates that global temperatures will increase by between 2.5 to 6 degrees Fahrenheit in the next 100 years, with a best guess of about 3.5 degrees Fahrenheit. While scientists believe that human activities are leading to a gradual warming of the *average* temperature of the earth, the change in temperature in a given region at a given time may differ substantially from this average. Indeed, models predict warming will be greater in high latitudes than in the tropics, and greater over land than ocean. Many models predict larger increases in evaporation than in precipitation over midlatitude land areas, which would result in drier conditions in those regions, especially during summer in North America and Europe.

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

Economic and Monetary Damages

The derivation of quantitative or monetary estimates of the damages from such climate changes is extremely difficult given the capacity of today's forecasting models. Estimates of the economic damages from climate change fall into the following broad areas: agriculture, sea-level rise, air conditioning and heating, water supply, human life and health, air pollution, and other costs (hurricanes, migration costs, human amenity, construction, leisure activities, urban infrastructure, and ecological damages such as forest loss and species loss).

A subject of great uncertainty and sensitivity is the "discount rate" that is applied to the benefits of averting future climate change. Such a discount rate is needed if the analysis is to be expressed in monetary terms, because a dollar today is not worth the same as a dollar tomorrow. And since the benefits of stemming future climate change accrue over not only decades but centuries, small changes in the discount rate can produce substantial changes in the results. But the precise discount rate that should be used to evaluate questions as important as the future climate of the planet remains a subject of intense debate. It is safe to say that there is, as of yet, no professional consensus on the issue.

A similar point concerns risk aversion. To what extent are we willing to take chances with our planet? The point applies particularly to catastrophe scenarios. Scientists have thought of many possible scenarios, most of which they are fortunately not yet prepared to pronounce as particularly likely based on current evidence, but which might be truly catastrophic for the planet if they were to occur. There is a strong argument for the Kyoto agreement as a form of planet insurance. But what numerical weight should one assign to these catastrophic risks? In other words, what is the value of the insurance policy? It is difficult for an economist, or anyone, to know.

Despite these shortcomings and potential problems, respected researchers have developed estimates of the monetary damages expected from an average worldwide temperature increase of approximately 4.5 degrees Fahrenheit (corresponding to, roughly, a doubling of pre-industrial carbon dioxide concentrations). For example, William Cline, then a Senior Fellow at the Institute for International Economics, estimated that such a temperature change would impose annual damages of more than \$70 billion per year on the U.S. economy in today's terms. These damages include \$22 billion in lost agricultural production, \$13 billion in additional electricity costs, and \$8 billion in new costs to maintain the existing supply of fresh water. (Cline's original estimates are quoted in 1990 dollars. The figures given above translated those numbers into 1997 dollars using the annual GDP price index.) William Nordhaus of Yale University has likewise computed estimates of the dollar loss attributable to a doubling of carbon dioxide concentrations. He finds that the Cline estimate is in the center of three estimates for the U.S., and that the high estimate is only 1.3 times greater than the low estimate.

It must be noted, however, that this similarity of aggregate estimates masks the true uncertainty associated with forecasts of the damages from given increases in global warming --

the estimates are all fundamentally based on extrapolations from current and past experience, and may not fully incorporate effects that will unfortunately become apparent only with future experience. In particular, the estimates may not fully reflect potential non-linearities in the relationships between carbon dioxide concentrations and temperature, between temperature and economic damages, or in the various other complicated relationships governing interactions between greenhouse gas emissions, the climate, and the economy. Current quantitative analyses do not, and cannot, accurately reflect the small and unknown possibility of large-scale and potentially irreversible discrete events with potentially catastrophic consequences.

Two such possibilities serve as illustrations. Warming of Northern tundra may release very large amounts of methane from the subarctic permafrost, thereby leading to potentially devastating acceleration of an otherwise controllable global warming process. We do not know at what point, if any, such unstable activity would be triggered. Second, evidence from climate models suggests that some types of climate change may lead to displacement of the Gulf Stream that warms Western Europe. Evidence from ocean core samples suggests that such reversals of ocean currents have occurred in previous ice ages. Reductions in the risk of such catastrophic outcomes must be considered in addition to the costs and benefits that can be reasonably quantifiable. Since human beings are typically averse to risk, such possibilities are especially important in evaluating whether the benefits of a particular climate control policy justify the costs. One must have at least some sympathy with those who criticize economists on the grounds that the effects of climate change are extremely difficult to quantify in a single monetary number.

III. Addressing Global Climate Change in an Efficient Manner

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

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

Need for Global Action

Climate change is a global problem requiring a global solution. As I mentioned earlier, no single country has an incentive to reduce emissions sufficiently to protect the global environment against climate change. Each has an economic incentive to “free ride” on the efforts of others. Even if the United States sharply reduced its emissions unilaterally, greenhouse gas emissions from all other countries would continue to grow, and the risks posed by climate change would not be significantly abated. It is important to emphasize that emissions of different gases anywhere in the world have very similar effects on global climate.

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

To address the lack of progress among many industrialized countries toward meeting the Rio objective, the United States and approximately 160 other nations agreed in negotiations held in Kyoto, Japan, last December, to take substantial steps to stabilize atmospheric concentrations of greenhouse gases. The Kyoto Agreement, which requires the advice and consent of the Senate, would place binding limits on industrial countries' emissions of the six principal categories of greenhouse gases: CO₂, N₂O, methane, sulfur hexafluoride, perfluorocarbons, and hydrofluorocarbons. **These limits apply to the 38 so-called Annex I countries, which are the industrialized countries, defined to include Russia, Ukraine, and most Eastern European countries.**

Under the Kyoto agreement, each industrial country's “1990 baseline” is actually based on its 1990 emissions of CO₂, methane, and N₂O and its choice of 1990 or 1995 levels of the other three categories of gases. The United States agreed to a target of 7 percent below 1990 levels by the period between 2008 and 2012. To meet that target, net U.S. emissions of greenhouse gases -- all emissions minus removals of CO₂ by certain forestry-related activities -- must average no more than 1,484 million metric tons of carbon equivalent per year during that period. The targets for the European Union and Japan are 8 percent and 6 percent below 1990 levels, respectively. Australia, New Zealand, Norway, Russia and Ukraine all have limits somewhat less ambitious when phrased as cuts relative to

their 1990 levels. In sum, over the period from 2008 to 2012, the industrial countries are expected to reduce their average emissions of greenhouse gases to about 5 percent below their 1990 levels.

The President has made clear that his support of the Kyoto Agreement is dependent on meaningful participation from key developing countries (who are not included in Annex I). The President has also made clear that he will not submit the treaty to the Senate without such participation.

There are several reasons why meaningful participation from developing countries is essential. First, developing countries are projected to contribute a majority of total emissions by 2030 under a continuation of business-as-usual. Without the participation of developing economies, emissions reductions by the industrialized countries will therefore not achieve necessary protection from climate change. Indeed, if developing countries do not participate in the international regime, their emissions could potentially increase by *more* than under their business-as-usual baselines. One mechanism for such an unintended consequence is as follows. As Annex I countries comply with their targets, their demand for oil will fall, which will probably work to reduce the price of oil on world markets, and perhaps to encourage non-participating countries to use more oil and emit more carbon than they otherwise would have.

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

Third, principles of basic fairness suggest all countries should do their part, depending on their ability to contribute to the solution. Thus even poor countries should contribute, although the existence of more pressing social needs in such countries will inevitably limit the magnitude of their contributions.

So far I have not mentioned the word “competitiveness.” One of the difficulties in analyzing concerns related to competitiveness is that the term itself is used to mean many different things. I have seen at least one study that uses “loss of competitiveness” to refer to predictions of negative effects on the *aggregate* trade balance. As a professional economist, I do not accept the logic upon which that particular argument is predicated: the aggregate trade

balance is determined by macroeconomic forces -- the difference between saving and investment -- and not by our environmental policies.

On the other hand, if competitiveness refers to adverse effects on a few specific manufacturing industries -- those that are especially energy-intensive, such as aluminum, paper, and chemicals -- the situation may be more complicated. It is difficult to undergo a significant structural change in the economy without having the effect of expanding some sectors and contracting others. But to provide some perspective on this issue, consider the following facts. First, on average, energy constitutes only 2.2 percent of total costs to U.S. industry. Second, energy prices already vary significantly across countries. According to the *1997 Statistical Abstract*, for example, in 1996 premium gasoline cost \$1.28 per gallon in the United States -- but only 8 cents in Venezuela. Yet U.S. industry is not moving en masse to Venezuela. Third, roughly two-thirds of all emissions are not in manufacturing at all, but in transportation and buildings. I therefore believe it more accurate to say that we need developing country participation for the reasons I outlined above, than to say that we need it to avoid adverse effects on competitiveness.

Flexibility and Market Mechanisms

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

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

1. "When flexibility" (timing)

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

The Kyoto Protocol incorporates this principle of "when flexibility" in four ways:

- First, the cuts to be made in the first period are less severe, and the first period ends much later, than what had been proposed by many other countries, most notably the Europeans. By adopting a gradual and credible path of reductions in the early years, we can greatly reduce costs such as those from prematurely scrapping coal-fired electricity plants still in the prime of their operating lives, while attaining the same ultimate environmental goals.
- Second, under the Kyoto agreement, the emissions target is not specified in terms of a specific year, but rather in terms of an average over a five-year period (2008-2012). Averaging over five years, instead of requiring countries to meet a specific target each year, can lower costs, especially given an uncertain future. The averaging can smooth out the effects of short-term events such as fluctuations in the business cycle and energy demand, or hard winters and hot summers that would increase energy use and emissions.
- Third, there is allowance for “banking” emission reductions within the 2008-2012 commitment period, for use in a subsequent commitment period [although the emission targets of the next period have not yet been specified].

2. “What flexibility” (gases and sinks)

The second type of flexibility is “what flexibility”, along two dimensions. The first is the inclusion in the agreement of all six greenhouse gases. Emissions of different kinds of gases, not just carbon dioxide, contribute to the greenhouse effect. Since the IPCC has developed conversion factors for all greenhouse gases by estimating their global warming potentials, reductions in emissions of one pollutant can be used to substitute for increases in emissions of another by an amount that has equivalent environmental effects. The Kyoto Protocol stipulates that countries with binding targets are expected to reduce their *total* greenhouse gas emissions by certain percentages, but does not require specific reductions for specific gases. Since a molecule of sulfur hexafluoride is 23,900 times more potent over 100 years than a molecule of CO₂, it may be cheaper to achieve the same environmental benefit by eliminating one molecular unit of SF₆ than nearly 24,000 units of CO₂.

Some initial rough analysis indicates that a strategy of reducing non-CO₂ greenhouse gases by *more* than 7 percent below their 1990/1995 baseline levels while reducing CO₂ by *less* than 7 percent below its 1990 level could reduce greenhouse gas emission permit prices by more than 10 percent. [This analysis is based on the integrated SGM/non-CO₂ cost curve.] Thus allowing countries flexibility in what gases they reduce -- essentially trading emissions reductions across gases -- can help lower significantly the costs of meeting their targets.

The second source of “what flexibility” is the treatment of sinks, i.e., land use activities that promote the removal of carbon from the atmosphere through the growth of plants. Promoting such sinks through afforestation and reforestation may reduce atmospheric

concentrations of CO₂ at much lower costs than reducing emissions of greenhouse gases.

3. "Where flexibility" (international)

The third type of flexibility, and perhaps the most important, is "where flexibility" (international). As I have already emphasized, emissions have the same environmental consequences regardless of where in the world they occur. Therefore, the least-cost approach to controlling climate change is to reduce emissions wherever such reductions are cheapest. The Kyoto agreement includes two important cost-saving provisions of this nature. First, it provides for industrial countries to trade rights to emit greenhouse gases with each other. This market in emissions permits will ensure that emission reductions occur where they are least expensive within the industrial countries. In particular, U.S. companies could purchase emissions reductions in other participating countries when doing so would reduce their costs -- lowering costs without affecting the level of environmental protection.

Second, the agreement allows industrial countries to invest in "clean development" projects in the developing world and use these projects' certified emissions reductions toward meeting their targets. Many such clean-development projects may be quite cheap in terms of the cost per ton of emissions avoided, as has been illustrated by the joint implementation pilot program that is already in place in the U.S. Details of these provisions will be worked out in negotiations in Buenos Aires later this year.

IV. Difficulties of Economic Analysis of Kyoto Agreement

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

The difficulties associated with economic analysis of climate change fall into three broad categories. First is the uncertainties that still remain over the terms of the ultimate treaty. Second is the inherent limitations of available models to analyze even short-term costs and benefits. And finally is a topic I discussed earlier: the impossibility of putting a single monetary number on the long-term benefits of climate change mitigation.

Uncertainties over Certain Provisions in International Effort to Combat Climate Change

The Kyoto Agreement was an historic accomplishment, delineating the broad terms of

the international effort to address climate change. But although we know a lot more than we did before Kyoto about how that international system will work, there is still much that we don't know.

First, as is often the case in a legal document of the length and complexity of the Kyoto Protocol, there are some provisions that require further clarification and interpretation. Of particular concern here is the treatment of so-called sinks -- activities that affect the rate at which carbon is removed from the atmosphere and "sequestered," specifically by the planting of trees.

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

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

Inherent Limitations of Models

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

One area in which the uncertainty is particularly large is the pace of technological progress -- including diffusion of existing energy-efficient technologies, as well as research and development of new technologies -- and the extent to which the pace will accelerate in response to government programs. Economics does not offer a good understanding of how technological progress is determined, in part because it is the stuff of experimentation, brainstorming, genius, breakthroughs, perceptions and habits. Invention is largely determined by inspiration -- notwithstanding Edison, who assigned a 99 percent share to perspiration -- and inspiration, in my

experience, is difficult to fit into mathematical formulae or economic models. Models and experts on climate change policy tend to have a wider range of disagreement on the speed with which technology can be changed and the scope for speeding the diffusion of existing energy-efficient technologies than on any other single issue.

Furthermore, each model has strengths and weaknesses; each has questions to which it is better or worse suited to answer. Some, for example, model the energy sector in detail. Some allow for the fact that a coal-fired power plant cannot costlessly be converted to one that runs on natural gas. Some have enough policy detail to distinguish alternative ways of redistributing revenues that would result if emission permits were to be auctioned. Some are capable of showing short-term macroeconomic disequilibria. Some include a long-term "carbon cycle" model that can keep track of the accumulation of greenhouse gas concentrations in the atmosphere and their climatological effects. Some break down the rest of the world into regions and so can model international trade. No one model does everything, and therefore we must not rely blindly on the results of any one model or set of models. Professional judgement and economic intuition are also crucial.

Benefits of Averting Climate Change

As I discussed above, it is evident that the benefits of averting climate change are potentially immense. But I have chosen not to try to quantify them in monetary terms for you, in light of the difficulties I have enumerated -- including the quantitative uncertainty of these benefits, and their timing and therefore the extreme sensitivity of the results to the chosen discount rate.

Instead, what I will do is draw upon a variety of sources in an attempt to add up the various possible costs and benefits of emissions policy *excluding* climate change. To give away the punch line, my conclusion is as follows: the net costs of our policies to reduce emissions are likely to be small, if those reductions are undertaken in an efficient manner, *even before taking into account the benefits of averting climate change itself*. That small net premium excluding the benefits of mitigating climate change, in effect, purchases a partial insurance policy against a serious environmental threat.

V. Assessing the Kyoto Agreement

The existence of modeling difficulties means that the results from any model must be treated with caution. We have therefore employed a broad set of economic tools to assess the Kyoto agreement.-__ We have drawn on the insights of a wide range of models of the energy sector and economy over the next 25 years, including but not limited to the results of the Stanford Energy Modeling Forum exercises, the IPCC's review of the economic and social dimensions of climate change, and the staff-level Interagency Analytical Team effort last year. Other tools include simple relevant statistics, "meta-analyses" of existing models, historical and

sectoral examples, and basic economic reasoning. Drawing on this broad array of analytical tools is crucial to an intelligent evaluation of the policy alternatives.

To my knowledge, as of December, no model -- whether used inside the government or not -- had been set up precisely to analyze the parameters of the agreement that was reached in Kyoto. Most model-builders outside the government tend to take as long as several years to incorporate changes in policy parameters into their models. And no model is currently designed to assess sinks, or all six greenhouse gases included in the treaty.

One of the leading models in the field is the Second Generation Model of Battelle Laboratories. The SGM is one of the models best positioned to analyze the role of international trade in emission permits, which we consider to be a critical element of the Kyoto Treaty. However, the SGM does not cover all six gases included in the Kyoto agreement or include a role for sinks. We have used the SGM model as a starting point for a preliminary assessment of the Kyoto treaty, but have attempted to supplement its results with additional analysis to account for such special features of the agreement as the inclusion of six gases, sinks and a possible Annex I trading scheme that could exclude the EU. I will share with you today some preliminary results of this analysis.

Mindful of the limitations of any single model, we are eager to see features of the Kyoto agreement assessed by other models to obtain a better feel for the range of possible effects. Much of this work will continue to go on outside the government. For example, we have had discussions with the Energy Modeling Forum, based at Stanford University. The EMF is a long-running exercise involving many of the leading climate models. We have given the EMF advice on how features of the Kyoto legal language can be translated into terms recognizable to an economist. Unfortunately, the Energy Modeling Forum believes that its members will need at least until mid-year to produce reliable results.

VI. Economic Analysis

With all of that as important background, let us now turn to the task at hand. As we do so, let me emphasize once again that the figures presented below do not incorporate the benefits of starting to mitigate climate change.

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

Within the Kyoto agreement, this means an insistence on international trading, joint implementation, and, ultimately, on full developing country participation. Domestically, this

means that we implement any emissions reductions through a market-based system of *tradeable* emissions permits, which ensures that we achieve reductions wherever they are least expensive. But this also means taking serious and responsible steps in the short run to prepare us to meet our obligations in the longer term.

The first such step is the inclusion in this year's budget of an aggressive, \$6.3 billion program of tax cuts and R&D -- \$1.3 billion more than the \$5 billion package the President promised in his October 22 speech on this issue. The goal is both to stimulate the development of new energy-saving and carbon-saving technologies and to encourage the dissemination of those that exist already. The proposed package contains \$3.6 billion over the next 5 years in tax cuts for energy efficient purchases and renewable energy, including tax credits of \$3,000 to \$4,000 for consumers who purchase highly fuel efficient vehicles, a 15 percent credit (up to \$2,000) for purchases of rooftop solar equipment, a 20 percent credit (subject to a cap) for purchasing energy-efficient building equipment, a \$2,000 credit for purchasing energy-efficient new homes, an extension of the wind and biomass tax credit, and a 10 percent investment credit for the purchase of combined heat and power systems. The package also contains \$2.7 billion over the next 5 years in additional research and development spending -- covering the four major carbon-emitting sectors of the economy (buildings, industry, transportation, and electricity), plus carbon removal and sequestration, Federal facilities, and cross-cutting analyses and research. One example of the R&D effort is the Partnership for a New Generation of Vehicles (PNGV). PNGV is a government-industry effort to develop attractive, affordable cars that meet all applicable safety and environmental standards and get up to three times the fuel efficiency of today's cars. In FY99, the combined proposal for PNGV is \$277 million, up from \$227 million appropriated in FY98. Similar government-industry efforts are proposed to develop more efficient diesel engines for both light trucks and heavy trucks. [ADD SOMETHING MORE ABOUT INDUSTRY-GOVERNMENT DIALOG. PERHAPS A CONCRETE EXAMPLE OF IDENTIFYING AN INDUSTRY REGULATION THAT COULD BE REMOVED.]

The second such step is the promotion of an environmentally-responsible electricity restructuring bill, which the President identified as part of his domestic climate change package in his address to the National Geographic Society on October 22. An electricity sector freed from government regulation would be a more efficient energy sector. Costs to consumers would fall. A reasonable overall estimate of the effects of adding federal electricity restructuring to the rest of the President's program to address climate change is to achieve the same environmental goals at a cost saving of roughly \$16 billion per year.

Estimated Reduction in Costs from Annex I Trading

In the language of the treaty, "Annex I," you will recall, is the set of countries that have agreed to take on binding limitations in emissions of greenhouse gases. Even without developing country participation -- which, again, the President has emphasized as essential before the treaty could be ratified -- costs would be reduced substantially by trading among the Annex I countries. To provide some indication of the possible efficiency improvements, Russia

and the Ukraine consume six times as much energy per dollar of output as does the United States.

Estimates derived from the SGM model suggest that trading among Annex I countries is likely to reduce the cost to the United States of achieving its targets for 2008-2012 emissions by about half relative to a situation in which such trading was not available. This concept of costs is meant to capture aggregate resource costs to the US economy, including the cost to domestic firms of purchasing emission permits from Russia and other countries where emission reductions are cheaper than in the United States. The dramatic reduction in costs available from Annex I trading within the SGM model -- cutting the costs involved by half -- highlights why the President insisted that international trading be part of the Kyoto Agreement.

Estimated reduction in costs from umbrella trading

One possibility that emerged in Kyoto, which none of us foresaw, was the idea that the United States might undertake trading with a subset of Annex I countries, dubbed the "umbrella," that would exclude the European Union. The initial list of proposed participants in the umbrella includes the United States, Australia, Canada, Japan, New Zealand and Russia, with strong indications of interest from some others. The motivation for this idea was that the Europeans have been reluctant to agree to the sort of international trading that we want (preferring that they achieve their goals collectively in a group of their own, called the "EU bubble").

It is too early to say whether the umbrella concept will in fact be accepted by the parties. But it is an important concept to consider, for three reasons. First, it is conceivable that it will be formally agreed to in future negotiations. Second, even if the final treaty does not explicitly include the umbrella, but rather allows trading among all signatories (as the United States has proposed all along), it is conceivable that umbrella countries will agree, outside the treaty, to trade only among themselves. Third, the aversion toward international trading that the Europeans have expressed suggests that they might refrain from making the trades to which they would be entitled -- which would mean that the umbrella would operate in practice, if not in formal international agreement.

The significance of the umbrella idea in the present context is that it has the potential to further reduce costs to the United States. The reason is that if the Europeans do not bid against us for the relatively abundant, low-cost opportunities to reduce emissions in Russia and Eastern Europe, then the price of emissions reductions will be even lower. Results that we have derived from various SGM simulations suggest that, relative to the situation in which there is no trading at all, the umbrella arrangement would reduce costs by an estimated 60-75 per cent, depending on whether the former Warsaw Pact countries are classed with the EU, or are instead assumed to fall within the umbrella.

Estimated reduction in costs from LDC participation

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

A moderate version of developing country participation is the Clean Development Mechanism, modeled after Joint Implementation (JI). JI cannot realistically be expected to yield all the gains of binding targets for developing countries, but it might shave costs by roughly another 20 to 25 percent from the reduced costs that result from trading among Annex I countries.

Another possibility is that we persuade some of the key developing countries that are the largest emitters to commit to targets, and allow us to buy emission reductions from those paths. We estimate that this could cut roughly 55 percent off the reduced costs that result from Annex I trading. [The four countries included in this particular estimate are China, India, Brazil and Korea.] Once these savings have been attained, the estimated reductions to US costs from persuading the rest of the developing world to go along with full commitments are relatively small.

A useful rough check on our estimate of the gains from international emissions trading can be obtained from other modeling efforts, notwithstanding that they are likely to be more distant approximations to the parameters of the Kyoto Treaty. Recent results from six leading models that participated in the Stanford Energy Modeling Forum show that worldwide permit trading would reduce the estimated costs -- defined as lost consumption -- of a full, long-term, global program to stabilize atmospheric concentrations at 550 ppmv by an average of 56 percent, although the results vary from model to model.

I offer these numbers because they show the potential effectiveness of trading in reducing costs dramatically. But it is important that I repeat three caveats: First, as always, there is a wide range of uncertainty around all these estimates. Second, they apply to an idealized version of trading, one that assumes no problems of enforcement or transactions costs. Third, it seems unlikely that we will convince all of our partners to agree in Buenos Aires to the most complete and cost-effective international trading arrangements. Nonetheless, despite these caveats, the numbers do show major savings even without getting the most optimistic case. And if we don't get enough of what we want, we won't submit the treaty for ratification to the Senate.

Moreover -- and I can't highlight this enough -- these cost-saving features are fundamental tenets of the U.S. position for ratifying the Kyoto Protocol. If we do not get very solid provisions for international emissions trading and meaningful participation by key developing countries, we won't submit the treaty for ratification to the Senate. So, while our analysis may be predicated on some ambitious conditions concerning trading and developing country participation, it is exactly those conditions that form the foundation of the U.S. position going into Buenos Aires.

VII. Non-Climate Benefits

The costs of undertaking greenhouse gas emission reductions must be compared to the benefits. As I have indicated, for various reasons our analysis does not quantify the benefits from averting climate change itself. But the relative price shifts that are necessary to reduce emissions should produce benefits in three areas: air pollution, traffic congestion, and highway accidents. These benefits are quantifiable.

Reductions in carbon emissions also lead to reductions in emissions of pollutants that contribute to excess concentrations of fine particulate matter and low-level ozone. Conservative estimates suggest that, at an emission permit price of \$20 per ton, such ancillary emissions reductions could be well in excess of a half million tons of pollutants per year, and entail cost savings of about \$0.9 billion per year. These cost savings be even larger if carbon emissions reduction efforts could be carefully coordinated with the implementation of the national ambient air quality standards.

Traffic congestion hurts motorists by causing delays and inconvenience. More efficient pricing -- which recognizes the externalities involved -- should lead to reductions in congestion as motorists choose other means of travel, share rides, or even forgo less important trips. We estimate, for example, that higher fuel prices resulting from carbon permit prices of say \$20/ton would reduce travel delays associated with congestion, and that the value of such time savings to consumers would be about \$0.4 billion per year.

Vehicle use also leads to costly accidents and to highway injuries including fatalities. Assuming that accidents fall proportionately with vehicle use, more efficient pricing will also create savings from reduced accidents and resultant mortality. We estimate that the savings from reduced accidents and the value of reduced mortality risk corresponding to a \$20/ton carbon price is approximately \$0.3 to \$2.7 billion per year [depending on whether lighter cars are less crash worthy].

A variety of other benefits that are harder to quantify are likely to result from reductions in carbon emissions. With respect to transportation, reduced vehicle use will also reduce the cost of road repair and maintenance. Second, reduced coal use will lower mercury emissions. Finally, reduced energy use will also increase U.S. energy independence. Our inability to estimate these effects quantitatively does not imply that they are necessarily small or unimportant.

VIII. Preliminary Estimate of the Net Effects of the Kyoto Agreement

We can now combine the various benefits and costs delineated above to provide a preliminary assessment of the net impact of the Kyoto agreement, excluding, however, the

benefits of averted damage from climate change. This assessment relies on SGM model results along with additional Administration analysis. It accounts for the impact of trading under the umbrella, and assumes full participation by four key LDCs. We find that the net resource costs of attaining our Kyoto targets for emission reductions are approximately \$7 to \$9 billion. Thus the net costs are \$5 billion to \$8 billion, or roughly 0.08 percent of projected GDP. **(i.e., net of ancillary non-climate benefits, predicted from a permit price of \$12-\$16 per ton, depending on which umbrella definition is used).**

A more tangible measure of costs is the estimated effects on energy prices. Excluding the impact of electricity restructuring, our SGM-based estimate is that the price of emissions would be in the range \$12 to \$16 per ton of carbon equivalent -- and that energy prices at the household level would rise by about 3 percent under the Kyoto accords. Fuel oil prices would rise by about 6 percent, natural gas prices by 4 percent, gasoline prices by 3 percent, and electricity prices by 3 percent. The 3 percent increase in energy prices at the household level would raise the average family's energy bill by about \$75 per year.

These estimates do *not* mean that households' energy expenses will in fact be higher in 2010 than today, however. In the first place, energy prices fluctuate year-by-year for all sorts of reasons. They could go either up or down. But even if we leave out unpredictable fluctuations, the energy price declines from Federal electricity restructuring would be enough to offset the impact estimated above. By 2008-2012, the projected 10 percent decline in electricity prices from the restructuring that is part of our climate change agenda will mean a net reduction in electricity prices in the U.S., even accounting for the small increases noted above.

As highlighted earlier, estimates of the type that I am presenting are fraught with uncertainty. The estimate I just discussed was predicated on the developing country participation that we will insist upon in Buenos Aires as a condition for our ratifying the Kyoto Protocol, but which is not yet part of that Protocol. At the same time, the numbers I have cited are in several respects conservative: they leave out several factors, such as the role of sinks, that could further reduce costs. But before I bring these factors into the analysis, allow me to say a few words about macroeconomics.

Effects on employment and aggregate output

So far I have said nothing about job losses resulting from climate change policy. Although there may be job gains in some sectors and job losses in others, I do not anticipate any significant aggregate effect. Some jobs could be lost in energy-intensive sectors, although given the very small predicted change in energy prices, impacts in most such sectors are apt to be minimal. Furthermore, a large number of jobs will be created in other sectors -- many of them high-tech jobs paying high wages. The President is firmly committed to assisting any workers

who are adversely affected during the transition to a climate-friendly economy.

The situation might be different if a large energy shock were to hit the economy with no warning, as happened in the oil crisis of 1973-74, when the real money supply, output and employment all contracted sharply. In addition to hitting with no warning, the oil shocks of the 1970s also entailed large transfers from the U.S. and other oil-importing countries to OPEC, thus depressing real income and spending in the former. A self-imposed shift in the relative price of carbon-intensive energy to address global climate change, on the other hand, need not entail such a transfer of purchasing power. Thus there are critical differences between the oil price shocks and the effort to reduce carbon emissions. Our reassuring conclusion regarding aggregate output might also be different if the policy were to be implemented inefficiently (by command-and-control style regulations of the sort put in place in that oil crisis) rather than efficiently (by market mechanisms of the sort that the President has proposed to use).

IX. The Foregoing Estimates Are Conservative Along Several Dimensions

I should emphasize that the estimates I have presented are conservative in the sense that they do not include the potential cost reductions resulting from the inclusion in the Kyoto treaty of carbon sinks, the potential payoffs to the President's technology or energy efficiency initiatives, or the benefits of mitigating climate change itself. The first omission, sinks, concerns a provision of the Kyoto Protocol that has received less attention than it merits. It is only *net* emissions -- emissions to the atmosphere minus sequestration -- that are to be reduced 7 percent below 1990 levels, not gross emissions. The United States plants many trees every year, and would receive credit for this activity under the Protocol. Very preliminary estimates of the implications for the United States of the Kyoto provision on sinks indicates that carbon sinks could comprise nearly 10% of total required emissions reductions. Decreasing the required emissions reduction by 10% would likely result in cost-savings greater than 10%.

The estimates I have cited so far also make little allowance for the payoff to the President's \$6.3 billion Climate Change Technology Initiative. The parameter that figures most prominently in analysis of technological progress in the energy field is the rate of improvement in the so-called Autonomous Energy Efficiency Index (AEEI), that is the rate at which the total use of energy falls relative to GDP. In the SGM model analysis that underlies our assessment, the AEEI is assumed to improve by 1.0 percent per year. Reflecting a conservative interpretation of the 15-year impact of the technology initiative, this is only a small increase above the 0.9 percent number in the Energy Information Administration's Annual Energy Outlook.

Our justification for incorporating into our assessment such a small assumed impact of Administration technology policies is somewhat analogous to the Administration's rationale for employing mainstream economic assumptions in our budget forecasts: in the presence of uncertainty, we are conservative in our estimates of the speed with which the economy will grow, tax receipts will rise, and the budget will improve. That way, any revisions or surprises that

occur are likely to be in the pleasant direction. In this instance, we have conservatively assumed that there will be substantial lags; in producing payoffs from new technology research and dissemination expenditures.

Clearly, this is neither the best outcome we *can* attain nor the best outcome we *expect* to attain as a consequence of our climate change strategy over the next decade. Many energy technology forecast more rapid technological progress; and engineering models suggest that some energy improving technologies are available now at negative costs.

If the Administration is successful in speeding the discovery and adoption of new technologies, the rate of improvement in energy efficiency could rise and such improvements would lower the cost of meeting our Kyoto target. For example, published results based on SGM model simulations with different assumed rates of AEEI improvement suggest an increase in the AEEI from 1.0 to 1.25 would be reflected in about a 40% decrease in the permit price.

The preceding estimates do not fully reflect potential entrepreneurial response to appropriate incentives. An instructive example of the ability of U.S. industry to perform beyond expectations when given appropriate economic incentives is EPA's highly acclaimed sulfur dioxide (SO₂) program, which relies, among other things, on a system of tradeable permits to reduce emissions of SO₂ from electric utilities. The SO₂ program has been successful in several ways: a large number of utilities participate, SO₂ emissions and ambient concentrations have fallen and the costs of reducing emissions are considerably lower than originally forecast.

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

Trading programs may not always bring cost savings as large as those achieved by the SO₂ program; trading programs will not always be accompanied by the discovery of much cheaper control strategies. However, the SO₂ experience demonstrates clearly how programs that offer important market incentives to find cheaper ways of reducing emissions can lead to unexpectedly low prices.

Finally, and most important: the estimates I have presented are conservative in that they leave out the benefits of mitigating climate change itself. A full cost-benefit analysis would include mitigation in the benefits column. The only reason we have not done so, as I have explained repeatedly above, is the difficulty in coming up with a number to capture the monetary benefits. But I trust that nobody will lose sight of our ultimate objective -- keeping our planet the hospitable home that we enjoy today.

CONCLUSION

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

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

I welcome your questions.

RECORD TYPE: PRESIDENTIAL (NOTES MAIL)

CREATOR: Jeffrey A. Frankel (CN=Jeffrey A. Frankel/OU=CEA/O=EOP [CEA])

CREATION DATE/TIME: 5-FEB-1998 08:57:28.00

SUBJECT: a testimony Q re G-3

TO: Janet L. Yellen (CN=Janet L. Yellen/OU=CEA/O=EOP @ EOP [CEA])

READ:UNKNOWN

TEXT:

Jon thinks the G-cubed reference below should be removed, because it is only one model, (it is less optimistic than the others). I could go either way (which is why I highlighted it before). What do you want?

p.13

A useful rough check on this estimate can be obtained from other model[s], notwithstanding that they are likely to be more distant approximations to the parameters of the Kyoto Treaty. The G-cubed model, for example, shows that trading among Annex I countries reduces reduces overall costs by roughly 20 percent [CHECK]. [The G-cubed model is better designed than most to analyze trading of permits in a system where the usual international trade in goods and services is also important.] Twelve leading models that participate in the Stanford Energy Modeling Forum show that trading among industrialized countries reduces estimated costs -- defined as lost consumption -- by an average of 56 percent, although the results vary from model to model.

RECORD TYPE: PRESIDENTIAL (NOTES MAIL)

CREATOR: Joseph E. Aldy (CN=Joseph E. Aldy/OU=CEA/O=EOP [CEA])

CREATION DATE/TIME: 5-FEB-1998 15:13:33.00

SUBJECT: conclusion section

TO: Janet L. Yellen (CN=Janet L. Yellen/OU=CEA/O=EOP @ EOP [CEA])

READ:UNKNOWN

TEXT:

Janet,

Attached is a write-up of the last 2 pages of the testimony based on our conversation we had in your office this morning. Let us know if you would like to talk about it.

Joe

===== ATTACHMENT 1 =====

ATT CREATION TIME/DATE: 0 00:00:00.00

TEXT:

Unable to convert ARMS_EXT:[ATTACH.D27]MAIL44445553K.026 to ASCII,
The following is a HEX DUMP:

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Clearly this is neither the best outcome we can attain nor the best outcome we expect to attain as a consequence of our climate change strategy over the next decade. Experts on the energy technology relating to climate change forecast more rapid technological progress; and engineering models suggest that some energy improving technologies are available now at negative costs.

If the Administration is successful in speeding the discovery and adoption of new technologies, the rate of improvement in energy efficiency could rise and such improvements would lower the cost of meeting our Kyoto target. For example, consider two results published last year from SGM. In an October working paper by Battelle, they estimate the permit price of Annex I trading of only CO₂ emissions to be \$39/ton, assuming an AEEI of 1.0. In the Interagency Analytical Team draft report, SGM estimated the permit price to be \$23/ton at an AEEI of 1.25, reflecting about a 40% decrease in the permit price.

The preceding estimates do not fully reflect the entrepreneurial response to appropriate incentives. An instructive example of the ability of U.S. industry to perform beyond expectations when given appropriate economic incentives is EPA's highly acclaimed sulfur dioxide (SO₂) program, which relies, among other things, on a system of tradeable permits to reduce emissions of SO₂ from electric utilities. The SO₂ program has been successful in several ways: a large number of utilities participate, SO₂ emissions and ambient concentrations have fallen and the costs of reducing emissions are considerably lower than originally forecast.

As has been frequently noted, the average cost of SO₂ emissions reductions has recently been significantly lower than was originally forecast, in part due to the role of incentives in fostering innovation. Emission permit prices, currently at approximately \$100 per ton of SO₂, are well below earlier estimates of around \$250 to \$350 per ton (See Chart 1.)

Trading programs may not always bring cost savings as large as those achieved by the SO₂ program; trading programs will not always be accompanied by the discovery of much cheaper control strategies. However, the SO₂ experience demonstrate clearly how programs that offer important market incentives to find cheaper ways of reducing emissions can lead to unexpectedly low prices.

Finally, and most important: the estimates I have presented are conservative in that they leave out the benefits of mitigating climate change itself. A full cost-benefit analysis would include mitigation in the benefits column. The only reason we have not done so, as I have explained repeatedly above, is the difficulty in coming up with a number to capture the monetary benefits. But I trust that nobody will lose sight of our ultimate objective -- keeping our planet the hospitable home that we enjoy today.

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I welcome your questions.

RECORD TYPE: PRESIDENTIAL (NOTES MAIL)

CREATOR: Randall W. Lutter (CN=Randall W. Lutter/OU=CEA/O=EOP [CEA])

CREATION DATE/TIME: 5-FEB-1998 14:37:43.00

SUBJECT: Revised climate change testimony

TO: Janet L. Yellen (CN=Janet L. Yellen/OU=CEA/O=EOP @ EOP [CEA])

READ:UNKNOWN

TEXT:

----- Forwarded by Randall W. Lutter/CEA/EOP on 02/05/98
02:34 PM -----

Janet L. Yellen

02/05/98 11:36:56 AM

Record Type: Record

To: Jeffrey A. Frankel/CEA/EOP, Randall W. Lutter/CEA/EOP, Joseph E.
Aldy/CEA/EOP

cc:

Subject: Revised climate change testimony

I attach a revised version of my testimony. I am perplexed about how Jeff
intended for you to fill in the holes. Let's talk about it. Jeff is off
at State, and we need to get this out this afternoon.

===== ATTACHMENT 1 =====

ATT CREATION TIME/DATE: 0 00:00:00.00

TEXT:

Unable to convert ARMS_EXT:[ATTACH.D61]MAIL45853553Q.026 to ASCII,
The following is a HEX DUMP:

**TESTIMONY OF DR. JANET YELLEN
CHAIR, COUNCIL OF ECONOMIC ADVISERS
BEFORE THE SENATE FOREIGN RELATIONS COMMITTEE
ON THE ECONOMICS OF THE KYOTO AGREEMENT
FEBRUARY 11, 1998**

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

The international agreement that was reached in Kyoto this past December is a crucial first step in addressing global climate change. But it is only a first step. Since the international effort to reduce greenhouse gas emissions is more of a work-in-progress than a completely finished product, it is not yet possible to provide a full authoritative analysis of it. Many of the specifics in several crucial areas are not completely resolved in the diplomatic arena, forcing analysts to make a variety of assumptions about the ultimate form of the international regime. In my testimony today, I will attempt to identify key elements of the agreement, such as global participation and reliance on flexible, market-based measures, that ensure that reductions in global greenhouse gas emissions are consistent with continued strong economic growth. I will do my best also to provide some rough estimates of costs and benefits.

The Administration is strongly committed to ensuring that these critical elements are reflected in our domestic and international climate change policies. We are firmly committed to meaningful developing country participation, as well as emissions trading both domestically and internationally. And as you know, the President's FY 1999 budget includes a \$6.3 billion package of tax cuts and R&D over the next 5 years to jumpstart our efforts.

I. Basic Economic Rationale of the Kyoto Treaty

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

The earth's surface is warming from the accumulation of greenhouse gases from myriad sources worldwide. None of these emitters presently pays the cost to others of warming's adverse effects -- a classic externality in the language of economists. As a result of these distorted incentives, disruption of the Earth's climate is likely to proceed at an excessive pace and if left uncontrolled may pose substantial costs in terms of disruption to commerce and the environment alike. The fundamental economic logic of the Kyoto agreement is thus that

without such an international agreement, individual nations will not have the proper incentives to address the threats from global climate change.

II. Costs of Climate Change

In evaluating efforts to mitigate global warming, the first step is to consider the costs that are likely if we fail to take any action -- for these costs provide the primary motivation for reducing greenhouse gas emissions. What, then, are the costs associated with allowing global climate change?

The Intergovernmental Panel on Climate Change (IPCC) jointly established by the World Meteorological Organization and the United Nations Environment Programme, concluded in 1995 that "the balance of evidence suggests that there is a discernible human influence on global climate." Current concentrations of carbon dioxide, methane, nitrous oxide, and the other so-called greenhouse gases have reached levels well above those of preindustrial times. Of these, carbon dioxide (CO₂) is the most important: net cumulative CO₂ emissions resulting from the burning of fossil fuels and deforestation account for about two-thirds of potential warming from changes in greenhouse gas concentrations related to human activity.

Climatic Impact

If growth in global emissions continues unabated, the atmospheric concentration of CO₂ will likely double relative to its preindustrial level by midway through the next century. As a result of the increased concentration of CO₂, the IPCC estimates that global temperatures will increase by between 2.5 to 6 degrees Fahrenheit in the next 100 years, with a best guess of about 3.5 degrees Fahrenheit. While scientists believe that human activities are leading to a gradual warming of the *average* temperature of the earth, the change in temperature in a given region at a given time may differ substantially from this average. Indeed, models predict warming will be greater in high latitudes than in the tropics, and greater over land than ocean. Many models predict larger increases in evaporation than in precipitation over midlatitude land areas, which would result in drier conditions in those regions, especially during summer in North America and Europe.

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

Economic and Monetary Damages

The derivation of quantitative or monetary estimates of the damages from such climate changes is extremely difficult given the capacity of today's forecasting models. Estimates of the economic damages from climate change fall into the following broad areas: agriculture, sea-level rise, air conditioning and heating, water supply, human life and health, air pollution, and other costs (hurricanes, migration costs, human amenity, construction, leisure activities, urban infrastructure, and ecological damages such as forest loss and species loss).

A subject of great uncertainty and sensitivity is the "discount rate" that is applied to the benefits of averting future climate change. Such a discount rate is needed if the analysis is to be expressed in monetary terms, because a dollar today is not worth the same as a dollar tomorrow. And since the benefits of stemming future climate change accrue over not only decades but centuries, small changes in the discount rate can produce substantial changes in the results. But the precise discount rate that should be used to evaluate questions as important as the future climate of the planet remains a subject of intense debate. It is safe to say that there is, as of yet, no professional consensus on the issue.

A similar point concerns risk aversion. To what extent are we willing to take chances with our planet? The point applies particularly to catastrophe scenarios. Scientists have thought of many possible scenarios, most of which they are fortunately not yet prepared to pronounce as particularly likely based on current evidence, but which might be truly catastrophic for the planet if they were to occur. There is a strong argument for the Kyoto agreement as a form of planet insurance. But what numerical weight should one assign to these catastrophic risks? In other words, what is the value of the insurance policy? It is difficult for an economist, or anyone, to know.

Despite these shortcomings and potential problems, respected researchers have developed estimates of the monetary damages expected from an average worldwide temperature increase of approximately 4.5 degrees Fahrenheit (corresponding to, roughly, a doubling of pre-industrial carbon dioxide concentrations). For example, William Cline, then a Senior Fellow at the Institute for International Economics, estimated that such a temperature change would impose annual damages of more than \$70 billion per year on the U.S. economy in today's terms. These damages include \$22 billion in lost agricultural production, \$13 billion in additional electricity costs, and \$8 billion in new costs to maintain the existing supply of fresh water. (Cline's original estimates are quoted in 1990 dollars. The figures given above translated those numbers into 1997 dollars using the annual GDP price index.) William Nordhaus of Yale University has likewise computed estimates of the dollar loss attributable to a doubling of carbon dioxide concentrations. He finds that the Cline estimate is in the center of three estimates for the U.S., and that the high estimate is only 1.3 times greater than the low estimate.

It must be noted, however, that this similarity of aggregate estimates masks the true uncertainty associated with forecasts of the damages from given increases in global warming --

the estimates are all fundamentally based on extrapolations from current and past experience, and may not fully incorporate effects that will unfortunately become apparent only with future experience. In particular, the estimates may not fully reflect potential non-linearities in the relationships between carbon dioxide concentrations and temperature, between temperature and economic damages, or in the various other complicated relationships governing interactions between greenhouse gas emissions, the climate, and the economy. Current quantitative analyses do not, and cannot, accurately reflect the small and unknown possibility of large-scale and potentially irreversible discrete events with potentially catastrophic consequences.

Two such possibilities serve as illustrations. Warming of Northern tundra may release very large amounts of methane from the subarctic permafrost, thereby leading to potentially devastating acceleration of an otherwise controllable global warming process. We do not know at what point, if any, such unstable activity would be triggered. Second, evidence from climate models suggests that some types of climate change may lead to displacement of the Gulf Stream that warms Western Europe. Evidence from ocean core samples suggests that such reversals of ocean currents have occurred in previous ice ages. Reductions in the risk of such catastrophic outcomes must be considered in addition to the costs and benefits that can be reasonably quantifiable. Since human beings are typically averse to risk, such possibilities are especially important in evaluating whether the benefits of a particular climate control policy justify the costs. One must have at least some sympathy with those who criticize economists on the grounds that the effects of climate change are extremely difficult to quantify in a single monetary number.

III. Addressing Global Climate Change in an Efficient Manner

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

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

Need for Global Action

Climate change is a global problem requiring a global solution. As I mentioned earlier, no single country has an incentive to reduce emissions sufficiently to protect the global environment against climate change. Each has an economic incentive to “free ride” on the efforts of others. Even if the United States sharply reduced its emissions unilaterally, greenhouse gas emissions from all other countries would continue to grow, and the risks posed by climate change would not be significantly abated. It is important to emphasize that emissions of different gases anywhere in the world have very similar effects on global climate.

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

To address the lack of progress among many industrialized countries toward meeting the Rio objective, the United States and approximately 160 other nations agreed in negotiations held in Kyoto, Japan, last December, to take substantial steps to stabilize atmospheric concentrations of greenhouse gases. The Kyoto Agreement, which requires the advice and consent of the Senate, would place binding limits on industrial countries' emissions of the six principal categories of greenhouse gases: CO₂, N₂O, methane, sulfur hexafluoride, perfluorocarbons, and hydrofluorocarbons. **These limits apply to the 38 so-called Annex I countries, which are the industrialized countries, defined to include Russia, Ukraine, and most Eastern European countries.**

Under the Kyoto agreement, each industrial country's “1990 baseline” is actually based on its 1990 emissions of CO₂, methane, and N₂O and its choice of 1990 or 1995 levels of the other three categories of gases. The United States agreed to a target of 7 percent below 1990 levels by the period between 2008 and 2012. To meet that target, net U.S. emissions of greenhouse gases -- all emissions minus removals of CO₂ by certain forestry-related activities -- must average no more than 1,484 million metric tons of carbon equivalent per year during that period. The targets for the European Union and Japan are 8 percent and 6 percent below 1990 levels, respectively. Australia, New Zealand, Norway, Russia and Ukraine all have limits somewhat less ambitious when phrased as cuts relative to

their 1990 levels. In sum, over the period from 2008 to 2012, the industrial countries are expected to reduce their average emissions of greenhouse gases to about 5 percent below their 1990 levels.

The President has made clear that his support of the Kyoto Agreement is dependent on meaningful participation from key developing countries (who are not included in Annex I). The President has also made clear that he will not submit the treaty to the Senate without such participation.

There are several reasons why meaningful participation from developing countries is essential. First, developing countries are projected to contribute a majority of total emissions by 2030 under a continuation of business-as-usual. Without the participation of developing economies, emissions reductions by the industrialized countries will therefore not achieve necessary protection from climate change. Indeed, if developing countries do not participate in the international regime, their emissions could potentially increase by *more* than under their business-as-usual baselines. One mechanism for such an unintended consequence is as follows.

As Annex I countries comply with their targets, their demand for oil will fall, which will probably work to reduce the price of oil on world markets, and perhaps to encourage non-participating countries to use more oil and emit more carbon than they otherwise would have.

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

Third, principles of basic fairness suggest all countries should do their part, depending on their ability to contribute to the solution. Thus even poor countries should contribute, although the existence of more pressing social needs in such countries will inevitably limit the magnitude of their contributions.

So far I have not mentioned the word "competitiveness." One of the difficulties in analyzing concerns related to competitiveness is that the term itself is used to mean many different things. I have seen at least one study that uses "loss of competitiveness" to refer to predictions of negative effects on the *aggregate* trade balance. As a professional economist, I do not accept the logic upon which that particular argument is predicated: the aggregate trade

balance is determined by macroeconomic forces -- the difference between saving and investment -- and not by our environmental policies.

On the other hand, if competitiveness refers to adverse effects on a few specific manufacturing industries -- those that are especially energy-intensive, such as aluminum, paper, and chemicals -- the situation may be more complicated. It is difficult to undergo a significant structural change in the economy without having the effect of expanding some sectors and contracting others. But to provide some perspective on this issue, consider the following facts. First, on average, energy constitutes only 2.2 percent of total costs to U.S. industry. Second, energy prices already vary significantly across countries. According to the *1997 Statistical Abstract*, for example, in 1996 premium gasoline cost \$1.28 per gallon in the United States -- but only 8 cents in Venezuela. Yet U.S. industry is not moving en masse to Venezuela. Third, roughly two-thirds of all emissions are not in manufacturing at all, but in transportation and buildings. I therefore believe it more accurate to say that we need developing country participation for the reasons I outlined above, than to say that we need it to avoid adverse effects on competitiveness.

Flexibility and Market Mechanisms

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

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

1. "When flexibility" (timing)

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

The Kyoto Protocol incorporates this principle of "when flexibility" in four ways:

- First, the cuts to be made in the first period are less severe, and the first period ends much later, than what had been proposed by many other countries, most notably the Europeans. By adopting a gradual and credible path of reductions in the early years, we can greatly reduce costs such as those from prematurely scrapping coal-fired electricity plants still in the prime of their operating lives, while attaining the same ultimate environmental goals.
- Second, under the Kyoto agreement, the emissions target is not specified in terms of a specific year, but rather in terms of an average over a five-year period (2008-2012). Averaging over five years, instead of requiring countries to meet a specific target each year, can lower costs, especially given an uncertain future. The averaging can smooth out the effects of short-term events such as fluctuations in the business cycle and energy demand, or hard winters and hot summers that would increase energy use and emissions.
- Third, there is allowance for “banking” emission reductions within the 2008-2012 commitment period, for use in a subsequent commitment period [although the emission targets of the next period have not yet been specified].

2. “What flexibility” (gases and sinks)

The second type of flexibility is “what flexibility”, along two dimensions. The first is the inclusion in the agreement of all six greenhouse gases. Emissions of different kinds of gases, not just carbon dioxide, contribute to the greenhouse effect. Since the IPCC has developed conversion factors for all greenhouse gases by estimating their global warming potentials, reductions in emissions of one pollutant can be used to substitute for increases in emissions of another by an amount that has equivalent environmental effects. The Kyoto Protocol stipulates that countries with binding targets are expected to reduce their *total* greenhouse gas emissions by certain percentages, but does not require specific reductions for specific gases. Since a molecule of sulfur hexafluoride is 23,900 times more potent over 100 years than a molecule of CO₂, it may be cheaper to achieve the same environmental benefit by eliminating one molecular unit of SF₆ than nearly 24,000 units of CO₂.

Some initial rough analysis indicates that a strategy of reducing non-CO₂ greenhouse gases by *more* than 7 percent below their 1990/1995 baseline levels while reducing CO₂ by *less* than 7 percent below its 1990 level could reduce greenhouse gas emission permit prices by more than 10 percent. [This analysis is based on the integrated SGM/non-CO₂ cost curve.] Thus allowing countries flexibility in what gases they reduce -- essentially trading emissions reductions across gases -- can help lower significantly the costs of meeting their targets.

The second source of “what flexibility” is the treatment of sinks, i.e., land use activities that promote the removal of carbon from the atmosphere through the growth of plants. Promoting such sinks through afforestation and reforestation may reduce atmospheric

concentrations of CO₂ at much lower costs than reducing emissions of greenhouse gases.

3. "Where flexibility" (international)

The third type of flexibility, and perhaps the most important, is "where flexibility" (international). As I have already emphasized, emissions have the same environmental consequences regardless of where in the world they occur. Therefore, the least-cost approach to controlling climate change is to reduce emissions wherever such reductions are cheapest. The Kyoto agreement includes two important cost-saving provisions of this nature. First, it provides for industrial countries to trade rights to emit greenhouse gases with each other. This market in emissions permits will ensure that emission reductions occur where they are least expensive within the industrial countries. In particular, U.S. companies could purchase emissions reductions in other participating countries when doing so would reduce their costs -- lowering costs without affecting the level of environmental protection.

Second, the agreement allows industrial countries to invest in "clean development" projects in the developing world and use these projects' certified emissions reductions toward meeting their targets. Many such clean-development projects may be quite cheap in terms of the cost per ton of emissions avoided, as has been illustrated by the joint implementation pilot program that is already in place in the U.S. Details of these provisions will be worked out in negotiations in Buenos Aires later this year.

IV. Difficulties of Economic Analysis of Kyoto Agreement

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

The difficulties associated with economic analysis of climate change fall into three broad categories. First is the uncertainties that still remain over the terms of the ultimate treaty. Second is the inherent limitations of available models to analyze even short-term costs and benefits. And finally is a topic I discussed earlier: the impossibility of putting a single monetary number on the long-term benefits of climate change mitigation.

Uncertainties over Certain Provisions in International Effort to Combat Climate Change

The Kyoto Agreement was an historic accomplishment, delineating the broad terms of

the international effort to address climate change. But although we know a lot more than we did before Kyoto about how that international system will work, there is still much that we don't know.

First, as is often the case in a legal document of the length and complexity of the Kyoto Protocol, there are some provisions that require further clarification and interpretation. Of particular concern here is the treatment of so-called sinks -- activities that affect the rate at which carbon is removed from the atmosphere and "sequestered," specifically by the planting of trees.

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

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

Inherent Limitations of Models

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

One area in which the uncertainty is particularly large is the pace of technological progress -- including diffusion of existing energy-efficient technologies, as well as research and development of new technologies -- and the extent to which the pace will accelerate in response to government programs. Economics does not offer a good understanding of how technological progress is determined, in part because it is the stuff of experimentation, brainstorming, genius, breakthroughs, perceptions and habits. Invention is largely determined by inspiration -- notwithstanding Edison, who assigned a 99 percent share to perspiration -- and inspiration, in my

experience, is difficult to fit into mathematical formulae or economic models. Models and experts on climate change policy tend to have a wider range of disagreement on the speed with which technology can be changed and the scope for speeding diffusion of existing energy-efficient technologies than on any other single issue.

Furthermore, each model has strengths and weaknesses; each has questions to which it is better or worse suited to answer. Some, for example, model the energy sector in detail. Some allow for the fact that a coal-fired power plant cannot costlessly be converted to one that runs on natural gas. Some have enough policy detail to distinguish alternative ways of redistributing revenues that would result if emission permits were to be auctioned. Some are capable of showing short-term macroeconomic disequilibria. Some include a long-term “carbon cycle” model that can keep track of the accumulation of greenhouse gas concentrations in the atmosphere and their climatological effects. Some break down the rest of the world into regions and so can model international trade. No one model does everything, and therefore we must not rely blindly on the results of any one model or set of models. Professional judgement and economic intuition are also crucial.

Benefits of Averting Climate Change

As I discussed above, it is evident that the benefits of averting climate change are potentially immense. But I have chosen not to try to quantify them in monetary terms for you, in light of the difficulties I have enumerated -- including the quantitative uncertainty of these benefits, and their timing and therefore the extreme sensitivity of the results to the chosen discount rate.

Instead, what I will do is draw upon a variety of sources in an attempt to add up the various possible costs and benefits of emissions policy *excluding* climate change. To give away the punch line, my conclusion is as follows: the net costs of our policies to reduce emissions are likely to be small, if those reductions are undertaken in an efficient manner, *even before taking into account the benefits of averting climate change itself*. That small net premium excluding the benefits of mitigating climate change, in effect, purchases a partial insurance policy against a serious environmental threat.

V. Models of the Kyoto Agreement

The existence of modeling difficulties means that the results from any model must be treated with caution. We have therefore employed a broad set of economic tools to assess the Kyoto agreement. We have drawn on the insights of a wide range of models of the energy sector and economy over the next 25 years, including but not limited to the results of the Stanford Energy Modeling Forum exercises, the IPCC’s review of the economic and social dimensions of climate change, and the staff-level Interagency Analytical Team effort last year. Other tools include simple relevant statistics, “meta-analyses” of existing models, historical and sectoral

examples, and basic economic reasoning. Drawing on this broad array of analytical tools is crucial to an intelligent evaluation of the policy alternatives.

To my knowledge, as of December, no model -- whether used inside the government or not -- had been set up precisely to analyze the parameters of the agreement that was reached in Kyoto. Most model-builders outside the government tend to take as long as several years to incorporate changes in policy parameters into their models. And no model is currently designed to assess sinks, or all six greenhouse gases included in the treaty.

One of the leading models in the field is the Second Generation Model of Battelle Laboratories. The SGM is one of the models best positioned to analyze the role of international trade in emission permits, which we consider to be a critical element of the Kyoto Treaty. However, the SGM does not cover all six gases included in the Kyoto agreement or include a role for sinks. We have used the SGM model as a starting point for a preliminary assessment of the Kyoto treaty, but have attempted to supplement its results with additional analysis to account for such special features of the agreement as the inclusion of six gases, sinks and a possible Annex I trading that could exclude the EU. I will share with you today some preliminary results of this analysis.

Mindful of the limitations of any single model, we are eager to see features of the Kyoto agreement assessed by other modelers to obtain a better feel for the range of possible effects. Much of this work will continue to go on outside the government. For example, we have had discussions with the Energy Modeling Forum, based at Stanford University. The EMF is a long-running exercise involving many of the leading climate models. We have given the EMF advice on how features of the Kyoto legal language can be translated into terms recognizable to an economist. Unfortunately, the Energy Modeling Forum believes that its members will need at least until mid-year to produce reliable results.

VI. Economic Analysis

With all of that as important background, let us now turn to the task at hand. As we do so, let me emphasize once again that the figures presented below do not incorporate the benefits of starting to mitigate climate change.

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

Within the Kyoto agreement, this means an insistence on international trading, joint implementation, and, ultimately, on full developing country participation. Domestically, this

means that we implement any emissions reductions through a market-based system of *tradeable* emissions permits, which ensures that we achieve reductions wherever they are least expensive. But this also means taking serious and responsible steps in the short run to prepare us to meet our obligations in the longer term.

The first such step is the inclusion in this year's budget of an aggressive, \$6.3 billion program of tax cuts and R&D -- \$1.3 billion more than the \$5 billion package the President promised in his October 22 speech on this issue. The goal is both to stimulate the development of new energy-saving and carbon-saving technologies and to encourage the dissemination of those that exist already. The proposed package contains \$3.6 billion over the next 5 years in tax cuts for energy efficient purchases and renewable energy, including tax credits of \$3,000 to \$4,000 for consumers who purchase highly fuel efficient vehicles, a 15 percent credit (up to \$2,000) for purchases of rooftop solar equipment, a 20 percent credit (subject to a cap) for purchasing energy-efficient building equipment, a \$2,000 credit for purchasing energy-efficient new homes, an extension of the wind and biomass tax credit, and a 10 percent investment credit for the purchase of combined heat and power systems. The package also contains \$2.7 billion over the next 5 years in additional research and development spending -- covering the four major carbon-emitting sectors of the economy (buildings, industry, transportation, and electricity), plus carbon removal and sequestration, Federal facilities, and cross-cutting analyses and research. One example of the R&D effort is the Partnership for a New Generation of Vehicles (PNGV). PNGV is a government-industry effort to develop attractive, affordable cars that meet all applicable safety and environmental standards and get up to three times the fuel efficiency of today's cars. In FY99, the combined proposal for PNGV is \$277 million, up from \$227 million appropriated in FY98. Similar government-industry efforts are proposed to develop more efficient diesel engines for both light trucks and heavy trucks. [ADD SOMETHING MORE ABOUT INDUSTRY-GOVERNMENT DIALOG. PERHAPS A CONCRETE EXAMPLE OF IDENTIFYING AN INDUSTRY REGULATION THAT COULD BE REMOVED.]

The second such step is the promotion of an environmentally-responsible electricity restructuring bill, which the President identified as part of his domestic climate change package in his address to the National Geographic Society on October 22. An electricity sector freed from government regulation would be a more efficient energy sector. Costs to consumers would fall. A reasonable overall estimate of the effects of adding federal electricity restructuring to the rest of the President's program to address climate change is to achieve the same environmental goals at a cost saving of roughly \$16 billion per year.

Estimated Reduction in Costs from Annex I Trading

In the language of the treaty, "Annex I," you will recall, is the set of countries that have agreed to take on binding limitations in emissions of greenhouse gases. Even without developing country participation -- which, again, the President has emphasized as essential before the treaty could be ratified -- costs would be reduced substantially by trading among the Annex I countries. To provide some indication of the possible efficiency improvements, Russia

and the Ukraine consume six times as much energy per dollar of output as does the United States.

Estimates derived from the SGM model suggest that trading among Annex I countries is likely to reduce the cost to the United States of achieving its targets for 2008-2012 emissions by about half relative to a situation in which such trading was not available. This concept of costs is meant to capture aggregate resource costs to the US economy, including the cost to domestic firms of purchasing emission permits from Russia and other countries where emission reductions are cheaper than in the United States. The dramatic reduction in costs available from Annex I trading within the SGM model -- cutting the costs involved by half -- highlights why the President insisted that international trading be part of the Kyoto Agreement.

A useful rough check on this estimate can be obtained from other modelling efforts, notwithstanding that they are likely to be more distant approximations to the parameters of the Kyoto Treaty. Recent results from twelve leading models that participate in the Stanford Energy Modeling Forum show that trading among industrialized countries reduces estimated costs -- defined as lost consumption -- by an average of 56 percent, although the results vary from model to model.

Estimated reduction in costs from umbrella trading

One possibility that emerged in Kyoto, which none of us foresaw, was the idea that the United States might undertake trading with a subset of Annex I countries, dubbed the "umbrella," that would exclude the European Union. The initial list of proposed participants in the umbrella includes the United States, Australia, Canada, Japan, New Zealand and Russia, with strong indications of interest from some others. The motivation for this idea was that the Europeans have been reluctant to agree to the sort of international trading that we want (preferring that they achieve their goals collectively in a group of their own, called the "EU bubble").

It is too early to say whether the umbrella concept will in fact be accepted by the parties. But it is an important concept to consider, for three reasons. First, it is conceivable that it will be formally agreed to in future negotiations. Second, even if the final treaty does not explicitly include the umbrella, but rather allows trading among all signatories (as the United States has proposed all along), it is conceivable that umbrella countries will agree, outside the treaty, to trade only among themselves. Third, the aversion toward international trading that the Europeans have expressed suggests that they might refrain from making the trades to which they would be entitled -- which would mean that the umbrella would operate in practice, if not in formal international agreement.

The significance of the umbrella idea in the present context is that it has the potential to further reduce costs to the United States. The reason is that if the Europeans do not bid against us for the relatively abundant, low-cost opportunities to reduce emissions in Russia and Eastern

Europe, then the price of emissions reductions will be even lower. Results that we have derived from various SGM simulations suggest that, relative to the situation in which there is no trading at all, the umbrella arrangement would reduce costs by an estimated 61-75 per cent, depending on whether the former Warsaw Pact countries are classed with the EU, or are instead assumed to fall within the umbrella. Thus, the umbrella arrangement raises the benefit to international trading significantly relative to full Annex I trading, reducing costs from roughly half their no-trading level to as low as one-quarter their no-trading level.

Estimated reduction in costs from LDC participation

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

A moderate version of developing country participation is the Clean Development Mechanism, modelled after Joint Implementation (JI). JI cannot realistically be expected to yield all the gains of binding targets for developing countries, but it might shave costs by roughly another 20 to 25 percent from the reduced costs that result from trading among Annex I countries.

Another possibility is that we persuade some of the key developing countries that are the largest emitters to commit to targets, and allow us to buy emission reductions from those paths. We estimate that this could cut roughly 55 percent off the reduced costs that result from Annex I trading. [The four countries included in this particular estimate are China, India, Brazil and Korea.] Once these savings have been attained, the estimated reductions to US costs from persuading the rest of the developing world to go along with full commitments are relatively small.

I offer these numbers because they show the potential effectiveness of trading in reducing costs dramatically. But it is important that I repeat three caveats: First, as always, there is a wide range of uncertainty around all these estimates. Second, they apply to an idealized version of trading, one that assumes no problems of enforcement or transactions costs. Third, it seems unlikely that we will get all our partners to agree in Buenos Aires to the very most optimistic or ambitious case. Nonetheless, despite these caveats, the numbers do show major savings even without getting the most optimistic case. And if we don't get enough of what we want, we won't submit the treaty for ratification to the Senate.

VII. Non-Climate Benefits

The costs of undertaking greenhouse gas emission reductions must be compared to the benefits. As I have indicated, for various reasons our analysis does not quantify the benefits from averting climate change itself. But the relative price shifts that are necessary to reduce

emissions should produce benefits in three areas: air pollution, traffic congestion, and highway accidents. These benefits are quantifiable.

Reductions in carbon emissions also lead to reductions in emissions of pollutants that contribute to excess concentrations of fine particulate matter and low-level ozone.

[FORTHCOMING, PENDING ANALYSIS FROM EPA and LUTTER.]

Traffic congestion hurts motorists by causing delays and inconvenience. More efficient pricing -- which recognizes the externalities involved -- should lead to reductions in congestion as motorists choose other means of travel, share rides, or even forgo less important trips.

We estimate, for example, that higher fuel prices resulting from carbon permit prices of, say \$20/ton, would reduce travel delays associated with congestion, and that the value of such time savings to consumers would be about \$0.4 billion per year.

Vehicle use also leads to costly accidents and to highway injuries including fatalities. Assuming that accidents fall proportionately with vehicle use, more efficient pricing will also create savings from reduced accidents and resultant mortality. We estimate that the savings from reduced accidents and the value of reduced mortality risk, corresponding to a \$20/ton carbon price, is approximately \$0.3 to \$2.7 billion/ year [depending on whether lighter cars are less crashworthy].

A variety of other benefits that are harder to quantify are likely to result from reductions in carbon emissions. With respect to transportation, reduced vehicle use will also reduce the cost of road repair and maintenance. Second, reduced coal use will reduce the cost of sulfur dioxide controls, as utilities switch to energy sources other than coal. Reduced coal use will also lower mercury emissions. Finally, reduced energy use will also increase U.S. energy independence. Our inability to estimate these effects quantitatively does not imply that they are necessarily small or unimportant.

VIII. Preliminary Estimate of the Net Effects of the Kyoto Agreement

We can now combine the various benefits and costs delineated above to provide a preliminary assessment of the net impact of the Kyoto agreement, excluding, however, the benefits of averted damage from climate change. This assessment relies on SGM model results along with additional Administration analysis. It accounts for the impact of trading under the umbrella, and assumes full participation by four key LDCs. We find that the net resource costs of attaining our Kyoto targets for emission reductions are \$7 to \$9 billion. **Thus the net costs are \$_ billion to \$_ billion, or roughly 0.0_ percent of projected GDP (i.e., net of ancillary non-climate benefits, predicted from a permit price of \$12-\$16 per ton, depending on which umbrella definition is used).**

A more tangible measure of costs is the estimated effects on energy prices. Excluding the impact of electricity restructuring, the SGM-based estimate is that the price of emissions would be in the range \$12 to \$16 per ton of carbon equivalent -- and that energy prices at the household level would rise by about 3 percent under the Kyoto accords [CHECK]. Fuel oil prices would rise by about 5 percent, natural gas prices by 4 percent, gasoline prices by 3 percent, and electricity prices by 2 percent. The 3 percent increase in energy prices at the household level would raise the average family's energy bill by about \$75.

These estimates do *not* mean that households' energy expenses will in fact be higher in 2010 than today, however. In the first place, energy prices fluctuate year-by-year for all sorts of reasons. They could go either up or down. But even if we leave out unpredictable fluctuations, the energy price declines from Federal electricity restructuring would be enough to offset the impact estimated above. By 2008-2012, the projected 10 percent decline in electricity prices from the restructuring that is part of our climate change agenda will mean a net reduction in energy prices in the U.S., even accounting for the small increases noted above.

As highlighted earlier, estimates of the type that I am presenting are fraught with uncertainty. The estimate I just discussed was predicated on the developing country participation that we will insist upon in Buenos Aires as a condition for our ratifying the Kyoto Protocol, but which is not yet part of that Protocol. At the same time, the numbers I have cited are in several respects conservative: they leave out several factors, such as the role of sinks, that could further reduce costs. But before I bring these factors into the analysis, allow me to say a few words about macroeconomics.

Effects on employment and aggregate output

So far I have said nothing about job losses resulting from climate change policy. Although there may be job gains in some sectors and job losses in others, I do not anticipate any significant aggregate effect. Some jobs could be lost in energy-intensive sectors, although given the very small predicted change in energy prices, impacts in most such sectors are apt to be minimal. Furthermore, a large number of jobs will be created in other sectors -- many of them high-tech jobs paying high wages. The President is firmly committed to assisting any workers who are adversely affected during the transition to a climate-friendly economy.

The situation might be different if a large energy shock were to hit the economy with no warning, as happened in the oil crisis of 1973-74, when the real money supply, output and employment all contracted sharply. In addition to hitting with no warning, the oil shocks of the 1970s also entailed large transfers from the U.S. and other oil-importing countries to OPEC, thus depressing real income and spending in the former. A self-imposed shift in the relative price of carbon-intensive energy to address global climate change, on the other hand,

need not entail such a transfer of purchasing power. Thus there are critical differences between the oil price shocks and the effort to reduce carbon emissions. Our reassuring conclusion regarding aggregate output might also be different if the policy were to be implemented inefficiently (by command-and-control style regulations of the sort put in place in that oil crisis) rather than efficiently (by market mechanisms of the sort that the President has proposed to use).

Consider for a moment the ability of U.S. industry to evolve to changes when there is sufficient lead time. [SO2 EXAMPLE to be added shortly]

VIII. The Foregoing Estimates Are Conservative along Several Dimensions

I should emphasize that the estimates I have presented are conservative in the sense that they do not include the potential cost reductions resulting from the inclusion in the Kyoto treaty of carbon sinks, the potential payoffs to the President's technology or energy efficiency policies, or the benefits of mitigating climate change itself. The first omission, sinks, concerns a provision of the Kyoto Protocol that has received less attention than it merits. It is only *net* emissions -- emissions to the atmosphere minus sequestration -- that are to be reduced 7 percent below 1990 levels, not gross emissions. The United States plants many trees every year, and would receive credit for this activity under the Protocol. Very preliminary estimates of the implications for the United States of the Kyoto provision on sinks reduce the resource cost by to 17 per cent. **This brings resource costs down to \$15-\$18 billion, depending on whether we count in no LDC participation at all or we count the benefits of joint implementation through the Clean Development Mechanism (as currently agreed to in the Kyoto Protocol).**

These numbers translate into net costs of __ and energy prices of __. If we get the full participation of LDCs, the costs come down further.

Even those estimates for the effect of sinks are conservative in one respect: they are based on an assumption for sink activity in the U.S. over the 2008-2012 period, and no assumed benefits from sinks elsewhere in the world. Very preliminary estimates suggest that incorporating the gains from sinks *throughout the world* can reduce the costs of meeting the Kyoto target by half or more, on top of the gains from trading among Annex I countries. (Furthermore, no model has yet even tried to take into account that government policies can help increase the amount of tree-planting, possibly through some version of the Conservation Reserve Program, for example.) But neither we nor other analysts are yet sure exactly how to interpret the legal language of the Protocol. Because the quantitative uncertainty is so large, we do not yet have an estimate with which I feel comfortable. But we do know that the effect of fully modelling the Kyoto provision on sinks is likely to be both favorable and large.

The estimates I have cited so far also make little allowance for the payoff to the President's \$6.3 billion Climate Change Technology Initiative. The parameter that figures most

prominently in analysis of technological progress in the energy field is the rate of improvement in the so-called Autonomous Energy Efficiency Index (AEEI), that is the rate at which the total use of energy falls relative to GDP. In the SGM model analysis that underlies our assessment, the AEEI is assumed to improve by 1.0 percent per year. Reflecting a conservative interpretation of the 15-year impact of the technology initiative, this is only a small increase above the 0.9 percent number in the Energy Information Administration's Annual Energy Outlook.

Our justification for incorporating into our assessment such a small assumed impact of Administration technology policies logic is somewhat analogous to the Administration's rationale for employing mainstream economic assumptions in our budget forecasts: in the presence of uncertainty, we are conservative in our estimates of the speed with which the economy will grow, tax receipts will rise, and the budget will improve. That way, any revisions or surprises that occur are likely to be in the pleasant direction. In this instance, we have conservatively assumed that there will be substantial lags in producing payoffs from new technology research and dissemination expenditures. Clearly, this is neither the best outcome we can attain nor the best outcome we expect to attain as a consequence of our climate change strategy over the next decade. Experts on the energy technology relating to climate change forecast more rapid technological progress; and engineering models suggest that some energy improving technologies are available now at negative net costs.

If the Administration is successful in speeding the discovery and adoption of new technologies, the rate of improvement in energy efficiency could rise and such improvements would lower the cost of meeting our Kyoto target. For example, model based analysis suggests that a 25 percent boost in the AEEI parameter has the effect of reducing resource costs **by 26 - 27 per cent, to \$13 to \$16 billion, again depending on whether we count no LDC participation at all or count the benefits of joint implementation.** These numbers translate into net costs of **__** and energy prices of **__**. If we were to get the full participation of some LDCs, the costs would again come down further.

The third, and most important, respect in which the estimates I have presented are conservative is that they leave out the benefits of mitigating climate change itself. A full cost-benefit analysis would include mitigation in the benefits column. The only reason we have not done so, as I have explained repeatedly above, is the difficulty in coming up with a number to capture the monetary benefits. But I trust that nobody will lose sight of our ultimate objective -- keeping our planet the hospitable home that we enjoy today.

CONCLUSION

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

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

I welcome your questions.

RECORD TYPE: PRESIDENTIAL (NOTES MAIL)

CREATOR: Joseph E. Aldy (CN=Joseph E. Aldy/OU=CEA/O=EOP [CEA])

CREATION DATE/TIME: 5-FEB-1998 19:43:44.00

SUBJECT: Meeting regarding EMF exercises

TO: ray.squitieri (ray.squitieri @ treas.sprint.com @ inet [UNKNOWN])
READ:UNKNOWN

TO: Adele C. Morris (CN=Adele C. Morris/OU=CEA/O=EOP @ EOP [CEA])
READ:UNKNOWN

TO: Jeffrey A. Frankel (CN=Jeffrey A. Frankel/OU=CEA/O=EOP @ EOP [CEA])
READ:UNKNOWN

TO: Peter R. Orszag (CN=Peter R. Orszag/OU=OPD/O=EOP @ EOP [OPD])
READ:UNKNOWN

TO: jonathan.gruber (jonathan.gruber @ treas.sprint.com @ inet [UNKNOWN])
READ:UNKNOWN

TO: Randall W. Lutter (CN=Randall W. Lutter/OU=CEA/O=EOP @ EOP [CEA])
READ:UNKNOWN

TO: Janet L. Yellen (CN=Janet L. Yellen/OU=CEA/O=EOP @ EOP [CEA])
READ:UNKNOWN

TEXT:

On Tuesday, February 24th, John Weyant, Richard Richels, and Jae Edmonds would like to meet with several of us from the economic agencies who have been working on analyses of the Kyoto Protocol to discuss their efforts in the next EMF exercise. Tentatively, we plan on meeting from 2-4pm that afternoon. Please let me know if you can attend, and if anyone else from your office is interested, and I will go ahead and confirm with them.

Joe

RECORD TYPE: PRESIDENTIAL (NOTES MAIL)

CREATOR: Randall W. Lutter (CN=Randall W. Lutter/OU=CEA/O=EOP [CEA])

CREATION DATE/TIME: 5-FEB-1998 01:35:05.00

SUBJECT: slightly updated version

TO: Jeffrey A. Frankel (CN=Jeffrey A. Frankel/OU=CEA/O=EOP @ EOP [CEA])
READ:UNKNOWN

TO: Michele Jolin (CN=Michele Jolin/OU=CEA/O=EOP @ EOP [CEA])
READ:UNKNOWN

TO: Janet L. Yellen (CN=Janet L. Yellen/OU=CEA/O=EOP @ EOP [CEA])
READ:UNKNOWN

CC: Adele C. Morris (CN=Adele C. Morris/OU=CEA/O=EOP @ EOP [CEA])
READ:UNKNOWN

CC: Joseph E. Aldy (CN=Joseph E. Aldy/OU=CEA/O=EOP @ EOP [CEA])
READ:UNKNOWN

TEXT:
Attached is the more complete of Jeff's files with slight amendments to it.

Below is his abbreviated version, with my revisions, that I forwarded to Peter, David, and Jon,

----- Forwarded by Randall W. Lutter/CEA/EOP on 02/05/98
01:28 AM -----

Randall W. Lutter
02/05/98 01:25:16 AM
Record Type: Record

To: David B Sandalow/CEQ/EOP, Peter R. Orszag/OPD/EOP, Jonathan.gruber @
treas.sprint.com @ inet
cc:
Subject: slightly updated version

The attached version of the draft testimony supercedes a recent transmission by Jeff and includes

1) (still preliminary new) estimates of cost savings from ancillary emissions reductions (NOx etc.) and

2) a couple new paragraphs on how SO2 prices are below expectations to illustrate the power of innovation response to appropriate incentives.

===== ATTACHMENT 1 =====
ATT CREATION TIME/DATE: 0 00:00:00.00

TEXT:

Unable to convert ARMS_EXT:[ATTACH.D16]MAIL49097053I.026 to ASCII,
The following is a HEX DUMP:

**TESTIMONY OF DR. JANET YELLEN
CHAIR, COUNCIL OF ECONOMIC ADVISERS
BEFORE THE SENATE FOREIGN RELATIONS COMMITTEE
ON THE ECONOMICS OF THE KYOTO AGREEMENT
FEBRUARY 11, 1998**

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

The international agreement that was reached in Kyoto this past December is a crucial first step in addressing global climate change. But it is only a first step. Since the international effort to reduce greenhouse gas emissions is more of a work-in-progress than a completely finished product, it is not yet possible to provide a full authoritative analysis of it. Many of the specifics in several crucial areas are not completely resolved in the diplomatic arena, forcing analysts to make a variety of assumptions about the ultimate form of the international regime. In my testimony today, I will attempt to identify the key elements of the agreement that ensure that reductions in global greenhouse gas emissions are consistent with continued strong economic growth. I will do my best also to provide some rough estimates of costs and benefits.

The Administration is strongly committed to ensuring that these critical elements -- including global participation and a reliance on flexible, market-based mechanisms -- are reflected in our domestic and international climate change policies. We are firmly committed to meaningful developing country participation, as well as emissions trading both domestically and internationally. And as you know, the President's FY 1999 budget includes a \$6.3 billion package of tax cuts and R&D over the next 5 years to jumpstart our efforts.

I. Basic Economic Rationale of the Kyoto Treaty

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

The earth's surface is warming from the accumulation of greenhouse gases from myriad sources worldwide. None of these emitters presently pays the cost to others of warming's adverse effects -- a classic externality in the language of economists. As a result of these distorted incentives, disruption of the Earth's climate is likely to proceed at an excessive pace and if left uncontrolled may pose substantial costs in terms of disruption to commerce and the environment alike. The fundamental economic logic of the Kyoto agreement is thus that

without such an international agreement, individual nations will not have the proper incentives to address the threats from global climate change.

II. Costs of Climate Change

In evaluating efforts to address climate change, the first step is to consider the costs that are likely if we fail to take any action -- for these costs provide the primary motivation for reducing greenhouse gas emissions. What, then, are the costs associated with allowing global climate change?

The Intergovernmental Panel on Climate Change (IPCC) jointly established by the World Meteorological Organization and the United Nations Environment Programme, concluded in 1995 that "the balance of evidence suggests that there is a discernible human influence on global climate." Current concentrations of carbon dioxide, methane, nitrous oxide, and the other so-called greenhouse gases have reached levels well above those of preindustrial times. Of these, carbon dioxide (CO₂) is the most important: net cumulative CO₂ emissions resulting from the burning of fossil fuels and deforestation account for about two-thirds of potential warming from changes in greenhouse gas concentrations related to human activity.

Climatic Impact

If growth in global emissions continues unabated, the atmospheric concentration of CO₂ will likely double relative to its preindustrial level by midway through the next century. As a result of the increased concentration of CO₂, the IPCC estimates that global temperatures will increase by between 2.5 to 6 degrees Fahrenheit in the next 100 years, with a best guess of about 3.5 degrees Fahrenheit. While scientists believe that human activities are leading to a gradual warming of the *average* temperature of the earth, the change in temperature in a given region at a given time may differ substantially from this average. Indeed, models predict warming will be greater in high latitudes than in the tropics, and greater over land than ocean. Many models predict larger increases in evaporation than in precipitation over midlatitude land areas, which would result in drier conditions in those regions, especially during summer in North America and Europe.

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

Economic and Monetary Damages

The derivation of quantitative or monetary estimates of the damages from such climate changes is extremely difficult given the capacity of today's forecasting models. Estimates of the economic damages from climate change fall into the following broad areas: agriculture, sea-level rise, air conditioning and heating, water supply, human life and health, air pollution, and other costs (hurricanes, migration costs, human amenity, construction, leisure activities, urban infrastructure, and ecological damages such as forest loss and species loss).

A subject of great uncertainty and sensitivity is the "discount rate" that is applied to the benefits of averting future climate change. Such a discount rate is needed if the analysis is to be expressed in monetary terms, because a dollar today is not worth the same as a dollar tomorrow. And since the benefits of stemming future climate change accrue over not only decades but centuries, small changes in the discount rate can produce substantial changes in the results. But the precise discount rate that should be used to evaluate questions as important as the future climate of the planet remains a subject of intense debate. It is safe to say that there is, as of yet, no professional consensus on the issue.

A similar point concerns risk aversion. To what extent are we willing to take chances with our planet? The point applies particularly to catastrophe scenarios. Scientists have thought of many possible scenarios, most of which they are fortunately not yet prepared to pronounce as particularly likely based on current evidence, but which might be truly catastrophic for the planet if they were to occur. There is a strong argument for the Kyoto agreement as a form of planet insurance. But what numerical weight should one assign to these catastrophic risks? In other words, what is the value of the insurance policy? It is difficult for an economist, or anyone, to know.

Despite these shortcomings and potential problems, respected researchers have developed estimates of the monetary damages expected from an average worldwide temperature increase of approximately 4.5 degrees Fahrenheit (corresponding to, roughly, a doubling of pre-industrial carbon dioxide concentrations). For example, William Cline, then a Senior Fellow at the Institute for International Economics, estimated that such a temperature change would impose annual damages of more than \$70 billion per year on the U.S. economy in today's terms. These damages include \$22 billion in lost agricultural production, \$13 billion in additional electricity costs, and \$8 billion in new costs to maintain the existing supply of fresh water. (Cline's original estimates are quoted in 1990 dollars. The figures given above translated those numbers into 1997 dollars using the annual GDP price index.) William Nordhaus of Yale University has likewise computed estimates of the dollar loss attributable to a doubling of carbon dioxide concentrations. He finds that the Cline estimate is in the center of three estimates for the U.S., and that the high estimate is only 1.3 times greater than the low estimate.

It must be noted, however, that this similarity of aggregate estimates masks the true uncertainty associated with forecasts of the damages from given increases in global warming --

the estimates are all fundamentally based on extrapolations from current and past experience, and may not fully incorporate effects that will unfortunately become apparent only with future experience. In particular, the estimates may not fully reflect potential non-linearities in the relationships between carbon dioxide concentrations and temperature, between temperature and economic damages, or in the various other complicated relationships governing interactions between greenhouse gas emissions, the climate, and the economy. Current quantitative analyses do not, and cannot, accurately reflect the small and unknown possibility of large-scale and potentially irreversible discrete events with potentially catastrophic consequences.

Two such possibilities serve as illustrations. Warming of Northern tundra may release very large amounts of methane from the subarctic permafrost, thereby leading to potentially devastating acceleration of an otherwise controllable global warming process. We do not know at what point, if any, such unstable activity would be triggered. Second, evidence from climate models suggests that some types of climate change may lead to displacement of the Gulf Stream that warms Western Europe. Evidence from ocean core samples suggests that such reversals of ocean currents have occurred in previous ice ages. Reductions in the risk of such catastrophic outcomes must be considered in addition to the costs and benefits that can be reasonably quantifiable. Since human beings are typically averse to risk, such possibilities are especially important in evaluating whether the benefits of a particular climate control policy justify the costs. One must have at least some sympathy with those who criticize economists on the grounds that the effects of climate change are extremely difficult to quantify in a single monetary number.

III. Addressing Global Climate Change in an Efficient Manner

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

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

Need for Global Action

Climate change is a global problem requiring a global solution. As I mentioned earlier, no single country has an incentive to reduce emissions sufficiently to protect the global environment against climate change. Each has an economic incentive to “free ride” on the efforts of others. Even if the United States sharply reduced its emissions unilaterally, greenhouse gas emissions from all other countries would continue to grow, and the risks posed by climate change would not be significantly abated. It is important to emphasize that emissions of different gases anywhere in the world have very similar effects on global climate.

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

To address the lack of progress among many industrialized countries toward meeting the Rio objective, the United States and approximately 160 other nations agreed in negotiations held in Kyoto, Japan, last December, to take substantial steps to stabilize atmospheric concentrations of greenhouse gases. The Kyoto Agreement, which requires the advice and consent of the Senate, would place binding limits on industrial countries' emissions of the six principal categories of greenhouse gases: CO₂, N₂O, methane, sulfur hexafluoride, perfluorocarbons, and hydrofluorocarbons. **These limits apply to the 38 so-called Annex I countries, which are the industrialized countries, defined to include Russia, Ukraine, and most Eastern European countries.**

Under the Kyoto agreement, each industrial country's “1990 baseline” is actually based on its 1990 emissions of CO₂, methane, and N₂O and its choice of 1990 or 1995 levels of the other three categories of gases. The United States agreed to a target of 7 percent below 1990 levels by the period between 2008 and 2012. To meet that target, net U.S. emissions of greenhouse gases -- all emissions minus removals of CO₂ by certain forestry-related activities -- must average no more than 1,484 million metric tons of carbon equivalent per year during that period. The targets for the European Union and Japan are 8 percent and 6 percent below 1990 levels, respectively. Australia, New Zealand, Norway, Russia and Ukraine all have limits somewhat less ambitious when phrased as cuts relative to

their 1990 levels. In sum, over the period from 2008 to 2012, the industrial countries are expected to reduce their average emissions of greenhouse gases to about 5 percent below their 1990 levels.

The President has made clear that his support of the Kyoto Agreement is dependent on meaningful participation from key developing countries (who are not included in Annex I). The President has also made clear that he will not submit the treaty to the Senate without such participation.

There are several reasons why meaningful participation from developing countries is essential. First, developing countries are projected to contribute a majority of total emissions by 2030 under a continuation of business-as-usual. Without the participation of developing economies, emissions reductions by the industrialized countries will therefore not achieve necessary protection from climate change. Indeed, if developing countries do not participate in the international regime, their emissions could potentially increase by *more* than under their business-as-usual baselines. One mechanism for such an unintended consequence is as follows.

As Annex I countries comply with their targets, their demand for oil will fall, which will probably work to reduce the price of oil on world markets, and perhaps to encourage non-participating countries to use more oil and emit more carbon than they otherwise would have.

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

Third, principles of basic fairness suggest all countries should do their part, depending on their ability to contribute to the solution. Thus even poor countries should contribute, although the existence of more pressing social needs in such countries will inevitably limit the magnitude of their contributions.

So far I have not mentioned the word “competitiveness.” One of the difficulties in analyzing concerns related to competitiveness is that the term itself is used to mean many different things. I have seen at least one study that uses “loss of competitiveness” to refer to predictions of negative effects on the *aggregate* trade balance. As a professional economist, I do not accept the logic upon which that particular argument is predicated: the aggregate trade

balance is determined by macroeconomic forces -- the difference between saving and investment -- and not by our environmental policies.

On the other hand, if competitiveness refers to adverse effects on a few specific manufacturing industries -- those that are especially energy-intensive, such as aluminum, paper, and chemicals -- the situation may be more complicated. It is difficult to undergo a significant structural change in the economy without having the effect of expanding some sectors and contracting others. But to provide some perspective on this issue, consider the following facts. First, on average, energy constitutes only 2.2 percent of total costs to U.S. industry. Second, energy prices already vary significantly across countries. According to the *1997 Statistical Abstract*, for example, in 1996 premium gasoline cost \$1.28 per gallon in the United States -- but only 8 cents in Venezuela. Yet U.S. industry is not moving en masse to Venezuela. Third, roughly two-thirds of all emissions are not in manufacturing at all, but in transportation and buildings. I therefore believe it more accurate to say that we need developing country participation for the reasons I outlined above, than to say that we need it to avoid adverse effects on competitiveness.

Flexibility and Market Mechanisms

A global solution is thus critical to the global problem of climate change. Globalizing the solution is not, however, enough by itself. We must also ensure that our efforts achieve their objectives in the most efficient manner possible. The nature of the climate change problem suggests some methods to lower costs of achieving given levels of environmental protection. Such methods have long been championed by economists interested in increasing the efficiency of protection. They were the sort of thing that 2,600 economists had in mind last year when they signed a letter, urging action on climate change:

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

What are these methods and policies? They can be characterized in terms of three categories of flexibility: (1) “when” flexibility; (2) “what” flexibility; and (3) “where” flexibility, which may be the most important of all.

1. “When flexibility” (timing)

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

The Kyoto Protocol incorporates this principle of “when flexibility” in four ways:

- First, the cuts to be made in the first period are less severe, and the first period ends much later, than what had been proposed by many other countries, most notably the Europeans. By adopting a gradual and credible path of reductions in the early years, we can greatly reduce costs such as those from prematurely scrapping coal-fired electricity plants still in the prime of their operating lives, while attaining the same ultimate environmental goals.
- Second, under the Kyoto agreement, the emissions target is not specified in terms of a specific year, but rather in terms of an average over a five-year period (2008-2012). Averaging over five years, instead of requiring countries to meet a specific target each year, can lower costs, especially given an uncertain future. The averaging can smooth out the effects of short-term events such as fluctuations in the business cycle and energy demand, or hard winters and hot summers that would increase energy use and emissions.
- Third, there is allowance for “banking” emission reductions within the 2008-2012 commitment period, for use in a subsequent commitment period [although the emission targets of the next period have not yet been specified].

2. “What flexibility” (gases and sinks)

The second type of flexibility is “what flexibility”, along two dimensions. The first is the inclusion in the agreement of all six greenhouse gases. Emissions of different kinds of gases, not just carbon dioxide, contribute to the greenhouse effect. Since the IPCC has developed conversion factors for all greenhouse gases by estimating their global warming potentials, reductions in emissions of one pollutant can be used to substitute for increases in emissions of another by an amount that has equivalent environmental effects. The Kyoto Protocol stipulates that countries with binding targets are expected to reduce their *total* greenhouse gas emissions by certain percentages, but does not require specific reductions for specific gases. Since a molecule of sulfur hexafluoride is 23,900 times more potent over 100 years than a molecule of CO₂, it may be cheaper to achieve the same environmental benefit by eliminating one molecular unit of SF₆ than nearly 24,000 units of CO₂.

Some initial rough analysis indicates that a strategy of reducing non-CO₂ greenhouse gases by *more* than 7 percent below their 1990/1995 baseline levels while reducing CO₂ by *less* than 7 percent below its 1990 level could reduce greenhouse gas emission permit prices by more than 10 percent. [This analysis is based on the integrated SGM/non-CO₂ cost curve.] Thus allowing countries flexibility in what gases they reduce -- essentially trading emissions reductions across gases -- can help lower significantly the costs of meeting their targets.

The second source of “what flexibility” is the treatment of sinks, i.e., land use activities

that promote the removal of carbon from the atmosphere through the growth of plants. Promoting such sinks through afforestation and reforestation may reduce atmospheric concentrations of CO₂ at much lower costs than reducing emissions of greenhouse gases.

3. "Where flexibility" (international)

The third type of flexibility, and perhaps the most important, is "where flexibility" (international). As I have already emphasized, emissions have the same environmental consequences regardless of where in the world they occur. Therefore, the least-cost approach to controlling climate change is to reduce emissions wherever such reductions are cheapest. The Kyoto agreement includes two important cost-saving provisions of this nature. First, it provides for industrial countries to trade rights to emit greenhouse gases with each other. This market in emissions permits will ensure that emission reductions occur where they are least expensive within the industrial countries. In particular, U.S. companies could purchase emissions reductions in other participating countries when doing so would reduce their costs -- lowering costs without affecting the level of environmental protection.

Second, the agreement allows industrial countries to invest in "clean development" projects in the developing world and use these projects' certified emissions reductions toward meeting their targets. Many such clean-development projects may be quite cheap in terms of the cost per ton of emissions avoided, as has been illustrated by the joint implementation pilot program that is already in place in the U.S. Details of these provisions will be worked out in negotiations in Buenos Aires later this year.

IV. Difficulties of Economic Analysis of Kyoto Agreement

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

The difficulties associated with economic analysis of climate change fall into three broad categories. First is the uncertainties that still remain over the terms of the ultimate treaty. Second is the inherent limitations of available models to analyze even short-term costs and benefits. And finally is a topic I discussed earlier: the impossibility of putting a single monetary number on the long-term benefits of climate change mitigation.

Uncertainties over Certain Provisions in International Effort to Combat Climate Change

The Kyoto Agreement was an historic accomplishment, delineating the broad terms of the international effort to address climate change. But although we know a lot more than we did before Kyoto about how that international system will work, **there is still much that we don't know.**

First, as is often the case in a legal document of the length and complexity of the Kyoto Protocol, there are some provisions that require further clarification and interpretation. Of particular concern here is the treatment of so-called sinks -- activities that affect the rate at which carbon is removed from the atmosphere and "sequestered," specifically by the planting of trees.

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

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

Inherent Limitations of Models

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

One area in which the uncertainty is particularly large is the pace of technological progress -- including diffusion of existing energy-efficient technologies, as well as research and development of new technologies -- and the extent to which the pace will accelerate in response to government programs. Economics does not offer a good understanding of how technological progress is determined, in part because it is the stuff of experimentation, brainstorming, genius, breakthroughs, perceptions and habits. Invention is largely determined by inspiration --

notwithstanding Edison, who assigned a 99 percent share to perspiration -- and inspiration, in my experience, is difficult to fit into mathematical formulae or economic models. Models and experts on climate change policy tend to have a wider range of disagreement on the speed with which technology can be changed than on any other single issue.

Furthermore, each model has strengths and weaknesses; each has questions to which it is better or worse suited to answer. Some, for example, model the energy sector in detail. Some allow for the fact that a coal-fired power plant cannot costlessly be converted to one that runs on natural gas. Some have enough policy detail to distinguish alternative ways of redistributing revenues that would result if emission permits were to be auctioned. Some are capable of showing short-term macroeconomic disequilibria. Some include a long-term "carbon cycle" model that can keep track of the accumulation of greenhouse gas concentrations in the atmosphere and their climatological effects. Some break down the rest of the world into regions and so can model international trade. No one model does everything, and therefore we must not rely blindly on the results of any one model or set of models. Professional judgement and economic intuition are also crucial.

Benefits of Averting Climate Change

As I discussed above, it is evident that the benefits of averting climate change are potentially immense. But I have chosen not to try to quantify them in monetary terms for you, in light of the difficulties I have enumerated -- including the quantitative uncertainty of these benefits, and their timing and therefore the extreme sensitivity of the results to the chosen discount rate.

Instead, what I will do is draw upon a variety of sources in an attempt to add up the various possible costs and benefits of emissions policy *excluding* climate change. To give away the punch line, my conclusion is as follows: the net costs of our policies to reduce emissions are likely to be small, if those reductions are undertaken in an efficient manner, *even before taking into account the benefits of averting climate change itself*. That small net premium excluding the benefits of mitigating climate change, in effect, purchases a partial insurance policy against the threat.

V. Models of the Kyoto Agreement

The existence of modeling difficulties means that the results from any model must be treated with caution. We have employed a broad set of economic tools available to analyze the policy options. Such tools include models of the energy sector and economy over the next 25 years, including but not limited to the results of the Stanford Energy Modeling Forum exercises, the IPCC's review of the economic and social dimensions of climate change, and the staff-level Interagency Analytical Team effort last year. Other tools include simple relevant statistics, "meta-analyses" of existing models, historical and sectoral examples, and basic economic reasoning. Drawing on this broad array of analytical tools is crucial to an intelligent evaluation

of the policy alternatives.

To my knowledge, as of December, no model -- whether used inside the government or not -- had been set up precisely to analyze the parameters of the agreement that was reached in Kyoto. Most model-builders outside the government tend to take as long as several years to incorporate changes in policy parameters into their models. And no model is currently designed to assess sinks, or all six greenhouse gases included in the treaty.

One of the leading models in the field is the Second Generation Model of Battelle Laboratories. The SGM is one of the models best positioned to analyze the role of international trade in emission permits, which we consider to be a critical element of the Kyoto Treaty. I would therefore like to share with you some preliminary analyses based on the SGM model that have been developed over the past two months to reflect what was agreed to in Kyoto. To do so, several modifications to the original SGM results are necessary. For example, the SGM does not cover all six gases included in the Kyoto agreement. We therefore integrated the SGM model results with cost analyses of the other gases by EPA.

Mindful of the limitations that any one model has, however, I am eager to see the Kyoto parameters fed into other models, to get a better feel for the range of possible effects. Much of this work will continue to go on outside the government. For example, we have had discussions with the Energy Modeling Forum, based at Stanford University. The EMF is a long-running exercise involving many of the leading climate models. We have given the EMF advice on how features of the Kyoto legal language can be translated into terms recognizable to an economist. Unfortunately, the Energy Modeling Forum believes that its members will need at least until mid-year to produce reliable results.

VI. Economic Analysis

With all of that as important background, let us now turn to the task at hand. As we do so, let me emphasize once again that the figures presented below do not incorporate the benefits of starting to mitigate climate change.

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

Within the Kyoto agreement, this means an insistence on international trading, joint implementation, and, ultimately, on full developing country participation. Domestically, this means that we implement any emissions reductions through a market-based system of *tradeable* emissions permits, which ensures that we achieve reductions wherever they are least expensive.

But this also means taking serious and responsible steps in the short run to prepare us to meet our obligations in the longer term.

The first such step is the inclusion in this year's budget of an aggressive, \$6.3 billion program of tax cuts and R&D -- \$1.3 billion more than the \$5 billion package the President promised in his October 22 speech on this issue. The goal is both to stimulate the development of new energy-saving and carbon-saving technologies and to encourage the dissemination of those that exist already. The proposed package contains \$3.6 billion over the next 5 years in tax cuts for energy efficient purchases and renewable energy, including tax credits of \$3,000 to \$4,000 for consumers who purchase highly fuel efficient vehicles, a 15 percent credit (up to \$2,000) for purchases of rooftop solar equipment, a 20 percent credit (subject to a cap) for purchasing energy-efficient building equipment, a \$2,000 credit for purchasing energy-efficient new homes, an extension of the wind and biomass tax credit, and a 10 percent investment credit for the purchase of combined heat and power systems. The package also contains \$2.7 billion over the next 5 years in additional research and development spending -- covering the four major carbon-emitting sectors of the economy (buildings, industry, transportation, and electricity), plus carbon removal and sequestration, Federal facilities, and cross-cutting analyses and research. One example of the R&D effort is the Partnership for a New Generation of Vehicles (PNGV). PNGV is a government-industry effort to develop attractive, affordable cars that meet all applicable safety and environmental standards and get up to three times the fuel efficiency of today's cars. In FY99, the combined proposal for PNGV is \$277 million, up from \$227 million appropriated in FY98. Similar government-industry efforts are proposed to develop more efficient diesel engines for both light trucks and heavy trucks. [ADD SOMETHING MORE ABOUT INDUSTRY-GOVERNMENT DIALOG. PERHAPS A CONCRETE EXAMPLE OF IDENTIFYING AN INDUSTRY REGULATION THAT COULD BE REMOVED.]

The second such step is the promotion of an environmentally-responsible electricity restructuring bill, which the President identified as part of his domestic climate change package in his address to the National Geographic Society on October 22. An electricity sector freed from government regulation would be a more efficient energy sector. Costs to consumers would fall. A reasonable overall estimate of the effects of adding federal electricity restructuring to the rest of the President's program to address climate change is to achieve the same environmental goals at a cost saving of roughly \$16 billion per year.

Estimated Reduction in Costs from Annex I Trading

In the language of the treaty, "Annex I," you will recall, is the set of countries that have agreed to take on binding limitations in emissions of greenhouse gases. Even without developing country participation -- which, again, the President has emphasized as essential before the treaty could be ratified -- costs can be reduced substantially by trading among the Annex I countries. To provide some indication of the possible efficiency improvements, Russia and the Ukraine consume six times as much energy per dollar of output as does the United States.

The estimate derived from the SGM model is that, under certain base-case assumptions, trading among Annex I countries reduces the cost to the United States of achieving its targets for 2008-2012 emissions by about half relative to a situation in which such trading was not available.

This concept of costs is meant to capture aggregate resource costs to the US economy, including the cost to domestic firms of purchasing emission permits from Russia and other countries where emission reductions are cheaper than in the United States. The dramatic reduction in costs available from Annex I trading within the SGM model -- cutting by half the costs involved -- highlights why the President insisted that international trading be part of the Kyoto Agreement.

A useful rough check on this estimate can be obtained from other model[s], notwithstanding that they are likely to be more distant approximations to the parameters of the Kyoto Treaty. The G-cubed model, for example, shows that trading among Annex I countries reduces reduces overall costs by roughly 20 percent [CHECK]. [The G-cubed model is better designed than most to analyze trading of permits in a system where the usual international trade in goods and services is also important.] Twelve leading models that participate in the Stanford Energy Modeling Forum show that trading among industrialized countries reduces estimated costs -- defined as lost consumption -- by an average of 56 percent, although the results vary from model to model.

Estimated reduction in costs from umbrella trading

One possibility that emerged in Kyoto, which none of us foresaw, was the idea that the United States might undertake trading with a subset of Annex I countries, dubbed the "umbrella," that would exclude the European Union. The initial list of proposed participants in the umbrella includes the United States, Australia, Canada, Japan, New Zealand and Russia, with strong indications of interest from some others. The motivation for this idea was that the Europeans have been reluctant to agree to the sort of international trading that we want (preferring that they achieve their goals collectively in a group of their own, called the "EU bubble").

It is too early to say whether the umbrella concept will in fact be accepted by the parties. But it is an important concept to consider, for three reasons. First, it is conceivable that it will be formally agreed to in future negotiations. Second, even if the final treaty does not explicitly include the umbrella, but rather allows trading among all signatories (as the United States has proposed all along), it is conceivable that umbrella countries will agree, outside the treaty, to trade only among themselves. Third, the aversion toward international trading that the Europeans have expressed suggests that they might refrain from making the trades to which they would be entitled -- which would mean that the umbrella would operate in practice, if not in formal international agreement.

The significance of the umbrella idea in the present context is that it has the potential to further reduce costs to the United States. The reason is that if the Europeans are not bidding against us for the cheap emission rights that the Russians and other Eastern Europeans have to

sell, then the price will be even lower. The SGM results suggest that, relative to the situation in which there is no trading at all, the umbrella arrangement would reduce costs by an estimated 61-75 per cent, depending on whether the former Warsaw Pact countries are classed with the EU, or are instead assumed to fall within the umbrella. Thus, the umbrella arrangement raises the benefit to international trading significantly relative to full Annex I trading, reducing costs from roughly half their no-trading level to as low as one-quarter their no-trading level.

Estimated reduction in costs from LDC participation

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

A moderate version of developing country participation is the Clean Development Mechanism, modelled after Joint Implementation (JI). JI cannot realistically be expected to yield all the gains of binding targets for developing countries, but it might shave costs by roughly another 20 to 25 percent from the reduced costs that result from trading among Annex I countries.

Another possibility is that we persuade some of the key developing countries that are the largest emitters to commit to targets, and allow us to buy emission reductions from those paths. The model estimate is that this would cut roughly 55 percent off the reduced costs that result from Annex I trading. [The four countries included in this particular estimate are China, India, Brazil and Korea.] Once these savings have been attained, the estimated reductions to US costs from persuading the rest of the developing world to go along with full commitments are relatively small.

I offer these numbers because they show the potential effectiveness of trading in reducing costs dramatically. But it is important that I repeat three caveats: First, as always, there is a wide range of uncertainty around all these estimates. Second, they apply to an idealized version of trading, one that assumes no problems of enforcement or transactions costs. Third, it seems unlikely that we will get all our partners to agree in Buenos Aires to the very most optimistic or ambitious case. Nonetheless, despite these caveats, the numbers do show major savings even without getting the most optimistic case. And if we don't get enough of what we want, we won't submit the treaty for ratification to the Senate.

VII. Non-Climate Benefits

The costs of undertaking greenhouse gas emission reductions must be compared to the benefits. As I have indicated, for various reasons our analysis does not quantify the benefits from averting climate change itself. But the relative price shifts that are necessary to reduce emissions should produce benefits in three areas: air pollution, traffic congestion, and highway

accidents. These benefits are quantifiable.

Reductions in carbon emissions also lead to reductions in emissions of pollutants that contribute to excess concentrations of fine particulate matter and low-level ozone. Conservative estimates suggest that given a price of carbon of \$20/ton, such ancillary emissions reductions could be well in excess of a half million tons of pollutants per year, and entail cost savings of about \$0.9 billion per year. These cost savings could be even larger if carbon emissions reduction efforts could be carefully coordinated with the implementation of the national ambient air quality standards.

Traffic congestion hurts motorists by causing delays and inconvenience. More efficient pricing -- which recognizes the externalities involved -- should lead to reductions in congestion as motorists choose other means of travel, share rides, or even forgo less important trips. . We estimate that higher fuel prices resulting from carbon permit prices of \$20/ton will reduce travel delays associated with congestion, and that the value of such time savings to consumers would be about \$0.4 billion per year.

Vehicle use also leads to costly accidents and to highway injuries including fatalities. Assuming that accidents fall proportionately with vehicle use, more efficient pricing will also create savings from reduced accidents and resultant mortality. The savings from reduced accidents and the value of reduced mortality risk is approximately \$0.3 to \$2.7 billion/ year [depending on whether lighter cars are less crashworthy] given a \$20/ton carbon price.

A variety of other benefits that are harder to quantify are likely to result from reductions in carbon emissions. With respect to transportation, reduced vehicle use will also reduce the cost of road repair and maintenance. Second, reduced coal use will lower mercury emissions. Finally, reduced energy use will also increase U.S. energy independence. Our inability to estimate these effects quantitatively does not imply that they are necessarily small or unimportant.

VIII. Estimated Net Effects For One Illustrative Case

We can now combine the various benefits and costs delineated above. By way of summary, it may be helpful to focus on an illustrative case. We consider the case of trading under the umbrella, together with full participation by four key LDCs. In this case, adding together the estimates derived from the SGM and other sources suggests that the resource costs of attaining our Kyoto targets for emission reductions are \$7 to \$9 billion. **Thus the net costs are \$_ billion to \$_ billion, or roughly 0.0_ percent of projected GDP** (i.e., net of ancillary non-climate benefits, predicted from a permit price of \$12-\$16 per ton, depending on which umbrella definition is used).

A more tangible measure of costs is the estimated effects on energy prices. Again excluding the impact of electricity restructuring, the SGM-based estimate is that the price of emissions would be in the range \$12 to \$16 per ton of carbon equivalent -- and that energy prices at the household level would rise by about 3 percent under the Kyoto accords [CHECK].

Fuel oil prices would rise by about 5 percent, natural gas prices by 4 percent, gasoline prices by 3 percent, and electricity prices by 2 percent. The 3 percent increase in energy prices at the household level would raise the average family's energy bill by about \$75.

These estimates do *not* mean that households' energy expenses will in fact be higher in 2010 than today, however. In the first place, energy prices fluctuate year-by-year for all sorts of reasons. They could go either up or down. But even if we leave out unpredictable fluctuations, the energy price declines from Federal electricity restructuring would be enough to offset the impact estimated above. By 2008-2012, the projected 10 percent decline in electricity prices from the restructuring that is part of our climate change agenda will mean a net reduction in energy prices in the U.S., even accounting for the small increases noted above.

As highlighted earlier, estimates of the type that I am presenting are fraught with uncertainty. The estimate I just discussed was predicated on the developing country participation that we will insist upon in Buenos Aires as a condition for our ratifying the Kyoto Protocol, but which is not yet part of that Protocol. At the same time, the numbers I have cited are in several respects conservative: they leave out several factors, such as the role of sinks, that could further reduce costs. But before I bring these factors into the analysis, allow me to say a few words about macroeconomics.

Effects on employment and aggregate output

So far I have said nothing about job losses resulting from climate change policy. Although there may be job gains in some sectors and job losses in others, I do not anticipate any significant aggregate effect. Some jobs may be lost in energy-intensive sectors, but a large number of jobs will be created in other sectors -- many of them high-tech jobs paying high wages. The President is firmly committed to assisting any workers who are adversely affected during the transition to a climate-friendly economy.

The situation might be different if a large energy shock were to hit the economy with no warning, as happened in the oil crisis of 1973-74, when the real money supply, output and employment all contracted sharply. In addition to hitting with no warning, the oil shocks of the 1970s also entailed large transfers from the U.S. and other oil-importing countries to OPEC, thus depressing real income and spending in the former. A self-imposed shift in the relative price of carbon-intensive energy to address global climate change, on the other hand, need not entail such a transfer of purchasing power. Thus there are critical differences between the oil price shocks

and the effort to reduce carbon emissions. Our reassuring conclusion regarding aggregate output might also be different if the policy were to be implemented inefficiently (by command-and-control style regulations of the sort put in place in that oil crisis) rather than efficiently (by market mechanisms of the sort that the President has proposed to use).

Effects of Incentives

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

As has been frequently noted, the average cost of SO₂ emissions reductions has recently been significantly lower than was originally forecast, in part due to the role of incentives in fostering innovation. Emission permit prices, currently at approximately \$100 per ton of SO₂, are well below earlier estimates of around \$250 to \$350 per ton (See Chart 1.)

Trading programs may not always bring cost savings as large as those achieved by the SO₂ program; trading programs will not always be accompanied by the discovery of much cheaper control strategies. However, the SO₂ experience demonstrate clearly how such programs offer important market incentives to find cheaper ways of reducing emissions and the flexibility to take advantage of them.

VIII. The Foregoing Estimates Are Conservative in That They Do Not Yet Include Several Factors

I should emphasize that the estimates I have presented are conservative in three very important ways: sinks, technology, and climate change benefits. The first omission, sinks, concerns a provision of the Kyoto Protocol that has received less attention than it merits. It is only *net* emissions -- emissions to the atmosphere minus sequestration -- that are to be reduced 7 percent below 1990 levels, not gross emissions. The United States plants many trees every year, and would receive credit for this activity under the Protocol. Very preliminary estimates of the implications for the United States of the Kyoto provision on sinks reduce the resource cost by to 17 per cent. This brings resource costs down to \$15-\$18 billion, depending on whether we count in no LDC participation at all or we count the benefits of joint implementation through the Clean Development Mechanism (as currently agreed to in the Kyoto Protocol). **These numbers translate into net costs of __ and energy prices of __.** If we get the full participation of LDCs, the costs come down further.

Even those estimates for the effect of sinks are conservative in one respect: they are based

on an assumption for sink activity in the U.S. over the 2008-2012 period, and no assumed benefits from sinks elsewhere in the world. Very preliminary estimates suggest that incorporating the gains from sinks *throughout the world* can reduce the costs of meeting the Kyoto target by half or more, on top of the gains from trading among Annex I countries. (Furthermore, no model has yet even tried to take into account that government policies can help increase the amount of tree-planting, possibly through some version of the Conservation Reserve Program, for example.) But neither we nor other analysts are yet sure exactly how to interpret the legal language of the Protocol. Because the quantitative uncertainty is so large, we do not yet have an estimate with which I feel comfortable. But we do know that the effect of fully modelling the Kyoto provision on sinks is likely to be both favorable and large.

The estimates I have cited so far also make little allowance for the payoff to the President's \$6.3 billion Climate Change Technology Initiative. The parameter that figures most prominently in analysis of technological progress in the energy field is the rate of improvement in the so-called Autonomous Energy Efficiency Index (AEEI), that is the rate at which the total use of energy falls relative to GDP. In the analysis on which the numbers I have reported to you is based, the AEEI improves by 1.0 percent per year. Reflecting a conservative interpretation of the 15-year impact of the technology initiative, this is only a small increase above the number in the Energy Information Administration's Annual Energy Outlook.

The logic with which one could justify such an assumption would be somewhat analogous to the rationale behind the macroeconomic assumptions that we feed into our budget forecasts: in the presence of uncertainty, we are conservative in our estimates of the speed with which the economy will grow, tax receipts will rise, and the budget will improve. That way, any revisions or surprises that occur are likely to be in the pleasant direction. The nature of the conservatism here would be that we assume in our modeling that, because of lags, most of the payoff from new technology research and dissemination expenditures (as opposed to those in the past) comes after 2012.

If the Administration is successful in speeding the discovery and adoption of new technologies, the rate of improvement in energy efficiency could rise. As a second example, we therefore report results assuming that the AEEI parameter is boosted to 1.25 percent. This has the effect of reducing resource costs by 26 - 27 per cent, to \$13 to \$16 billion, again depending on whether we count no LDC participation at all or count the benefits of joint implementation. **These numbers translate into net costs of __ and energy prices of __.** If we were to get the full participation of some LDCs, the costs would again come down further.

This "technology case" is far from the most optimistic outcome that might occur. Some experts in the technology of climate change policy forecast more rapid technological progress. Estimates coming from engineering models predict even higher rates of AEEI improvement, and thus even lower costs.

The third, and most important, respect in which the estimates I have presented are conservative is that they leave out the benefits of mitigating climate change itself. A full cost-benefit analysis would include mitigation in the benefits column. The only reason we have not done so, as I have explained repeatedly above, is the difficulty in coming up with a number to capture the monetary benefits. But I trust that nobody will lose sight of our ultimate objective -- keeping our planet the hospitable home that we enjoy today.

CONCLUSION

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

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

I welcome your questions.

**TESTIMONY OF DR. JANET YELLEN
CHAIR, COUNCIL OF ECONOMIC ADVISERS
BEFORE THE SENATE FOREIGN RELATIONS COMMITTEE
ON THE ECONOMICS OF THE KYOTO AGREEMENT
FEBRUARY 11, 1998**

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

The international agreement that was reached in Kyoto this past December is a crucial first step in addressing global climate change. But it is only a first step. Since the international effort to reduce greenhouse gas emissions is more of a work-in-progress than a completely finished product, it is not yet possible to provide a full authoritative analysis of it. Many of the specifics in several crucial areas are not completely resolved in the diplomatic arena, forcing analysts to make a variety of assumptions about the ultimate form of the international regime. In my testimony today, I will attempt to identify the key elements of the agreement that ensure that reductions in global greenhouse gas emissions are consistent with continued strong economic growth. I will do my best also to provide some rough estimates of costs and benefits.

The Administration is strongly committed to ensuring that these critical elements -- including global participation and a reliance on flexible, market-based mechanisms -- are reflected in our domestic and international climate change policies. We are firmly committed to meaningful developing country participation, as well as emissions trading both domestically and internationally. And as you know, the President's FY 1999 budget includes a \$6.3 billion package of tax cuts and R&D over the next 5 years to jumpstart our efforts.

I. Basic Economic Rationale of the Kyoto Treaty

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

The earth's surface is warming from the accumulation of greenhouse gases from myriad sources worldwide. None of these emitters presently pays the cost to others of warming's adverse effects -- a classic externality in the language of economists. As a result of these distorted incentives, disruption of the Earth's climate is likely to proceed at an excessive pace and if left uncontrolled may pose substantial costs in terms of disruption to commerce and the environment alike. The fundamental economic logic of the Kyoto agreement is thus that

without such an international agreement, individual nations will not have the proper incentives to address the threats from global climate change.

II. Costs of Climate Change

In evaluating efforts to address climate change, the first step is to consider the costs that are likely if we fail to take any action -- for these costs provide the primary motivation for reducing greenhouse gas emissions. What, then, are the costs associated with allowing global climate change?

The Intergovernmental Panel on Climate Change (IPCC) jointly established by the World Meteorological Organization and the United Nations Environment Programme, concluded in 1995 that "the balance of evidence suggests that there is a discernible human influence on global climate." Current concentrations of carbon dioxide, methane, nitrous oxide, and the other so-called greenhouse gases have reached levels well above those of preindustrial times. Of these, carbon dioxide (CO₂) is the most important: net cumulative CO₂ emissions resulting from the burning of fossil fuels and deforestation account for about two-thirds of potential warming from changes in greenhouse gas concentrations related to human activity.

Climatic Impact

If growth in global emissions continues unabated, the atmospheric concentration of CO₂ will likely double relative to its preindustrial level by midway through the next century. As a result of the increased concentration of CO₂, the IPCC estimates that global temperatures will increase by between 2.5 to 6 degrees Fahrenheit in the next 100 years, with a best guess of about 3.5 degrees Fahrenheit. While scientists believe that human activities are leading to a gradual warming of the *average* temperature of the earth, the change in temperature in a given region at a given time may differ substantially from this average. Indeed, models predict warming will be greater in high latitudes than in the tropics, and greater over land than ocean. Many models predict larger increases in evaporation than in precipitation over midlatitude land areas, which would result in drier conditions in those regions, especially during summer in North America and Europe.

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

Economic and Monetary Damages

The derivation of quantitative or monetary estimates of the damages from such climate changes is extremely difficult given the capacity of today's forecasting models. Estimates of the economic damages from climate change fall into the following broad areas: agriculture, sea-level rise, air conditioning and heating, water supply, human life and health, air pollution, and other costs (hurricanes, migration costs, human amenity, construction, leisure activities, urban infrastructure, and ecological damages such as forest loss and species loss).

A subject of great uncertainty and sensitivity is the "discount rate" that is applied to the benefits of averting future climate change. Such a discount rate is needed if the analysis is to be expressed in monetary terms, because a dollar today is not worth the same as a dollar tomorrow. And since the benefits of stemming future climate change accrue over not only decades but centuries, small changes in the discount rate can produce substantial changes in the results. But the precise discount rate that should be used to evaluate questions as important as the future climate of the planet remains a subject of intense debate. It is safe to say that there is, as of yet, no professional consensus on the issue.

A similar point concerns risk aversion. To what extent are we willing to take chances with our planet? The point applies particularly to catastrophe scenarios. Scientists have thought of many possible scenarios, most of which they are fortunately not yet prepared to pronounce as particularly likely based on current evidence, but which might be truly catastrophic for the planet if they were to occur. There is a strong argument for the Kyoto agreement as a form of planet insurance. But what numerical weight should one assign to these catastrophic risks? In other words, what is the value of the insurance policy? It is difficult for an economist, or anyone, to know.

Despite these shortcomings and potential problems, respected researchers have developed estimates of the monetary damages expected from an average worldwide temperature increase of approximately 4.5 degrees Fahrenheit (corresponding to, roughly, a doubling of pre-industrial carbon dioxide concentrations). For example, William Cline, then a Senior Fellow at the Institute for International Economics, estimated that such a temperature change would impose annual damages of more than \$70 billion per year on the U.S. economy in today's terms. These damages include \$22 billion in lost agricultural production, \$13 billion in additional electricity costs, and \$8 billion in new costs to maintain the existing supply of fresh water. (Cline's original estimates are quoted in 1990 dollars. The figures given above translated those numbers into 1997 dollars using the annual GDP price index.) William Nordhaus of Yale University has likewise computed estimates of the dollar loss attributable to a doubling of carbon dioxide concentrations. He finds that the Cline estimate is in the center of three estimates for the U.S., and that the high estimate is only 1.3 times greater than the low estimate.

It must be noted, however, that this similarity of aggregate estimates masks the true uncertainty associated with forecasts of the damages from given increases in global warming --

the estimates are all fundamentally based on extrapolations from current and past experience, and may not fully incorporate effects that will unfortunately become apparent only with future experience. In particular, the estimates may not fully reflect potential non-linearities in the relationships between carbon dioxide concentrations and temperature, between temperature and economic damages, or in the various other complicated relationships governing interactions between greenhouse gas emissions, the climate, and the economy. Current quantitative analyses do not, and cannot, accurately reflect the small and unknown possibility of large-scale and potentially irreversible discrete events with potentially catastrophic consequences.

Two such possibilities serve as illustrations. Warming of Northern tundra may release very large amounts of methane from the subarctic permafrost, thereby leading to potentially devastating acceleration of an otherwise controllable global warming process. We do not know at what point, if any, such unstable activity would be triggered. Second, evidence from climate models suggests that some types of climate change may lead to displacement of the Gulf Stream that warms Western Europe. Evidence from ocean core samples suggests that such reversals of ocean currents have occurred in previous ice ages. Reductions in the risk of such catastrophic outcomes must be considered in addition to the costs and benefits that can be reasonably quantifiable. Since human beings are typically averse to risk, such possibilities are especially important in evaluating whether the benefits of a particular climate control policy justify the costs. One must have at least some sympathy with those who criticize economists on the grounds that the effects of climate change are extremely difficult to quantify in a single monetary number.

III. Addressing Global Climate Change in an Efficient Manner

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

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

Need for Global Action

Climate change is a global problem requiring a global solution. As I mentioned earlier, no single country has an incentive to reduce emissions sufficiently to protect the global environment against climate change. Each has an economic incentive to “free ride” on the efforts of others. Even if the United States sharply reduced its emissions unilaterally, greenhouse gas emissions from all other countries would continue to grow, and the risks posed by climate change would not be significantly abated. It is important to emphasize that emissions of different gases anywhere in the world have very similar effects on global climate.

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

To address the lack of progress among many industrialized countries toward meeting the Rio objective, the United States and approximately 160 other nations agreed in negotiations held in Kyoto, Japan, last December, to take substantial steps to stabilize atmospheric concentrations of greenhouse gases. The Kyoto Agreement, which requires the advice and consent of the Senate, would place binding limits on industrial countries' emissions of the six principal categories of greenhouse gases: CO₂, N₂O, methane, sulfur hexafluoride, perfluorocarbons, and hydrofluorocarbons. **These limits apply to the 38 so-called Annex I countries, which are the industrialized countries, defined to include Russia, Ukraine, and most Eastern European countries.**

Under the Kyoto agreement, each industrial country's “1990 baseline” is actually based on its 1990 emissions of CO₂, methane, and N₂O and its choice of 1990 or 1995 levels of the other three categories of gases. The United States agreed to a target of 7 percent below 1990 levels by the period between 2008 and 2012. To meet that target, net U.S. emissions of greenhouse gases -- all emissions minus removals of CO₂ by certain forestry-related activities -- must average no more than 1,484 million metric tons of carbon equivalent per year during that period. The targets for the European Union and Japan are 8 percent and 6 percent below 1990 levels, respectively. Australia, New Zealand, Norway, Russia and Ukraine all have limits somewhat less ambitious when phrased as cuts relative to

their 1990 levels. In sum, over the period from 2008 to 2012, the industrial countries are expected to reduce their average emissions of greenhouse gases to about 5 percent below their 1990 levels.

The President has made clear that his support of the Kyoto Agreement is dependent on meaningful participation from key developing countries (who are not included in Annex I). The President has also made clear that he will not submit the treaty to the Senate without such participation.

There are several reasons why meaningful participation from developing countries is essential. First, developing countries are projected to contribute a majority of total emissions by 2030 under a continuation of business-as-usual. Without the participation of developing economies, emissions reductions by the industrialized countries will therefore not achieve necessary protection from climate change. Indeed, if developing countries do not participate in the international regime, their emissions could potentially increase by *more* than under their business-as-usual baselines. One mechanism for such an unintended consequence is as follows.

As Annex I countries comply with their targets, their demand for oil will fall, which will probably work to reduce the price of oil on world markets, and and perhaps to encourage non-participating countries to use more oil and emit more carbon than they otherwise would have.

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

Third, principles of basic fairness suggest all countries should do their part, depending on their ability to contribute to the solution. Thus even poor countries should contribute, although the existence of more pressing social needs in such countries will inevitably limit the magnitude of their contributions.

So far I have not mentioned the word “competitiveness.” One of the difficulties in analyzing concerns related to competitiveness is that the term itself is used to mean many different things. I have seen at least one study that uses “loss of competitiveness” to refer to predictions of negative effects on the *aggregate* trade balance. As a professional economist, I do not accept the logic upon which that particular argument is predicated: the aggregate trade

balance is determined by macroeconomic forces -- the difference between saving and investment -- and not by our environmental policies.

On the other hand, if competitiveness refers to adverse effects on a few specific manufacturing industries -- those that are especially energy-intensive, such as aluminum, paper, and chemicals -- the situation may be more complicated. It is difficult to undergo a significant structural change in the economy without having the effect of expanding some sectors and contracting others. But to provide some perspective on this issue, consider the following facts. First, on average, energy constitutes only 2.2 percent of total costs to U.S. industry. Second, energy prices already vary significantly across countries. According to the *1997 Statistical Abstract*, for example, in 1996 premium gasoline cost \$1.28 per gallon in the United States -- but only 8 cents in Venezuela. Yet U.S. industry is not moving en masse to Venezuela. Third, roughly two-thirds of all emissions are not in manufacturing at all, but in transportation and buildings. I therefore believe it more accurate to say that we need developing country participation for the reasons I outlined above, than to say that we need it to avoid adverse effects on competitiveness.

Flexibility and Market Mechanisms

A global solution is thus critical to the global problem of climate change. Globalizing the solution is not, however, enough by itself. We must also ensure that our efforts achieve their objectives in the most efficient manner possible. The nature of the climate change problem suggests some methods to lower costs of achieving given levels of environmental protection. Such methods have long been championed by economists interested in increasing the efficiency of protection. They were the sort of thing that 2,600 economists had in mind last year when they signed a letter, urging action on climate change:

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

What are these methods and policies? They can be characterized in terms of three categories of flexibility: (1) “when” flexibility; (2) “what” flexibility; and (3) “where” flexibility, which may be the most important of all.

1. “When flexibility” (timing)

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

The Kyoto Protocol incorporates this principle of “when flexibility” in four ways:

- First, the cuts to be made in the first period are less severe, and the first period ends much later, than what had been proposed by many other countries, most notably the Europeans. By adopting a gradual and credible path of reductions in the early years, we can greatly reduce costs such as those from prematurely scrapping coal-fired electricity plants still in the prime of their operating lives, while attaining the same ultimate environmental goals.
- Second, under the Kyoto agreement, the emissions target is not specified in terms of a specific year, but rather in terms of an average over a five-year period (2008-2012). Averaging over five years, instead of requiring countries to meet a specific target each year, can lower costs, especially given an uncertain future. The averaging can smooth out the effects of short-term events such as fluctuations in the business cycle and energy demand, or hard winters and hot summers that would increase energy use and emissions.
- Third, there is allowance for “banking” emission reductions within the 2008-2012 commitment period, for use in a subsequent commitment period [although the emission targets of the next period have not yet been specified].

2. “What flexibility” (gases and sinks)

The second type of flexibility is “what flexibility”, along two dimensions. The first is the inclusion in the agreement of all six greenhouse gases. Emissions of different kinds of gases, not just carbon dioxide, contribute to the greenhouse effect. Since the IPCC has developed conversion factors for all greenhouse gases by estimating their global warming potentials, reductions in emissions of one pollutant can be used to substitute for increases in emissions of another by an amount that has equivalent environmental effects. The Kyoto Protocol stipulates that countries with binding targets are expected to reduce their *total* greenhouse gas emissions by certain percentages, but does not require specific reductions for specific gases. Since a molecule of sulfur hexafluoride is 23,900 times more potent over 100 years than a molecule of CO₂, it may be cheaper to achieve the same environmental benefit by eliminating one molecular unit of SF₆ than nearly 24,000 units of CO₂.

Some initial rough analysis indicates that a strategy of reducing non-CO₂ greenhouse gases by *more* than 7 percent below their 1990/1995 baseline levels while reducing CO₂ by *less* than 7 percent below its 1990 level could reduce greenhouse gas emission permit prices by more than 10 percent. [This analysis is based on the integrated SGM/non-CO₂ cost curve.] Thus allowing countries flexibility in what gases they reduce -- essentially trading emissions reductions across gases -- can help lower significantly the costs of meeting their targets.

The second source of “what flexibility” is the treatment of sinks, i.e., land use activities

that promote the removal of carbon from the atmosphere through the growth of plants. Promoting such sinks through afforestation and reforestation may reduce atmospheric concentrations of CO₂ at much lower costs than reducing emissions of greenhouse gases.

3. "Where flexibility" (international)

The third type of flexibility, and perhaps the most important, is "where flexibility" (international). As I have already emphasized, emissions have the same environmental consequences regardless of where in the world they occur. Therefore, the least-cost approach to controlling climate change is to reduce emissions wherever such reductions are cheapest. The Kyoto agreement includes two important cost-saving provisions of this nature. First, it provides for industrial countries to trade rights to emit greenhouse gases with each other. This market in emissions permits will ensure that emission reductions occur where they are least expensive within the industrial countries. In particular, U.S. companies could purchase emissions reductions in other participating countries when doing so would reduce their costs -- lowering costs without affecting the level of environmental protection.

Second, the agreement allows industrial countries to invest in "clean development" projects in the developing world and use these projects' certified emissions reductions toward meeting their targets. Many such clean-development projects may be quite cheap in terms of the cost per ton of emissions avoided, as has been illustrated by the joint implementation pilot program that is already in place in the U.S. Details of these provisions will be worked out in negotiations in Buenos Aires later this year.

IV. Difficulties of Economic Analysis of Kyoto Agreement

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

The difficulties associated with economic analysis of climate change fall into three broad categories. First is the uncertainties that still remain over the terms of the ultimate treaty. Second is the inherent limitations of available models to analyze even short-term costs and benefits. And finally is a topic I discussed earlier: the impossibility of putting a single monetary number on the long-term benefits of climate change mitigation.

Uncertainties over Certain Provisions in International Effort to Combat Climate Change

The Kyoto Agreement was an historic accomplishment, delineating the broad terms of the international effort to address climate change. But although we know a lot more than we did before Kyoto about how that international system will work, there is still much that we don't know.

First, as is often the case in a legal document of the length and complexity of the Kyoto Protocol, there are some provisions that require further clarification and interpretation. Of particular concern here is the treatment of so-called sinks -- activities that affect the rate at which carbon is removed from the atmosphere and "sequestered," specifically by the planting of trees.

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

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

Inherent Limitations of Models

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

One area in which the uncertainty is particularly large is the pace of technological progress -- including diffusion of existing energy-efficient technologies, as well as research and development of new technologies -- and the extent to which the pace will accelerate in response to government programs. Economics does not offer a good understanding of how technological progress is determined, in part because it is the stuff of experimentation, brainstorming, genius, breakthroughs, perceptions and habits. Invention is largely determined by inspiration --

notwithstanding Edison, who assigned a 99 percent share to perspiration -- and inspiration, in my experience, is difficult to fit into mathematical formulae or economic models. Models and experts on climate change policy tend to have a wider range of disagreement on the speed with which technology can be changed than on any other single issue.

Furthermore, each model has strengths and weaknesses; each has questions to which it is better or worse suited to answer. Some, for example, model the energy sector in detail. Some allow for the fact that a coal-fired power plant cannot costlessly be converted to one that runs on natural gas. Some have enough policy detail to distinguish alternative ways of redistributing revenues that would result if emission permits were to be auctioned. Some are capable of showing short-term macroeconomic disequilibria. Some include a long-term "carbon cycle" model that can keep track of the accumulation of greenhouse gas concentrations in the atmosphere and their climatological effects. Some break down the rest of the world into regions and so can model international trade. No one model does everything, and therefore we must not rely blindly on the results of any one model or set of models. Professional judgement and economic intuition are also crucial.

Benefits of Averting Climate Change

As I discussed above, it is evident that the benefits of averting climate change are potentially immense. But I have chosen not to try to quantify them in monetary terms for you, in light of the difficulties I have enumerated -- including the quantitative uncertainty of these benefits, and their timing and therefore the extreme sensitivity of the results to the chosen discount rate.

Instead, what I will do is draw upon a variety of sources in an attempt to add up the various possible costs and benefits of emissions policy *excluding* climate change. To give away the punch line, my conclusion is as follows: the net costs of our policies to reduce emissions are likely to be small, if those reductions are undertaken in an efficient manner, *even before taking into account the benefits of averting climate change itself*. That small net premium excluding the benefits of mitigating climate change, in effect, purchases a partial insurance policy against the threat.

V. Models of the Kyoto Agreement

The existence of modeling difficulties means that the results from any model must be treated with caution. We have employed a broad set of economic tools available to analyze the policy options. Such tools include models of the energy sector and economy over the next 25 years, including but not limited to the results of the Stanford Energy Modeling Forum exercises, the IPCC's review of the economic and social dimensions of climate change, and the staff-level Interagency Analytical Team effort last year. Other tools include simple relevant statistics, "meta-analyses" of existing models, historical and sectoral examples, and basic economic reasoning. Drawing on this broad array of analytical tools is crucial to an intelligent evaluation

of the policy alternatives.

To my knowledge, as of December, no model -- whether used inside the government or not -- had been set up precisely to analyze the parameters of the agreement that was reached in Kyoto. Most model-builders outside the government tend to take as long as several years to incorporate changes in policy parameters into their models. And no model is currently designed to assess sinks, or all six greenhouse gases included in the treaty.

One of the leading models in the field is the Second Generation Model of Battelle Laboratories. The SGM is one of the models best positioned to analyze the role of international trade in emission permits, which we consider to be a critical element of the Kyoto Treaty. I would therefore like to share with you some preliminary analyses based on the SGM model that have been developed over the past two months to reflect what was agreed to in Kyoto. To do so, several modifications to the original SGM results are necessary. For example, the SGM does not cover all six gases included in the Kyoto agreement. We therefore integrated the SGM model results with cost analyses of the other gases by EPA.

Mindful of the limitations that any one model has, however, I am eager to see the Kyoto parameters fed into other models, to get a better feel for the range of possible effects. Much of this work will continue to go on outside the government. For example, we have had discussions with the Energy Modeling Forum, based at Stanford University. The EMF is a long-running exercise involving many of the leading climate models. We have given the EMF advice on how features of the Kyoto legal language can be translated into terms recognizable to an economist. Unfortunately, the Energy Modeling Forum believes that its members will need at least until mid-year to produce reliable results.

VI. Economic Analysis

With all of that as important background, let us now turn to the task at hand. As we do so, let me emphasize once again that the figures presented below do not incorporate the benefits of starting to mitigate climate change.

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

Within the Kyoto agreement, this means an insistence on international trading, joint implementation, and, ultimately, on full developing country participation. Domestically, this means that we implement any emissions reductions through a market-based system of *tradeable* emissions permits, which ensures that we achieve reductions wherever they are least expensive.

But this also means taking serious and responsible steps in the short run to prepare us to meet our obligations in the longer term.

The first such step is the inclusion in this year's budget of an aggressive, \$6.3 billion program of tax cuts and R&D -- \$1.3 billion more than the \$5 billion package the President promised in his October 22 speech on this issue. The goal is both to stimulate the development of new energy-saving and carbon-saving technologies and to encourage the dissemination of those that exist already. The proposed package contains \$3.6 billion over the next 5 years in tax cuts for energy efficient purchases and renewable energy, including tax credits of \$3,000 to \$4,000 for consumers who purchase highly fuel efficient vehicles, a 15 percent credit (up to \$2,000) for purchases of rooftop solar equipment, a 20 percent credit (subject to a cap) for purchasing energy-efficient building equipment, a \$2,000 credit for purchasing energy-efficient new homes, an extension of the wind and biomass tax credit, and a 10 percent investment credit for the purchase of combined heat and power systems. The package also contains \$2.7 billion over the next 5 years in additional research and development spending -- covering the four major carbon-emitting sectors of the economy (buildings, industry, transportation, and electricity), plus carbon removal and sequestration, Federal facilities, and cross-cutting analyses and research. One example of the R&D effort is the Partnership for a New Generation of Vehicles (PNGV). PNGV is a government-industry effort to develop attractive, affordable cars that meet all applicable safety and environmental standards and get up to three times the fuel efficiency of today's cars. In FY99, the combined proposal for PNGV is \$277 million, up from \$227 million appropriated in FY98. Similar government-industry efforts are proposed to develop more efficient diesel engines for both light trucks and heavy trucks. [ADD SOMETHING MORE ABOUT INDUSTRY-GOVERNMENT DIALOG. PERHAPS A CONCRETE EXAMPLE OF IDENTIFYING AN INDUSTRY REGULATION THAT COULD BE REMOVED.]

The second such step is the promotion of an environmentally-responsible electricity restructuring bill, which the President identified as part of his domestic climate change package in his address to the National Geographic Society on October 22. An electricity sector freed from government regulation would be a more efficient energy sector. Costs to consumers would fall. A reasonable overall estimate of the effects of adding federal electricity restructuring to the rest of the President's program to address climate change is to achieve the same environmental goals at a cost saving of roughly \$16 billion per year.

Estimated Reduction in Costs from Annex I Trading

In the language of the treaty, "Annex I," you will recall, is the set of countries that have agreed to take on binding limitations in emissions of greenhouse gases. Even without developing country participation -- which, again, the President has emphasized as essential before the treaty could be ratified -- costs can be reduced substantially by trading among the Annex I countries. To provide some indication of the possible efficiency improvements, Russia and the Ukraine consume six times as much energy per dollar of output as does the United States.

The estimate derived from the SGM model is that, under certain base-case assumptions, trading among Annex I countries reduces the cost to the United States of achieving its targets for 2008-2012 emissions by about half relative to a situation in which such trading was not available.

This concept of costs is meant to capture aggregate resource costs to the US economy, including the cost to domestic firms of purchasing emission permits from Russia and other countries where emission reductions are cheaper than in the United States. The dramatic reduction in costs available from Annex I trading within the SGM model -- cutting by half the costs involved -- highlights why the President insisted that international trading be part of the Kyoto Agreement.

A useful rough check on this estimate can be obtained from other model[s], notwithstanding that they are likely to be more distant approximations to the parameters of the Kyoto Treaty. The G-cubed model, for example, shows that trading among Annex I countries reduces overall costs by roughly 20 percent [CHECK]. [The G-cubed model is better designed than most to analyze trading of permits in a system where the usual international trade in goods and services is also important.] Twelve leading models that participate in the Stanford Energy Modeling Forum show that trading among industrialized countries reduces estimated costs -- defined as lost consumption -- by an average of 56 percent, although the results vary from model to model.

Estimated reduction in costs from umbrella trading

One possibility that emerged in Kyoto, which none of us foresaw, was the idea that the United States might undertake trading with a subset of Annex I countries, dubbed the "umbrella," that would exclude the European Union. The initial list of proposed participants in the umbrella includes the United States, Australia, Canada, Japan, New Zealand and Russia, with strong indications of interest from some others. The motivation for this idea was that the Europeans have been reluctant to agree to the sort of international trading that we want (preferring that they achieve their goals collectively in a group of their own, called the "EU bubble").

It is too early to say whether the umbrella concept will in fact be accepted by the parties. But it is an important concept to consider, for three reasons. First, it is conceivable that it will be formally agreed to in future negotiations. Second, even if the final treaty does not explicitly include the umbrella, but rather allows trading among all signatories (as the United States has proposed all along), it is conceivable that umbrella countries will agree, outside the treaty, to trade only among themselves. Third, the aversion toward international trading that the Europeans have expressed suggests that they might refrain from making the trades to which they would be entitled -- which would mean that the umbrella would operate in practice, if not in formal international agreement.

The significance of the umbrella idea in the present context is that it has the potential to further reduce costs to the United States. The reason is that if the Europeans are not bidding against us for the cheap emission rights that the Russians and other Eastern Europeans have to

sell, then the price will be even lower. The SGM results suggest that, relative to the situation in which there is no trading at all, the umbrella arrangement would reduce costs by an estimated 61-75 per cent, depending on whether the former Warsaw Pact countries are classed with the EU, or are instead assumed to fall within the umbrella. Thus, the umbrella arrangement raises the benefit to international trading significantly relative to full Annex I trading, reducing costs from roughly half their no-trading level to as low as one-quarter their no-trading level.

Estimated reduction in costs from LDC participation

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

A moderate version of developing country participation is the Clean Development Mechanism, modelled after Joint Implementation (JI). JI cannot realistically be expected to yield all the gains of binding targets for developing countries, but it might shave costs by roughly another 20 to 25 percent from the reduced costs that result from trading among Annex I countries.

Another possibility is that we persuade some of the key developing countries that are the largest emitters to commit to targets, and allow us to buy emission reductions from those paths. The model estimate is that this would cut roughly 55 percent off the reduced costs that result from Annex I trading. [The four countries included in this particular estimate are China, India, Brazil and Korea.] Once these savings have been attained, the estimated reductions to US costs from persuading the rest of the developing world to go along with full commitments are relatively small.

I offer these numbers because they show the potential effectiveness of trading in reducing costs dramatically. But it is important that I repeat three caveats: First, as always, there is a wide range of uncertainty around all these estimates. Second, they apply to an idealized version of trading, one that assumes no problems of enforcement or transactions costs. Third, it seems unlikely that we will get all our partners to agree in Buenos Aires to the very most optimistic or ambitious case. Nonetheless, despite these caveats, the numbers do show major savings even without getting the most optimistic case. And if we don't get enough of what we want, we won't submit the treaty for ratification to the Senate.

VII. Non-Climate Benefits

The costs of undertaking greenhouse gas emission reductions must be compared to the benefits. As I have indicated, for various reasons our analysis does not quantify the benefits from averting climate change itself. But the relative price shifts that are necessary to reduce emissions should produce benefits in three areas: air pollution, traffic congestion, and highway

accidents. These benefits are quantifiable.

Reductions in carbon emissions also lead to reductions in emissions of pollutants that contribute to excess concentrations of fine particulate matter and low-level ozone. Conservative estimates suggest that given a price of carbon of \$20/ton, such ancillary emissions reductions could be well in excess of a half million tons of pollutants per year, and entail cost savings of about \$0.9 billion per year. These cost savings could be even larger if carbon emissions reduction efforts could be carefully coordinated with the implementation of the national ambient air quality standards.

Traffic congestion hurts motorists by causing delays and inconvenience. More efficient pricing -- which recognizes the externalities involved -- should lead to reductions in congestion as motorists choose other means of travel, share rides, or even forgo less important trips. . We estimate that higher fuel prices resulting from carbon permit prices of \$20/ton will reduce travel delays associated with congestion, and that the value of such time savings to consumers would be about \$0.4 billion per year.

Vehicle use also leads to costly accidents and to highway injuries including fatalities. Assuming that accidents fall proportionately with vehicle use, more efficient pricing will also create savings from reduced accidents and resultant mortality. The savings from reduced accidents and the value of reduced mortality risk is approximately \$0.3 to \$2.7 billion/ year [depending on whether lighter cars are less crashworthy] given a \$20/ton carbon price.

A variety of other benefits that are harder to quantify are likely to result from reductions in carbon emissions. With respect to transportation, reduced vehicle use will also reduce the cost of road repair and maintenance. Second, reduced coal use will lower mercury emissions. Finally, reduced energy use will also increase U.S. energy independence. Our inability to estimate these effects quantitatively does not imply that they are necessarily small or unimportant.

VIII. Estimated Net Effects For One Illustrative Case

We can now combine the various benefits and costs delineated above. By way of summary, it may be helpful to focus on an illustrative case. We consider the case of trading under the umbrella, together with full participation by four key LDCs. In this case, adding together the estimates derived from the SGM and other sources suggests that the resource costs of attaining our Kyoto targets for emission reductions are \$7 to \$9 billion. **Thus the net costs are \$_ billion to \$_ billion, or roughly 0.0_ percent of projected GDP** (i.e., net of ancillary non-climate benefits, predicted from a permit price of \$12-\$16 per ton, depending on which umbrella definition is used).

A more tangible measure of costs is the estimated effects on energy prices. Again excluding the impact of electricity restructuring, the SGM-based estimate is that the price of emissions would be in the range \$12 to \$16 per ton of carbon equivalent -- and that energy prices at the household level would rise by about 3 percent under the Kyoto accords [CHECK].

Fuel oil prices would rise by about 5 percent, natural gas prices by 4 percent, gasoline prices by 3 percent, and electricity prices by 2 percent. The 3 percent increase in energy prices at the household level would raise the average family's energy bill by about \$75.

These estimates do *not* mean that households' energy expenses will in fact be higher in 2010 than today, however. In the first place, energy prices fluctuate year-by-year for all sorts of reasons. They could go either up or down. But even if we leave out unpredictable fluctuations, the energy price declines from Federal electricity restructuring would be enough to offset the impact estimated above. By 2008-2012, the projected 10 percent decline in electricity prices from the restructuring that is part of our climate change agenda will mean a net reduction in energy prices in the U.S., even accounting for the small increases noted above.

As highlighted earlier, estimates of the type that I am presenting are fraught with uncertainty. The estimate I just discussed was predicated on the developing country participation that we will insist upon in Buenos Aires as a condition for our ratifying the Kyoto Protocol, but which is not yet part of that Protocol. At the same time, the numbers I have cited are in several respects conservative: they leave out several factors, such as the role of sinks, that could further reduce costs. But before I bring these factors into the analysis, allow me to say a few words about macroeconomics.

Effects on employment and aggregate output

So far I have said nothing about job losses resulting from climate change policy. Although there may be job gains in some sectors and job losses in others, I do not anticipate any significant aggregate effect. Some jobs may be lost in energy-intensive sectors, but a large number of jobs will be created in other sectors -- many of them high-tech jobs paying high wages. The President is firmly committed to assisting any workers who are adversely affected during the transition to a climate-friendly economy.

The situation might be different if a large energy shock were to hit the economy with no warning, as happened in the oil crisis of 1973-74, when the real money supply, output and employment all contracted sharply. In addition to hitting with no warning, the oil shocks of the 1970s also entailed large transfers from the U.S. and other oil-importing countries to OPEC, thus depressing real income and spending in the former. A self-imposed shift in the relative price of carbon-intensive energy to address global climate change, on the other hand, need not entail such a transfer of purchasing power. Thus there are critical differences between the oil price shocks

and the effort to reduce carbon emissions. Our reassuring conclusion regarding aggregate output might also be different if the policy were to be implemented inefficiently (by command-and-control style regulations of the sort put in place in that oil crisis) rather than efficiently (by market mechanisms of the sort that the President has proposed to use).

Effects of Incentives

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

As has been frequently noted, the average cost of SO₂ emissions reductions has recently been significantly lower than was originally forecast, in part due to the role of incentives in fostering innovation. Emission permit prices, currently at approximately \$100 per ton of SO₂, are well below earlier estimates of around \$250 to \$350 per ton (See Chart 1.)

Trading programs may not always bring cost savings as large as those achieved by the SO₂ program; trading programs will not always be accompanied by the discovery of much cheaper control strategies. However, the SO₂ experience demonstrate clearly how such programs offer important market incentives to find cheaper ways of reducing emissions and the flexibility to take advantage of them.

VIII. The Foregoing Estimates Are Conservative in That They Do Not Yet Include Several Factors

I should emphasize that the estimates I have presented are conservative in three very important ways: sinks, technology, and climate change benefits. The first omission, sinks, concerns a provision of the Kyoto Protocol that has received less attention than it merits. It is only *net* emissions -- emissions to the atmosphere minus sequestration -- that are to be reduced 7 percent below 1990 levels, not gross emissions. The United States plants many trees every year, and would receive credit for this activity under the Protocol. Very preliminary estimates of the implications for the United States of the Kyoto provision on sinks reduce the resource cost by to 17 per cent. This brings resource costs down to \$15-\$18 billion, depending on whether we count in no LDC participation at all or we count the benefits of joint implementation through the Clean Development Mechanism (as currently agreed to in the Kyoto Protocol). **These numbers translate into net costs of __ and energy prices of __.** If we get the full participation of LDCs, the costs come down further.

Even those estimates for the effect of sinks are conservative in one respect: they are based

on an assumption for sink activity in the U.S. over the 2008-2012 period, and no assumed benefits from sinks elsewhere in the world. Very preliminary estimates suggest that incorporating the gains from sinks *throughout the world* can reduce the costs of meeting the Kyoto target by half or more, on top of the gains from trading among Annex I countries. (Furthermore, no model has yet even tried to take into account that government policies can help increase the amount of tree-planting, possibly through some version of the Conservation Reserve Program, for example.) But neither we nor other analysts are yet sure exactly how to interpret the legal language of the Protocol. Because the quantitative uncertainty is so large, we do not yet have an estimate with which I feel comfortable. But we do know that the effect of fully modelling the Kyoto provision on sinks is likely to be both favorable and large.

The estimates I have cited so far also make little allowance for the payoff to the President's \$6.3 billion Climate Change Technology Initiative. The parameter that figures most prominently in analysis of technological progress in the energy field is the rate of improvement in the so-called Autonomous Energy Efficiency Index (AEEI), that is the rate at which the total use of energy falls relative to GDP. In the analysis on which the numbers I have reported to you is based, the AEEI improves by 1.0 percent per year. Reflecting a conservative interpretation of the 15-year impact of the technology initiative, this is only a small increase above the number in the Energy Information Administration's Annual Energy Outlook.

The logic with which one could justify such an assumption would be somewhat analogous to the rationale behind the macroeconomic assumptions that we feed into our budget forecasts: in the presence of uncertainty, we are conservative in our estimates of the speed with which the economy will grow, tax receipts will rise, and the budget will improve. That way, any revisions or surprises that occur are likely to be in the pleasant direction. The nature of the conservatism here would be that we assume in our modeling that, because of lags, most of the payoff from new technology research and dissemination expenditures (as opposed to those in the past) comes after 2012.

If the Administration is successful in speeding the discovery and adoption of new technologies, the rate of improvement in energy efficiency could rise. As a second example, we therefore report results assuming that the AEEI parameter is boosted to 1.25 percent. This has the effect of reducing resource costs by 26 - 27 per cent, to \$13 to \$16 billion, again depending on whether we count no LDC participation at all or count the benefits of joint implementation. **These numbers translate into net costs of __ and energy prices of __.** If we were to get the full participation of some LDCs, the costs would again come down further.

This "technology case" is far from the most optimistic outcome that might occur. Some experts in the technology of climate change policy forecast more rapid technological progress. Estimates coming from engineering models predict even higher rates of AEEI improvement, and thus even lower costs.

The third, and most important, respect in which the estimates I have presented are conservative is that they leave out the benefits of mitigating climate change itself. A full cost-benefit analysis would include mitigation in the benefits column. The only reason we have not done so, as I have explained repeatedly above, is the difficulty in coming up with a number to capture the monetary benefits. But I trust that nobody will lose sight of our ultimate objective -- keeping our planet the hospitable home that we enjoy today.

CONCLUSION

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

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

I welcome your questions.

ADDENDUM. NOT FOR DISTRIBUTION *** SAVE FOR Q AND A**

Q -- Senator Brown: I have seen one study that claims large losses in output and employment from climate change policy [EPI, 8/14/97].

A: But this study is misleading in three important ways. First, it did not in my view take into account the points I have made about the ability of the economy to adjust to structural change with a 15-year warning. In particular, a number of commentators on this specific model have highlighted that this is a model best designed to predict economic impacts in the very near future, two to three years from now, and that it is not useful for long term predictions of this type. Second, the model fully assumes that we “do this dumb”, ignoring the efficiencies from international emissions trading, joint implementation, LDC participation. Third, the model ignores any of the benefits of reducing emissions noted above, as well as any benefits of averting climate change, and it does not embody any technological advance in response to our \$6.3 billion technology package, nor any benefits to the economic from our electricity restructuring proposal. These results are therefore exaggerated and present a misleading portrait of the effects of our climate change plan.

Q -- Senator Red-White-&-Blue: Your solution seems to be to buy all the reductions abroad. I can't see American taxpayers paying foreigners for the right to pollute. What share of reductions is done at home?

A: [Unspoken answer: a lot, in the base case...]
I believe the case where we rely heavily on international trading should be viewed as a safety-net case -- a backup if all else fails. Toward the end of my testimony, I discussed the cases where we make some allowances for the effects of sinks and for the payoff from the President's technology initiative. Under those assumptions, with simple Annex I trading, we can accomplish our Kyoto targets by making half our reductions at home: more precisely 52% in the sinks case and 48 percent in the technology case (or 53 % if we allow for *both* the U.S. sinks and the 1.25 AEEI). [If we allow for JI, then the percent of reductions accomplished at home falls into the 40s.]

Q -- Senator Green: What is the single trading combination that is most advantageous for the United States?

A: That would be an umbrella that excludes the EU, but that otherwise includes full worldwide participation and trading. In this case, admittedly one that is not particularly likely, the

cumulative reduction in costs relative to obtaining all reductions domestically is an estimated 88 percent. (And that's before we count accelerated technology or sinks!)