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THE CHAIRMAN

EXECUTIVE OFFICE OF THE PRESIDENT
COUNCIL OF ECONOMIC ADVISERS
WASHINGTON, D.C. 20500

October 3, 1997

MEMORANDUM FOR THE PRESIDENT

FROM: JANET YELLEN *JY*
LAWRENCE SUMMERS *LS*

SUBJECT: Targets and Timetables for Reducing Greenhouse Gas Emissions

Executive Summary

This memo provides a preliminary evaluation of the likely economic consequences for the United States of a program to attain 1990 CO₂ emissions levels by 2010. It concludes that the attainment of such a goal would necessitate at least a doubling in energy prices and impose substantial economic costs. In contrast, a more gradual emissions reduction path that eliminates emissions growth by 2010-2020 and reduces emissions to 1990 levels thereafter captures nearly identical environmental benefits as the more aggressive approach while entailing costs between one tenth and one third as large.

If attained through domestic emissions reductions alone the "1990 by 2010" target requires a reduction in CO₂ emissions of roughly 30% relative to projected 2010 emissions assuming "business as usual". *The reduction in energy use needed to meet this goal would be comparable to that achieved during the decade of the OPEC price hikes, so that energy price increases of similar magnitude are likely.* Economic analysis and historical precedent suggest that energy price increases of this size would have stagflationary consequences. As in the decade of the oil shocks, both unemployment and inflation would undoubtedly rise, at least for a time.

An "idealized" system of international permit trading among Annex I countries could hypothetically halve the change in carbon emissions prices needed to attain a 1990 by 2010 goal. This would mean paying Russia and other Eastern European countries to reduce emissions in place of the United States. However, such an arrangement could prove infeasible for a number of reasons, including difficulties in establishing adequate enforcement and monitoring mechanisms in the near term. Joint implementation with non-Annex I countries is likely to marginally reduce the impact on energy prices in the United States.

The memo argues that a more gradual timetable for emissions reduction can deliver virtually identical environmental benefits at a fraction of the cost. The aggressive "1990 by 2010" path is extremely inefficient because it requires premature scrapping of capital and foregoes the considerable advantages of waiting for the development of carbon-lean technologies

before replacing existing plant and equipment. In contrast, a timetable that eliminates emissions growth in the second decade of the program (2010-2020) and reduces emissions to 1990 levels and below in subsequent decades is consistent with a long-term goal of stabilizing atmospheric CO₂ concentrations. *The total cost of this "back-loaded" approach is likely one third to one tenth that of the "front-loaded" 1990 by 2010 program.* Implementation of the gradual timetable requires an early, modest increase in the price of carbon emissions, along with a credible commitment to further emissions price increases over time.

In comparison with a more gradual emissions reduction timetable, the environmental benefits of an aggressive abatement target are minimal. For example, the expected difference in global average temperature in 2100 along a fast-takeoff abatement path that attains 1990 emissions by 2010 and a slow-takeoff abatement path that peaks in 2015 and attains 1990 emissions by 2040 is less than 0.05 degrees Celsius. Between now and 2100, global average temperature is expected to rise about 2½ degrees Celsius irrespective of the path chosen for Annex I stabilization, assuming developing countries continue with business as usual.

The body of this memorandum lays out the rationale for these conclusions.

I. Introduction

The Framework Convention on Climate Change signed at the 1992 earth summit in Rio de Janeiro called for carbon dioxide emissions in 2000 at 1990 levels. Most countries, including the United States, are unlikely to achieve these emissions reductions. But the Rio approach remains historically important, and most quantitative proposals that have been advanced in the run up to Kyoto can be understood as variants of the Rio target and timetable. In particular, a proposal to "stabilize CO₂ emissions at 1990 levels by 2010" (and variants thereof, including a more stringent proposal by several EU countries to stabilize at 10% below 1990 levels by 2010) has received considerable attention.

This memo assesses the consequences for the U.S. economy of a program to attain 1990 CO₂ emissions levels by 2010. It compares the costs and cost effectiveness of this baseline proposal with those of alternative targets and timetables that entail a less rapid initial reduction in CO₂ emissions levels. The conclusions described here rely on the substantial body of economic analysis that has been conducted by researchers worldwide, including the Intergovernmental Panel on Climate Change (IPCC), and Administration economists.

II. 1990 by 2010: The Scope of the Task

To appreciate the ambitiousness of a program to curb U.S. emissions levels to 1990 by 2010 it is necessary to recognize that, by 2010, emissions are likely to exceed their 1990 levels by about 31 percent.¹ As of 1996, energy related carbon emissions were already 9 percent above 1990 levels. Growth in the economy through the end of the next decade would further raise energy use and carbon emissions. Even under an optimistic assumption concerning the pace of improvement of energy efficiency (0.9 percent per year), there would be further increases in carbon emissions of about 22 percent over current levels by 2010 if we continue with business as usual. A substantial increase in the price of carbon emissions will be needed to induce such a large emissions decline.

An increase in the price of carbon emissions--whether achieved through a system of tradeable emissions permits or a carbon tax--creates incentives to reduce emissions in two separate ways: by reducing overall energy use; and by inducing switches among fuels, away from high-carbon fuels like coal and toward low- and no-carbon fuels, such as natural gas and renewable energy. Reasonable estimates suggest that interfuel substitution in response to higher carbon emissions prices could accomplish between 25 and 45 percent of the overall task, with the remainder occurring through reduced energy use. The implication is that overall energy use must

¹ This assumes a 2.4 percent annual GDP growth rate. Even with a more moderate assumption of 2.2 percent annual GDP growth, carbon emissions in 2010 would exceed their 1990 level by about 28 percent.

decline by about 15% to 18% relative to "business as usual" levels to attain the 1990 by 2010 emissions target. Energy use *does* respond to changes in the price of energy; but history suggests that the responsiveness is *low* over periods as short as a decade. In particular, the experience of the United States during the 1970s and 1980s suggests that energy prices would need to at least double--as they did during the OPEC oil shock period--to attain a 1990 by 2010 target.

Comparison with the Oil Shocks. Figure 1 shows aggregate energy use in the United States and the relative price of energy over the period 1960 to 1990. During the oil-shock period --1973 to 1984--energy use remained virtually constant in absolute terms while GDP grew about 2.5% per annum in real terms. The relative price of energy rose about 130 percent during these years. Again assuming a 0.9 percent pace of improvement in energy efficiency with constant energy prices, the 130 percent energy price hike served to reduce energy use about 16 percent relative to the "business as usual" baseline. *This experience suggests that an increase in relative energy prices roughly comparable to the 130% OPEC-induced rise will be needed to lower energy use by the 15 to 18 percent required to reach the 1990 by 2010 target. A 130% increase in energy prices translates into a carbon tax of roughly \$170 per ton.*

Model results. Numerous economic/energy models have been used to estimate the impact of a 1990 by 2010 program on energy prices. These models arrive at the same conclusion as was generated above using no model whatsoever: a program to achieve 1990 emissions by 2010 would likely entail *at least* a doubling of energy prices. A broad range of models place the carbon permit price required to achieve 1990 emissions by 2010 in the range of \$80 to \$250 per ton. If fully passed through to energy prices, a permit price of \$100 per ton, for example, entails a 76 percent increase in energy prices. The impact on the prices of different sources of energy are all large, but the effect on coal is particularly severe. The price of coal would more than triple, while the price of a barrel of petroleum would increase by about fifty percent. Gas at the pump would increase in price by about 26 cents. Relative to the BTU tax proposed by the Administration in 1993 a \$100 implicit carbon tax is about 5 times as large. Thus, attaining a goal of 1990 by 2010 would have very large effects on our economy.

Evidence from International Comparisons. A final piece of evidence confirming the conclusion that a strong price signal over a long period of time is necessary to alter energy use comes from comparisons of energy usage between the United States and Europe. It should hardly be surprising that energy use per dollar of GDP is lower in Europe than the United States. Energy prices in Europe have long been substantially higher--roughly double U.S. energy prices. Moreover, major differences in living patterns between the United States and Europe result in higher European energy efficiency. In addition to the geographical "advantage", from an energy efficiency standpoint, of Europe's higher population density, resulting in lower transportation requirements, Europe has locked in place many long-run adaptations to high energy prices. Innovations in the design of housing and transportation systems and the configuration of residential areas have occurred in response to high energy prices. But in spite of its natural advantages and its long history of high energy prices, energy per dollar of GDP is only 44% lower in Europe than in the United States. This means that even if the United States were to

become Europe--energywise per dollar of GDP--its energy savings, even in the long run, would be no greater than 44 percent. This U.S.-Europe comparison supports the conclusions drawn from the natural experiment of the oil shock: namely, a return to 1990 emissions will not occur without very major price measures over a long period of time.

The Role of Technology and the Scope for "No Regrets" Policies. According to the preceding assessment, a large price inducement is necessary to meet a 1990 by 2010 target. Your economic advisers agree on this conclusion. However several of your advisers are more optimistic about the chances of achieving a 1990 by 2010 target. They emphasize the current availability of "no regrets" (cost-saving) technologies that promise substantial opportunities for abatement. A recent report by the Department of Energy research laboratories, for example, catalogues emissions-saving technologies that, by their calculations, are currently "cost effective." If put in place now, such practices could allegedly reduce emissions by between 30 to 50 percent of the amount needed to reach a 1990 by 2010 target. Even so, the report finds that "aggressive" and "invigorated" government policies--including potentially costly and intrusive regulations and standards--as well as a \$50 carbon tax would be necessary to reach the 1990 by 2010 target.

Your economic advisers agree that there now exist unused technological opportunities for emissions reduction, but we question by what means, over what time frame, and at what expense government policies could change private behavior if such opportunities are currently underutilized. Engineering studies generally ignore the sometimes subtle disadvantages of available cost-saving technologies or overestimate their hypothetical returns. An example is illustrative: significant energy and cost savings could result if consumers replace incandescent bulbs with compact fluorescents. Over the long lifetime of such bulbs there would also be a substantial monetary gain. However, actual adoption of these light bulbs has been slow to date, possibly due to pure inertia, possibly because consumers dislike their color, or perhaps because they apply a high "discount rate" when valuing energy savings that accrue after the purchaser may have switched residence. Several recent studies have demonstrated that the actual returns to home improvement investments, such as attic insulation, often fall short of those predicted by engineering studies.

Regardless of the reasons, if consumers have not adopted "no regrets" measures at a faster rate, it is likely that additional incentives will be necessary for them to change their minds. Rather than stressing the mere availability of alternative technologies, your economic advisers insist on realistic estimates of likely rates of adoption and diffusion and they stress the need for economic incentives--in the form of a higher implicit price for carbon emissions--to induce the adoption of emissions-saving technology. They point out too that the baseline energy demand estimates used to predict the price increase needed to attain a 1990 by 2010 target already assume substantial ongoing improvements in energy efficiency due to the diffusion of existing technologies and the development of new ones. Significant adoption of such technologies is necessary merely to meet this assumed baseline. Finally, it is important to note that the DOE labs study includes as part of its policy package to reach 1990 emissions by 2010 extensive

regulations, including stringent CAFE and appliance standards and national building codes--command and control policies that your economic advisers would oppose--along with a \$50 carbon tax.

To summarize, your economic advisers consider it unrealistic to predict a substantial increase in the pace of adoption of new emissions-saving technologies in the absence of a large increase in the price of carbon emissions--and hence of energy. Based in part on the evidence from the energy shocks of the 1970s, in part on international comparisons, and in part on model results, they are optimistic that such an increase in prices would bring forth a reduction in CO₂ emissions--with larger responses to a given price change likelier the longer the time period for response. The evidence is strong that a very large price increase will be necessary to attain emissions reductions of 20 to 30 percent over a period as short as a decade. *Moreover, other approaches that apparently do not involve large price increases (such as performance standards) will impose even higher costs on the American economy.*

III. Why are the costs of early emissions reductions so high?

The previous section argued that a "1990 by 2010" target would entail high carbon emissions prices and significant economic costs. This section shows that the 1990 by 2010 timepath for emissions reductions is so aggressive as to be inefficient--in the sense of raising substantially the total projected economic cost of reaching a given environmental goal. There are three major reasons why an aggressive takeoff in curtailing emissions raises overall costs: (1) it induces premature obsolescence of the capital stock because it does not allow adequate time for the capital stock to turn over naturally; (2) it provides insufficient lead time to develop and implement new technologies; (3) it causes a significant stagflationary short-term macroeconomic shock. Additionally, an aggressive timetable for emissions reductions does not allow time for the resolution of uncertainty and it does not take advantage of the time-value of money (resources not spent on emissions reductions early on can be invested at a positive return which could purchase more emissions reductions later).

The Role of Turnover of the Capital Stock. The most clear-cut and easily quantifiable reason for the high price tag associated with rapid emissions reductions relates to the need for premature replacement of plant and equipment in response to large increases in the price of carbon emissions. It is expensive enough to replace plants that are fully depreciated, but vastly more so if those plants are still in the prime of their productive lives. Within 20 to 40 years, much of our existing plant and equipment will be ready for replacement anyway; therefore building in greater carbon efficiency at that time will be relatively cheap. *It is important to emphasize that the case we are making here is not based on procrastinating for the sake of avoiding the problem; rather, it is based on simple principles of hard-headed business efficiency.*

The advantage of a more gradual emissions reduction timetable in avoiding the large

costs associated with premature obsolescence of the capital stock can be illustrated by considering electrical power generation. The case of electricity generation is important in its own right since this industry is responsible for 88% of coal use and more than one third of all carbon dioxide emissions in the United States. But the principle concerning the costs of premature replacement applies broadly because reduced greenhouse gas emissions may entail the accelerated retrofitting of housing and commercial structures, the premature scrapping of vehicles and appliances, and the premature replacement of plant and equipment in energy intensive industries.

Figure 2 illustrates the effect of an accelerated retirement schedule for today's U.S. electric power generation capacity installed during the last 40 years. Imagine, to take an extreme case, that a timetable is adopted that necessitates replacing all power plants with less-polluting technology within ten years. This would require retiring 630 out of 670 gigawatts of generating capacity before the end of its normal life span, or 94 percent of the total. If the timetable were extended so that all power plants instead had to be replaced within 20 years, the accelerated replacement of capacity would affect 450 gigawatts of capacity, or 67 percent of the total. Allowing this additional 10 years for turnover avoids the premature retirement of 27 percent of existing electric power plant capacity. With a 30 year horizon, complete turnover would mean accelerated retirement of only 21 percent of the total capacity and, with a 40 year timetable, there would be almost no additional costs due to premature obsolescence.^{2, 3}

The Advantage of Waiting for Superior Technologies. The example of electric power generation also illustrates a second important reason why a gradual takeoff in curbing greenhouse gas emissions is ultimately less costly: new technologies take a long time to develop. Waiting until these new technologies are available before making expensive emissions-saving investments offers the potential of both lower economic costs and higher environmental payoffs. Under a tight target and timetable with its associated high carbon emissions price, electric utilities will be forced to replace existing capacity in the very near future and to rely on currently available lean-carbon technologies, likely gas-turbine plants. If some delay can be factored in, however, they will be able to install more effective and less costly alternative technologies. A rapid timetable forces long-term investments to be made before superior technologies have been

²The distribution has been truncated at 40 years, the average lifespan of existing electric power plants. A few plants of yet older vintage are still in use.

³The same exercise can be performed for coal-fired power plants. These generators produce the most carbon per kilowatt hour of electricity and thus will have a high incidence of replacement even under a moderate abatement plan. If a complete change-over of coal plants were to be accomplished in 10 years, 96 percent of total capacity would be retired early. If retirement occurred over 20 years, only 64 percent would be retired early. Allowing an additional 10 years for turnover would avoid premature retirement of one-third of existing coal-fired plant capacity.

developed and refined.

Implication: The Need for a Credible, Long-Term Price Increase. The example of electricity generation illustrates two general principles. First, the responsiveness of both demand and supply are greater in the long run than in the short run. This means that, with a longer horizon, any given amount of abatement can be accomplished with a smaller increase in carbon emissions prices. Second, and perhaps even more important for policy, any credible emissions reduction strategy must include both a price increase at the outset and also a clear commitment to maintain and likely increase prices further over time. Without such a commitment, the changes in behavior required to meet even a long-run target of emissions reduction will likely not occur. Consider a utility that today is drawing up its plans for a new power plant. That utility will choose among today's technologies, which vary in their costs and CO₂ emissions. In order to induce the utility to choose a more costly, lean-emissions technology today, it must be clear that CO₂ emissions will be costly enough over the 40 years or more lifetime of the plant to justify a more expensive investment option today. A large cumulative reduction in emissions can be achieved over the long term with only a modest carbon emissions price increase now, but only if the commitment to still higher prices in the future is credible and clear.

Stagflationary Macroeconomic Impact. From a macroeconomic perspective, increases in energy prices constitute an adverse "supply shock." Such developments are stagflationary--even if anticipated--because they raise both inflation and unemployment simultaneously, creating a painful macroeconomic dilemma. As noted above, a plan to attain 1990 emissions levels by 2010 would require a change in energy prices over the first decade of the 21st century at least comparable in magnitude to the two oil shocks of the 1970s. Those shocks are widely acknowledged to have raised both unemployment and inflation. Similarly, the energy price increases required by a 1990 by 2010 program would raise inflation, lower real wages, and raise unemployment. Unemployment in the four years after the first oil shock averaged 7.2 percent in comparison to 5.0 percent in the four years prior; and unemployment rose further, to an average of 8.6 percent, in the four-year aftermath of the second oil shock.⁴ Although the increases in energy prices associated with a treaty to reduce greenhouse gases would be anticipated, rather than a surprise, we should nevertheless expect that the efforts of the Federal Reserve to contain inflation, coupled with likely efforts on the part of workers to recoup real wage losses will lead to a period of higher unemployment.

Furthermore, it is important to note that most model-based estimates of the costs of a program to attain 1990 emissions levels by 2010 assume that resources are fully employed, thereby ignoring these potential short-term effects. Such models therefore provide no assessment of the consequent increases in unemployment.

⁴ There is debate about how much of this was due directly to the oil shocks, because there was a simultaneous decline in productivity growth and transfers of real income to OPEC producers.

IV. Quantifying the Economic Costs of Gradual versus Fast Take-off

The relative costs of gradual versus fast takeoff timetables in curbing CO₂ emissions has recently been analyzed by the Stanford Energy Modeling Forum (EMF-14).⁵ The Stanford group used six large-scale economic/energy models to compare the total projected cost of two alternative emissions reduction time paths—one “frontloaded”, the second more “backloaded”. *Importantly, both paths were designed eventually to stabilize atmospheric concentrations of CO₂ at double the pre-industrial level--550 ppmv.*⁶ Although a high degree of uncertainty is inherent in particular numerical estimates from individual models, the simulations nevertheless point to some robust qualitative conclusions. *The major conclusion to be drawn from this project is that an emissions reductions path characterized by an aggressive initial phase is substantially more costly--3 to 10 times more costly--than a path with a slower takeoff but larger eventual reductions.*

To enable a comparison of the costs of gradual and rapid takeoff strategies, the EMF investigators asked each of six modeling groups to simulate the economic impacts of two alternative strategies to attain stabilization of CO₂ concentrations at 550 ppmv. The first strategy (the WG-1 path) corresponds to an emissions pathway published in 1994 by Working Group 1 (WG-1) of the Intergovernmental Panel on Climate Change (IPCC). The working group computed a set of global CO₂ emissions pathways consistent with stabilization of concentrations at 550 ppmv and several alternative concentration levels. The WG-1 path entails an immediate departure from the baseline or “business as usual” emissions path. Subsequently, Wigley, Richels and Edmonds (WRE) published an alternative set of emissions profiles to achieve the same concentration targets. In contrast to the WG-1 paths, the WRE emissions path was constructed to follow the baseline or “business as usual” scenario in the early years with sharper reductions after this initial phase. Wigley, Richels and Edmonds hypothesized that their more gradual takeoff emissions pathways would yield identical environmental objectives with substantially lower economic costs, for the reasons discussed above. The EMF-14 exercise validates this hypothesis.

⁵ To enable meaningful comparisons of results across models, the EMF has coordinated a series of projects in which a number of large scale energy models are used to estimate the impact of given, specified emissions reduction scenarios under common standardized, benchmark assumptions concerning population and economic activity, discount rates, energy resource availability and prices and technology availability.

⁶ All energy models make numerous simplifications and approximations in order to describe the energy sector globally and over the span of a century or more. In particular, all of the models assume full employment, thereby abstracting from the likely short-run macroeconomic costs of an emissions reduction program.

The EMF-14 comparison project assessed the total costs to the OECD, the EEFSU (Eastern Europe and the former Soviet Union) and the non-Annex I countries of the WG-1 and WRE pathways to stabilization of CO₂ concentrations at 550 ppmv. The appropriate economic measure of total cost is the present discounted value of losses in future consumption relative to a "business as usual" scenario. Estimates of regional costs depend on the extent of burden sharing--namely, the assumed "division of labor"--between Annex I and non-Annex I countries in controlling emissions as well as the extent of international emissions trading. Recall that, by the end of the next century--by 2100-- assuming "business as usual"--non-Annex I countries will have more than 90 percent of CO₂ emissions. Thus, developing country participation is absolutely essential to achieving stabilization of concentrations. Consistent with the Berlin Mandate, the simulations assumed that the burden of emissions reduction would fall on Annex I countries exclusively during the early decades; that by 2030, non-Annex I countries would begin to participate; and by 2050, a full transition to targets based on equal per capita emissions rights is assumed.

Figure 3 plots the OECD emissions paths in the WG-1 and WRE scenarios. Under the WG-1 scenario, OECD emissions begin to decline immediately and continue to decline for roughly four decades. For example, OECD emissions fall 10 percent below initial levels ten years after implementation. This corresponds roughly to the requirement of a "1990 by 2010" timetable--that emissions decline about 15 percent from their projected 2000 level during the decade between 2000 and 2010. In contrast, OECD emissions along the WRE path continue to rise for roughly two decades--corresponding closely to a plan calling for emissions to peak around 2020--return to 1990 levels around 2040 and decline substantially further in subsequent decades.

Table 1 illustrates a robust conclusion that emerges from this exercise: fast takeoff in emissions reductions greatly increases the costs. Table 1 shows the cost for both the aggressive (WG-1) and gradual (WRE) paths--both with and without idealized international trading of permits. In 10 out of 12 simulations--for six different models with and without permit trading--the costs on the gradual WRE path is less than a third of the cost on the corresponding fast take-off path. Taking account of the likely adverse short-run macroeconomic consequences of an aggressive path would further strengthen this conclusion.

Table 2 illustrates a second, robust conclusion from the EMF-14 exercise: a viable system of international permit trading would very much reduce OECD costs. With global permit trading, the sharp, early emissions reductions required of OECD countries under the aggressive (WG-1) approach would be avoided through the purchase of emissions permits from countries with lower abatement costs. The average reduction in cost is 56 percent.⁷

⁷ The computations in Table 2 verify that the gradual (WRE) path, which permits emissions to depart relatively little from business as usual for several decades, is a substantially less costly than the alternative WG-1 path with its sharper immediate reductions. Since both

Finally, it is important to note that in most of the EMF models, policy actions to raise carbon emissions prices must be taken at the inception of the gradual (WRE) program and a commitment to increasing emissions prices over time is required to achieve additional emissions reductions. Naturally, the required initial carbon emissions price is substantially lower, at the outset, under the gradual (WRE) than under the aggressive (WG-1) path. Thus, although the gradual emissions path initially approximates the business as usual baseline, credible incentives must be put into place immediately, and strengthened over time, to achieve the needed investments in carbon-efficient technologies.

V. The Environmental Consequences of Gradual versus Fast Takeoff.

While the excess cost of a fast, compared to a gradual emissions reduction path is large, the difference in projected global temperatures over the next century between the fast and the gradual paths is quite small, both in absolute amount and relative to temperature changes expected even if an aggressive policy path is adopted. Under "business as usual" assumptions, average global temperatures are expected to rise about 1 degree Celsius by 2050 and about 2½ degrees Celsius by 2100. An aggressive Annex I emissions reduction path that stabilizes emissions at 1990 levels by 2010 and maintains emissions at the 1990 level thereafter would mitigate this temperature increase by roughly 0.1 degrees by 2050 and 0.2 degrees by 2100.⁸ In contrast, a more gradual Annex I emissions path that peaks around 2015, stabilizes emissions at 1990 levels by 2040, and holds emissions constant at 1990 levels thereafter yields virtually identical environmental benefits: the temperature difference between the aggressive and gradual paths diverges by no more than 0.05 degrees at any time over the next century. Similarly, the temperature differences along the aggressive WG-1 and less aggressive WRE paths--both designed ultimately to stabilize concentrations at 550 ppmv--differ by a maximum of 0.2 degrees over the next several centuries.⁹

paths are arbitrarily chosen to conform with the 550 ppmv concentration target, a natural question concerns the characteristics of an optimal or least-cost path for achieving this concentration target. An important recent study by Alan Manne and Richard Richels uses their MERGE model (included in the EMF-14 project) to compute the least-cost path with 550 ppmv stabilization and international permit trading. The optimal path, while not identical to the WRE path, is similar in character. This least-cost path peaks approximately three decades after the initiation of the program and declines thereafter.

⁸ Successful stabilization would require very large cuts from "business as usual" in China, India, and other non-Annex I countries.

⁹ If a model assumes that sulfur dioxide emissions decline with the decline in carbon dioxide emissions under climate policy (as predicted, given the extent of sulfur emissions associated with fossil fuel combustion, and incorporated in the IPCC's IS92 emissions

The limited climatological impact of even an extremely aggressive emissions reduction program measured in terms of temperature impacts during the next century reflects the extremely long lags involved in the underlying physical processes and the dependence of temperature on the total stock of carbon dioxide in the atmosphere, rather than the flow of emissions at a given time. Emissions reductions do matter to temperature, but only over an extremely long horizon. The cumulative nature of the process suggests that there is little effect on global temperature from a gradual rather than from a fast abatement takeoff. The addition to the total stock of carbon from a gradual rather than a fast start to abatement adds relatively little to the total atmospheric stock of CO₂ between now and 2100 for four separate reasons: the difference in carbon emissions between a gradual and a fast start over the initial decades of abatement is only a small fraction of total emissions in that period; the stock of CO₂ in the atmosphere is itself the result of many decades of emissions; some of the CO₂ emissions of the early decades will have been re-absorbed; and the most serious build-up in CO₂ under business as usual occurs late in the next century, as a consequence of burgeoning emissions from non-Annex I countries.

Even the potential for a catastrophic environmental event, such as the melting of the West Antarctic ice sheet, a runaway greenhouse effect (e.g., from release of trapped methane with the melting of the permafrost), or a structural change in ocean currents such as the Gulf Stream, which the preceding abstracts from, does not fundamentally affect the basic trade-offs between the high costs of fast vs. gradual takeoff paths. These factors do, however, add--perhaps greatly--to the urgency of adopting moderate long-term greenhouse gas concentration targets and a program involving an immediate, albeit moderate, increase in the price of CO₂ emissions.

VI. International Trading of Permits

As has already been noted, an effective system of international carbon emissions permit trading among Annex I countries could substantially diminish the cost of a CO₂ abatement program. An Annex I trading system could, potentially, reduce the size of the carbon emissions price to attain a 1990 by 2010 goal by up to 50%. Moreover, joint implementation projects with non-Annex I countries could, hypothetically, reduce this figure by half again.

Although international trading and joint implementation--so-called "where flexibility"--has enormous advantages in theory, your economic advisers are concerned that substantial barriers would stand in the way of implementing any workable analogue of such an idealized system--at least in the near term. Consequently, they stress that Annex I international permit trading and joint implementation between the U.S. and non-Annex I countries realistically can

projections), the more aggressive WG-1 path will be *warmer* than the WRE path between 2000 and 2040. This result reflects the negative impact of sulfate aerosols on the greenhouse effect. Early and substantial cuts in fossil fuel combustion, while decreasing the carbon emissions that warm the atmosphere, also decrease the sulfate aerosols that cool the atmosphere.

serve only a limited role in reducing the costs associated with meeting a "1990 by 2010" target.

A *hypothetical* example shows how an international trading system would work, and why it would reduce each participant country's abatement costs. Suppose, ideally, that every country adopts a domestic permit system to implement its Kyoto target. Absent international trading, the price of emissions permits would surely differ across countries, reflecting differing marginal costs of abatement internationally. With different permit prices in different national markets, profit-seeking traders would be motivated to buy permits in countries where they are cheap and resell them in countries where they are more expensive. Such arbitrage activities would create an international permit market, bringing permit prices into equality worldwide. This idealized system promotes global efficiency in achieving any worldwide abatement goal. Countries with permit prices below world levels have the incentive to reduce emissions more than they otherwise would in order to profit in the international permit market. Countries with high permit prices would have the incentive to purchase permits, thereby relaxing their Kyoto emissions constraints. The U.S. government could avoid any direct participation in such a system as long as it deems foreign-issued permits presented to the U.S. government by U.S. carbon-emitting entities as valid as those issued by the U.S. government itself.

The preceding description of how an international permit trading system would work provides an idealized picture of its possibilities. But the actual benefits of such a system are apt to fall short of this utopian portrayal in part because countries are not obliged to fulfill their Kyoto commitments via a domestic permit trading scheme; indeed, few Annex I countries have indicated an intention to do so. For example, consider a government that has decided to limit domestic emissions through regulatory controls. International permit sales that result in tighter domestic constraints could well be politically unpopular so that a government would hesitate before selling its emissions rights to the United States. Similarly, international permit sales by a country that is meeting its Kyoto obligations through domestic carbon or energy taxes would necessitate a hike in those taxes. In either case, international trading would involve government to government negotiations, and difficult political decisions. In contrast, in the idealized system, trades result from profit-oriented transactions among individuals, mediated through the market.

Monitoring and enforcement issues are also likely to be paramount in insuring the workability of international trading. If domestic enforcement is effective in all countries, so that, in the aggregate, consumers and firms in each country actually limit their emissions to the national permit levels, international permit sales by private agents in the country actually translate into lower domestic emissions. But consider the difficulties that can occur with imperfect enforcement. If the government of a country--country X--finds it difficult either to measure domestic emissions or to enforce the purchase of permits by domestic emitters, then reductions in X's emissions may be insufficient to reach the Kyoto target. Those firms or individuals in X that are lucky enough to have been assigned the rights to X's permits will be able to sell them, at a quick profit, on the international market. With imperfect enforcement, international sales, without corresponding domestic emissions reductions, could emanate from countries with the weakest systems of enforcement. To prevent such "paper trades", which profit

some participants and increase emissions, many countries, including the United States, will want controls to ensure the integrity of international permits. Buyers, too, will want clear concrete guarantees of the validity of permits so as to be sure they are not being passed counterfeit goods. These controls and guarantees will surely inhibit the efficiency of the market and render some--possibly much--of the estimated savings illusory. In fact, most of the benefits projected from the international sale of permits come from inducing emissions reductions from countries in Eastern Europe and the former Soviet Union--countries with particularly weak tax collection and enforcement mechanisms. Without these countries in the scheme the gains from international trading of permits will be very small.

Joint implementation with non-Annex I countries also has the potential to reduce the U.S. burden of attaining any given timetable. Under this type of approach, U.S. businesses could receive credit for the construction of nuclear, oil, or natural gas electricity generation plants in China if it were confidently expected that China would instead have constructed coal-fired plants with much higher CO₂ emissions. Certification of such credits might be overseen by an international agency to ensure that the projects were emissions-replacing. Such a project-by-project system is likely the most that is feasible in the absence of quantitative targets. Your economics advisers have concerns about even this level of endeavor due to the inherent difficulty in establishing that a particular set of projects has actually reduced a country's emissions, absent a reference path enabling a clear quantitative comparison. For example, the construction of a nuclear power plant in place of a coal-powered plant in China could indirectly raise CO₂ emissions elsewhere in the Chinese economy--partially offsetting the direct CO₂ reducing effect of the project--if the reduced demand for coal lowers its domestic price and encourages greater use elsewhere in the Chinese economy. A project-oriented approach to joint implementation will, in effect, constitute a limited form of international trading with high transaction costs. As a result, it will probably capture only a small fraction of the total benefits of full international trading. In contrast, model results concerning the benefits of joint implementation treat it as equivalent to idealized international trading.

VII. Recycling of Revenues

The ultimate economic cost of an emissions abatement program depends upon how the revenues realized from carbon taxes or auctioned permits are used. It has been estimated that the efficiency loss from collecting an extra dollar of tax revenue amounts to around 30 cents. If the revenues from a carbon tax or auctioned permits are used to reduce inefficient taxes inhibiting work or investment, the resulting gains would partially offset the micro-efficiency losses from energy curtailment. The simple lesson is that the costs of emissions abatement may be greatly reduced if the revenues from the taxes levied can be put to good use.

So far we have approached the recycling of revenues from the standpoint of microeconomic efficiency. There is also the potential for using the revenues to abate the macroeconomic consequences of the emissions program. The oil shocks are believed by many

economists to have resulted in increased unemployment because workers resisted the fall in real wages that was associated with the inflationary impact of higher energy prices. Increased wage demands added inflationary pressures to the economy that could only be suppressed by tighter monetary policy. Thus it might be argued that the effects of the real wage shock on inflation and unemployment could be diminished by lowering payroll or other worker taxes to offset the real wage losses from higher energy prices.

But England's experience points to the need for caution in assessing the potential for revenue recycling to allay the macroeconomic consequences of the rising energy costs. In 1979, immediately after her election, Margaret Thatcher increased the VAT tax and simultaneously decreased the income tax. These two policy changes had offsetting effects on real after tax incomes, and therefore might have been expected to have had no effect on wage bargaining. However, the increase in the VAT tax resulted in an immediately noticeable increase in the CPI. A wage-price spiral ensued as workers attempted to maintain their pre-tax real wages.

VIII. Policy Implications

The foregoing arguments point to the attractiveness, from both an economic and environmental standpoint, of a U.S. policy to raise the price of carbon emissions--either through a carbon tax or a system of auctioned permits--by a moderate amount--for example, between \$5 and \$15 per ton of carbon--in the near term, with further increases scheduled over the longer term. A realistic target and timetable corresponding to such a program would entail continued emissions growth in the first decade of the program, say 2000-2010; elimination of emissions growth in the second decade (2010-2020) and reductions in emissions thereafter. This program entails significant, early policy action and is consistent with a strong U.S. commitment to attaining the ultimate objective of the Framework Convention--namely to stabilize atmospheric concentrations of CO₂ and hence global temperatures.

Figure 1: Energy Prices and Changes in Energy Use
OPEC price hikes lowered energy use substantially

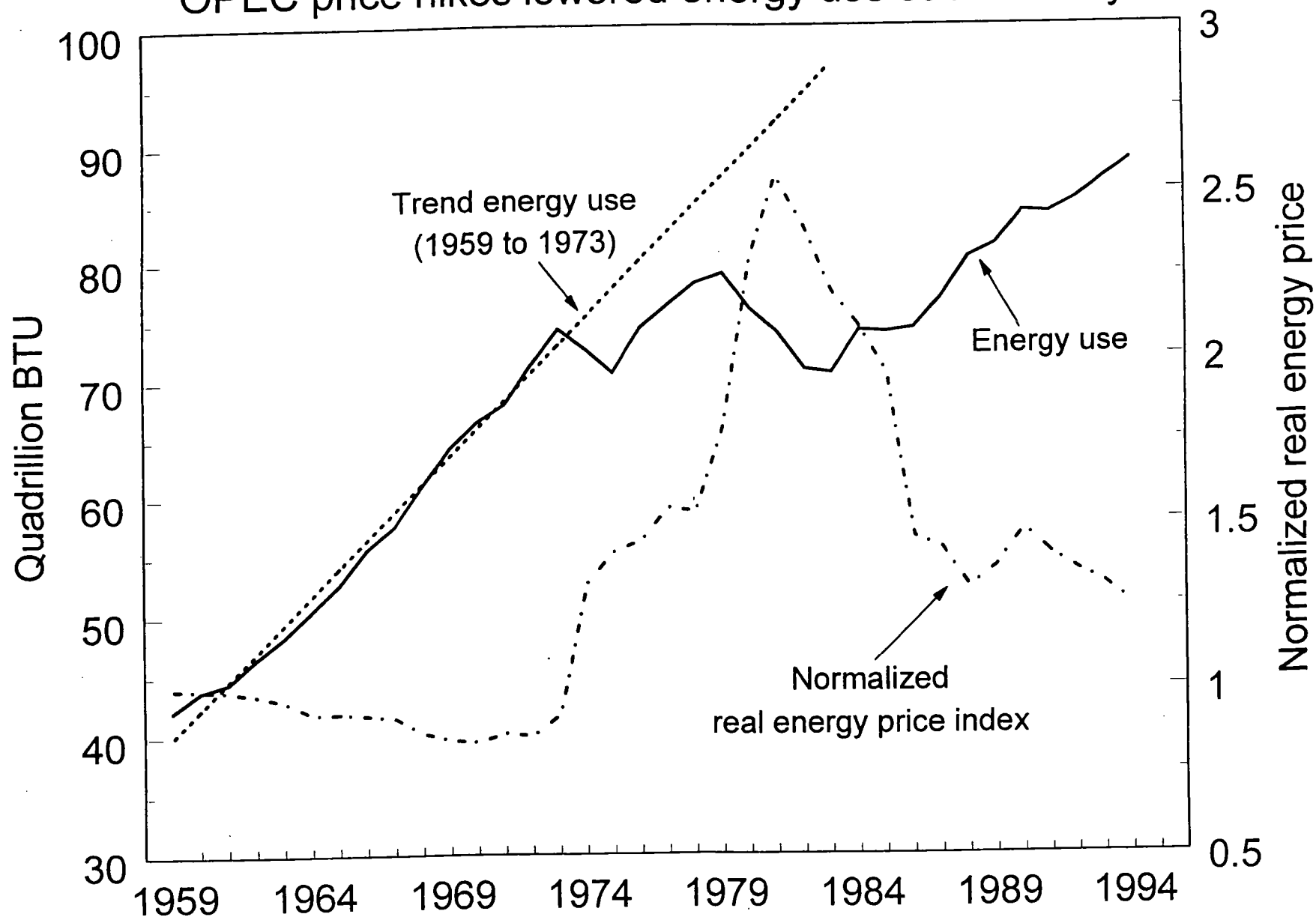
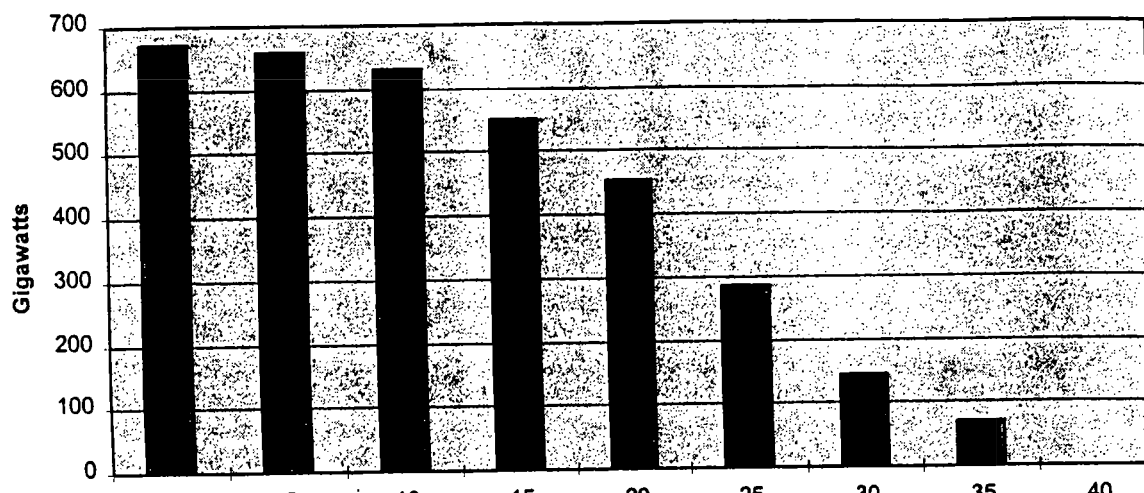


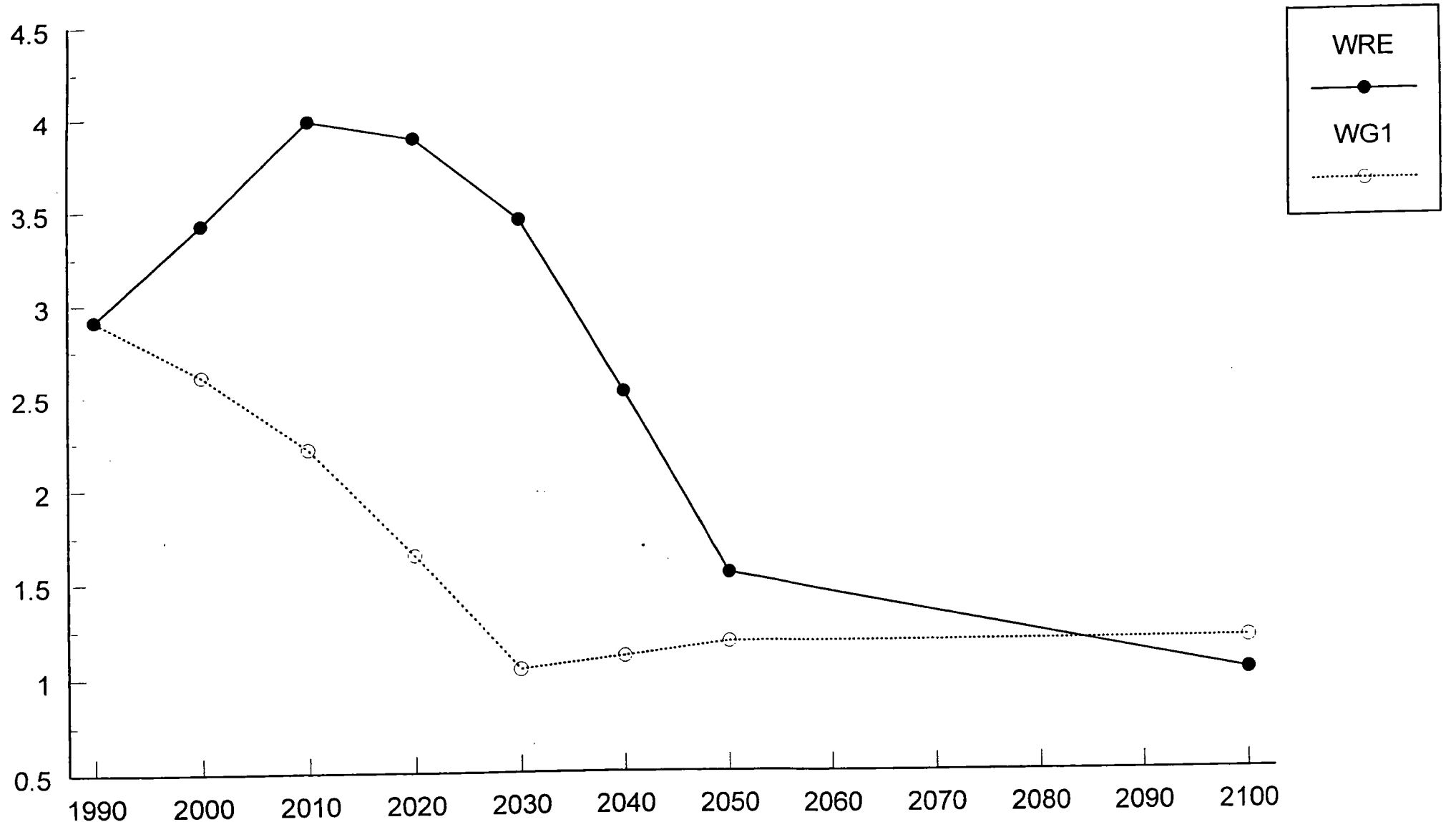
Figure 2: Accelerated Retirement of Electric Power Plant Capacity



Bar height shows capacity to retire early if complete change-over occurs within number of years indicated on the axis. Normal life span of a generator is 40 years.

Figure 3: WRE and WG-1 Emissions Pathways for OECD
to Stabilize Concentrations at 550 ppmv

billion tons of carbon



Source: M... e and Richels

Table 1

**The Effects of Emissions Pathway on Consumption Losses by OECD Countries,
No International Permit Trading (trillions of 1990 U.S. dollars)^a**

Model	WRE	WG1	WRE/WG1
CETA	1.83	5.94	0.31
CPBRIVM	0.64	3.25	0.20
FUND	9.82	11.71	0.84
MERGE	0.85	6.12	0.14
MiniCAM	1.58	6.51	0.24
SGM	1.84	6.17	0.30
		Average:	0.34

**The Effects of Emissions Pathway on Consumption Losses by OECD Countries,
International Permit Trading (trillions of 1990 U.S. dollars)^a**

Model	WRE	WG1	WRE/WG1
CETA	1.86	4.03	0.46
CPBRIVM	0.17	0.99	0.17
FUND	1.47	4.97	0.30
MERGE	0.60	3.24	0.19
MiniCAM	0.54	3.44	0.16
SGM	0.13	1.48	0.088
		Average:	0.23

^a Losses measure the present discounted value of foregone consumption through 2100 in trillions of 1990 U.S. dollars.

Table 2

**The Effects of International Permit Trading on Consumption Losses by OECD Countries,
WRE Emissions Pathway to 550 ppmv Stabilization (trillions of 1990 U.S. dollars)^a**

Model	Trading	No Trading	Trading/No Trading
CETA	1.86	1.83	1.02
CPBRIVM	0.17	0.64	0.27
FUND	1.47	9.82	0.15
MERGE	0.60	0.85	0.71
MiniCAM	0.54	1.58	0.34
SGM	0.13	1.84	0.07
		Average:	0.43

**The Effects of International Permit Trading on Consumption Losses by OECD Countries,
WG1 Emissions Pathway to 550 ppmv Stabilization (trillions of 1990 U.S. dollars)^a**

Model	Trading	No Trading	Trading/No Trading
CETA	4.03	5.94	0.68
CPBRIVM	0.99	3.25	0.30
FUND	4.97	11.71	0.42
MERGE	3.24	6.12	0.53
MiniCAM	3.44	6.51	0.53
SGM	1.48	6.17	0.24
		Average:	0.45

^a Losses measure the present discounted value of foregone consumption through 2100 in trillions of 1990 U.S. dollars.

**TESTIMONY OF DR. JANET YELLEN
CHAIR, COUNCIL OF ECONOMIC ADVISERS
BEFORE THE
U.S. HOUSE OF REPRESENTATIVES
COMMITTEE ON SMALL BUSINESS**

APRIL 29, 1999

Thank you, Mr. Chairman. I appreciate having this opportunity to discuss with you the economics of climate change and the Administration's efforts to address this significant environmental challenge. As you know, the Administration released a report last July, entitled "The Kyoto Protocol and the President's Policies to Address Climate Change: Administration Economic Analysis." The report states that, in the Administration's view, the costs of achieving our Kyoto target would be modest if we can succeed in implementing international trading, joint implementation, and the Clean Development Mechanism in an efficient manner and we achieve meaningful developing country participation. In addition, since the 1997 Kyoto Conference, a variety of research on the economics of Kyoto, and especially on the economics of Kyoto's flexibility mechanisms, has been undertaken. Today, I will provide a brief summary of the Administration's Economic Analysis and review several of the key findings in the recent economic literature on climate change.

The Potential Impact of Climate Change

The Intergovernmental Panel on Climate Change (IPCC) concluded in 1995 that "the balance of evidence suggests that there is a discernible human influence on global climate." Current concentrations of greenhouse gases have reached levels well above those of preindustrial times. If growth in global emissions continues unabated, the atmospheric concentration of carbon dioxide (CO₂) will likely double relative to its preindustrial level by midway through the next century and continue to rise thereafter. As a result of the increased concentration of CO₂, the IPCC estimates that global temperatures will increase by between 2 to 6 degrees Fahrenheit in the next 100 years, with a best guess of about 3.5 degrees Fahrenheit. 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. Further discussion of the costs of climate change is contained in the Administration Economic Analysis.¹

¹ Please refer to the attached paper copy or <http://www.whitehouse.gov/WH/New/html/kyoto.pdf> for a PDF version of this document.

The Kyoto Protocol and the Buenos Aires Conference of the Parties

The Kyoto Protocol provides several mechanisms that would allow countries to achieve the emissions targets established in this agreement in a cost-effective fashion. These mechanisms, which permit what we have termed “when”, “what”, and “where” flexibility in meeting the Kyoto emissions targets, are described in detail in the Administration Economic Analysis. Since securing international emissions trading, the Clean Development Mechanism, and joint implementation in Kyoto, the Administration has worked in bilateral and multilateral arenas to promote understanding of these mechanisms and to develop rules that will promote their efficient operation. Last fall in Buenos Aires, a workplan to resolve key implementation issues regarding these mechanisms by the end of 2000 was agreed to by all the participating countries. I want to reiterate that efficient implementation of these flexibility mechanisms is critical to reducing the costs of achieving the targets established in the Kyoto Protocol.

Costs of Action

In assessing the economic effects of the Kyoto Protocol, the Administration has drawn on the insights of a wide range of models and analysis. Examples include models of the energy sector and economy over the next 25 years, such as those participating in the Stanford Energy Modeling Forum, the Intergovernmental Panel on Climate Change’s review of the economic and social dimensions of climate change, the work of the Organisation for Economic Co-operation and Development (OECD) on the economic dimensions and policy responses to global warming, and the Administration’s staff-level interagency analysis. In addition, the Administration used other tools, such as a meta-analysis, basic economic reasoning, overviews of the domestic and international energy sectors, statistics regarding energy efficiency and greenhouse gas emissions, and economic indicators from World Bank, International Energy Agency, and Energy Information Administration databases.

Assuming that effective mechanisms for international trading, joint implementation, and the Clean Development Mechanism are established, and assuming also that the United States achieves meaningful participation by key developing countries, the Administration’s overall assessment is that the economic cost of attaining the targets and timetables specified in the Kyoto Protocol will be modest for the United States in aggregate and for typical households. This conclusion is not entirely dependent upon, but is fully consistent with, formal model results. The Administration believes that there are limitations to relying on any single model to assess the economic impact of the Kyoto Protocol. However, model results can further inform and improve the understanding of the effects of climate change policy. To complement the economic analysis of the Administration’s policy to address climate change, we have conducted an illustrative assessment with a modified version of the Second Generation Model (SGM). The results from the SGM substantiate the conclusion that the economic effects of an efficient, effective, and global policy to address the risks of climate change will be modest.

An assessment using the SGM model that accounts for effective trading and developing country participation yields permit price estimates ranging between \$14/ton and \$23/ton, and direct resource costs to the U.S. between \$7 billion and \$12 billion/year (1997 dollars). The range reflects uncertainty about the extent of Annex I participation in international trading.

Under the assumptions of the Administration's analysis, permit prices in the range of \$14/ton to \$23/ton translate into energy price increases at the household level between 3 and 5%. Under these permit prices, fuel oil prices would increase about 5 to 9 percent, natural gas prices about 3 to 5 percent, gasoline prices about 3 to 4 percent (or around 4 to 6 cents per gallon), and electricity prices about 3 to 4 percent. This increase in energy prices at the household level would raise the average household's energy bill in ten years by between \$70 and \$110 per year, although such predictions may not be observable because they would be small relative to typical energy price changes, and nearly fully offset by electricity price declines from Federal electricity restructuring. By 2008-2012, the anticipated 10 percent decline in electricity prices from restructuring is projected to lead to expenditure reductions of about \$90 per year for the average household.

The illustrative modeling analysis does not account for several key components of the Kyoto Protocol and the Administration's policies to reduce greenhouse gas emissions. These include the benefits of reducing net emissions through carbon sinks, the Administration's electricity restructuring proposal, the Administration's Climate Change Technology Initiative (increases in R&D funding and new tax incentives in the Administration's FY 2000 Budget), the Administration's sectoral consultations to encourage and support voluntary efforts by U.S. industry to undertake emissions reductions, including the provision of credit for early action, and the Administration's efforts to reduce federal energy use. There are also ancillary benefits of reducing greenhouse gas emissions -- in particular, the corresponding reductions in conventional air pollutants like sulfur dioxide and fine particulate matter. These benefits alone could produce savings equal to about a quarter of the costs of meeting our Kyoto target.

The Administration released earlier this month its electricity restructuring legislation. The Administration's proposed Comprehensive Electricity Competition Act (CECA) is estimated to reduce greenhouse gas emissions by about 40 to 60 million metric tons of carbon equivalent per year by 2010. Further, the electricity restructuring proposal provides potential cost-savings in four areas: dispatch efficiency, improved capital utilization, savings in capital additions and cost reductions in fuel procurement, non-fuel operation and maintenance expenses, and administrative and general expenses. These four categories of savings, when translated to consumers, are likely to reach or exceed \$20 billion annually. The Department of Energy is revising its technical analysis of last year's proposal to reflect changes in the latest proposed legislation and will release the new analysis to the public in the near future.

Recent Research on the Economics of Climate Change

Since December 1997, many economists have conducted and made available their analyses of the Kyoto Protocol. I have noted in previous appearances before Congressional Committees that there are limitations to relying on one or a small set of models and that we were eager to see assessments of the Kyoto Protocol by other models. Two large efforts have been undertaken to coordinate and compile modeling results on the Kyoto Protocol. First, the Stanford University Energy Modeling Forum (EMF), a long-running model comparison exercise involving many of the leading climate and energy models, has coordinated full scale analyses of the Kyoto Protocol. Second, the Organisation for Economic Co-operation and Development (OECD) held an economic modeling workshop this past fall, and has since published the proceedings of this workshop which includes 16 papers. In addition, several research teams have undertaken work in evaluating the potential for intergas trading and the cost-savings of a six-gas target relative to a carbon dioxide-only target. I would like to take this opportunity to provide an overview of this recent research.

Kyoto Modeling Analyses

The final results of the Energy Modeling Forum comparison exercise of the Kyoto Protocol reflect the work of twelve modeling teams from the United States, Europe, and Asia.² In evaluating the Kyoto Protocol, all of the participating teams used economic models that incorporate the potential for international trading in greenhouse gas permits. The OECD workshop included presentations by 10 modeling teams, 9 of which had global models as well.^{3,4} By explicitly incorporating international trading, these models can evaluate the opportunities for cost-savings through trading among Annex I nations and among Annex I and developing countries were they to adopt emissions targets. Since the Kyoto Protocol enables all countries with emissions targets to trade emissions allowances among other countries with targets, these models are well-suited to assess the economic implications of the international trading component of the agreement.

While the models used in the EMF exercise and the OECD workshop can assess international trading, there are several other flexibility mechanisms of the Kyoto Protocol that they cannot, at present, readily assess. For example, these models did not incorporate the effects of sinks. While several modelers did assess the economic costs of achieving the Kyoto targets

² The results of the Stanford Energy Modeling Forum's Kyoto Protocol exercise will be published in a forthcoming issue of the *Energy Journal*.

³ Please note that several modeling teams participating in the EMF exercise made presentations at the OECD workshop.

⁴ PDF-formatted files of the OECD workshop proceedings can be downloaded from the OECD webpage at <http://www.oecd.org/dev/news/Environment/Modelling.htm>.

with “off-line” assumptions about sink activity, none incorporated an integrated energy-land use model. Further, most of the modelers did not evaluate opportunities to reduce costs by trading across greenhouse gases. These models are primarily energy models and are focused on the economics of reducing carbon emissions from fossil fuel combustion. Again, some modelers analyzed the Protocol by making some “off-line” assumptions about the potential reductions in non-carbon dioxide greenhouse gases, but none employed a model with cost curves for these gases. Finally, it should be noted that these models did not include opportunities for emissions reduction through Administration proposals, such as electricity restructuring or the Climate Change Technology Initiative, that could slow the growth over time of greenhouse gas emissions thereby lowering greenhouse gas permit prices.

The results from both the EMF and OECD efforts provide very useful context for the Administration’s economic analysis. First, the illustrative model used by the Administration, the Second Generation Model of the Pacific Northwest National Laboratory, tends to fall in the middle of the range of this set of models in terms of U.S. permit prices.⁵ For example, under Annex I trading SGM generates a permit price which is above the median of this set of models, while under full global trading, the SGM permit price is just below the median permit price. Second, the EMF exercise found that the reduction in permit prices as trading expands from no trading to Annex I trading to full global trading is robust. On average, the EMF models found that Annex I trading would cut the U.S. permit price by 60% relative to a no trading scenario. Of these models, one estimated a 77% reduction in the permit price under Annex I trading. In full global trading, the permit price would be, on average, 81% lower than the no trading price. Several models estimated permit price reductions of about 90%.

The reported results from the OECD workshop found similar reductions in permit prices by going from no trading to Annex I trading. On average, the OECD workshop models found that Annex I trading would cut the U.S. permit price by 57% relative to a no trading scenario. Moreover, they found that the European Union and Japan would benefit more from unconstrained Annex I trading. For both the E.U. and Japan, the average reduction in permit prices across these models would be nearly 75%.

Analyses of Trading Constraints

In addition to the modeling of various efficient international trading scenarios, several EMF modeling teams have considered the impact of constraints on the opportunity to buy or sell emissions allowances in an international market. While the United States is unambiguously

⁵ Please note that the version of SGM used in EMF differs from the analysis conducted by the Administration because the EMF version does not include cost curves for non-carbon dioxide greenhouse gases used by the Administration. Since efficient trading across gases would lower costs and permit prices, and accounting for six gases affects the stringency of some countries’ targets, the EMF version of SGM yields slightly higher permit prices than the Administration version.

opposed to trading restrictions, several parties to the agreement have indicated support for some form of a trading constraint, for example, by setting a limit on the amount a party can purchase through the trading system. Trading restrictions would generate no benefit for the global climate while they could significantly increase the costs of achieving the Kyoto targets.

Before describing the economic costs of trading constraints, I would like to explain why such constraints yield no climate benefits. Regardless of where a greenhouse gas emission reduction occurs, it has the same effect on total emissions and the same effect on the climate. A ton reduced in New York generates the same climate benefit as a ton reduced in Berlin. In proposing trading constraints, some have focused on countries such as Russia, that will have emissions below their Kyoto targets during the commitment period because of the decline in their economic output associated with the transition to market economies. If trading constraints are established that restrict the ability of Russia to sell permits (or restrict the opportunity for other Annex I countries to buy Russian permits), then emissions during the first commitment period would be lower than in the absence of such constraints. However, Russia would simply bank its allowances and use these allowances in a subsequent commitment period when its emissions exceed its target. While a trading constraint might lower emissions during the first commitment period, the cumulative emissions over several commitment periods from Annex I countries would be the same with and without the trading constraint. Given the long residence times of greenhouse gases (on the order of a 100 or more years), the cumulative effect is what is most relevant in terms of changes in the global climate.

To provide a sense of the economic implications of trading constraints, I would like to share with you two examples from work done by EMF modeling teams. First, consider a trading constraint that mandates that at least two-thirds of the emissions reductions necessary for a country to achieve its Kyoto target must occur through domestic actions. Evaluating this trading constraint with the EPPA model based at the Massachusetts Institute of Technology, the permit price for the United States is almost four times higher with the constraint than under an unconstrained global trading system. It is important to note that the effects of this constraint are even more pronounced for the European Union and for Japan. The permit price for the EU would be more than five times higher than the unconstrained global trading permit price, and the Japanese permit price would be thirteen times higher. As these results indicate, the trading constraint would result in each country experiencing a different marginal cost of abatement, and there would be no common permit price for a ton of carbon equivalent. Since the constraint restricts opportunities for countries like the United States, Japan, and members of the EU to buy emissions allowances, the competitive price for emission allowances from countries like Russia would fall below the unconstrained level.

Second, consider a trading constraint that mandates that acquisitions of permits through international trading could not exceed 10% of a country's emissions allocation. For example, the U.S. target is approximately 1.5 billion tons of carbon equivalent on an annualized basis. Under this trading constraint, the United States, or private firms in the United States, could not purchase more than 150 million tons on an annual basis from other countries. Assessing this trading

constraint with the Second Generation Model, the permit price for the United States would more than triple relative to the unconstrained global trading permit price. For the E.U., the permit price would nearly double, and for Japan, the permit price would be eleven times as high as the unconstrained global price.

While trading constraints increase greenhouse gas permit prices (and subsequently, energy prices) in the United States, the European Union, and Japan, they also reduce the gains from trade by the countries likely to be sellers of emissions allowances. For example, Russia and large developing countries that adopt emissions growth targets and participate in international trading, e.g., China and India, would sell fewer emissions allowances at lower international permit prices under such trading constraints than in an unconstrained global trading environment. Such restrictions lessen the benefits of participation by developing countries in international trading.

Estimated reduction in costs from trading across gases

As we note in the Administration Economic Analysis, the Kyoto Protocol provides additional flexibility in achieving emissions targets by specifying these targets as a basket of 6 types of greenhouse gases (carbon dioxide, methane, nitrogen dioxide, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride). Countries can effectively trade across gases, based on their global warming potential, so that the aggregate weighted emissions reductions occur at least cost. Most models used to evaluate the Kyoto Protocol have not incorporated this kind of flexibility, although several modeling teams are actively working to modify their models to include emissions of non-CO₂ greenhouse gases. In the Administration's analysis, cost curves for these other gases for the United States were used in conjunction with the SGM model. These simulations suggest that trading across greenhouse gases can lower costs up to 15% relative to a situation where no trading across gases occurs.

Complementing this finding, recent work by a group of researchers at the Massachusetts Institute of Technology has found that including the opportunity to abate non-CO₂ greenhouse gas emissions and promote carbon sinks reduces the costs to the United States by about 25% relative to a carbon-only approach (assuming no international trading). On average, they find that Annex I countries' costs would fall by more than 20%. In addition, work by University of Illinois researchers and others has evaluated the changes in costs of abating methane and carbon dioxide to achieve the U.S. Kyoto target instead of abating carbon dioxide alone. They found that meeting an emissions target through cost-effective trading between carbon dioxide and methane reductions could reduce costs by nearly 20% relative to a case with no intergas trading. Finally, research by several Dutch analysts presented at the OECD workshop found significant opportunities for the European Union to substitute abatement of non-CO₂ greenhouse gas emissions for carbon dioxide reductions. They found that 27% of the total reduction effort necessary for E.U. countries to achieve their emissions targets could occur through the abatement of these non-carbon dioxide gases.

Developing Country Participation

Last year during the Buenos Aires Conference, two non-Annex I countries, Argentina and Kazakhstan stated that they will announce emissions targets and expressed their interest in engaging in international emissions trading. We believe that these two countries' efforts may encourage other non-Annex I countries to follow their lead. Economic and environmental benefits could accrue to developing countries if they adopt binding emissions targets and participate in international trading. Setting a target below the business as usual emissions level for the commitment period would generate climate benefits by reducing global emissions below what they would otherwise have been. In addition, if the target is set not too far below the business as usual emissions level, the participation of the country in a global trading system would produce economic benefits or "gains from trade" for both the developing country and its trading partners. Emissions trading by developing countries would occur only if they chose to undertake emissions reductions above and beyond their commitments -- reductions that would generate trading extra income for them as long as their marginal abatement cost is below the world trading price for greenhouse gas permits. Many of the EMF models reveal that, for large developing countries, like China, such excess reductions would indeed be profitable, so that these countries would export allowances and gain from trade. Developing countries would also reap ancillary benefits of reducing conventional air pollutants, which may be substantial. Benefits from trading would also accrue to Annex I countries. Annex I countries (and private firms in these countries), who would purchase these emissions allowances in the world market, would achieve their targets at lower costs than without the participation of the developing countries. However, it should be noted that the more stringent the target for the developing country, the lower the gains from trade both for that country and for Annex I countries such as the United States. Indeed, an extremely stringent target could conceivably make the developing country a net importer of emissions allowances, and raise the international trading price for a greenhouse gas permit. Still, these models illustrate the potential to create targets that simultaneously make the environment, the developing country, and Annex I countries all better off.

Conclusion

The Administration's overall conclusion is that the economic impact of the Protocol will be modest under the conditions we have identified in our economic analysis. The purpose of this testimony has been to summarize the analysis we have presented in the Administration Economic Analysis on climate change and to provide a brief update of recent research efforts outside of the government.

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

I welcome your questions.

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THE KYOTO PROTOCOL
AND THE
PRESIDENT'S POLICIES TO
ADDRESS
CLIMATE CHANGE:

ADMINISTRATION
ECONOMIC ANALYSIS

July 1998