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The Uses and Misuses of Technology Development as a Component of Climate Policy

Paper

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The Uses and Misuses of Technology Development as a Component of Climate Policy

by
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Executive Summary*

The search for cleaner technology for the long run must be a central element in the global response to the threat of climate change. Unfortunately, we run the risk of crippling the U.S. effort to explore this avenue—in effect throwing out the baby with what is perceived by some to be policy bathwater. In the current focus on short-term Kyoto-type emissions targets, and the reaction within the U.S. Congress to the process, the United States is wasting time and effort that could be put to the search for cost-competitive, low-carbon ways of powering the modern economy. It is a tragic mistake. At the heart of the problem is a push for a short-term technical "fix," driven by domestic political exigencies and unfortunately supported by badly flawed analyses of the process of technical change.

The focus of this paper is a particular study of technology options by five U.S. national government laboratories that is widely cited in current discussions, and its uses and misuses as a guide to policy. The Five-Lab study divides the U.S. energy economy into four sectors (buildings, industry, transportation, and electric utilities) and compiles estimates of how, through a technology push, carbon emissions in 2010 could be reduced. Reductions in energy and carbon emissions are calculated from a baseline or "business as usual" case drawn from forecasts in the U.S. Department of Energy's 1997 Annual Energy Outlook.

Two general points should be made about the analytical method. First, only in the case of the electric utilities sector has the Five-Lab group conducted any numerical analysis of the potential effects of carbon prices. For all other sectors the net decreases in carbon emissions are the result of judgments about the effects of price and the assumed effect of a "greater commitment" by government and the "very active" private sector that might accompany the imposition of a permit scheme.

Second, the Five-Lab study does not describe the policies that might be used to accomplish higher penetration of energy-efficient and/or low-carbon technologies. The central critique is that this study is not an appropriate vehicle for analysis of the policy questions which its main conclusion addresses, i.e., how hard it would be to return to 1990 U.S. carbon emissions by 2010. A look at the details of just three of the many components of the analysis—for automobile fuel economy, building efficiency, and reduction of coal use in electric power—indicates the cause for concern.

One important consequence of this Five-Lab approach to technology development is the subversion of what is essentially a long-term policy tool to the service of short-term emissions goals. In February 1998, when the 1999 budget was put forward, the Administration's October proposal emerged as a $6.3 billion Climate Change Technology Initiative (CCTI). The major portion of this funding was proposed not for R&D but for tax expenditures and other measures intended to spur adoption of existing technologies.

Even worse, this focus on short-term emissions goals could lead to loss of or drastic reduction in the CCTI program itself, including the portion that does contribute to long-term R&D. This is because of a backlash in the Congress over "implementation without ratification." Some members fear that

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the Administration is trying to achieve the goals of the Kyoto agreement even though it has not been ratified (or even submitted for ratification), and despite the fact that conditions set by the Senate for ratification seem unlikely to be met.

Technology-costing studies, like the Five-Lab report and its cousins, can be a useful input to climate policymaking. They point to possible market failures; they help sort out the most important targets for R&D and perhaps for selected technology-push investments; and they help provide justification for these activities. However, it is very important to avoid misuse of these studies. There is no technical fix in the short run of a decade or so, as implied by the Five-Lab study. Science does not run on the policymakers' clock; technologies take time to develop; markets for new consumer devices and industrial processes, including needed distribution and materials supply systems, require time to evolve. Further, capital turnover has its own dynamic, particularly in the heavily capital-intensive sub-sectors of energy supply. In the long run of several decades, and with a well-designed effort, the prospects are brighter. Indeed, they must be brighter if we are to have any hope of an effective response, should the climate picture darken.

THE USES AND MISUSES OF TECHNOLOGY DEVELOPMENT AS A COMPONENT OF CLIMATE POLICY

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1. INTRODUCTION

The search for cleaner technology for the long run must be a central element the global response to the threat of climate change. Unfortunately, we run the risk of crippling the U.S. effort to explore this avenue—in effect throwing out the baby with what is perceived by some to be policy bathwater. In the current focus on short-term Kyoto-type emissions targets, and the reaction within the Congress to the process, the United States is wasting time and effort that could be put to the search for cost-competitive, low-carbon ways of powering the modern economy. It is a tragic mistake. At the heart of the problem is a push for a short-term technical "fix", driven by domestic political exigencies and unfortunately supported by badly flawed analyses of the process of technical change. The focus of this paper is a particular study of technology options by five U.S. national laboratories that is widely cited in current discussions, and its uses and misuses as a guide to policy.

This critique of the work, and the way it is being applied in policy discussions, is motivated by a sense of the possible seriousness of the consequences, should we fail to use technology development in an intelligent manner in response to the climate issue. At present the risk of human influence on climate appears substantial. No doubt there is great uncertainty about the possible magnitude of potential change. Our own MIT analysis (Prinn *et al*, 1998) shows that the range of possible outcomes over the next century is very wide. We have only a partial understanding of the behavior of the climate system, and our ability to forecast the future path of economic growth and technical change, and the resulting greenhouse emissions, is naturally limited. Our understanding of the ecosystem effects of rapid climate change is even weaker. But this type of uncertainty means that the problem may turn out to be not so important, or worse than we imagine. Thus, whatever one's position regarding the current conflict over near-term emissions controls, we should in my view be able to agree that we are taking considerable risks with global climate in the long term. Further, we should anticipate that increased knowledge could well lead to general international agreement that stringent measures are needed.

Unfortunately, even the emergence of universal consensus that the problem is serious, and agreement that something dramatic should be done, may not lead to meaningful action. The nations whose participation is essential for an effective response have very different interests and priorities. A treaty that could meet the needs of each, and suppress the incentive to free-riding, is difficult even to formulate as a theoretical exercise, much less to negotiate among dozens of nations. In principle, rich countries could use various forms of foreign aid, permit trade, or other side payments to gain the participation of hold-outs, but the amounts of money involved are very large in terms of historical experience, or perceptions of what would prove politically feasible.

Even assuming the best of intentions among nations, therefore, it may well be that the key to future response capability is the development of low-carbon technologies that can compete head-to-head with conventional fossil-fuel burning, or at least involve only small cost penalties. We do not have these options in hand now, and their development is a long-term, multi-decade process. Moreover, at least within the next few decades we cannot look to resource depletion to have a substantial effect on the costs of conventional fossil fuels, to allow relatively costly alternatives to compete. If limited R&D resources, and managerial and political attention, are shifted to short-term policy targets, we could forfeit potential long-term developments, to our considerable regret in the future. Unfortunately, in recent months key technology studies have appeared to lend support to just this unhappy outcome.

2. Analysis of Emissions Control Policy

2.1 Alternative Approaches to the Task

To provide a context for discussion of these studies, it is helpful to have a map of the methods usually applied to studies of emissions control As illustrated in Figure 1, they fall into two rough categories, each encompassing a rich variety of detailed methods. As the figure suggests, some efforts involve a mix of the two so that the categories overlap, but the distinction nonetheless remains a useful one.

One approach, usually carried out by economists, might be called "market-based". Its concern is with how markets respond under assumed policy intervention, and the essential question is, "What price?" That is, the focus is on market price as the essential mechanism through which policies act. Frequently, this approach also is referred to as "top-down" analysis, meaning that it encompasses the economy as a whole (or at least a number of interacting sectors), and it analyzes the interplay of policies within this larger system. The most common alternative is "engineering-cost" analysis. Frequently associated with studies dominated by engineers, its essential question is, "What cost?" Its focus is on estimation of the cost of particular technologies and/or devices, and comparison of these costs with reduced energy expenditures and/or other environmental benefits. It is frequently referred to as "bottom-up", in that analysis of a policy is compiled by adding up the energy savings or emissions reductions from the various technologies it might influence, each considered independently.

Each of these two approaches to analysis has its strengths and weaknesses. Market-based methods take account of interactions in the markets for goods, and for inputs to production like capital, labor and natural resources, and they can take explicit account of consumer preferences and how they change with increasing wealth. They can consider the fiscal effects of policy measures such as carbon taxes or permit auctions. They also can reflect the ways that policy impacts are mediated through international trade. In short, they can consider the side effects, spillovers and feedbacks that flow from a policy change, the so-called "general equilibrium" adjustment of the economy.

There is a tradeoff, of course. The gaining of multi-sector, multi-region interactions involves a sacrifice of technical detail, through the incorporation of simplified representations of production processes and aggregation of industrial sectors. However, for an economic change as large as, say, the emissions reductions under the Kyoto Protocol, these market interactions are crucial, and so (as long as the unavoidable uncertainty is appropriately expressed) the market-based methods are the better approach for addressing the implications of such a commitment.

The advantage of the technology-costing methods, naturally, is their technical detail, which makes it possible to study specific cases where markets may not be working efficiently, and to guide expenditures on technology development to the areas of greatest payoff. To gain this detail they usually must assume prices of energy and other key inputs rather than analyze them, and omit consideration of the many substitutions that take place among goods and processes in response to any policy action.

If done well, studies following a technology-costing approach could offer insight into larger economy-wide questions, like the implications of climate agreements. But in the attempt these studies frequently encounter one of several pitfalls, which can make them positively misleading as a guide to broad policy. Three of these are of particular relevance to this discussion.

2.2 PITFALLS OF TECHNOLOGY-COSTING

Confusion of Market Failures and Market Barriers. Technology-costing studies usually start with a list of particular technologies or devices, among which is a set of energy-saving or otherwise greener items which look attractive but are "under-used". An analytical basis for this judgment is constructed by means of an NPV calculation, taking account of capital and other components of cost, and the discounted value of the savings to be realized in energy expenditures. Typical examples of such supposed opportunities include highly-efficient windows or higher mile-per-gallon cars. If such good things go wanting something must be wrong in the economy, as the argument goes, so the analysis proceeds to show how much improvement could be gained at a low cost, or even a net benefit, with only small changes in policy or perhaps just general encouragement.

The question is, what is the reason for the under-use, which is to be corrected by policy intervention? Here it is useful to distinguish two possible reasons why an apparently attractive technology is not quickly taken up. One is appropriately classified as a market "failure", and the other we will call a market "barrier".[1] The difference between them can be illustrated using Figure 2, which is adapted from the IPCC (1996). An economy cannot produce everything its citizens want; there are tradeoffs. Here the textbook choice of "guns *vs.* butter" is restated in terms of some traditional measure of economic welfare *vs.* climate-related environmental quality. In this example, the vertical axis includes output of market-priced goods plus all environmental benefits *except* those of reducing the risk of climate change; the horizontal axis is the level of carbon emissions reduction. (For simplicity, the other greenhouse gases are ignored in this discussion.) In this way the figure illustrates the components of a cost-effectiveness analysis of climate policy, which is the type of calculation being reviewed here. An economy is said to be "efficient" when it is not possible to have lower carbon emissions without some welfare losses elsewhere. In the economist's jargon, an efficient economy is on its production possibility frontier, at points like *A*, *B* or *C* in the figure.

A market "failure" occurs when there is some flaw in the way markets are organized which causes consumers and/or producers to be working with the wrong price signals. That is, the economy is operating in a state like point *Z*, where there may be so-called "no regrets" opportunities to move to point *B*, or even *C*, thereby achieving environmental improvement at no cost or even a net benefit. Or it may be possible to move from *Z* to point *A*, which would involve economic costs but which might be justified on a benefit-cost basis. Such failures include situations were decision-makers have insufficient or incorrect information (consumers don't perceive how costly it is to own an power guzzling air conditioner), where there is an asymmetry between the person

[1] For a lucid analysis of this distinction, using somewhat different terminology, see Jaffe and Stavins (1994).

making the energy use decisions and the one paying the bills (the landlord-tenant problem), or where there is some form of non-priced externality (like urban air pollution). These conditions lead to calls for government action, in the interest of economic efficiency, ranging from labeling rules to device standards to various forms of direct government expenditure or tax subsidy.

In contrast to these market failures are another set of conditions that may retard the spread of a technology, even when analyst's calculations show it has a positive NPV, that are better thought of as market "barriers". In these cases the economy is operating efficiently, and emissions reduction (say, through the use of a new technology) can be had only at some cost, as with a move from *A* to *B*, or *B* to *C*, in the figure. In other words, the technology is not economically competitive apart from the influence of expected benefits from reduced climate risk.

A wide range of causes can contribute to this result, where technology-cost analysis shows the move is costless or a net benefit but buyer behavior indicates otherwise. First, potential buyers simply may not like the technology. That is, it may have undesired attributes that matter to users but are not priced in the technology-cost analysis.[2] Or there may be transactions costs or other expenses of adoption that are hard to include in the calculations. Uncertainty about performance, or about energy prices, may lead users (quite rationally) to exercise their option to wait and reconsider it next year. And most significant is the issue of discount rates. Consumers and/or industry decision-makers may appear to operate at discount rates higher than those that analysts feel are appropriate for their NPV calculations. Sorting out the influence of discount rates from that those of un-priced attributes and options behavior is a very complex matter (Jaffe and Stavins, 1994). For example, do I not buy more energy-efficient fluorescent lightbulbs because I over-discount the electricity savings, or because they don't look good in my existing appliances? Still, in those technology-costing studies that apply discount rates below the levels generally seen in practice, this aspect of purchaser behavior can be appropriately included as a "barrier".

The key difference between these two causes of non-use is that correcting failures may in some circumstances offer a net benefit, whereas overcoming barriers always involves cost. The problems of concern here arise in technology studies when these two effects are mixed indiscriminately. Too often market intervention to advance a particular technology is implicitly assumed to be correcting failures, and therefore the analysts feel no need to dig into specific policy instruments and their costs. A classic example of this phenomenon will be seen below.

Lack of Attention to Market Structure. In analyzing how a new technology may enter use, be it a consumer device or a production process, it may be difficult to account for all the factors (besides engineering NPV) that must be in place before it can take market share. And it can be even harder to estimate how long the process may take. Aspects of market structure, which are outside the usual boundaries of technology-cost analysis, are crucial at this point. These include the structure of distribution channels, and of industries supplying key (and perhaps new) inputs. They may involve regulatory and legal-liability issues, particularly as regards health, safety and environmental quality. Most important, they include the internal organization of the particular industry which is

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[2] A classic example is the finding that a highly cost-effective energy-saving technology would be to cover the roofs of all U.S. residences with white paint (NAS, 1991). The analysis does not ask the question

to adopt the technology, and its interaction with the consumer units that may decide to use it.

These aspects of detailed market structure may or may not determine of the fate of a new technology in the long run, but they have a huge influence on the likely pace of spread. Failure to consider them may lead both to an incorrect judgment that something is "wrong" with the market (or if wrong that it is fixable), and thus to bad policy advice.

Failure to Account for Inter-Market Adjustments. Finally, in a partial analysis built-up from individual technologies, and policies to aid them, it is very difficult to consider the interactions across markets. If the changes are small, then this aspect can be ignored. If they are large in relation to the markets at issue, however, then failure to consider these effects can lead to serious flaws in the analysis. Proposed climate policies, which involve major shifts in the structure of energy supply and use, present such a case. An obvious source of concern is the evaluation of a large-scale policy-induced change in use of a particular fuel or other input within a country, when the study assumes an exogenous (and constant) estimate of its domestic price. Some changes in technology may also influence the prices of capital and specialized labor. Less obvious, but nonetheless significant in some cases, are interactions though international trade.

3. EXAMPLE: THE 5-LAB STUDY

An example of how a study can suffer from of the ills above, and yet be applied to an important policy issue, is the analysis of U.S. carbon reductions prepared by a consortium of five national government laboratories, frequently referred to as the Five-Lab Report (Interlaboratory Working Group, 1997). Beginning with an observation that many

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whether people want to do this, and what they might pay to avoid it.

energy-efficient technologies remain "underutilized", it sets out to ". . . quantify the reductions in carbon emissions that can be attained through the improved performance and increased penetration of efficient and low-carbon technologies by the year 2010." It has proved a influential piece of work, as discussed in Section 4, and to further motivate this exploration into its structure, and its flaws as a guide to policy, it is useful to start where the Report comes out. Its dominant and much-publicized conclusion is that, by a technology path, the United States could stabilize carbon emissions at 1990 levels, at no cost or even a positive net benefit. As stated in the Report, if certain measures discussed are taken, " . . . the cases analyzed in the study are judged to yield energy savings that are roughly equal to or greater than the costs" (p. 1.1).

3.1 THE STUDY STRUCTURE

The Five-Lab study divides the U.S. energy economy into four sectors (buildings, industry, transportation and electric utilities) and compiles estimates of how, through a technology push, carbon emissions in 2010 could be reduced. Reductions in energy and carbon emissions are calculated from a baseline or "business as usual" case drawn from forecasts in the U.S. Department of Energy's 1997 *Annual Energy Outlook.* Possible carbon reductions are compiled for three policy cases:

Efficiency case. This case presumes, ". . . an invigorated public- and private-sector effort to promote energy efficiency through enhanced R&D and market transformation activities."

High-Efficiency/Low Carbon (HE/LC) Case with a $25 price per ton of carbon ($/tC). It is presumed that the carbon premium is attained through a cap-trade-system. This policy is accompanied by a "greater commitment" through federal programs, strengthened state programs, and "very active" private sector involvement.

High-Efficiency/Low Carbon (HE/LC) case with a $50/tC price. This is the same as that immediately above, only with the higher carbon price.

Given the "Business as Usual" DOE forecast of emissions in 2010 which the study uses, a return to 1990 levels requires a reduction in the annual emissions rate of 390 million tons of carbon (MtC).[3]

The sectors where the Five-Lab Study achieved these reductions is shown in Table 1, which is drawn from Table 1.2 of the Report. Before looking at some of the details behind these estimates, two general points should be made about the analytical method. First, only in the case of the electric sector has the Five-Lab group conducted any numerical analysis of the potential effects of carbon prices. For all other sectors the net decreases in carbon emission are the result of judgments about the effects of price and the assumed effect of a "greater commitment" by government and the "very active" private sector that might accompany the imposition of a permit scheme.

Second, the study does not describe the policies that might be used to accomplish higher penetration of energy-efficient and/or low-carbon technologies. There is not even any explicit treatment of the reasons why emissions should be lower in the Efficiency case than under Business as Usual. The report simply posits a "host of market barriers [that] account for the lost opportunities", with no attempt to sort out the failures-*vs*.-barriers puzzle discussed above.

Based on these observations, and others to be made below, there are many criticisms that can be leveled at this study (for example, see Sutherland, 1998). It also should be noted that the authors are aware of many of its shortcomings and cite them in the body of the Report and its appendices. The argument here is not that the Lab staff

[3] It is worth pointing out that the size of the needed reduction is subject to considerable uncertainty (Webster, 1997). Our own MIT base implies a 470 MMtC reduction to achieve 1990 levels, and the latest Administration analysis is uses a 2010 baseline which would yield a number in the same range (U.S. Administration, 1998). The larger the number the higher the cost.

didn't know what they were doing, or that they hid the blemishes from the diligent reader. Indeed, the Five-Lab-type analysis can be very useful for some purposes, as noted earlier. The central critique is that the study is not an appropriate vehicle for analysis of the policy question which its main conclusion addresses, *i.e.*, how hard it would be to return to 1990 U.S. carbon emissions by 2010. A look at the details of just three of the many components of the analysis--for automobile fuel economy, building efficiency and reduction of coal use in electric power--will indicate the cause for concern.

3.2 AUTOMOTIVE FUEL ECONOMY: REGULATION IS COSTLESS

As can be seen in Table 1, over half of the carbon reduction in the Efficiency case is realized in the transport sector. Of the 73 MtC reduction, 61 MtC is from increases in vehicle efficiency and the rest from the introduction of ethanol from biomass. Here we focus on just the main component of this estimate. The efficiency increase is the result of the assumed introduction of new technologies such as direct-injection stratified charge engines, direct injection diesels and gasoline- and/or diesel-electric hybrids, and other changes in vehicle design and materials. In the overall cost analysis, the additional capital cost of these vehicles is weighed against the assumed fuel savings, with market penetration rates and other calculations performed using the Energy Information Administration's National Energy Modeling System (NEMS) model.

The question is, why should these efficiencies appear in the Efficiency case but not in the baseline, when there are no price incentives such as higher gasoline prices? The answer comes two parts. First, vastly increased R&D is assumed to reduce by 25% the time required for market introduction of new technologies (the mechanism not explained). But second and most important is the following:

> [The study] assumes that policies necessary to draw energy-efficiency technology into the market are implemented as needed . . . [including] fuel economy standards, revenue neutral feebates, fuel taxes, public information or some other initiative . . . (p. 5.3)

That is, underlying the analysis which is supposedly about technology is a regulatory and tax program. This policy program receives no analysis in the Report, or even the barest description beyond what is quoted here. As noted earlier, the Report is explicit about absence of analysis of specific policies, but less clear is the fact that any costs of such a regulatory/tax program are omitted from their benefit-cost analysis. In effect, regulation and tax programs are treated as freely available politically, and free of economic cost. Thus the analysis is best described as an unfettered scenario exercise, not a plausible economic forecast as implied by the study's conclusions and their interpretation in policy discussions.

When the Report comes to the HE/LC cases, the analysis enters even deeper into the world of "what if". As noted earlier, there is no analysis of the potential effect of the $25 or $50 carbon price ($50/tC would add 25 cents per gallon to the gasoline price). Instead, the additional reductions shown for these cases, shown in Table 1, are based on "technological breakthroughs" and "a certain degree of luck" (p. 5.3). Lost in references to this study in policy discussions is the fact that the report itself declares that the HE/LC case is best called "optimistic" or "possible" and that in addition to a major intensification of R&D it presumes the adoption of, ". . . significant policy measures aimed at pushing the market towards giving fuel efficiency a much higher priority" (p 5.3). In the terms introduced above, the Study implicitly assumes that regulatory or tax intervention is justified by the correction of (unspecified) market failures, so the costs are not important to the analysis. As a result, the economic cost analysis is not correct, the considerable political cost of "pushing the market" is hidden, and thus the future the Report lays out is not realistic.

3.3 BUILDING EFFICIENCY: ARBITRARY ASSUMPTIONS ABOUT MARKETS

The study's handling of the building sector provides a disturbing example of the failure to consider the structure of markets when preparing this form of technology-cost analysis. To prepare the figures shown in Table 1, the study first constructed an estimate of how much energy and carbon would be saved if maximum cost-effective energy improvements were installed in 100% of U.S. homes and commercial and public buildings. These improvements include consumer appliances, heating and air conditioning equipment, and building design. The definition of "cost effective" for this analysis is a positive NPV to the user, assuming a 7% real discount rate.

For the Efficiency case, it is assumed that 35% of this maximum reduction is achieved. Why the efficiency case should differ from the baseline in this way (with no price incentives) is not discussed, except to say that that the expected savings result from a "moderately vigorous effort" to reduce energy use using a, ". . . combination of mechanisms that may include higher prices . . . energy-efficiency standards and information programs" (p. 3.11). The HE/LC cases assume that 65% of the maximum is achieved. Again, prices of energy, as they might be influenced by the carbon permit system, are not considered explicitly. Rather, the 65% result flows from a judgment as to the effect of a "vigorous effort" to reduce energy use (in contrast to a "moderately-vigorous" effort in the Efficiency case). That is the extent of the analysis.

The study imagines an appliance and construction market with a structure quite different than the one we actually have. The Five Lab analysis uses a 7% discount rate for the building sector analysis because, "The long term average return for the utility industry is about 6% real and the typical rates for auto loans and business loans are also in this range" (Appendix C, p. 1.5). The controversy over the economics of demand-side management programs conducted by U.S. electric utilities has spawned a large amount of careful work on consumer and industry behavior in the area of energy efficiency investments (e.g., Joscow and Marron, 1992; Levine and Sonnenblick, 1994; Nichols, 1994). In the light of this work, it is not clear how a calculation using 7% bears any relation to the United States economy and the way it actually works.

Also included in the savings in building efficiency is the effect of "vigor" and "moderate vigor" on the design, construction and equipping of new residential and commercial structures. Here again, forecasting the response of this industry to heightened societal concern for conservation, and perhaps to price incentives flowing from the carbon permit scheme, requires some consideration of its peculiar structure. The U.S. construction industry is notorious for the fragmentation of its various components such as building codes, development and finance, design, construction (with its various layers of sub-contractors), materials manufacture and supply, certification and training of construction trades. Any analysis of response to policy needs to reflect the sluggishness of this system (Hansen, 1998). It is an issue that the Report does not address.

Thus the 35% or 65% numbers, which reflect progress toward some maximum potential, encompass questionable assumptions about the structure of markets in this sector, and unspecified policy intervention. As such it may be a start toward an analysis of long-term potential and sector-specific policies, but it is not a realistic approach to likely developments by 2010.

3.4 ELECTRICITY: IGNORE INTER-MARKET ADJUSTMENTS

The electric sector is the one place in the study where explicit account is taken of the potential effect of a cap and trade system. As Table 1 shows it accounts for one-third of the reduction needed to achieve the 390 MtC reduction in 2010. Of its 136 MtC contribution, roughly 70% results from shifts away from coal in existing generators. Here we focus just on this coal issue. The rest of the savings come from a compilation of small contributions from biomass, wind, hydro and nuclear, and various system improvements.

The results in Table 1 come from the calculation of only one case of an emissions permit system, *i.e.*, the one yielding a carbon price of $50/tC. The $25 case was constructed using analysts judgment. System calculations were made using a simulation model of the generation sector. It is a complicated analysis, requiring a substantial analysis effort. A base case was constructed to approximate the results under the EIA 1997 *Annual Energy Outlook*, which underlies the analysis of other sectors, and an attempt was made to adjust the model for market changes that will accompany the current process of electricity deregulation. The analysis of the $50/tC carbon case was conducted in two parts: adjustments on the demand side, and changes in the supply structure. First, as a result of lowered end-use of electricity in the Building and Industry sectors, the demand for electric generation will be reduced. Some of this effect is already accounted for in these other sectors, but not counted there is the fact that, with lower overall electricity demand and the new carbon charge, there will be a re-dispatching of existing generating units, in general away from coal. Second, whatever the demand level there will be a re-powering of coal-fired units with lower-carbon-emitting natural gas.

Unfortunately, at this point the Study drops into the third of the pitfalls laid out above. Underlying all the model calculations is a key assumption: the prices of oil, natural gas and coal are constant across all cases (Appendix F-2). This of course means that the coal-gas price ratio, which is a crucial input to the calculation of coal to gas conversion, also is constant. In reality, as climate policy leads coal demand to fall domestically (electric generation accounts for about 80% of U.S. coal use), coal prices will fall as well. Since the United States is a net exporter of coal, and any carbon control policy presumably has counterparts in other countries, this effect may be augmented through international trade. Also, the conversion of coal plants to natural gas will cause a substantial increase in gas demand, driving up its price. In the Five Lab analysis, omitting these intermarket effects leads to an overestimate of the carbon reductions from re-dispatch and re-powering. It is not possible to say how big the error is without re-analysis, taking account of the changing market equilibria in these closely related markets. Note that this price assumption will bias the estimates of the penetration of other contributors to carbon reduction in this sector, such as biomass, wind, and solar power.

In short, it is not correct to calculate these changes in generation patterns in a partial or one-sector analysis, ignoring the response of fuel prices. To be fair to the Five Lab effort, it should be said that the authors provide a full description of their method in one place or another, and they are explicit about the fact that they did no analysis of natural gas or coal prices (p. 7.3 and Appendix F-1). Thus, as with the other points of specific criticism above, it is not that the sector chapters and appendices are misleading, or that an honest effort was not made to lay out a set of interesting scenarios. The problem is that this technology-costing analysis, with its particular structure, is inappropriate for the policy question at which it is directed.

4. Application to Application Policy, and Its Consequences

It would be easy to overstate the influence of a particular piece of analysis on government policy. Diverse forces come to bear, many of them much more powerful than the computer model and the word processor. However, recent U.S. climate policy, particularly as it concerns the role of new technology, is a case where this influence merits greater attention. By the same token, it is not altogether fair to single out the 5-Lab Report for criticism, because it is only one of a number of studies that offer the same brand of technological optimism (e.g., National Academy of Sciences, 1991; Alliance to Save Energy *et al.*, 1997). On the other hand, the 5-Lab Study has proved to be an influential piece of work, frequently cited as justification for a technology-based approach to climate policy in the short term. The consequences should be attributed to the 5-Lab Study itself, but equally to those who misapply its results, and those of other studies like it, in climate policy discussions.

4.1 U.S. Climate Policy and Its Analytical Justification

The outlines of U.S. climate policy were laid out by the President in an October 1997 speech before the National Geographic Society (U.S. White House, 1997a). In addition to instructing U.S. negotiators to seek agreement to a target of returning to 1990 emissions by a 2008-2012 budget period, a target tightened to *minus* 7% in the subsequent Kyoto Conference of Parties (United Nations, 1997), the speech laid out a three-stage approach to attaining this goal. The first and key stage was a technology initiative. The original plan involved $5 billion in additional federal expenditures over five years for tax incentives and R&D spending, and various federal energy initiatives, plus a program of jawboning of U.S. industry. No additional actions were foreseen for seven years or more! Only after, " . . . a decade of experience, a decade of data, a decade of technical innovation" did the plan foresee significant economy-wide economic incentives. These are to be in the form of a system of tradable emissions caps, "to insure that we hit the binding targets."

Most forecasts show U.S. carbon emissions, without policy, to be one-quarter to one-third above 1990 levels by 2010, yet at the time of the "launch" of this permit system the start of the first budget period would be less than three years away. At one point in the press briefing that followed the President's announcement, the Chair of the National Economic Council, Gene Sperling, declared, "The plan that we have as you look forward does not include increased energy prices" (U.S. White House, 1997b). Thus the plan had to assume great success from the technology initiative. As one wag put it, "It was the tooth fairy in reverse: put $1 billion per year under your pillow, and in the year 2010 you'll find teeth capable of eating 500 million tons of carbon!"

How could this proposal pass the laugh test? One aid was the 5-Lab Study, with its forecast that emissions stabilization could be achieved at a net gain to the economy (Interlaboratory Working Group, 1997; Romm *et al.*, 1998). Indeed, when questioned in the briefing about the analytical basis for the plan, Sperling replied,

> But we have certainly been locked in doing a tremendous amount of economic analysis . . . for example there is the five-lab study . . . from the Energy Department, there is very careful analysis on what the potential is for reducing metric tons of carbon through the efficiencies in three main sectors—the building, the transportation, and the industrial sectors. (U.S. White House, 1997b)

As the year wore on, this piece of analysis continued to be used as a validation of the proposed policy. In Senate hearings in the wake of the Kyoto meeting, the chief U.S.

negotiator, Undersecretary if State Stuart Eisenstat, was questioned about the analytical basis for the positions agreed there. At one point the response was,

> We also have . . . something called a five labs study that was done by the five national labs. They're totally independent—you know, nobody told them what to come up with—and they made some findings about what technology can do and how we can reduce the burdens and costs on coal miners and others by coming up with what is the hallmark of America, and that is ingenuity and technology. (U.S. Senate, 1998)

As late as June 1998, a top DOE official testified that R&D was a key element of our response to climate change, and that,

> Last year, a peer-reviewed study conducted by five national laboratories recognized that the United States can hold down the costs of meeting climate change goals . . . In fact, the study concluded that significant progress in reducing greenhouse emissions could be achieved without increasing the nation's total energy bill. (U.S. House of Representatives, 1998b)

Later, in an effort led by the President's Council of Economic Advisors, the Administration presented a full analysis of its Kyoto position, this time based on top-down models (U.S. Administration, 1998). The study included unreasonably optimistic assumptions about the international permit trading systems to be in place in time for the first budget period, but at least the paper is clear about the policies intended and their economic basis. Interestingly, the 5-Lab Study merited only a passing reference in this latest Administration analysis. This type of technology-costing study nonetheless continues to be influential in public discourse, because it makes a point that many players want to hear: even large scale short-term carbon reductions will be cheap.

4.2 THE CONSEQUENCES

On important consequence of this approach to technology development is the subversion of what is essentially a long-term policy tool to the service of short-term emissions goals. In February 1998, when the 1999 budget was put forward, the Administration's October proposal emerged as a $6.3 billion Climate Change Technology Initiative (CCTI). The major portion of this funding was proposed not for R&D but for tax expenditures and other measures intended to spur adoption of *existing* technologies. That is, " . . . to stimulate adoption of more efficient technologies in buildings, industrial processes, vehicles, and power generation" (U.S. Bureau of the Budget, 1998). In essence, the plan is heavily biased toward resolving problems of market barriers, as discussed above, often with justifications that sound a lot like the assumptions in the 5-Lab Report.

By coincidence, it was also in the fall of 1997 that a study by a panel of the President's Committee of Advisors on Science and Technology (PCAST) presented carefully reasoned recommendations for a program of long-term R&D focused on climate issues (PCAST, 1997). The CCTI does contain useful expansions of some existing federal R&D programs, but the PCAST report and other studies of the long-term climate issue appear to have had little effect on the overall allocation of the proposed new resources. To the contrary, a desire to produce results by a technology path within the 2008-2012 budget period appears to have been the stronger influence on the design of the CCTI.[4]

Even worse, this focus on short-term emissions goals could lead to loss of or drastic reduction in the CCTI program itself, including the portion that *does* contribute to long-term R&D. This is because of a backlash in the Congress over "implementation without ratification". Some members fear that the Administration is trying to achieve the goals of the Kyoto agreement even though it has not been ratified (or even submitted for

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[4] As argued by Jacoby, Prinn and Schmalensee (1998), long-term R&D was only one of several long-term tasks which have taken a back seat to the push for short-term targets for the richer countries.

ratification), and despite the fact that conditions set by the Senate for ratification **[add cite]** seem unlikely to be met.

This larger issue of ratification and implementation are beyond the scope of this paper. The one aspect that is of concern here is the fact that long-term R&D, which might receive wide-spread congressional support as prudent preparation for an uncertain and risky future, is caught in the fray. So, for example, Senator Hegel, an author of the Senate resolution setting strict conditions for ratification, argues against the CCTI precisely on these grounds, citing a lead author of the 5-Lab Study,

> The Administration has asked for $6.3 billion over 5 years. In yesterday's Financial Times, Joe Romm of the Department of Energy was quoted as admitting [the] $6.3 billion initiative is intended to help meet emissions reductions mandated in the Kyoto Protocol. (U.S. House of Representatives, 1998a)

Just as one study does make a policy policy proposal, a single official's statement and a key senator's reaction do not determine the Congressional response. Still, it is lamentable that key preparations for the long road are so deeply tangled in a debate about the first steps.

5. Conclusion

Technology-costing studies, like the 5-Lab Report and its cousins, can be a useful input to climate policymaking. They point to possible market failures; they help sort out the most important targets for R&D and perhaps for selected technology-push investments; and they help provide justification for these activities. However, it is very important to avoid misuse of these studies. There is no technical fix in the short run of a decade or so, as implied by the 5-Lab Report. Science does not run on the policymakers clock; technologies take time to develop; markets for new consumer devices and industrial processes, including needed distribution and materials supply systems, require time to evolve. Further, capital turnover has its own dynamic, particularly in the heavily capital-intensive sub-sectors of energy supply. In the long run of several decades, and with a well-designed effort, the prospects are brighter. Indeed they must be brighter of we are to have any hope of an effective response, should the climate picture darken. For example, the Kyoto commitments are just an easy first step, compared to the carbon reductions needed to achieve ultimate stabilization of atmospheric concentrations.

However, enthusiasm for the task does not mean that it will be easy to do well, or even that we know very clearly how to proceed. At the level of basic science, with its public good characteristics, the role of government expenditure is clear. At subsequent stages of technology development and application, however—like pilot facilities, commercial demonstration plants, and subsidy schemes to seek benefits of economies of scale and learning—the history is mixed. Picking winners is a difficult art, and spending money effectively is a daunting challenge in the midst of regional and industrial demands for a share of the pie. Most important, the expertise in many technical areas resides in private industries—particularly oil, chemicals and electric power. Government-industry partnerships and tax subsidies can help direct their efforts, and useful experiments are now being tried. But the only way to truly attract industry attention is through an influence on the bottom line, which means (among other things) price expectations. In the energy sector, at least, large-scale technical change with no anticipated price incentive is a non sequitur.

Precisely because it is such a complex task to devise policies that can hasten major technical advances in energy supply and use, it is important to free decisions about these important long-term measures from disputes over short-term policy issues. A key step in this process is to put studies of technology cost in their proper place, and avoid their misuse as guides to short-term policy development.

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Table 1. Forecast Carbon Reduction Below the 2010 Baseline (MtC)

	Efficiency	High Efficiency/Low-Carbon	
		$25/tC	$50/tC
Buildings	25	44	62
Industry	28	54	93
Transportation	73	88	103
Electricity	0	48	136
Total (rounded)	120	230	390

Figure 1. Different Approaches to Control Cost

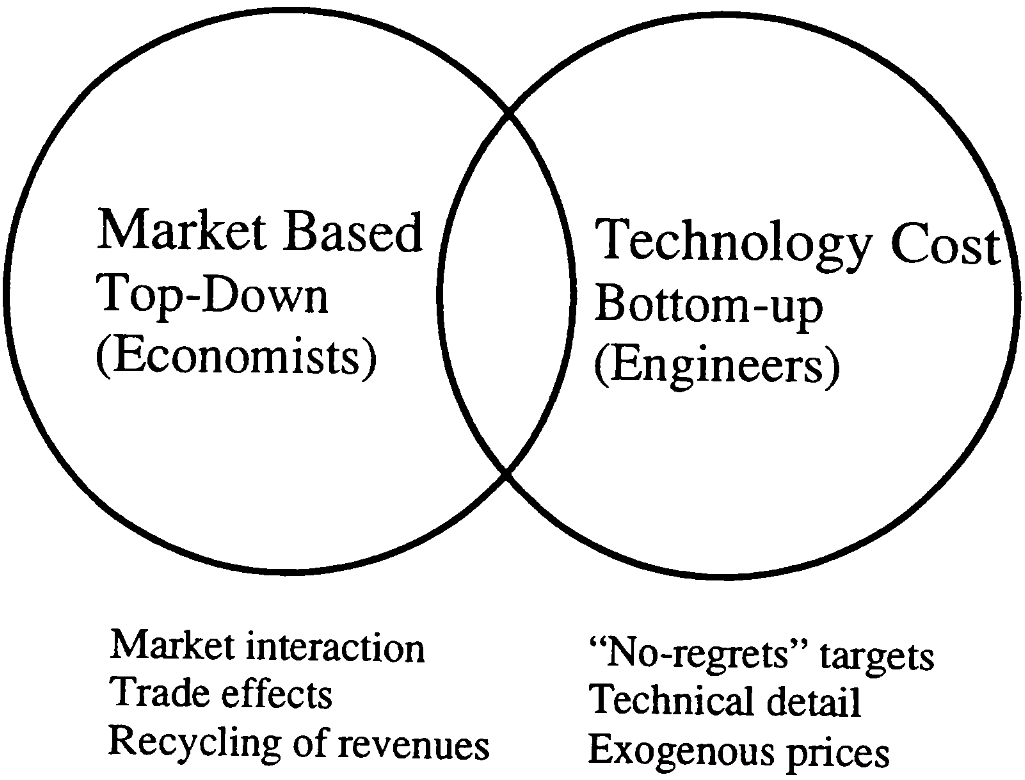
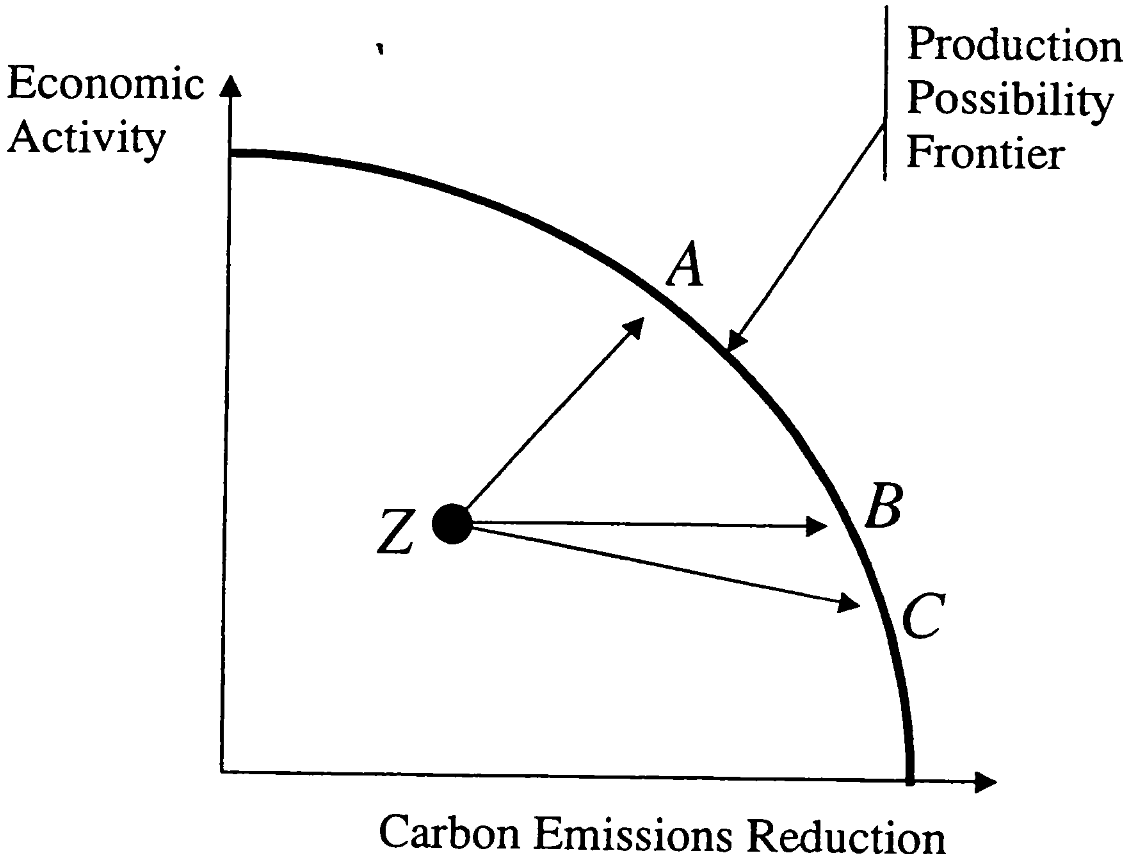


Figure 2. Tradeoff of Economic Welfare vs. Emissions Reduction



Energy, Carbon Dioxide Emissions, and Economic Growth

Paper

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Energy, Carbon Dioxide Emissions, and Economic Growth

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Executive Summary*

The United States emits about 22 percent of the world's man-made carbon dioxide. Carbon dioxide is the most important greenhouse gas that could cause global warming. Its atmospheric concentration is now increasing at about four-tenths of one percent per year, and further buildup will occur for the next hundred years even if global emissions were stabilized today. Government officials are now discussing steps to stabilize or reduce global emissions of greenhouse gases, especially carbon dioxide.

In December 1997, the Clinton Administration, but not the U.S. Congress, endorsed an international agreement whereby the world's industrial countries and a few transitional economies would voluntarily reduce their greenhouse gas emissions, particularly carbon dioxide. This agreement, known as the Kyoto Protocol, would cause the United States to cut its greenhouse gas emissions to a rate 7 percent below those of 1990, sometime between the years 2008–2012.

This paper analyzes the reduction in macroeconomic productivity growth if the United States were to reduce fossil fuel usage to the extent implied by the Kyoto Protocol. Since 99 percent of U.S. carbon dioxide emissions come from burning fossil fuels, the only way for this country to cut carbon dioxide is to cut its use of fossil fuels.

The United States economy depends heavily on fossil fuels. They account for 85 percent of our total energy consumption. Reaching the Kyoto Protocol target of CO_2 emissions 7 percent below those of 1990 would require that the United States reduce total fossil fuel use by 15 percent and total energy use by 13 percent from current levels. To reach the Kyoto Protocol target by 2010 would require a total reduction in energy per worker of 28 percent, or 1.8 percent per year from now until 2010.

I project that without any constraints on energy use, or in a "Business as Usual" setting, GDP per worker would grow by 2.0 percent per year. But with the constraint of a 1.8 percent annual reduction in energy per worker, I project that GDP per worker would grow by 1.1 percent per year. In short, I project that the proposed reduction in U.S. carbon dioxide emissions achieved by lower fossil fuel consumption would cut productivity growth by one-half, resulting in an overall standard of living 15 percent lower than would be realized without such a reduction.

A major cut in fossil fuel consumption would reduce the supply of electricity because its generation relies heavily on steam coal. It would also raise production costs in the industrial sector, where fossil fuels account for 84 percent of total energy usage. Finally, it would adversely affect the transportation sector, which relies almost entirely on liquid petroleum products for energy.

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Energy, Carbon Dioxide Emissions, and Economic Growth

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I. Introduction

The United States consumes much more energy than any other country. It also produces more carbon dioxide. Energy consumption and carbon dioxide emissions are closely linked in our country.

We use energy intensely for three main reasons: First, because we have the world's most energy intensive capital stocks. Second, because we are the world's wealthiest nation and therefore demand much energy for our energy-intensive capital and lifestyles.[1] Third, because energy is inexpensive in the United States, and it has been inexpensive for a long time. These three reasons are obviously interrelated, but in complex ways. Historically cheap energy made it rational to produce and use energy-intensive capital stocks. Energy-intensive capital combined with cheap energy to generate rising living standards and wealth. Rising living standards

[1] See Donald Norman (1995 and 1997).

generated growing demand for energy and the capital stocks that use it. So it has gone in the U.S. and Western Europe since the Industrial Revolution. So it goes now.

The Clinton Administration proposed in December, 1997 that between now and the years 2008 and 2012 the United States reduce its greenhouse gas emissions to 93% of its 1990 level. Carbon dioxide (CO_2) is by far the most important greenhouse gas (GHG). And United States CO_2 emissions could be cut to meet this target by reducing fossil fuels (coal, liquid petroleum, and natural gas) consumption to 93% of their 1990 levels. Since U.S. energy from fossil fuels in 1990 was 71.98 quadrillion Btu, the target level of energy from fossil fuels is 93% of 71.98 quadrillion Btu, or 66.94 quadrillion Btu.[2]

This proposed reduction in U.S. fossil fuel usage, if approved by Congress, would be the U.S. commitment according to the Kyoto Protocol. This Clinton administration proposal is intended to be a cooperative agreement among the industrial countries that now consume much energy and the several transitional countries that now consume less.[3]

I have three goals in this paper. The first is to demonstrate how important energy is in the U.S. economy. To do so, we examine aggregate energy and energy consumption per capita from 1950 through 1996. The second is to show the vital role of energy in real economic growth.

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[2] Total 1990 U. S. energy consumption of 84.2 quadrillion Btu is taken from Statistical Abstract of the United States, 1997, p. 583. Energy from fossil fuels in 1990 is taken from the U.S. Energy Information Agency, reported in De Golyer and Mac Naughton, Twentieth Century Petroleum Statistics, 1997, pp. 109-112.

[3] The so-called Annex 1 countries are the main participants in the Kyoto Protocol. These countries include the OECD (Western Europe, the United States, Canada, Australia, New Zealand, and Japan) and certain economies in transition (Eastern Europe and most of the Former Soviet Union).

Here we examine the growth in real Gross National Product (GNP) per hour, energy per hour, and utilized capital per hour from 1950 through 1984. These 35 years are instructive because they encompass a period of rapid growth in productivity, energy, and physical capital per worker, 1950-1972, followed by 10 years of slow growth in productivity attributable to declining energy per worker.

The third goal is to show that the United States could meet the energy reduction required by the Kyoto Protocol only by sacrificing productivity growth. Others, including Jorgenson and Wilcoxen (1992), Norman (1995 and 1997), Yohe (1997), Horowitz (1996), and WEFA (1998) have investigated this question as well.

The Plan of This Paper

In Section II, we review trends in U.S. energy consumption since 1950. In Section III, we establish the important role of rising energy consumption in promoting productivity growth.

In Section IV, I show that fossil fuels account for 85% of all energy consumed in the United States. Energy from renewable resources (including hydroelectricity) accounts for 7.5%, and nuclear power another 7.5%.

The reduction in U.S. fossil fuels that would be required by the Kyoto Protocol is discussed in Section V. I show why the United States cannot increase energy from other sources (renewable resources and nuclear power) between now and 2010. So a prospective reduction in fossil fuels would mean a reduction in total energy consumption.

Section VI demonstrates that the Kyoto Protocol would cut U.S. fossil fuels from current (1996) levels by 15%, and total energy by 13%. This 13% reduction in total energy implies a 28% reduction in energy per worker, shown in Section VII.

In Section VIII, I project U.S. productivity growth with two scenarios. (1) With no restrictions on energy per worker ("Business as Usual"), I project 2.0% annual growth in real GDP per worker. (2) With reductions in energy per worker required by the Kyoto Protocol, I project 1.1% annual growth in real GDP per worker. So I estimate the sacrifice in productivity growth to be 9/10 of 1% per year.

Section IX shows that a prospective reduction in fossil fuels would have major negative impacts on our industrial and transportation sectors, which use fossil fuels most intensely.

II. Trends in Energy Consumption Since 1950

Total Energy

Total U.S. energy from fossil fuels, nuclear and hydroelectricity from 1950-1996 is shown in Table 1. You can see that total energy increased 2.6-fold, from 33.992 quadrillion to 89.843 quadrillion Btu per year. Growth in consumption averaged 3.5% per year during the years 1950-1972, but only 8/10 of 1% per year from 1973 through 1996. There are two important reasons for the sharper growth during the period 1950-1972: real energy prices declined by 30% during these years, and real GDP grew more rapidly during the period 1950-1972 than during the years 1973-1996. The decline in real energy prices from 1950 until 1972 combined with rapid growth in real GDP to promote strong growth in the demand for energy.

But matters changed abruptly between 1973 and 1982. Following the initial OPEC embargo on oil exports, real energy prices jumped 55% in 1974, then rose more gradually each year through 1978. As a consequence of the Iraq-Iran War and cutbacks in OPEC oil exports, energy prices doubled between 1979 and 1981. Total energy consumption dipped from 1973

Table 1. Total and Per Capita Energy Consumption from Fossil Fuels, Hydro and Nuclear Power in the United States, 1950-1996

Year	Total Energy (Quadrillion Btu)	Per Capita Energy (Million Btu)	Year	Total Energy (Quadrillion Btu)	Per Capita Energy (Million Btu)
1950	33.992	223.8	1973	74.243	351.3
1951	36.775	238.8	1974	72.431	339.5
1952	36.458	233.1	1975	70.461	327.0
1953	37.586	236.5	1976	74.281	341.4
1954	36.263	224.0	1977	76.192	346.7
1955	39.703	240.5	1978	77.896	350.7
1956	41.700	248.1	1979	78.745	350.7
1957	41.706	243.6	1980	75.876	333.9
1958	41.696	239.4	1981	73.879	322.0
1959	43.140	243.5	1982	70.761	305.4
1960	44.569	247.6	1983	70.407	301.2
1961	45.319	247.7	1984	73.982	313.7
1962	47.422	255.3	1985	73.781	310.1
1963	49.308	261.6	1986	74.082	308.5
1964	51.240	268.1	1987	76.640	316.3
1965	53.343	275.6	1988	79.943	327.0
1966	56.412	288.4	1989	81.078	328.5
1967	58.265	295.1	1990	81.057	325.0
1968	61.763	309.7	1991	80.915	321.0
1969	64.979	322.7	1992	81.926	321.3
1970	67.143	329.2	1993	83.667	324.5
1971	68.348	330.5	1994	85.398	328.0
1972	71.643	342.1	1995	87.050	331.1
			1996	89.843	338.7

Source: De Golyer and MacNaughton (1997), p. 108.

until 1975, rose until 1979, then dropped sharply from 1979 until 1983. Notice that energy consumption in 1986 was practically identical to energy use in 1973.

Energy prices began to drift downward after 1981, then plunged during 1986. As energy prices fell during and after 1986, total energy consumption grew by about 21% between 1986 and 1996.

Energy Per Capita

Energy per capita is also shown in Table 1. You can see that energy per capita increased from 223.8 million Btu in 1950 to 351.3 million Btu in 1973. This amounts to an average increase of 2% per year. But between 1973 and 1982, rising energy prices caused energy per capita to fall by 14%, from 351.3 million to 305.4 million Btu. Then as real energy prices fell after 1986, energy per capita increased from 308.5 million to 338.7 million Btu, or by 10%.

These trends in total and per capita energy consumption show that energy use responds to changes in real energy prices. During periods of falling prices, such as 1950-1972 and 1986-1996, energy consumption increases. But when prices rise, as between 1973 and 1982, energy use declines.

Technological progress, energy per worker and capital per worker are important determinants of productivity. Productivity growth is enhanced by growth in energy and capital per worker, but is diminished when either energy or capital per worker declines.

III. Increasing Energy and Physical Capital Promote Productivity Growth

Why is commercial energy so vitally important in the United States? The reasons are straightforward. To operate modern capital equipment requires commercial energy. Factories must have energy from natural gas or refined oil products or coal or electricity. Otherwise they are idle. Modern transportation -- cars, trucks, buses, railroads, airplanes, and ships -- requires energy embodied in refined oil products: gasoline, diesel fuel, jet fuel, and bunker fuel for ships.[4] Modern agricultural equipment cannot run without diesel fuel. To maintain comfort in our homes, hospitals, and offices requires natural gas, heating oil, or electricity generated chiefly by fossil fuels. Energy permeates our modern lives.[5]

In an earlier paper (Moroney, 1992), I examined the roles of energy and physical capital formation in U.S. productivity growth from 1950 until 1984. These 35 years were marked by two distinct epochs. Epoch 1 is from 1950 through 1972, years of falling real energy prices, steady growth in energy and utilized capital per worker hour, and rapid productivity growth of 2.6% per year. Epoch 2 is from 1973 through 1984. During most of this period energy prices increased, energy per worker hour declined, and productivity growth dropped to only 1.0% per year.

Details are shown in Table 2. Between 1950 and 1972, real Gross National Product per hour (an economy-wide measure of labor productivity) increased from \$9.44 to \$16.50 per hour. This 75% increase amounts to an average annual increase of 2.6%. Energy per hour grew from 259.56 thousand Btu to 450.89 thousand Btu per hour, or by 74%. Utilized capital increased

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[4] Because the United States covers such a large area, its transportation sector accounted for 22.504 quadrillion Btu of energy consumed in 1990. And of this 22.504 quadrillion Btu, 21.810 quadrillion Btu (or 97%) came from liquid petroleum products -- gasoline, diesel fuel, and jet fuel. See DeGolyer and MacNaughton (1997, p. 111).

[5] A full discussion of the importance of energy in U.S. living standards appears in Norman (1997).

Table 2. Real Gross National Product, Utilized Capital, and Energy per Worker Hour, 1950-1984

EPOCH 1				EPOCH 2			
Year	**GNP ($1982) per Hour**	**Utilized Capital ($1982) per Hour**	**Thousand Btu of Energy per Hour**	**Year**	**GNP ($1982) per Hour**	**Utilized Capital ($1982) per Hour**	**Thousand Btu of Energy per Hour**
1950	9.44	35.71	259.56	1973	16.83	64.09	455.72
1951	10.10	37.10	269.96	1974	16.60	62.42	441.49
1952	10.43	37.99	267.00	1975	16.82	57.64	440.40
1953	10.77	40.85	272.35	1976	17.08	61.53	449.35
1954	10.96	38.93	272.47	1977	17.30	64.73	446.23
1955	11.19	42.53	290.65	1978	17.52	66.74	439.26
1956	11.24	42.84	297.52	1979	17.56	67.98	434.18
1957	11.55	43.41	301.72	1980	17.60	65.89	419.59
1958	11.75	41.07	308.32	1981	17.85	66.54	406.54
1959	12.12	44.91	313.72	1982	17.69	62.22	395.97
1960	12.23	44.81	321.85	1983	18.19	66.71	391.29
1961	12.55	44.44	326.65	1984	18.73	72.58	397.53
1962	13.10	47.83	338.97				
1963	13.44	49.94	346.98				
1964	13.89	51.98	355.60	Average Annual Growth 1973-1984	1.0%	1.1%	-1.3%
1965	14.35	55.12	362.26				
1966	14.93	57.33	376.53				
1967	15.20	55.97	385.54				
1968	15.64	57.62	403.47				
1969	15.67	58.28	415.25				
1970	15.75	55.47	433.23				
1971	16.81	56.08	442.24				
1972	16.50	60.49	450.89				
Average Annual Growth 1950-1972	2.6%	2.4%	2.6%				

from \$35.71 to \$60.49 per hour, an increase of 69%. The rapid 2.6% per year growth in productivity during Epoch 1 is attributable to balanced growth in energy and capital per hour and technological progress.

Sharply rising energy prices during Epoch 2 caused several abrupt changes. First, between 1973 and 1984 energy declined from 455.72 thousand Btu to 397.53 thousand Btu per hour, a decrease of 13%. Utilized capital per hour continued to increase, but more slowly than during Epoch 1. The reduction in energy per hour combined with slower growth in capital per hour to restrict productivity growth during Epoch 2 to only 1.0% per year (and 8/10 of 1% per year between 1973 and 1982). Increasing energy and capital per hour play important roles in promoting productivity growth. To restrict energy per worker is to curtail productivity growth.

IV. United States Energy: Fossil Fuels Dominate

Renewable energy from all sources accounts for about 7.5% of total U.S. energy consumption. Hydroelectric power accounts for half of this 7.5% (*Statistical Abstract of The United States*, Table 957, p. 599). This means that renewable energy from all non-hydroelectric sources (geothermal, wind, biofuels, solar and photovoltaic) combined make up a scant 3.75% of total U.S. energy consumption.[6]

Renewable energy produces no CO_2, so can be ignored for analyzing the Kyoto Protocol. Nuclear energy likewise produces no CO_2, so has no direct bearing on meeting the terms of the

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[6] In 1995, total renewable energy other than hydroelectricity amounted to 3.64 quadrillion Btu, while total energy consumption from all sources was 90.69 quadrillion Btu. Sources: U.S. Energy Information Administration as reported in Statistical Abstract of the United States, 1997, Table 957, and in De Golyer and MacNaughton, Twentieth Century Petroleum Statistics, 1997, p. 108.

Kyoto Protocol. Since nuclear-generated electricity now accounts for 7.5% of total U.S. energy (De Golyer and MacNaughton, Twentieth Century Petroleum Statistics, 1997, p. 108), and renewable energy another 7.5%, a whopping 85% of U.S. energy comes from fossil fuels. Fossil fuels are the foundations of current U.S. energy. They are the targets of the Kyoto Protocol.

V. Fossil Fuels: The Kyoto Protocol Target

In 1996, the United States consumed 89.84 quadrillion Btu of energy from fossil fuels, hydroelectricity, and nuclear-generated electricity (De Golyer and MacNaughton, 1997, p. 108) and 92.83 quadrillion Btu from all sources. Of this total, 78.83 quadrillion Btu, or 85% came from fossil fuels.

In 1990, we consumed 84.16 quadrillion Btu of energy from all sources. Fossil fuels made up 71.98 quadrillion Btu, or 85.5% of the total. The Kyoto Protocol calls for the United States to reduce GHG emissions to 93% of the 1990 rate sometime during the years 2008-2012. I will use 2010 as the target year. Reducing GHG emissions is not the same as reducing CO_2 emissions to 93% of the 1990 rate because CO_2 is not the only GHG. But it is by far the most important as a potential source of global warming. The Kyoto Protocol mentions tradeoffs between different GHG reductions, but they are too vague to be analytically useful.

So to analyze the cost of meeting the Kyoto Protocol targets, I am going to assume that the United States reduces its CO_2 emissions to 93% of the 1990 rate. I also assume that the only way for us to reduce CO_2 emissions is to reduce fossil fuel usage. This assumption is 99% correct because fossil fuels account for 99% of U.S. CO_2 emissions.

Reducing CO_2 with a Fixed Fossil Fuel Mix

If the ratios in which petroleum, natural gas, and coal are consumed remain as they were in 1996, then reducing CO_2 from fossil fuels would require that the 1996 fuel mix be scaled back to get aggregate Btu from fossil fuels in 2010 equal to 93% of aggregate Btu from fossil fuels in 1990, or .93 x 71.98 quadrillion Btu = 66.94 quadrillion Btu. This amounts to a reduction from 1996 of 78.83 - 66.94 = 11.89 quadrillion Btu. So, to meet Kyoto Protocol targets would require that U.S. fossil fuel consumption be cut back to (66.94 / 78.83) = .849, or to 84.9% of actual consumption in 1996.

Total energy consumption need not be cut back so much, of course, because renewable energy and nuclear energy do not produce CO_2. In theory, renewable and nuclear energy could grow to fill the gap created by reduced fossil fuels. But in practice, this energy loss of 11.89 quadrillion Btu cannot be filled in 12 years by expanding either renewable or nuclear energy.

There are two compelling reasons. First, U.S. nuclear-generation capacity has not increased since 1990 (Statistical Abstract of the United States, 1997, Table 950). We had 110 nuclear power plants in 1996, the same number as in 1989 (Statistical Abstract of the United States, 1997, Table 949). No new nuclear plants have been licensed since 1978. Nuclear power in the U.S. cannot be increased without new plants. Even if licensing were to be resumed immediately, and it almost surely will not, nuclear energy could be increased very little, if at all, by 2010. For the next 12 years, it seems best to project U.S. nuclear energy as either fixed or declining.[7]

Second, for the next 12 years, expansion of renewable energy is strictly limited. Hydroelectric power is the same in 1996 as it was in 1990, and only marginally greater than in 1980 (Statistical Abstract of the United States, 1997, Table 955). The estimated remaining undeveloped hydropower in the United States is a drop in the bucket (Statistical Abstract of the United States, 1997, Table 955). Further development of hydroelectricity faces strong opposition from environmental groups. Since hydroelectricity is half of all renewable energy, and renewable energy amounted to only 7.5% of all U.S. energy in 1996, we can regard renewable energy as practically fixed for the next 12 years.[8] Even if non-hydro renewable energy were to double in the next 12 years (it cannot do so), renewables would not begin to offset the 12 quadrillion Btu loss attributable to the reduction in fossil fuels.

VI. The Kyoto Protocol Would Cut Fossil Fuels by 15%

To analyze the energy reduction imposed on the United States by the Kyoto Protocol requires 5 steps:

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[7] The U.S. Energy Information Administration projects that electricity produced by nuclear units will increase slightly until the year 2000, then will decline as nuclear plants are retired. In its Annual Energy Outlook 1998 reference case, the U.S. Energy Information Agency projects a 20% decline in nuclear capacity between 1996 and 2010, then a rapid decline between 2010 and 2020. Projected nuclear capacity in 2020 is only about 45% of nuclear capacity in 1996. See U.S. Energy Information Administration (1997, pp. 55 and 103).

[8] The U.S. Energy Information Administration projects that total renewable energy will increase from 6.93 quadrillion Btu in 1996 to 7.44 quadrillion Btu in 2010, with most of the increase concentrated in higher industrial use of biomass (U.S. Energy Information Administration, 1997, p. 123). This small increase is practically equivalent to my assumption of constant renewable energy.

Step 1. Benchmark current (1996) energy consumption and its fossil fuels component (85% of the total). <u>We must understand where we stand, using 1996 as the benchmark</u>.

Step 2. Tabulate total energy and fossil fuels consumption in 1990. Fossil fuels account for 99% of CO_2 emitted in the United States, so we can pretend that all of our CO_2 comes from fossil fuels.[9] <u>We must know where we stood in 1990.</u>

Step 3. By the year 2010, reduce total U.S. fossil fuel consumption to 93% of 1990 consumption, because that is a feasible way to meet our Kyoto Protocol commitment. <u>We must know where the commitment would take us.</u>

Step 4. Assume that renewable and nuclear energy remain at their 1996 levels, for the reasons discussed above.

Step 5. Subtracting our actual fossil fuel consumption in 1996 from what the Kyoto Protocol would commit us to in 2010, gives the reduction in fossil fuels and total energy required by 2010.

Results of this exercise are shown in Table 3. Current (1996) total energy consumption is 92.83 quadrillion Btu. Fossil fuels constitute 85% of the total (78.83 quads/92.83 quads = .849, or 85%).

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[9] In 1989, an estimated 4,834 million metric tons of CO_2 came from burning coal, liquid petroleum products, and natural gas. Another 35 million metric tons was attributable to manufacturing cement, and 22 million metric tons attributable to land use change, making a total of 4,891 million metric tons of CO_2. Thus burning fossil fuels accounted for 4,834/4,891 = .988, or 99% of total U.S. CO_2 emissions. See <u>World Resources, 1992-1993</u>, Tables 24.1 and 24.2, pp. 346 and 348.

Table 3. U.S. Energy Consumption from Fossil Fuels, Renewables, and Nuclear Power (Quadrillion Btu)

	(1) Fossil Fuels	(2) Renewables (including hydro)	(3) Nuclear	(4) Total
Where we were in 1996	78.83	6.83	7.17	92.83
Where we were in 1990	71.98	6.16	6.02	84.16
Where Kyoto Protocol would put us in 2010	66.94	6.83	7.17	80.94
Reduction from 1996 in Energy Consumption due to Kyoto Protocol	(-)11.89	0	0	(-)11.89

Sources: Energy from all renewable resources is from the U.S. Energy Information Administration, reported in Statistical Abstract of the United States, 1997, page 599. The estimate of 6.83 quads is for 1995, not 1996.

Energy estimates from fossil fuels and nuclear power are from the U.S. Energy Information Administration, reported in De Golyer and Mac Naughton, 1997, pages 109-112. Fossil fuel energy in the year 2010 under the Kyoto Protocol is seven percent less than that in 1990, i.e. 71.98 x .93 = 66.94 quadrillion Btu.

The Kyoto Protocol requires no reduction in renewable or nuclear energy. So to cut CO_2 emissions to 93% of the 1990 level commits the U.S. to reduce fossil fuels from 78.83 quads in 1996 to 66.94 quads in 2010. This amounts to a 15% cutback from fossil fuels in 1996 (- 11.89 / 78.83 = -.151, or -15%). It also amounts to a 13% cutback in overall energy between now and 2010 (-11.89/92.83) = -.128, or -13%).

The United States has seldom experienced such a large energy reduction. Two comparisons are suggestive. Between 1973 and 1975, the period of the first OPEC oil embargo, energy consumption fell from 74.2 to 70.5 quads, but rebounded sharply between 1975 and 1979. Then from 1979 to 1983, a period of rising energy prices caused by lower OPEC production, energy consumption fell from 78.7 to 70.4 quads, but rebounded to 79.9 quads by 1988.[10] The decade 1973-1983 was marked by energy shocks and economic stagnation: Maddison (1995) shows that real GDP per capita increased by only 1.1% per year, and we can see in Table 2 that real GNP per hour increased scarcely 8/10 of 1% per year. We recall the decade 1973-1983 as a period of slow growth in productivity and living standards.[11]

VII. The Kyoto Protocol Would Reduce Energy per Worker by 28%

The Kyoto Protocol would require a 15% cutback in fossil fuels and a 13% reduction in total energy by the year 2010. It would require an even larger cutback in energy per worker because our population and labor force will continue to grow. Energy per worker and capital per

[10] See Table 1.

[11] For an interesting study of whether year-to-year and longer-run changes in real GDP are mainly based on changes in energy consumption or instead on changes in the money stock, see Santini (1994).

worker are primary determinants of productivity. A major cutback in energy per worker would shackle productivity growth.

To analyze the reduction in energy per worker implied by the Kyoto Protocol, I must project population and labor force growth from now (pretending it's 1996) until 2010. I assume that both grow by 1% per year. So I assume that the labor force remains a constant fraction of the population.[12]

I start with the actual population estimates for 1990 (249.4 million) and 1996 (265.3 million) according to the United States Census Bureau, shown in Table 4. I then project the population in 2010 to be 305 million.

Then divide the actual energy consumption in 1990 and 1996 (shown in Table 3) by the actual population in those years to obtain energy consumption per capita: 320 million Btu per capita in 1990 and 349.9 million Btu per person in 1996.

Next divide energy consumption in 2010 required by the Kyoto Protocol (shown in Table 3) by the projected population in 2010 (305 million) to find that energy per capita would be 265.4 million Btu per person, shown in Table 4. By comparison with 1996, the Kyoto Protocol and labor force growth would require a reduction of 84.5 million Btu per person, a cutback of 28% per worker.[13]

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[12] The projections are that $\text{population}_{2010} = (1.01)^{14}\,\text{population}_{1996}$ and $\text{labor force}_{2010} = (1.01)^{14}\,\text{labor force}_{1996}$.

[13] To calculate the percentage reduction, I divide the numerical reduction (-84.5 million Btu per capita) by the average of energy per capita in 1996 and 2010, namely 307.7 million Btu per capita.

Table 4. U.S. Per Capita Energy Consumption from Fossil Fuels, Renewables, and Nuclear Power (Million Btu)

	(1) Fossil Fuels	(2) Renewables (including hydro)	(3) Nuclear	(4) Total
Where we were in 1996 (Actual population of 265.3 million)	297.1	25.8	27.0	349.9
Where we were in 1990 (Actual population of 249.4 million)	271.2	24.7	24.1	320.0
Where Kyoto Protocol would put us in 2010 (Projected population of 305 million)	219.5	22.4	23.5	265.4
Reduction from 1996 in Per Capita Energy due to Kyoto Protocol and population growth	(-) 77.6	(-) 3.4	(-) 3.5	(-) 84.5

Sources: Energy from all renewable resources is from the U.S. Energy Information Administration (see Table 3).

Energy from fossil fuels and nuclear power is from the U.S. Energy Information Administration (see Table 3).

Population in 1990 and 1996 is from the U.S. Census Bureau, reported in De Golyer and Mac Naughton, 1997, page 106.

Projected population in 2010 is based on one percent net annual growth for the years 1996-2010.

If this 28% reduction were to occur smoothly between 1996 and 2010, the reduction in energy per worker would be 1.8% per year.

VIII. The Kyoto Protocol Would Reduce Productivity Growth

What would be the effect on productivity of this 1.8% annual reduction in energy per worker? To obtain an answer, I use a macroeconomic productivity equation that I developed and estimated a few years ago (Moroney, 1992). The central idea is that real GDP per worker (macroeconomic productivity) depends on utilized capital per worker, energy per worker, and technological progress. Technical details are shown in the Appendix.

The productivity growth equation is

Annual % change in real GDP per worker	=	Annual rate of technological progress	+	.142 (annual % change in utilized capital per worker)	+	.289 (annual % change in energy per worker)

"Business As Usual" Productivity Growth

To project annual productivity growth from 1996 until 2010 with no restrictions placed on energy, I assume that utilized capital per worker increases at 2.0% annually (as it did from 1950 until 1984) and that energy per worker increases at 1.3% annually (as it did from 1950 until 1984). Substituting these numbers into equation (3) gives "Business as Usual" annual productivity growth

(1) Annual % change in real GDP per worker = .013 + .142 (.020) + .289 (.013) = .020, or 2.0% per year.

With no restrictions on energy consumption, historically accurate growth of capital per worker, and historically accurate technological progress, I project 2.0% annual growth of real GDP per worker from 1996 until 2010. This projection is consistent with the actual 2.6% annual growth in U.S. labor productivity from 1950 until 1972 (see Table 2).

Kyoto Protocol Productivity Growth

To project productivity growth with a 1.8% annual decrease in energy per worker required by the Kyoto Protocol, but retaining all other assumptions, I obtain

(2) Annual % change in real GDP per worker = .013 + .142 (.020) + .289 (-.018) = .011, or 1.1% per year.

The reduction in energy per worker implied by the Kyoto Protocol would reduce annual productivity growth from 2.0% to 1.1%, or by 9/10 of 1% per year. This projection of 1.1% productivity growth caused by declining energy per worker fits with the facts from 1973 until 1983: Energy per worker hour fell from 456 thousand Btu to 391 thousand Btu, and real GNP per hour increased by 8/10 of 1% per year (See Table 2).

I should stress several things about this projection. First, it has no energy shocks, but instead a steady annual reduction in energy per worker. Second, it retains the assumption of steady total factor productivity growth of 1.3% annually. Some might think this too optimistic under the 1.8% annual reduction in energy per worker. If a lot of energy-intensive capital must be scrapped, they are probably right. Third, it retains the assumption that utilized capital per worker continues to grow at 2.0% per year. If much energy-intensive capital must be scrapped, the net utilized capital stock may actually decrease. If so, gross investment in new energy-efficient capital will have to be much greater than it is now. Finally, it implies that Btu of energy per unit of capital declines quite rapidly at 3.8% per year. Such a strong decrease would require much higher gross investment in energy-efficient capital stocks than we have today.

My projections show that a shift from 1.3% annual growth in energy per worker ("Business as Usual") to a 1.8% annual decrease (required by the Kyoto Protocol) would cut productivity growth from 2.0% to 1.1%. If the labor force grows by 1% (as I assume), then meeting the Kyoto Protocol would cut the U.S. GDP growth rate from 3.0% to 2.1%.

The differences between projected productivity growth of 1.1% under the Kyoto Protocol and 2.0% without it imply major differences in U.S. living standards by the year 2010. With productivity growth of 1.1% per year, U.S. living standards would be 17% higher in 2010 than in 1996. But with productivity growth of 2.0% per year, living standards would be 32% higher in 2010. The central conclusion is this: A 1.8% annual reduction in energy per capita that would be our commitment according to the Kyoto Protocol would lead to living standards in 2010 that are 15% lower than they would be with no restrictions on energy usage.

These projections are transparent because they are based on 3 estimated coefficients of a simple productivity growth equation shown in the Appendix. I believe simplicity is a virtue here for two reasons: (1) you can easily agree or disagree with the projections, and (2) your grounds in either case are clear.

IX. Impacts of Fossil Fuel Reductions on Different Economic Sectors

The Kyoto Protocol cuts in fossil fuels would permeate the economy. The impacts would be especially strong in the manufacturing and transportation sectors because they rely so heavily on fossil fuels. The effects would be less severe for residential households and commercial business because they depend on fossil fuels less than manufacturing and transportation. Chart 1 shows the total energy usage in these sectors in 1996.

Let's begin with electric utilities. As shown in Chart 2, 66% of electricity is generated by fossil fuels, mostly coal and relatively small volumes of natural gas. Nuclear energy produces 21% of America's electricity, and renewable resources (mostly hydropower) the remaining 13%. A cut in fossil fuels, especially coal, would reduce total electricity supply. As shown earlier, we cannot anticipate any increase in nuclear or hydroelectricity between now and 2010. Fossil fuels consumed to generate electricity do not appear as direct fossil fuel consumption in other sectors. Instead, they are consumed indirectly by all other sectors of the economy. In what follows, I calculate the direct use of fossil fuels and their indirect use embodied in each sector's electricity consumption.

Energy use in the residential sector is shown in Chart 3. About 76% of residential energy comes directly or indirectly from fossil fuels, and about 24% from other sources, chiefly electricity generated by nuclear and hydropower. A 15% reduction in fossil fuels in the next 12 years would represent an 11.5% cutback in residential energy.

Energy in the commercial sector is shown in Chart 4. About 75% of commercial energy is derived directly or indirectly from fossil fuels, about 25% from other types of energy, mainly nuclear and hydroelectricity. A 15% cut in fossil fuels would amount to an 11.25% decrease in overall energy in the commercial sector.

The industrial sector relies heavily on fossil fuels. Chart 5 shows that 84% of industrial energy is attributable to fossil fuels, and only 16% from other types of energy. A 15% cut in fossil fuels consumed directly or indirectly by industry would be a major energy loss.

The U. S. transportation sector is composed of automobiles, light trucks, buses, heavy commercial trucks, trains, airplanes, ships, and barges. You can see in Chart 6 that our transportation sector depends on fossil fuels for 99.2% of its energy, with 96.2% from refined liquid petroleum products. A 15% reduction in fossil fuels would mean a 15% cutback in energy to American transportation industries. They would bear the brunt of fossil fuel cutbacks more intensely than most others.

X. Conclusions

The United States consumes much more energy and fossil fuels than any other country. We do so because fossil fuels have historically been cheap here, and they still are. Because the United States relies so heavily on fossil fuels, we emit more CO_2 than any other country. About 99% of our CO_2 emissions come from burning fossil fuels. Our only means to reduce CO_2 emissions is to curtail fossil fuel consumption.

To meet the current terms of the Kyoto Protocol would require the United States to cut annual fossil fuels by 15% and total energy by 13% between now and 2010. This cutback in fossil fuels required by the Kyoto Protocol could not offset by increased renewable or nuclear energy as soon as by the year 2010.

The 13% reduction in total energy combined with 1% annual labor force growth implies an overall decrease in energy per worker of 28% by 2010. If the 28% decrease were to occur smoothly over 14 years, the decrease in energy per worker would be 1.8% per year.

I project that this 1.8% annual decrease in energy per worker would reduce the annual growth in real GDP per worker from 2.0% to 1.1%. This reduction in productivity growth is the price we would pay for the Kyoto Protocol. This reduction in productivity growth would cause

U.S. living standards to be 15% lower in 2010 than they would be without any restrictions on fossil fuel usage and without any energy price shocks.

I think this projected reduction in productivity growth from 2.0% to 1.1% is probably a conservative estimate. The main reason is that it does not account for the replacement of energy-intensive capital by more energy-efficient capital that the energy cutback would call for. This capital replacement would place a strain on private and government saving, and would require a much higher ratio of gross investment to Gross Domestic Product than we have today.

My analysis of the cutback in fossil fuels treats the mix of natural gas, oil, and coal as fixed. In short, I ignore any prospective substitution among fuels. Doing so allows me to sidestep an important question: How would the prospective cutback be achieved? One widely-discussed proposal is to impose a tax on the carbon contained in fossil fuels.[14] Their carbon content and emissions rates differ quite a lot. Coal is the most carbon-intensive fuel, natural gas the least carbon-intensive.

The emissions rate for coal is 26.9 kilograms (about 59.2 pounds) of carbon per million Btu, that for oil is 21.4 kilograms (about 47.1 pounds) of carbon per million Btu, and that for natural gas is 14.5 kilograms (about 31.9 pounds) of carbon per million Btu (Jorgenson and Wilcoxen, 1992, p. 136). Because the carbon (and carbon dioxide) emissions rate per unit of energy from coal is nearly twice as great as that from natural gas, a carbon tax would increase the price of coal the most, the price of natural gas the least.

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[14] This proposal, and the costs of meeting different emissions goals, have been analyzed thoroughly by Jorgenson and Wilcoxen (1992).

Without knowing the carbon tax rates, we cannot know how much the relative costs of coal, oil, and natural gas would change, only that natural gas would become cheaper relative to oil and coal, and oil cheaper relative to coal. With carbon taxes, firms, households, and governments would have incentives (stronger with higher taxes) to substitute natural gas for oil, and both for coal.

Very little substitution could occur within a year or so, because most capital equipment designed to burn one fuel cannot easily be adapted to use another. How much fuel substitution would occur over several years depends on several things: (1) the tax-induced changes in relative fuel costs, (2) the rate of retirement of coal-using capital, and (3) rates of investment in capital designed to burn other fuels. The important point is that a carbon tax would provoke long-run substitution of less carbon-intensive for more carbon-intensive fuels. Given so many uncertainties surrounding carbon taxes, tradable emissions permits, and the Kyoto Protocol itself, you can see why I have finessed the question: It cannot yet be answered.

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Appendix

Details of the Productivity Growth Equation

The key assumptions are these:

1. Aggregate U.S. GDP is given by a constant-returns-to-scale Cobb-Douglas production function with utilized capital, energy, and labor as inputs.

2. Total factor productivity growth occurs independently of capital, energy, or labor and is Hicks-neutral, meaning it increases the productivity of these inputs proportionately.

3. Total factor productivity takes place independently of input prices, so there is no price-induced technical change.

The assumptions of constant returns to scale and Hicks-neutral technical progress allow us to write real GDP per worker in year t as

(1) $$q_t = A_0 e^{\lambda t} k_t^{\alpha} z_t^{\beta}$$

where q_t is real GDP per worker

k_t is utilized capital per worker

z_t is energy per worker

λ is the annual rate of total factor productivity growth (the annual rate of Hicks-neutral technical progress)

A_0 is a scaling parameter

Economists will recognize α as the elasticity of GDP per worker with respect to capital per worker, and β as the elasticity of GDP per worker with respect to energy per worker. Equation (1) has the advantage of allowing considerable long-run substitution among energy, labor, and capital.

I estimated the parameters of equation (1) using U.S. time series for the years 1950-1984 (Moroney, 1992). The estimates are:

$$\lambda = .013$$

$$\alpha = .142$$

$$\beta = .289$$

The annual percentage growth in real GDP per worker is

(2) $d \ln q_t/dt = \lambda + a\,(d \ln k_t/dt) + \beta\,(d \ln z_t/dt)$

Using the estimated values of λ , α , β , we obtain an empirical productivity growth equation

(3) $d \ln q_t/dt = .013 + .142\,(d \ln k_t/dt) + .289\,(d \ln z_t/dt)$

Chart A. Macroeconomic Productivity

Measured As: GNP/worker or GDP/worker
GNP/hour worked or GDP/hour worked

Macroeconomic Productivity is Closely Linked with Living Standards

Determinants of Productivity Growth:

1. Technological Progress
2. Growth in Utilized Physical Capital per Worker
3. Growth in Energy per Worker

These Determinants are Related in Several Ways

1. Many new technologies are embodied in new capital equipment and new uses for energy (jet airliners)
2. New technologies are often designed to use more capital per worker and/or more energy per worker
3. Energy is required to operate all types of capital equipment: household appliances; heating and cooling systems; furnaces to generate electricity and to make iron and steel products; autos, trucks, trains, airplanes, and ships
4. New capital can be designed to be either more or less energy efficient

The United States employs more capital and energy per worker than any other country in the world.

Chart B. Proc uc ivity Growth in the United States, 1950-1972

EPOCH 1: Declining Real Energy Prices, 1950-1972

2.6% Average Annual Productivity Growth

2.4% Average Annual Growth in Capital per Worker Hour

2.6% Average Annual Growth in Energy Per Worker Hour

EPOCH 2: Increasing Real Energy Prices, 1973-1982

0.8% Average Annual Productivity Growth

1.1% Average Annual Growth in Capital per Worker Hour

-1.3% Average Annual Decline in Energy per Worker Hour

Details are in Table 2

Chart C. Fossil Fuels Accounted For 85% of U.S. Energy Consumption in 1996

Total Energy from All Sources: 92.83 Quadrillion Btu

Fossil Fuel Energy: 78.83 Quadrillion Btu(85%)

Nuclear Energy : 7.17 Quadrillion Btu (7.5%)

Renewable Energy (Includes Hydro):
6.83 Quadrillion Btu (7.5%)

Details are in Table 3

Chart D. Energy ʾrojections, 996-20 0

1. Nuclear Energy Will Remain Stable or Decline.

2. Renewable Energy Will Remain Constant.

3. Any Prospective Increase in Energy Must Come from Fossil Fuels.

4. EIA Reference Case Projects Total U.S. Energy Consumption at 112 Quads in 2010. All of the Increase is from Fossil Fuels.

5. Kyoto Protocol Would Cut Total U.S. Energy from 92.83 Quads in 1996 to Approximately 80.94 Quads in 2010.

6. This Would be a 13% Reduction from Actual Energy Used in 1996, and Would be 28% Below the EIA Projection of 112 Quads in 2010.

7. With 1% Annual Growth in the Labor Force, this 13% Reduction in Total Energy, 1996-2010, Implies a 28% Reduction in Energy per Worker Between 1996 and 2010.
8. 28% Overall Reduction in Energy per worker Means 1.8% Average Annual Reduction in Energy per Worker Between 1996 and 2010.

Chart E. Productivity Growth Projections

1. % Change in GDP per Worker

   = 1.3% Annual Technical Change
   + .149 (%Change in Capital/Worker)
   + .289 (% Change in Energy/Worker)
   = Annual % Change in Productivity

2. "Business as Usual" Productivity Growth

   % Change in GDP/Worker
   = 1.3% Annual Technical Change
   + .149(2% Growth in Capital/Worker)
   + .289 (1.3% Growth in Energy/Worker)
   = 2.0% Annual Growth in Productivity

3. Productivity Growth Under Kyoto Protocol

   % Change in GDP/Worker
   = 1.3% Annual Technical Change
   + .149(2% Growth in Capital/Worker
   + .289(-1.8% Decline in Energy/Worker
   = 1.1% Annual Growth in Productivity

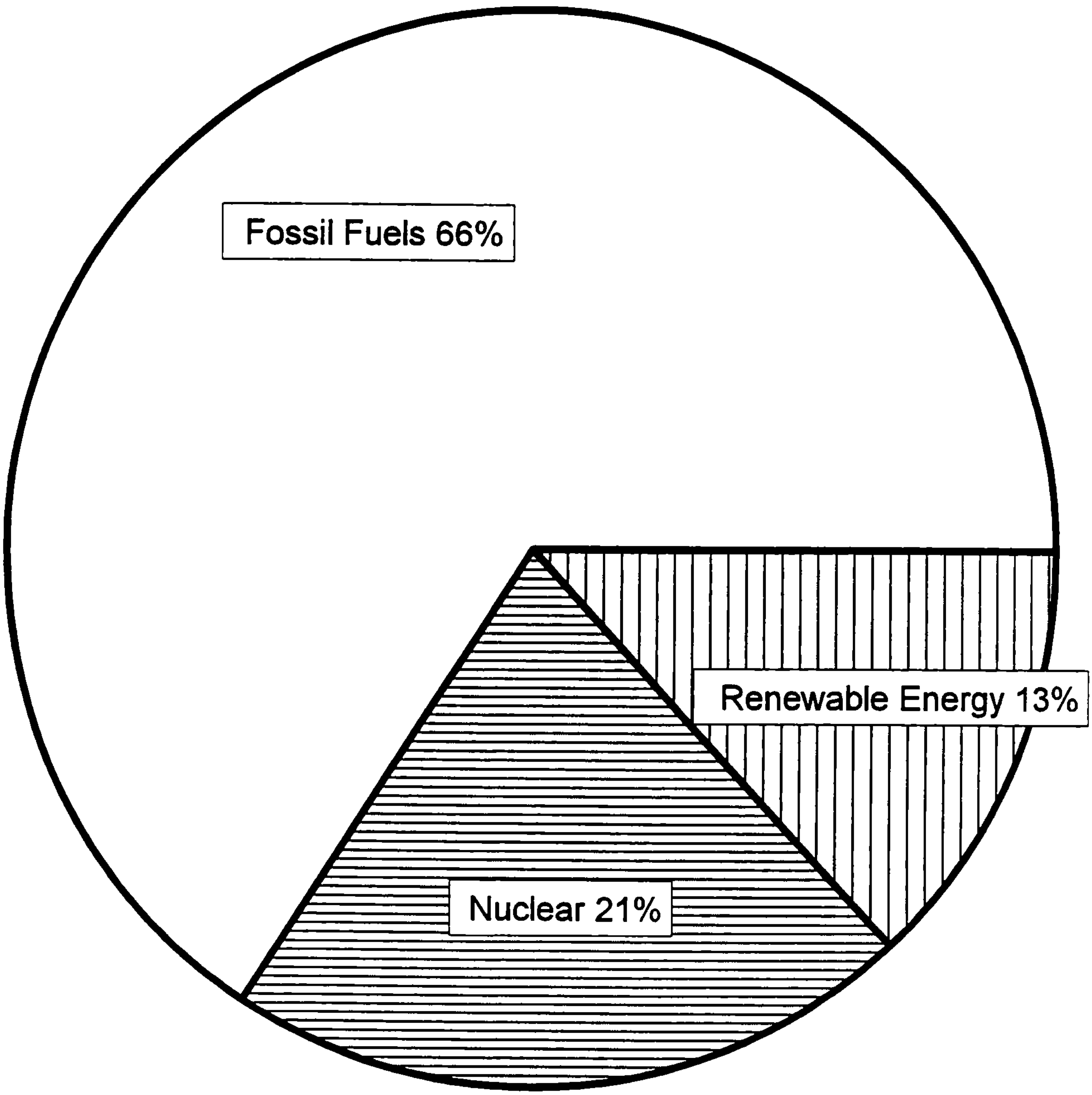
4. Caveats

Chart 1. Total Usage of Energy, by Sector, 1996

RESIDENTIAL SECTOR:	19.36 Quadrillion Btu, or 20.6%
COMMERCIAL SECTOR:	15.01 Quadrillion Btu, or 16.0%
INDUSTRIAL SECTOR:	34.79 Quadrillion Btu, or 37.0%
TRANSPORTATION SECTOR:	24.85 Quadrillion Btu, or 26.4%

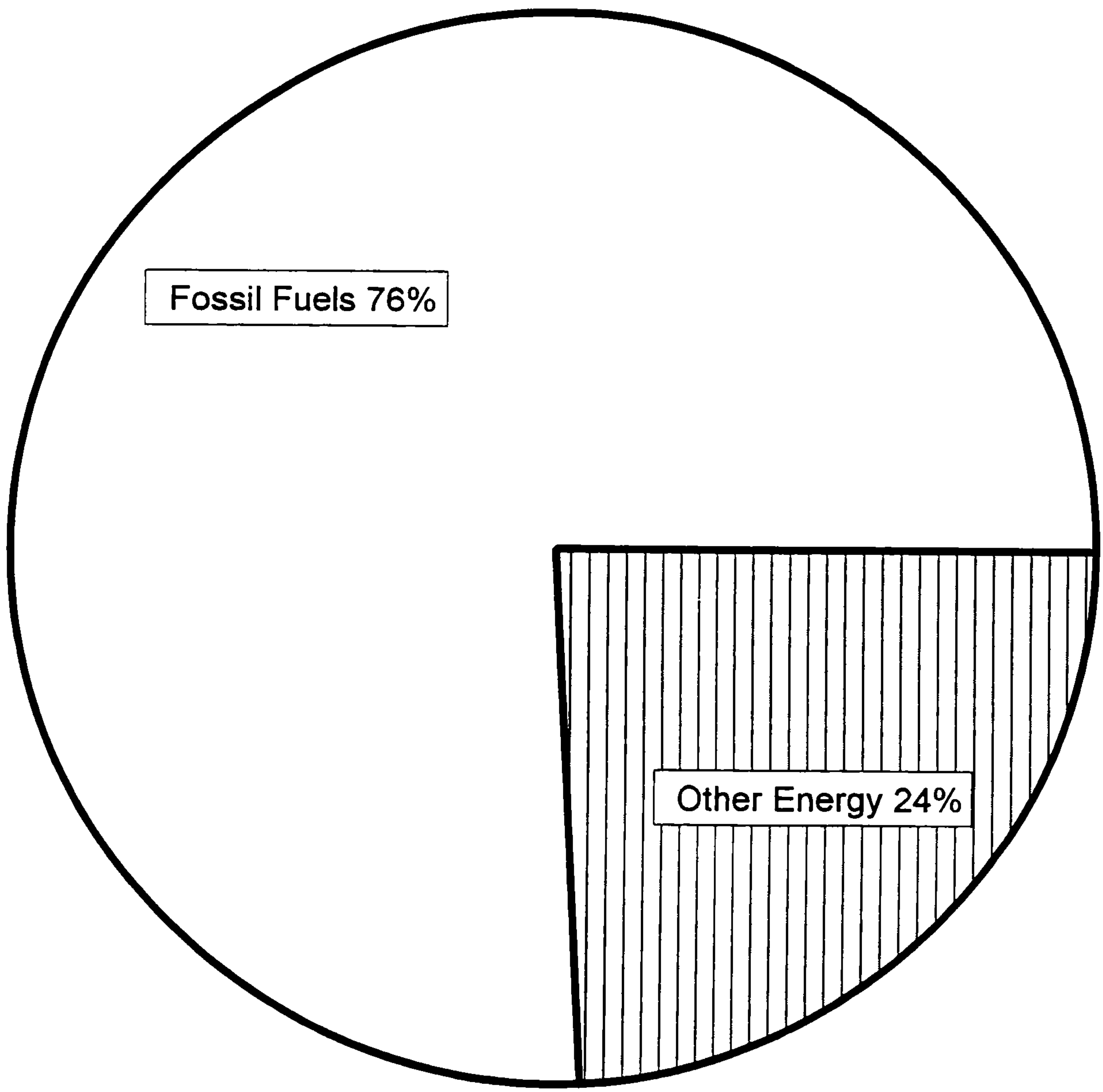
Source: U.S. Energy Information Administration, Annual Energy Outlook 1998, pp. 101-102

Char 2. Direc Jsage of Fossil Fuels, Nuclear, and Other Renewable Energy to Generate Electricity, 1996



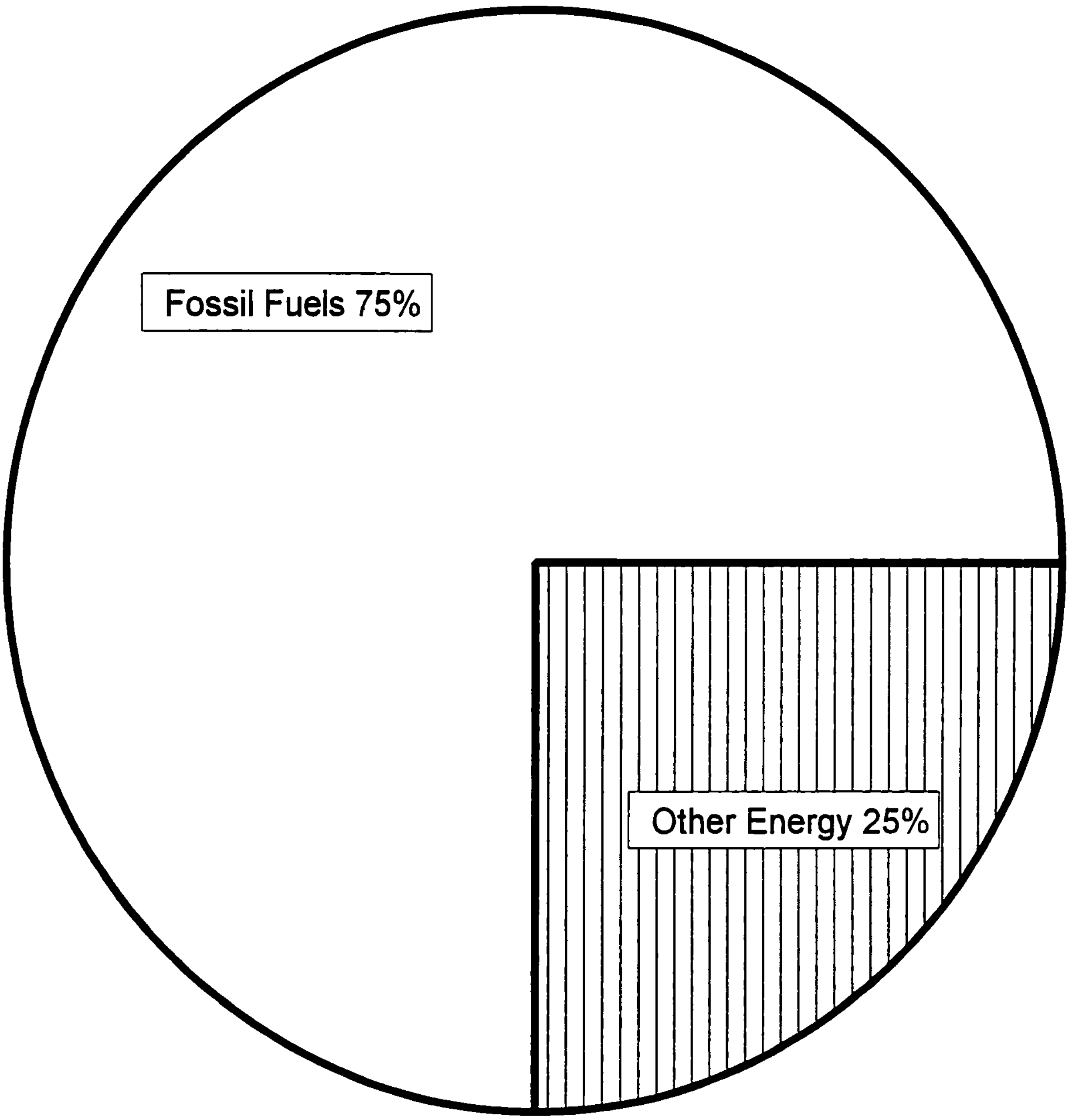
Source: U. S. Energy Information Administration, Annual Energy Outlook 1998, p. 102.

Chart 3. Direct and Indirect Usage of Fossil Fuels and Other Types of Energy in Residential Sector, 1996



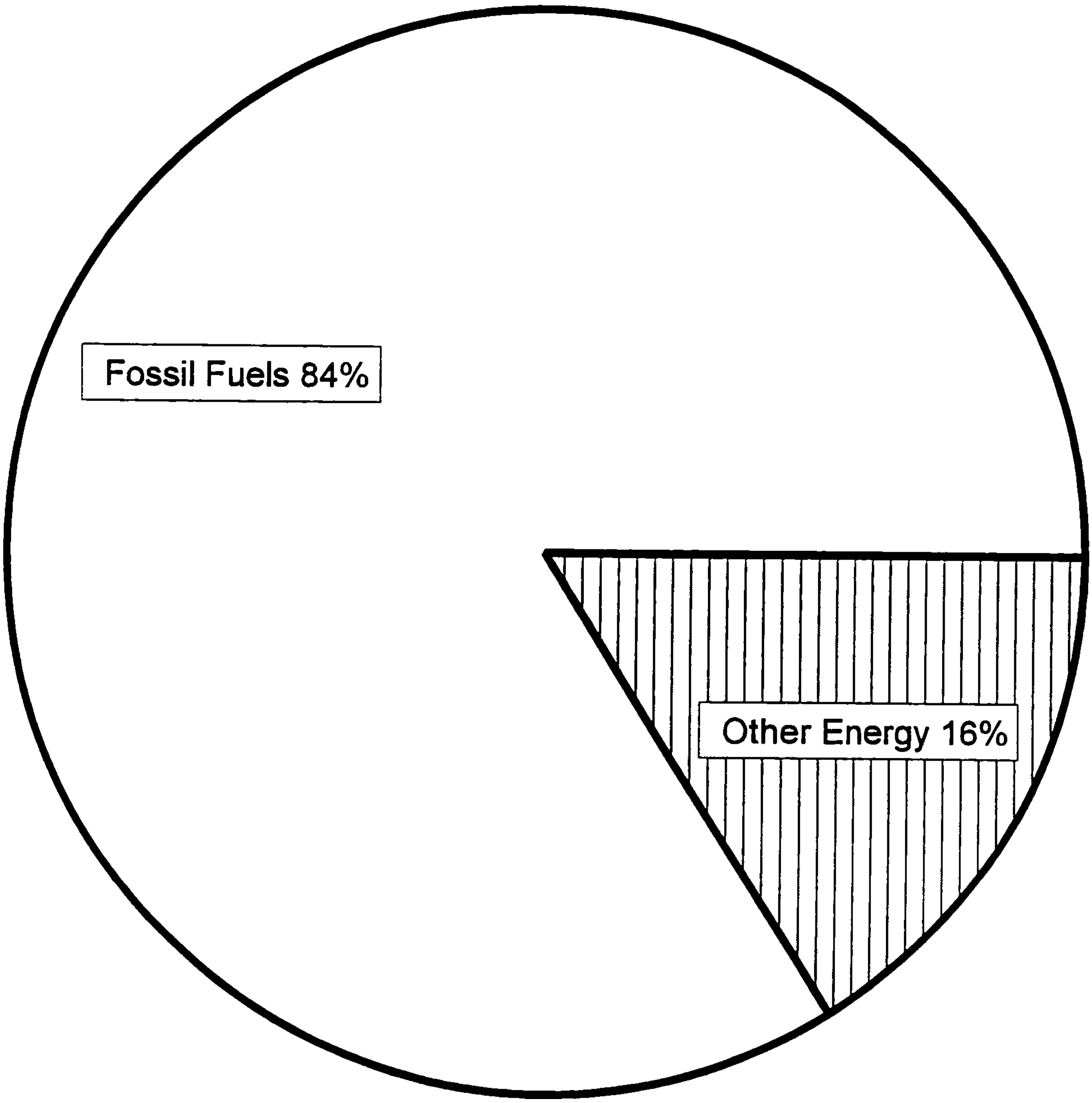
Source: U. S. Energy Information Administration, Annual Energy Outlook 1998, p. 101.

Chart 4. Direct and Indirect Usage of Fossil fuels and Other Types of Energy in Commercial Sector, 1996



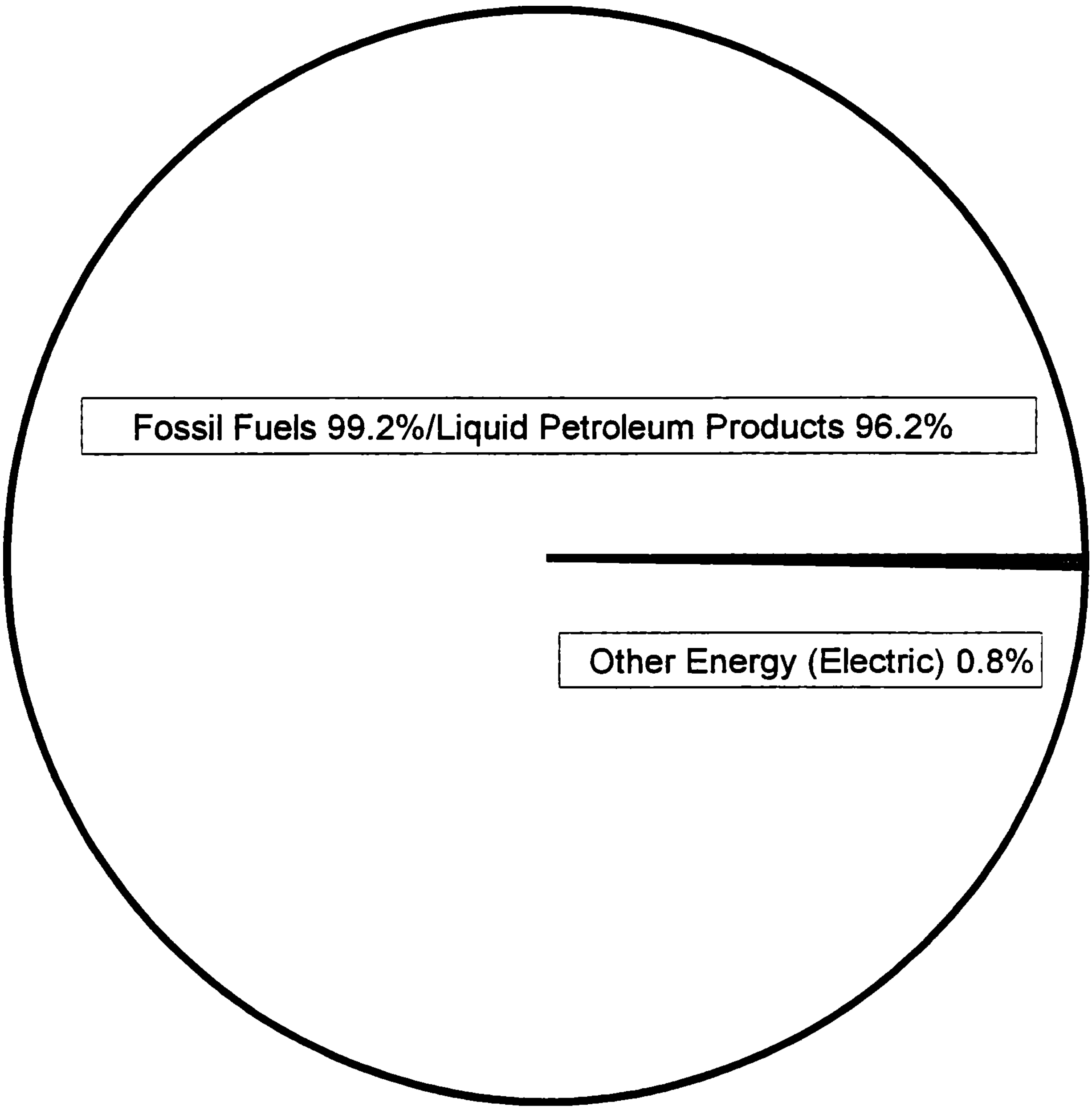
Source: U.S. Energy Information Administration, Annual Energy Outlook 1998, p. 101.

Chart 5. Direct and Indirect Usage of Fossil Fuels and Other Types of Energy in Industrial Sector, 1996



Source: U.S. Energy Information Administration, Annual Energy Outlook 1998, p. 101.

Chart 6. Direct and Indirect Usage of Fossil Fuels andOther Types of Energy in Transportation Sector, 1996



Source: U.S. Energy Information Administration, <u>Annual Energy Outlook 1998</u>, p. 102.

THE KYOTO PROTOCOL: A COST-EFFECTIVE STRATEGY FOR MEETING ENVIRONMENTAL OBJECTIVES?

PAPER

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The Kyoto Protocol: A Cost-Effective Strategy for Meeting Environmental Objectives?

by

Alan S. Manne, Stanford University, and
Richard G. Richels, EPRI

Executive Summary*

The Kyoto Protocol represents a milestone in climate policy. For the first time, negotiators have attempted to lay out emission reduction targets for the early part of the twenty-first century. The goal is for Annex I countries (developed countries plus economies in transition) to reduce their aggregate anthropogenic carbon dioxide equivalent emissions by at least 5 percent below 1990 levels in the commitment period 2008 to 2012. The Protocol, however, has yet to enter into force. To do so will require ratification by 55 countries representing 55 percent of the total Annex I CO_2 emissions in 1990.

As each country considers ratification, important questions will arise. High on the U.S. list is the issue of economic costs. This paper is intended to help clarify our understanding of compliance costs. The focus is on three questions, which we believe to be of particular relevance: (1) What are the near-term costs of implementation; (2) How significant are the so-called "flexibility provisions"; and (3) Perhaps most importantly, is the Protocol cost-effective in the context of the long-term goals of the Framework Convention on Climate Change?

This analysis is based on MERGE, a model for evaluating the regional and global effects of greenhouse gas reduction policies. MERGE is an intertemporal market equilibrium model. The following scenarios are modeled: (1) no CO_2 emissions trading; (2) Annex I trading plus the Clean Development Mechanism; and (3) full global trading of emissions. These three options are representative of alternative implementations of the Kyoto Protocol. Each option has its own advocates and opponents, but we do not consider them equally likely. In our opinion, there is little likelihood of enticing all major countries to participate in a global market in emission rights during the initial commitment period (2008–2012).

The MERGE results suggest that the immediate costs of Kyoto might range from 0.25 percent of GDP (with full global trading) to 1.0 percent of GDP (with no trading). This would be equivalent to a real GDP loss of $20 billion to $80 billion per year. The price of tradable emission permits ranges from $70 per ton (with full global trading) to $240 per ton (with no trading).

Some suggest that models such as MERGE tend to overestimate the costs of mitigation. They argue that when prospects for technical progress are incorporated, the costs of a carbon constraint, even a sharp near-term constraint, will be minimal. We, too, are optimistic about the outlook for technical innovation. Indeed, such innovation is embedded both in our reference case and in the policy scenarios. The disagreement is over the rate at which such progress will occur. We do not believe that economically competitive substitutes will become available at such a rate as to trivialize the costs of a Kyoto-like Protocol.

A more valid concern may be that we are underestimating the costs of a carbon constraint. There are several reasons why this may be the case. To begin with, intertemporal optimization models assume that decision makers have perfect foresight. That is, the models assume that investors are fully informed about the nature of future constraints, and act accordingly. Given the present state of uncertainty, this is highly unlikely. Models such as MERGE also tend to ignore short-term macro

*Prepared for a symposium entitled *Climate Change Policy: Practical Strategies to Promote Economic Growth and Environmental Quality*, sponsored by the American Council for Capital Formation Center for Policy Research, September 23, 1998, at the National Press Club in Washington, D.C.

shocks. For example, the higher energy prices brought about by a carbon constraint are likely to be inflationary. If this leads to higher interest rates, investment may be dampened. The result would be a further slowdown in economic growth beyond the GDP losses mentioned above.

In addition, we assume that policies will be efficient. That is, market mechanisms will be chosen over "command-and-control" approaches to accomplishing environmental objectives. In recent years, there has been an increasing trend toward market mechanisms, but the approach to be taken with climate policy is by no means guaranteed. Moreover, even if such a commitment were made, we have no assurances that the requisite international institutions will be available when needed.

Although it is easy to quibble over the numbers, the real value of these analyses lies more in insights than in numerical values. And, indeed we believe that the current exercise has yielded several insights that may be of value to those charged with interpreting the current proposal. Here, we summarize what we have learned:

- First, it is extremely unlikely that a "Kyoto Forever" scenario will stabilize global emissions—much less concentrations. Non-Annex I emissions are quickly overtaking those of the OECD and of the economies in transition. In order to meet the stabilization goal of the Framework Convention on Climate Change, the developing countries will eventually need to participate.

- Second, the Protocol appears to be inconsistent with a cost-effective long-term strategy for stabilizing CO_2 concentrations. Rather than requiring sharp near-term reductions, it appears that a more sensible strategy would be to make the transition at the point of capital stock turnover. This would eliminate the need for premature retirement of existing plant and equipment and would provide the time that is needed to develop low-cost, low-carbon substitutes.

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The Kyoto Protocol: A Cost-Effective Strategy for Meeting Environmental Objectives?

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July 27, 1998

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1. Introduction

The Kyoto Protocol represents a milestone in climate policy.[1] For the first time, negotiators have attempted to lay out emission reduction targets for the early part of the 21st century. The goal is for Annex 1 (developed countries plus economies in transition) to reduce their aggregate anthropogenic carbon dioxide equivalent emissions by at least 5 percent below 1990 levels in the commitment period 2008 to 2012. The Protocol, however, has yet to enter into force. To do so will require ratification by 55 countries representing 55 percent of total Annex 1 CO_2 emissions in 1990.

As each country considers ratification, important questions will arise. High up on the US list is the issue of economic costs. The Senate, for example, has stated that "any Protocol should be accompanied by a detailed financial analysis of impacts on the economy."[2] Not surprisingly, US negotiators had hardly returned from Kyoto before the first hearings were scheduled on Capitol Hill. Although the issue of costs is but one of many important considerations, policy makers are keenly interested in the economic implications of ratification.

This paper is intended to help clarify our understanding of compliance costs. The focus is on three questions, which we believe to be of particular relevance: What are the near-term costs of implementation? How significant are the so-called "flexibility provisions"? And, perhaps most importantly, is the Protocol cost-effective in the context of the long-term goals of the Framework Convention?[3]

Unfortunately, the answers to these questions will not come easily. It has always been difficult to calculate the economic costs of implementing climate policy. Kyoto has done little to simplify matters. Indeed, it raises at least as many questions as it resolves. These questions fall into two categories: those related to the near-term implementation of the Protocol and those related to the evolution of climate policy over the longer term.

The Protocol is unclear on a number of topics. These include the rules governing emission trading, joint implementation (JI), the Clean Development Mechanism (CDM), and the treatment of carbon sinks. In addition, there is a weak knowledge base regarding the costs of sink enhancement and of controlling several of the relevant trace gases. Until these issues are clarified, analyses will be highly speculative.

Calculating the costs of Kyoto is also complicated by the issue of "what happens next?" Energy sector investments are typically long-lived. Today's investment decisions are not only influenced by what happens during the next decade, but also by what happens thereafter. In order to estimate the costs of implementing emission cuts in the first commitment period, assumptions are required concerning the longer-term requirements. Unfortunately, the international negotiation process offers little guidance on this issue. This further complicates the process of analysis.

We do not wish to suggest that economic analysis is premature at the present time. Uncertainty is rarely an excuse for paralysis. It does mean, however, that we must be careful to highlight the tentative nature of the projections and focus, to the extent possible, on the insights for decision making. Here, sensitivity analysis can be particularly useful. For example, in the case of several of the flexibility provisions (emission trading, joint implementation and the Clean Development Mechanism), we explore a variety of scenarios regarding constraints on the purchase of carbon emission rights. While the exact magnitude of the benefits will continue to be debated, the insights, nevertheless, appear to be quite robust.

We also examine the Protocol in the context of the longer-term goal of the Framework Convention, i.e., the stabilization of greenhouse gas concentrations in the earth's atmosphere. A particular concentration goal can be reached through a variety of emission pathways. Considerable effort has been devoted to trying to understand the characteristics of cost-effective pathways.[4] It is interesting to examine Kyoto in the context of this work. The price tag for moving forward may be formidable. Consistent with the Framework Convention, it is essential that "policies and measures to deal with climate change should be cost-effective so as to ensure global benefits at the lowest possible costs."[5]

2. The model

This analysis is based on MERGE (a model for evaluating the regional and global effects of greenhouse gas reduction policies).[6,7] MERGE is an intertemporal market equilibrium model. It combines a bottom-up representation of the energy supply sector together with a top-down perspective on the remainder of the economy. Savings and investment decisions are modeled as though each of the regions maximizes the discounted utility of its consumption subject to an intertemporal wealth constraint. Each region's wealth includes not only capital, labor and exhaustible resources, but also its negotiated international share in carbon emission rights.

For the present version of the model, known as MERGE 3.0, we have adopted 10-year time intervals through 2050 and 25-year intervals through 2100. Geographically, the world is divided into nine geopolitical regions: 1) the USA, 2) OECDE (Western Europe), 3) Japan, 4) CANZ (Canada, Australia and New Zealand), 5) EEFSU (Eastern Europe and the Former Soviet Union), 6) China, 7) India, 8) MOPEC (Mexico and OPEC) and, 9) ROW (the rest of world). Note that the OECD (regions 1 through 4) together with EEFSU constitute Annex 1 of the Framework Convention.

Particularly relevant for the present analyses, MERGE provides a general equilibrium formulation of the global economy. We model the possibility of international trade in carbon emission rights. This is sometimes known as "where" flexibility. It would allow regions with high marginal abatement costs to purchase emission rights from regions with low marginal abatement costs. In addition, MERGE can be used to examine the related issue of "when" flexibility - intertemporal transfers of carbon emission rights.

We also model international trade in oil, natural gas, and energy-intensive basic materials. We are therefore able to examine issues related to "carbon leakage". Such leakage can occur through a variety of pathways. For example, Annex 1 emission reductions will result in lower oil demand, which in turn will lead to a decline in the international price of oil. As a result, non-Annex 1 countries may increase their oil imports and emit more than they would otherwise.

The present version of the model includes the notion of endogenous technical diffusion. Specifically, in the electric sector, the near-term adoption of high-cost carbon-free technologies leads to accelerated future introduction of lower cost versions. The model also includes both price-induced and non-price conservation. For most regions and time periods, the AEEI (autonomous energy efficiency improvement) rate is taken to be 40% of the rate of GDP growth. By 2100, this leads to regional energy-GDP ratios that are much closer to each other than they were in 1990.

In calibrating MERGE for the present analysis, several supply- and demand-side parameters were adjusted so that the global emissions baseline would approximate the Intergovernmental Panel on Climate Change (IPCC) central case "no policy" scenario (IS92a).[8] Figure 2.1 shows carbon emissions for each region in the reference case scenario. For more on the model and its key assumptions, see our website:

http://www-leland.stanford.edu/group/MERGE/

3. Treatment of sinks and non-CO2 greenhouse gases

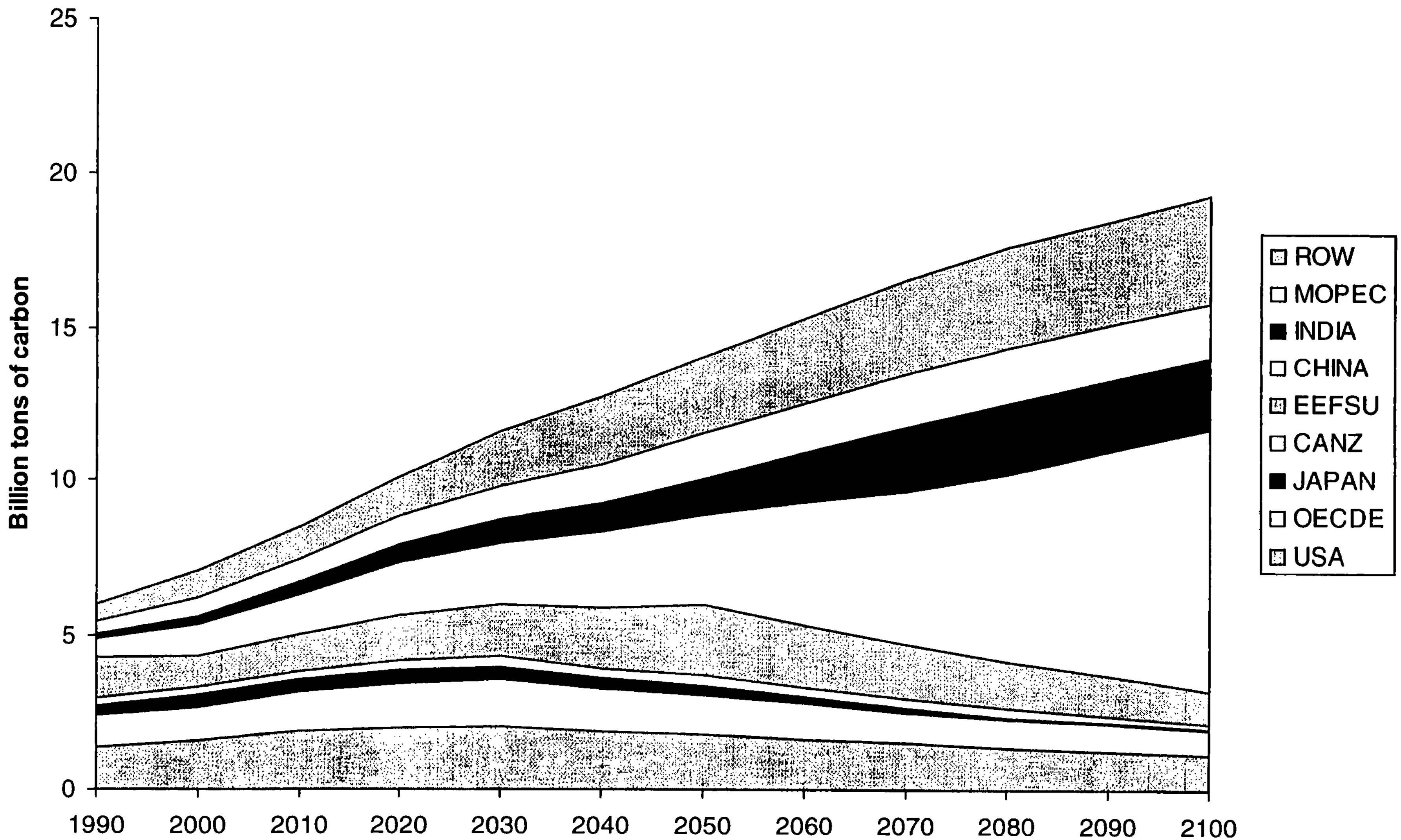
Few issues have engendered as much confusion as that of carbon sinks. Key questions include their definition, the extent to which they are included in the Protocol, the amount currently being sequestered, their time profile, and the costs of sink enhancement.

The Protocol states that Annex 1 commitments can be met by "the net changes in greenhouse gas emissions from sources and removal by sinks resulting from direct human-induced land use change and forestry activities limited to afforestation, reforestation, and deforestation since 1990, measured as verifiable changes in stocks in each commitment period."[9] The confusion results from alternative interpretations regarding the treatment of soil carbon, an issue flagged for further study in the Protocol. Their inclusion may result in large increases in the international legal definition of sink potential.

The quality of the data is uneven. The supply curves for sink enhancement are particularly questionable. The degree of confidence concerning current and predicted future levels of carbon sequestration varies enormously across regions of the globe. Not surprisingly, information is most reliable (albeit still poor) for Annex 1 countries. Comparatively little effort has been made to collect such data elsewhere.

As placeholders, we have adopted the values shown in Table 1. To provide some perspective, in order for the US to reduce industrial carbon emissions by 7% below 1990 levels in 2010, it would have to reduce emissions by approximately 550 million tons below its reference trajectory. Sink enhancement would satisfy 9 percent of this

Figure 2.1 Regional Carbon Emissions -- reference case



obligation. For purposes of the present analysis, we assume that this sink enhancement is costless.

Table 1. Sink Enhancement (million metric tons of carbon annually)

USA	50
OECDE	17
Japan	0
CANZ	50
EEFSU	34

CO2 is by far the most important of the greenhouse gases. In addition, the Protocol includes five other trace gases (methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulphur hexafluoride). Given the scarcity of reliable emissions and cost data, the treatment of the non-CO2 greenhouse gases is also problematic. For purposes of the present analysis, we assume that each gas is reduced proportionately. With this proportionality assumption, the inclusion of the non-CO2 greenhouse gases does not affect the requirements for CO2 reductions.

As with our treatment of sinks, we do not include the costs of abating the non-CO2 greenhouse gases in our estimates of the costs of complying with the Protocol. Clearly, an important next step would be to develop supply curves for the cost of abating non-CO2 greenhouse gases and for sink enhancement. Neither of these costs is included in the present version of MERGE.

4. "Kyoto Forever"

We begin with an examination of a "Kyoto Forever" scenario. This is a case in which the Kyoto constraints on Annex 1 countries are maintained throughout the 21^{st} century. With regard to non-Annex 1 emissions, we assume they will continue to be bounded by their business-as-usual baseline (Figure 2.1). The latter constraint is imposed in order to prevent carbon leakage. Later on, we will explore the impact of relaxing this constraint.

Numerous studies have shown that global mitigation costs can be reduced substantially by allowing emission reductions to take place wherever it is cheapest to do so - regardless of geographical location.[10] The Kyoto Protocol includes several provisions allowing for a limited amount of "where" flexibility. These include emission trading and joint implementation among Annex 1 countries. They also include provisions for a Clean Development Mechanism (CDM) that is intended to facilitate joint implementation between Annex 1 and non-Annex 1 countries.

As with the definition of sinks, the Protocol leaves many critical details unresolved. For example, it remains unclear whether there will be limits on the extent to which a country can rely upon the purchase of emission rights to satisfy its obligations. The Protocol states that "the Conference of the Parties shall define the relevant principles, modalities, rules and guidelines ..."[11] Similar ambiguity surrounds the Clean Development

Mechanism. Again, the elaboration of "modalities and procedures" is left to a future meeting of the Conference of the Parties.[12]

In this section, we explore three scenarios: 1) no trading, 2) Annex 1 trading plus CDM, and 3) full global trading. These three options are representative of alternative implementations of the Kyoto Protocol. Each has its own advocates and opponents, but we do not consider them equally likely. In our opinion, there is little likelihood of enticing all major countries to participate in a global market in emission rights during the initial commitment period (2008-2012).

The full global trading scenario places an upper bound on the CDM's potential to reduce GDP losses. In calculating the potential size of the contribution from a CDM, we therefore calculate this upper bound on the export of emission rights from non-Annex 1 regions. Because of the difficulties in implementation of the CDM, however, we assume that only 15% of the potential would be available for purchase through this mechanism. This is a highly subjective estimate. Given the complexities of the CDM, however, we are not inclined to assign a higher value

Figure 4.1 reports the incremental value of carbon emission rights to the US in 2010 and 2020. We focus first on 2010. In the most constrained scenario, the US must satisfy its emission reduction requirements within its own geographical boundaries. In this case, the value of emission rights approaches $240 per ton. With Annex 1 trading plus CDM, the value drops to slightly less than $100 per ton. As might be expected, the value of emission rights is lowest with full global trading. Here, it falls below $70 per ton.

For the two scenarios in which trading is permitted, the value of emission rights increases in 2020. This is because EEFSU's projected emissions lie below its negotiated constraint for 2010. It has been allocated more emission rights than it needs to satisfy its internal obligations. By 2020, however, EEFSU's economic growth is expected to be such that it no longer enjoys an excess of emission rights. As a result, there is more competition for emission rights in the international marketplace, and there is an increase in their price.

Another way to view the costs of abatement is to show the GDP losses. Figure 4.2 contains those for the US. Losses are highest in the absence of trade. Here, they exceed $80 billion dollars in 2010. This is approximately one percent of US GDP. To the extent that trade is introduced, losses decline. In the most optimistic scenario (full global trade), losses are approximately $20 billion or one-quarter of one percent of GDP in 2010.

Of the three scenarios, "Annex 1 trading plus the CDM" is most consistent with the Protocol as it currently stands. However, the US Senate has stated that the US should not be a signatory to the Protocol if it does not mandate specific commitments for developing countries.[13] If this were to result in full global emission trading, we move in the direction of the right-most bar of Figure 4.2.

There is, however, strong sentiment among many parties to the Framework Convention to substantially limit the extent to which Annex 1 countries can meet their obligation

Figure 4.1 Incremental Value of Carbon Emission Rights in US Under Kyoto Forever

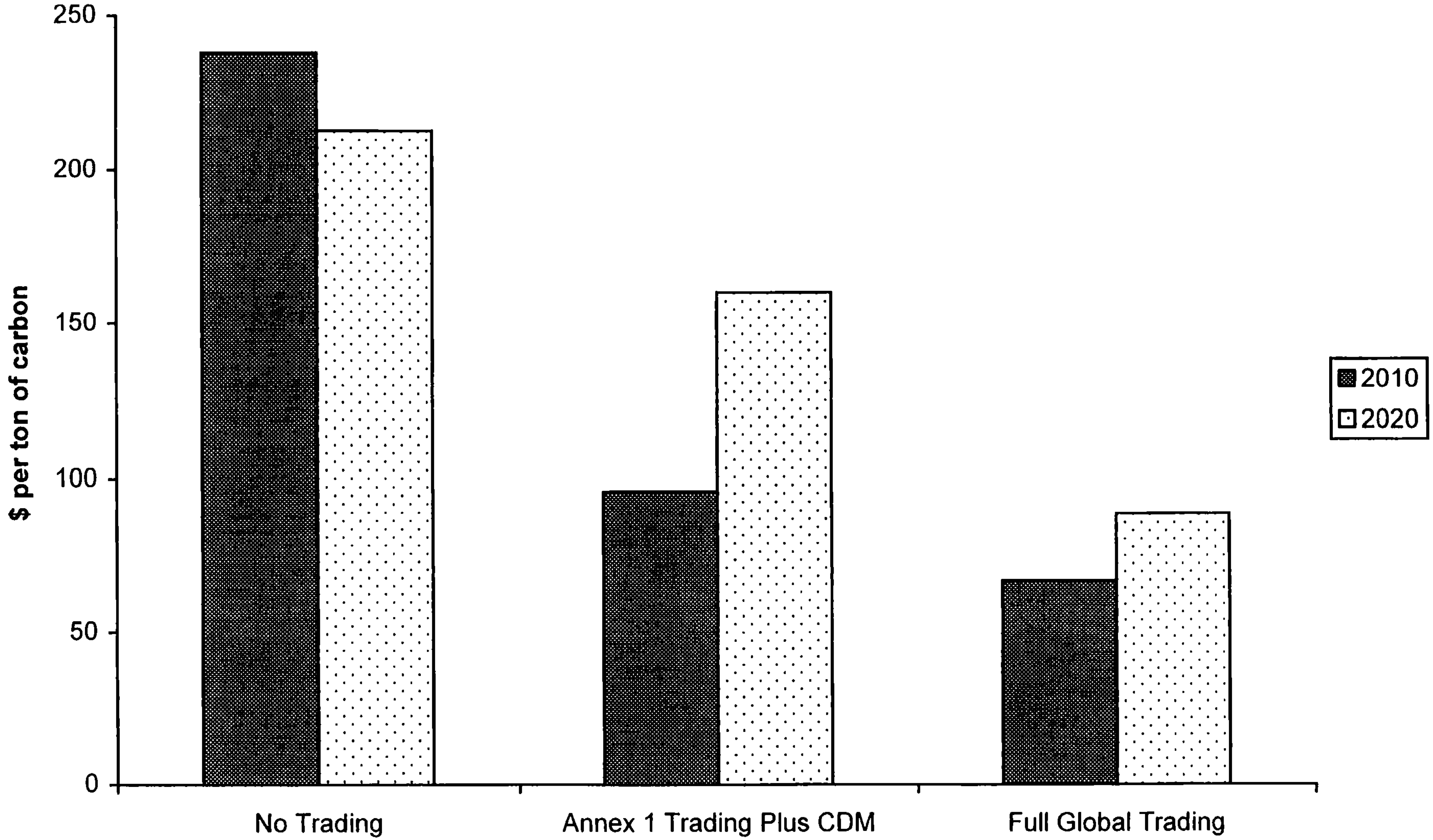
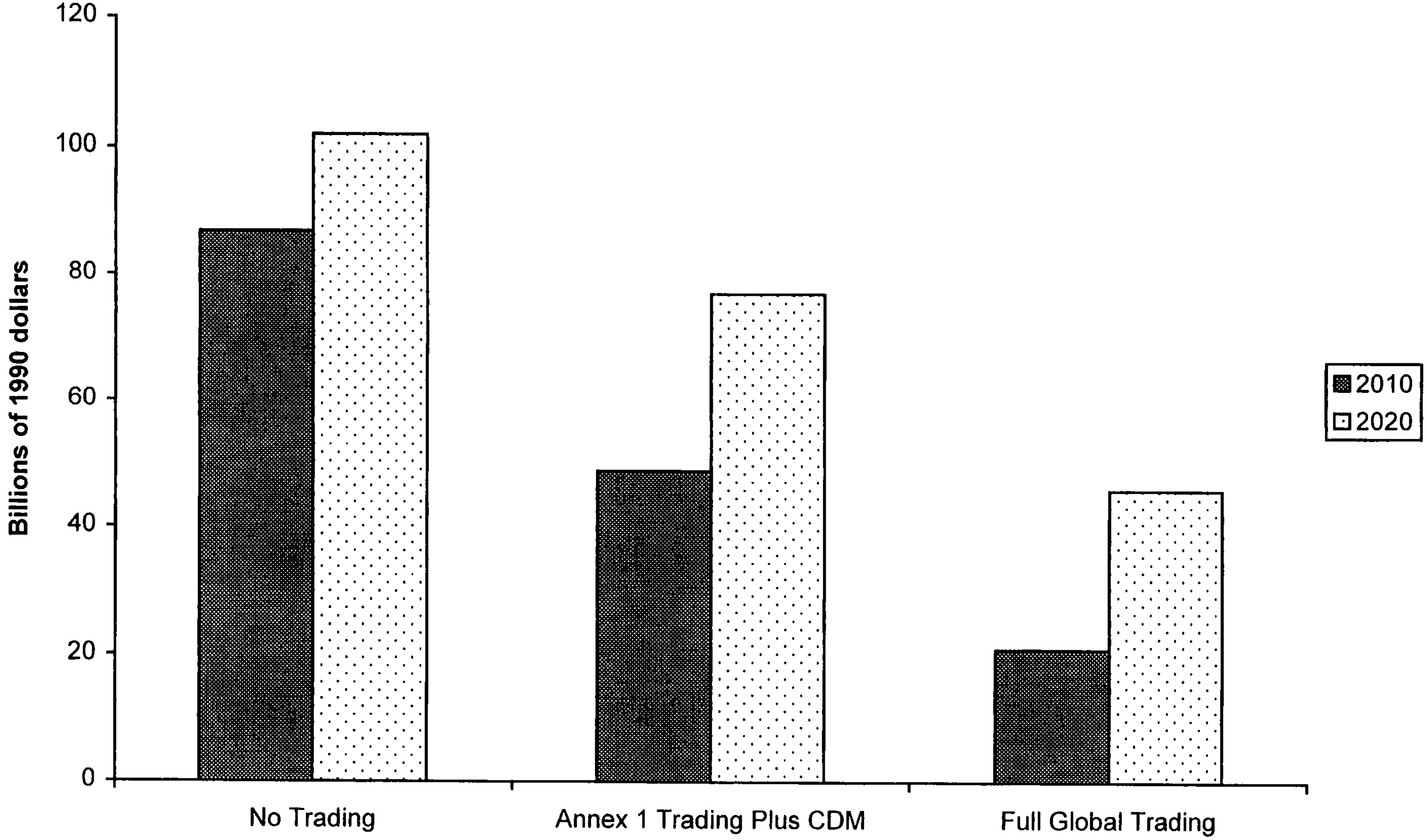


Figure 4.2 Annual US GDP Losses Under Kyoto Forever
($ billions)



through the purchase of emission rights. Several influential developing countries have expressed strong opposition to the concept altogether. Figure 4.2 shows the costs of the no trading scenario. We now turn to the case where trading is permitted, but with limitations on the purchase of emission rights.

5. Limits on the purchase of carbon emission rights

Figure 5.1 shows our estimates of the percentage of the US emission reduction obligation that would be satisfied through the purchase of emission rights under base case assumptions. With full global trading (the least-cost of our three scenarios), trading is used to satisfy more than 50% of the US obligation. But suppose that limits are placed on the purchase of emission rights? For example, suppose that international negotiators agree that Annex 1 buyers can satisfy only one-third of their obligation through this means. What would be the impact on GDP losses?

Figure 5.2 compares three cases. All assume full global participation in an international market for carbon emission rights, but only the first assumes no limits on the amount a country can buy. The second and third case are based upon the one-third limitation. We further make the distinction between a buyers' market and a sellers' market. With the former, sellers of emission rights are price takers. Buyers exert sufficient market power to hold the international price to the marginal cost of abatement in the selling countries. However, since a country is only able to satisfy one-third of its obligation through the purchase of emission rights, it must eventually rely on its own domestic marginal abatement capabilities to meet its obligations. Hence, there is an important distinction between the international price and the domestic price. Conversely, with a sellers' market, buyers face but one price. Here, the rents accrue to the sellers.

Figure 5.3 shows the GDP losses associated with the three scenarios. Note that losses in 2010 are two and one-half to three times higher with the constraint on the purchase of carbon emission rights. That is, the benefits from "where" flexibility are greatly diminished. The message is clear. Developing country participation in the market for carbon emission rights is a necessary, but by no means a sufficient condition for reaping the full benefits of "where" flexibility. To achieve a cost-effective solution, buyers must also be unconstrained in the manner in which they fulfill their obligation.

Also note that the distribution of the rents makes a difference to GDP losses. US losses are 25% higher in 2020 when market power resides with the sellers. The analysis provides an additional message for Annex 1 buyers. If at a given point in time, low-cost sellers are concentrated among a few countries (e.g., EEFSU), they may have considerable potential for extracting monopoly rents.

6. The issue of carbon leakage

The Kyoto Protocol refers specifically to the period centered about 2010. During this period, the onus for emission reductions falls on Annex 1. No specific obligations are imposed on countries outside Annex 1, and there is the possibility of "leakage". That is,

Figure 5.1 Percent of US Obligation Satisfied Through the Purchase of Emission Rights

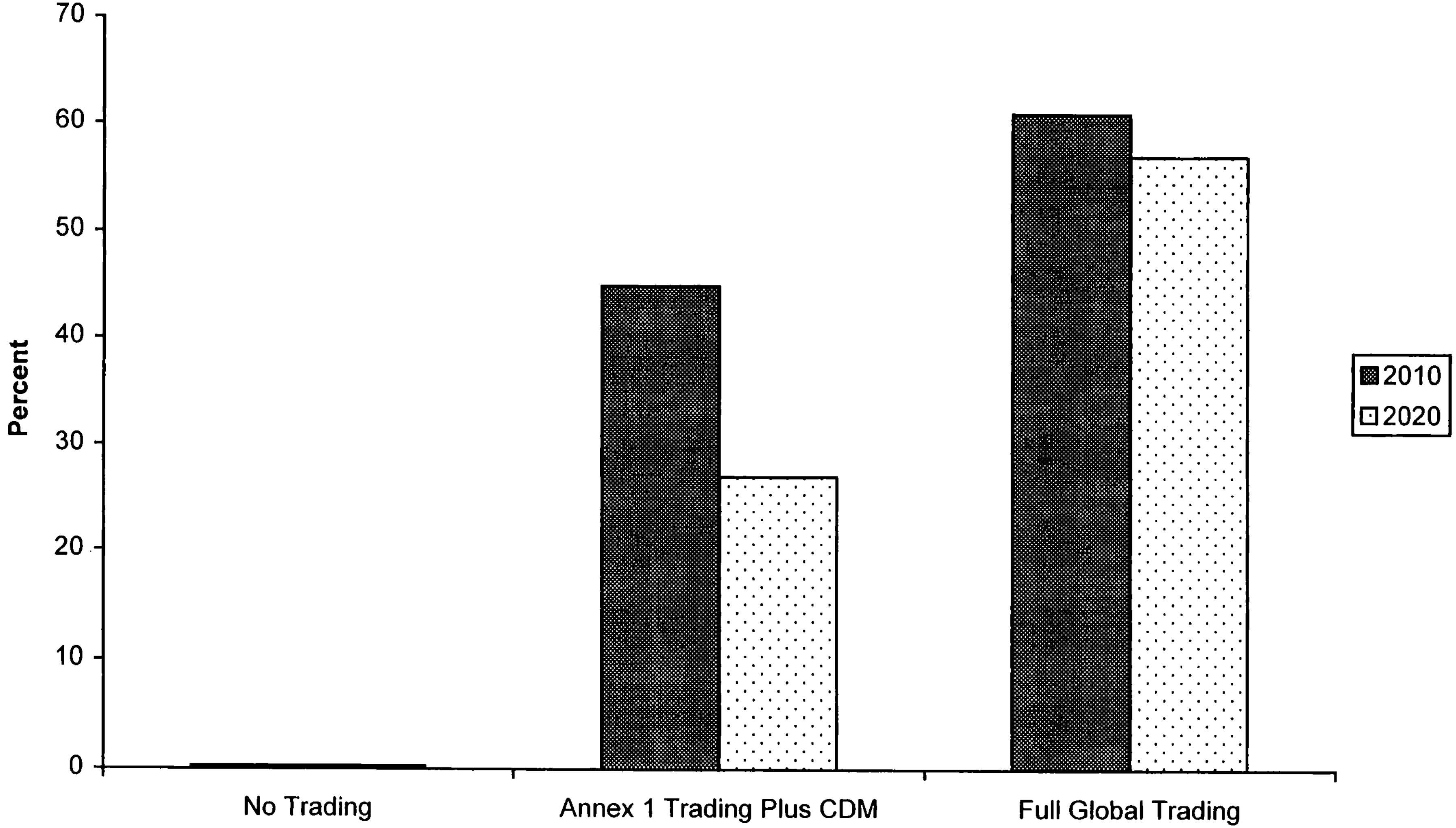


Figure 5.2 Incremental Value of Carbon Emission Rights With and Without Limits on the Purchase of Emission Rights -- Kyoto Forever

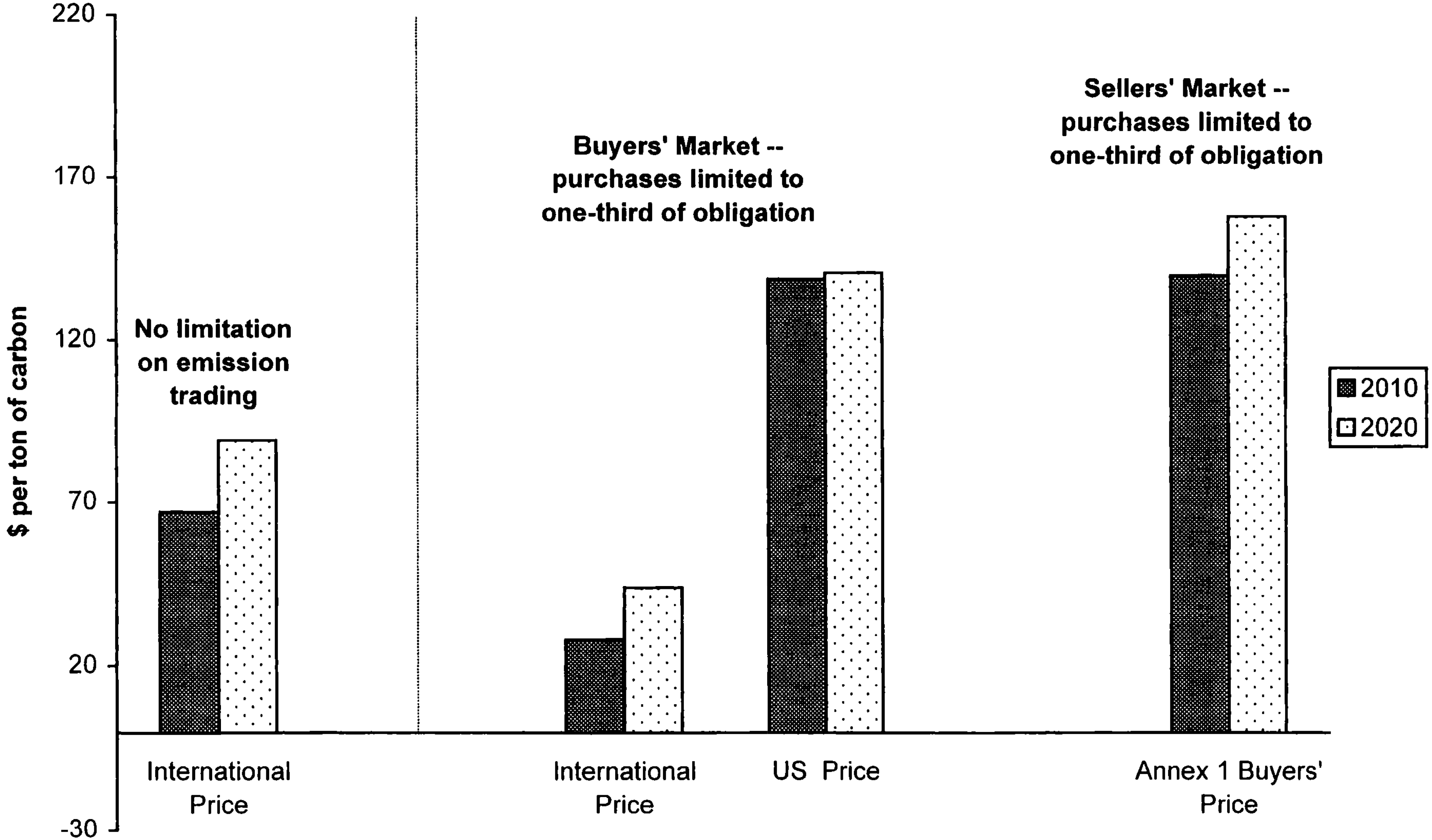
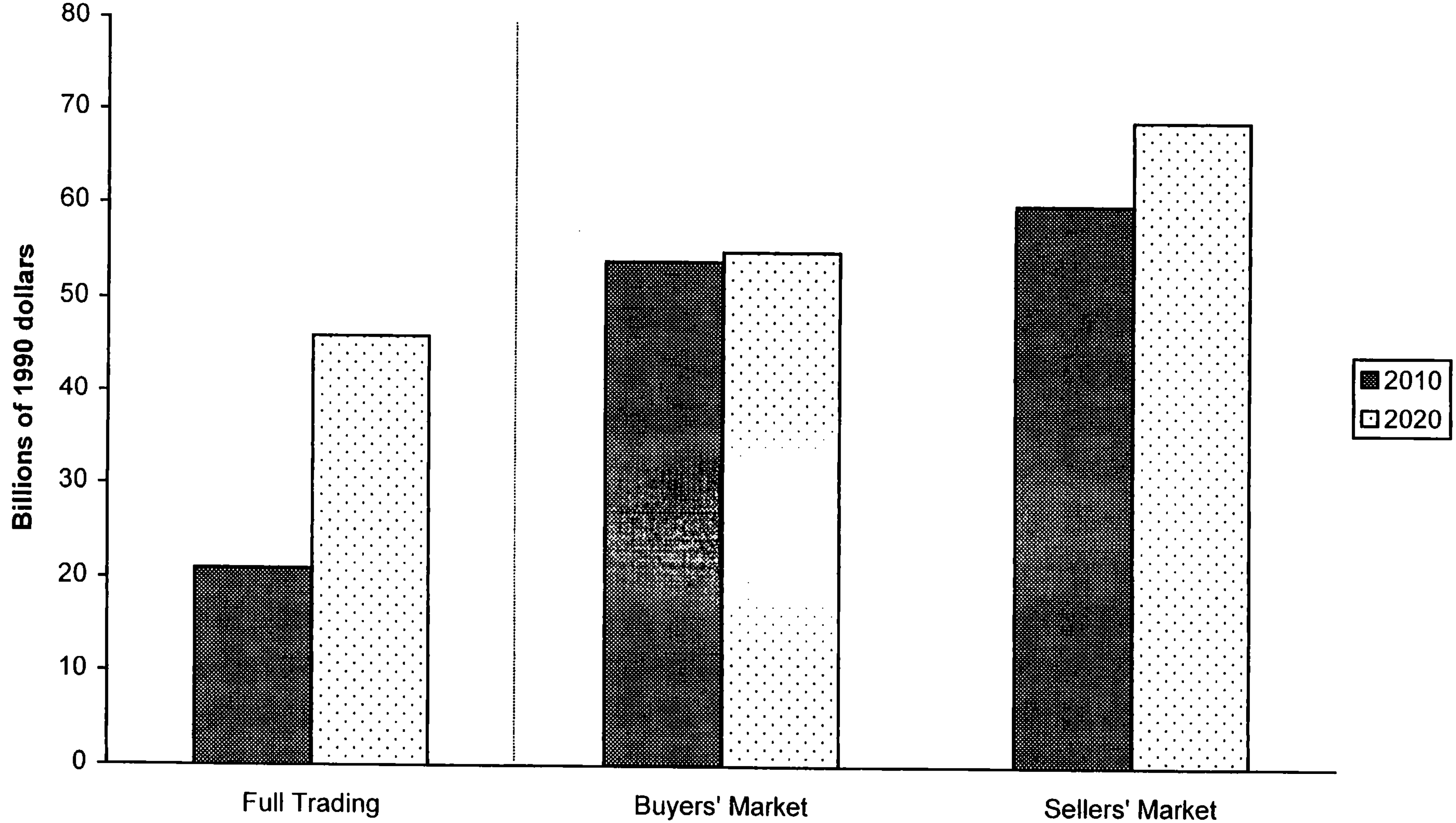


Figure 5.3 Annual US GDP Losses with Full Trading - Annex 1 May Satisfy Only One-Third of Obligation Through the Purchase of Emission Rights -- Kyoto Forever



the reductions in Annex 1 might be partially offset by increased emissions from China, India, Brazil and other countries that do *not* belong to Annex 1.

In this section, we examine the potential for leakage through international fuel markets and through the migration of energy-intensive industries. We therefore drop the assumption that non-Annex I countries are constrained to their reference case emissions. Two variants on the reference scenario are reported. In the first, the only trade impact of the Protocol consists of limiting the ability of the Annex 1 countries to import oil and gas. There is a lower international price of these goods, and there is a modest increase in price-induced demands by non-Annex 1 countries. However, there is no international trade in carbon emission rights, and there is no international migration of production within the energy-intensive sectors (EIS).

The second alternative is the same as the first, except that we now permit EIS trade. For a description of how the model has been modified to account for international trade in the energy-intensive sectors, see Appendix A. Figure 6.1 summarizes the overall results. According to this figure, neither of the two trade alternatives leads to a dramatic increase in carbon emissions outside Annex 1. Apparently there is an international leakage problem, but it appears to be of manageable dimensions.

Figure 6.2 suggests a somewhat different interpretation. Here we report the EIS trade scenario, and we compare the impact upon production-consumption ratios in each region. Under the reference case, these ratios are close to unity (the horizontal line) in most regions. The bars in Figure 6.2 show that the Protocol could lead to serious competitive problems for EIS producers in the USA, Japan and OECD Europe. The Protocol would lead to significant reductions in their output and employment, and there would be offsetting increases in regions with low energy costs. One can easily anticipate calls for protection against "unfair competition". In its present form, the Protocol could lead to acrimonious conflicts between those who advocate free international trade and those who advocate a low-carbon global environment.

7. Evaluating Kyoto in the context of the longer-term goal

The objective of the Framework Convention is "the stabilization of greenhouse gas concentrations at a level that would prevent dangerous anthropogenic interference with the climate system."[14] The drafters of the Protocol focused exclusively on the initial steps to be taken by Annex 1 countries. Little attention was paid to the ultimate goal. We now examine the Protocol in the context of a long-term stabilization objective.

From Figure 2.1 it is clear that the "Kyoto Forever" scenario will fail to stabilize global emissions and concentrations. A particular concentration target can be achieved through a variety of emission pathways. In this section, we explore three pathways for stabilizing concentrations at 550ppmv (twice preindustrial levels) by 2100. We stress, however, that the issue of what constitutes "dangerous interference" has yet to be determined. Indeed, it is likely to be the subject of intense scientific and political debate for decades to come. Hence, our choice of a target is meant to be purely illustrative.

Figure 6.1 Carbon Emissions Outside Annex 1 -- Alternative Leakage Scenarios

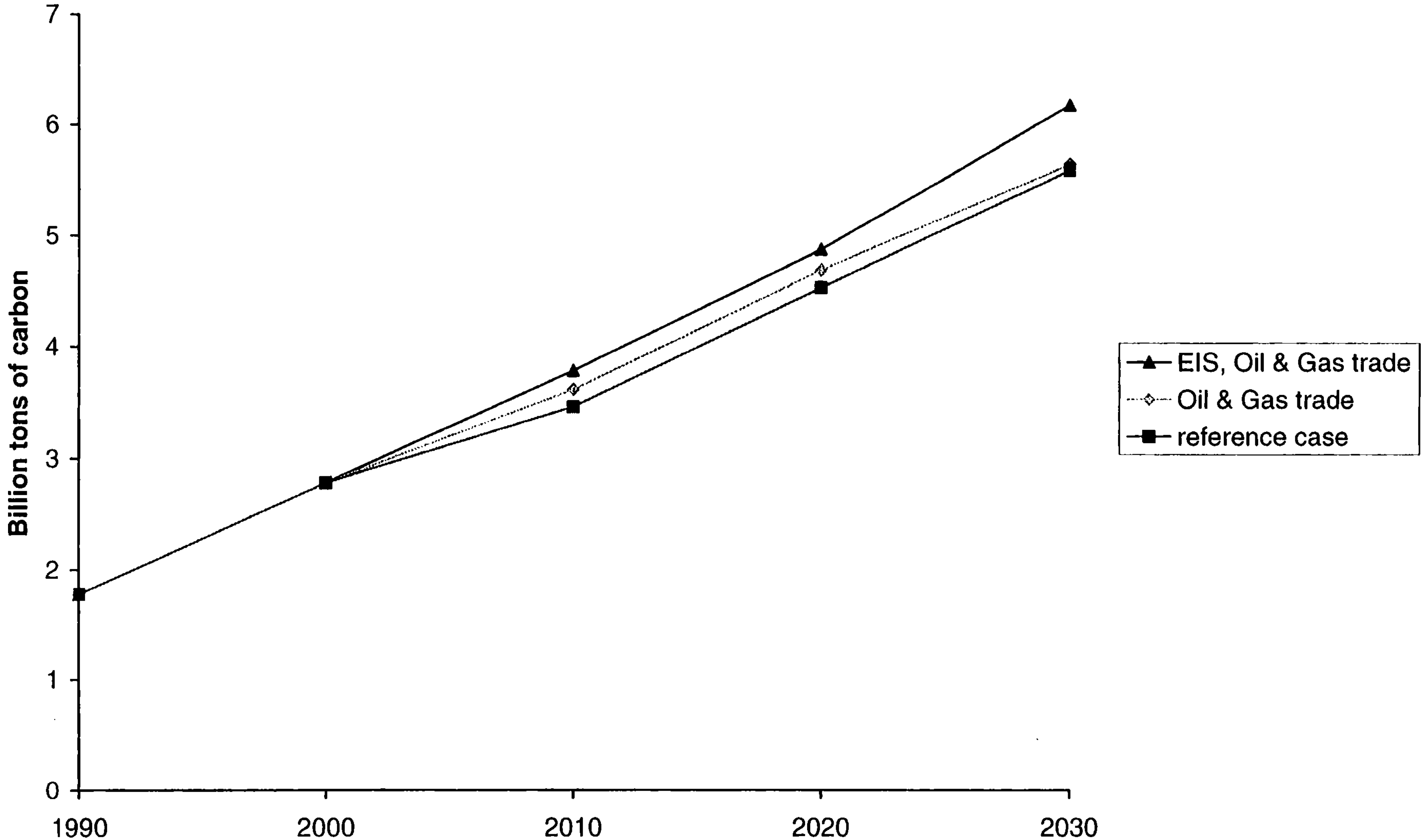
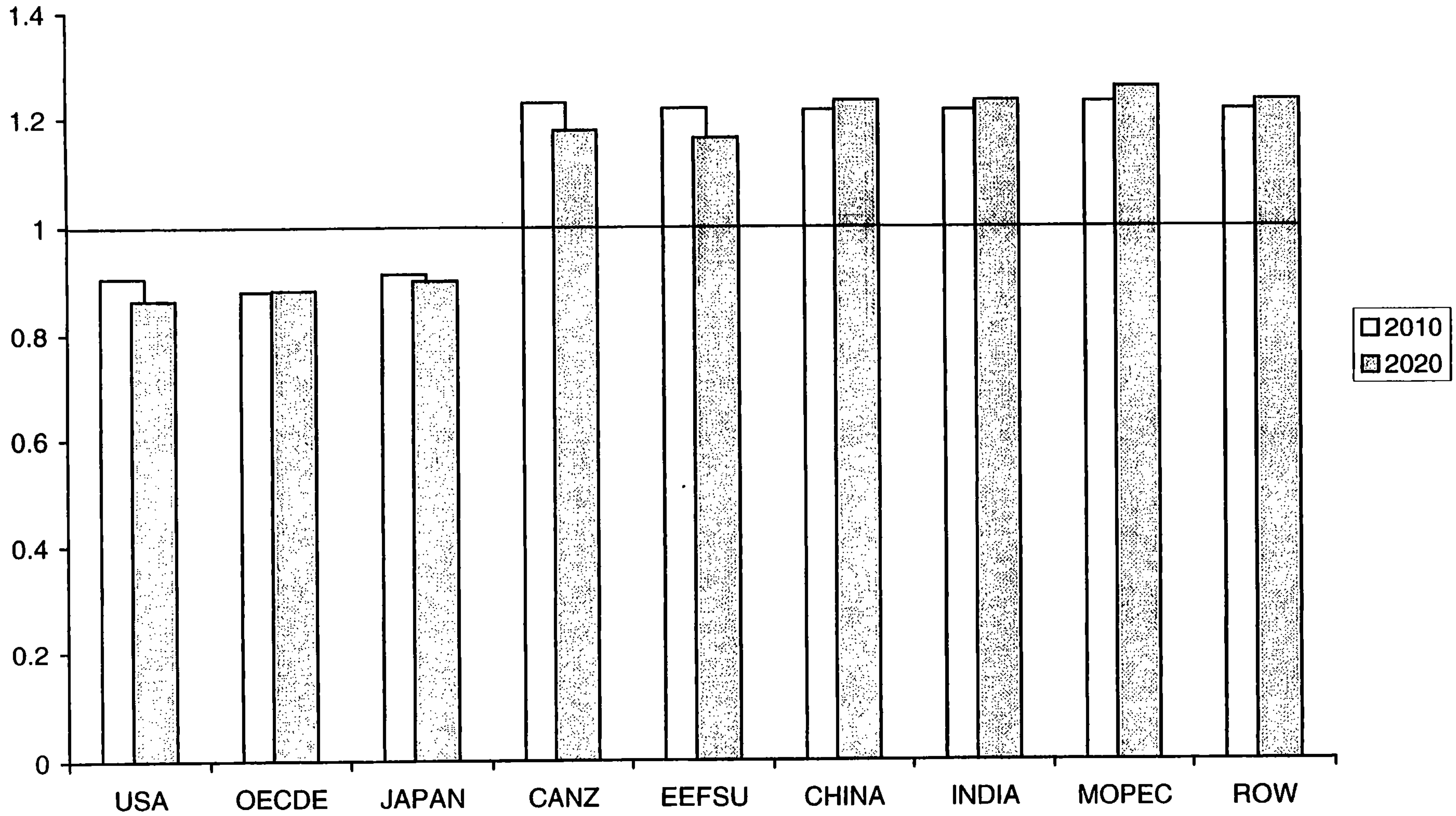


Figure 6.2 Ratios of Domestic EIS Supplies to Demands -- Kyoto with Leakage



Our three pathways are intended to illustrate the benefits of "when" flexibility. They are titled: 1) "Kyoto followed by arbitrary reductions"; 2) "Kyoto followed by least-cost"; and, 3) "least-cost". As their names imply, the first two are designed to be consistent with the Protocol during the first commitment period. The third assumes a clean slate in the choice of emissions pathway throughout the 21st century.

For the first scenario, we assume that Annex 1 countries reduce emissions through 2030 at the same rate as the OECD during the first decade of the 21st century (2% per year). During this period, non Annex-1 countries are permitted to emit up to their reference case levels. By 2020, emissions in the developing nations are larger than those in Annex I. We then choose a pathway to stabilization which represents a relatively smooth transition to the target. As for the post-2030 burden-sharing scheme, we assume that between 2030 and 2050 all regions move to equal per capita emission rights (based on their 1990 population). Equal per capita emission rights have been proposed as one approach to international fairness, but there are others that might also serve to separate the issue of equity from that of economic efficiency.

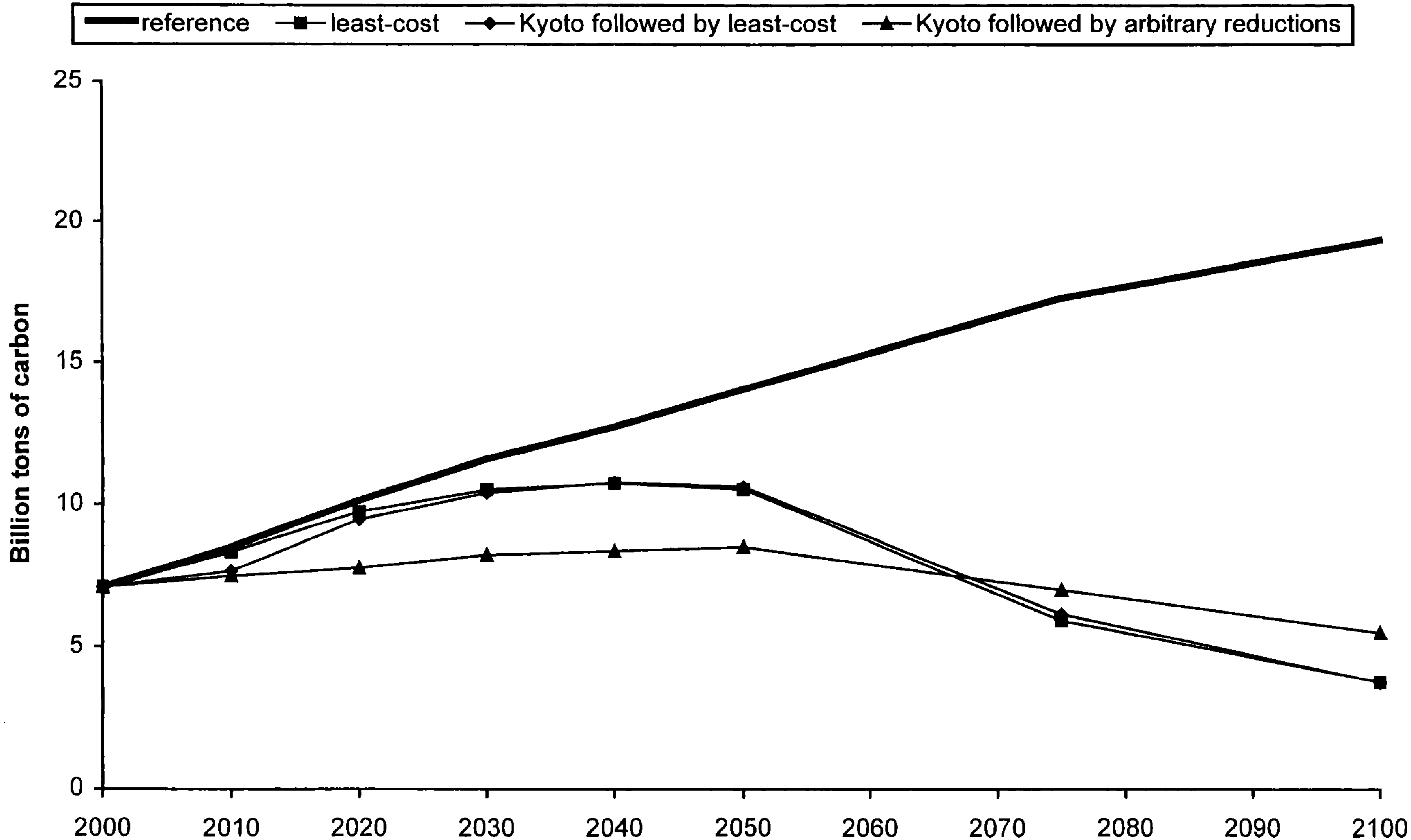
With "Kyoto followed by least-cost", the Protocol is adopted for the initial commitment period. Thereafter, the most cost-effective pathway is followed for stabilizing concentrations at 550ppmv. With "least-cost", the most cost-effective pathway for stabilizing concentrations at 550ppmv is followed from the outset. The latter two scenarios adopt the same proportionate burden-sharing scheme as the first.

All three scenarios assume Annex 1 trading plus the CDM. However, they differ as to the timing of developing country involvement in the international market for carbon emission rights. By definition, least-cost assumes that emission reductions will be made where it is cheapest to do so, regardless of the geographical location. Hence, in the least-cost scenario, we assume global emission trading from the outset. In the case of "Kyoto followed by least-cost", we assume that global emission trading is delayed until after the first commitment period. With "Kyoto followed by arbitrary reductions", global emission trading does not begin until 2030, the year that developing countries agree to lower their emissions below business-as-usual.

Global carbon emissions. Figure 7.1 shows global carbon emissions for the reference case and the three stabilization scenarios. Following a least-cost strategy from the outset results in an emissions pathway that tracks the reference path through 2010 and then departs at an increasing rate thereafter. There are several reasons why a gradual transition to a less carbon-intensive economy is preferable to one involving sharper near-term reductions.

Concentrations at a given point in time are determined more by cumulative, rather than year-by-year, emissions. Indeed, a concentration target defines an approximate carbon budget, i.e., an amount of carbon that can be emitted between now and the date at which the target is to be reached. At issue is the optimal allocation of the budget. Reasons for relying more heavily on the budget in the early years include: 1) providing more time for the economic turnover of existing plant and equipment, 2) providing more time to

Figure 7.1 Global Carbon Emissions -- Reference Case and Three Alternative Emission Pathways for Stabilizing Concentrations at 550ppmv



develop low-cost substitutes to carbon-intensive technologies, 3) providing more time to remove carbon from the atmosphere via the carbon cycle, and 4) the effect of time discounting on mitigation costs.[15]

We next turn to the two scenarios where we adopt the Protocol for the first commitment period. Notice that the two emission pathways behave quite differently post-2010. "Kyoto followed by least-cost" follows the least-cost pathway once the Protocol's constraints are relaxed. "Kyoto followed by arbitrary reductions", on the other hand, bears no resemblance to the least-cost pathway. What is striking about Figure 7.1 is that with a 550ppmv target, the Protocol is inconsistent with the most cost-effective mitigation pathway, i.e. "least-cost". Indeed, it appears that the ultimate target would have to be considerably lower than 550ppmv for the Protocol to be justified in terms of cost-effectiveness.

Near-term losses. It is instructive to look at the incremental value of emission rights for the three stabilization scenarios (Figure 7.2). With the least-cost path, the value is relatively low in the early years ($11 per ton of carbon in 2010), and it rises gradually over time. With "Kyoto followed by least-cost", the value is $130 per ton in 2010 and then tracks the least-cost path thereafter. In the case labeled "Kyoto followed by arbitrary reductions", the incremental value of emission rights starts at about $160 per ton and it remains high.

Figure 7.3 shows US GDP losses in 2010 and 2020 under the three stabilization scenarios. Notice that GDP losses in 2010 differ for the two scenarios involving the initial adoption of the Protocol Because of the long-lived nature of energy investments, investors are concerned both with what happens in the initial commitment period and what happens thereafter. In the case of the more rapid transition away from the baseline ("Kyoto followed by arbitrary reductions"), investors will be forced to invest more heavily in high–cost substitutes in the early years. With "Kyoto followed by least-cost", they will have more flexibility.

It is striking by how much GDP losses can be lowered under the "least-cost" scenario. This strategy involves a more gradual transition away from the baseline in the early years. It relieves much of the pressure for premature retirement of existing plant and equipment and for dependence on high-cost substitutes (both on the supply- and demand-sides of the energy sector). Relative to the reference case, the US also receives some benefits as an oil importer. Recall that a carbon constraint decreases the overall demand for oil and lowers its price on the international market.

Global losses. Finally, it is instructive to examine losses from a global perspective (Figure 7.4). For purposes of the present comparison, we focus on the present value of consumption losses over the 21st century discounted to 1990 at 5 percent. The relative magnitude of the cumulative losses for the three stabilization scenarios comes as no surprise given the previous discussion. "Kyoto followed by arbitrary reductions" is by far the most expensive of the three paths. "Kyoto followed by least-cost" is a considerable

Figure 7.2 Incremental Value of Carbon Emission Rights under Three Alternative Emission Pathways for Stabilizing Concentrations at 550ppmv -- Global Trading

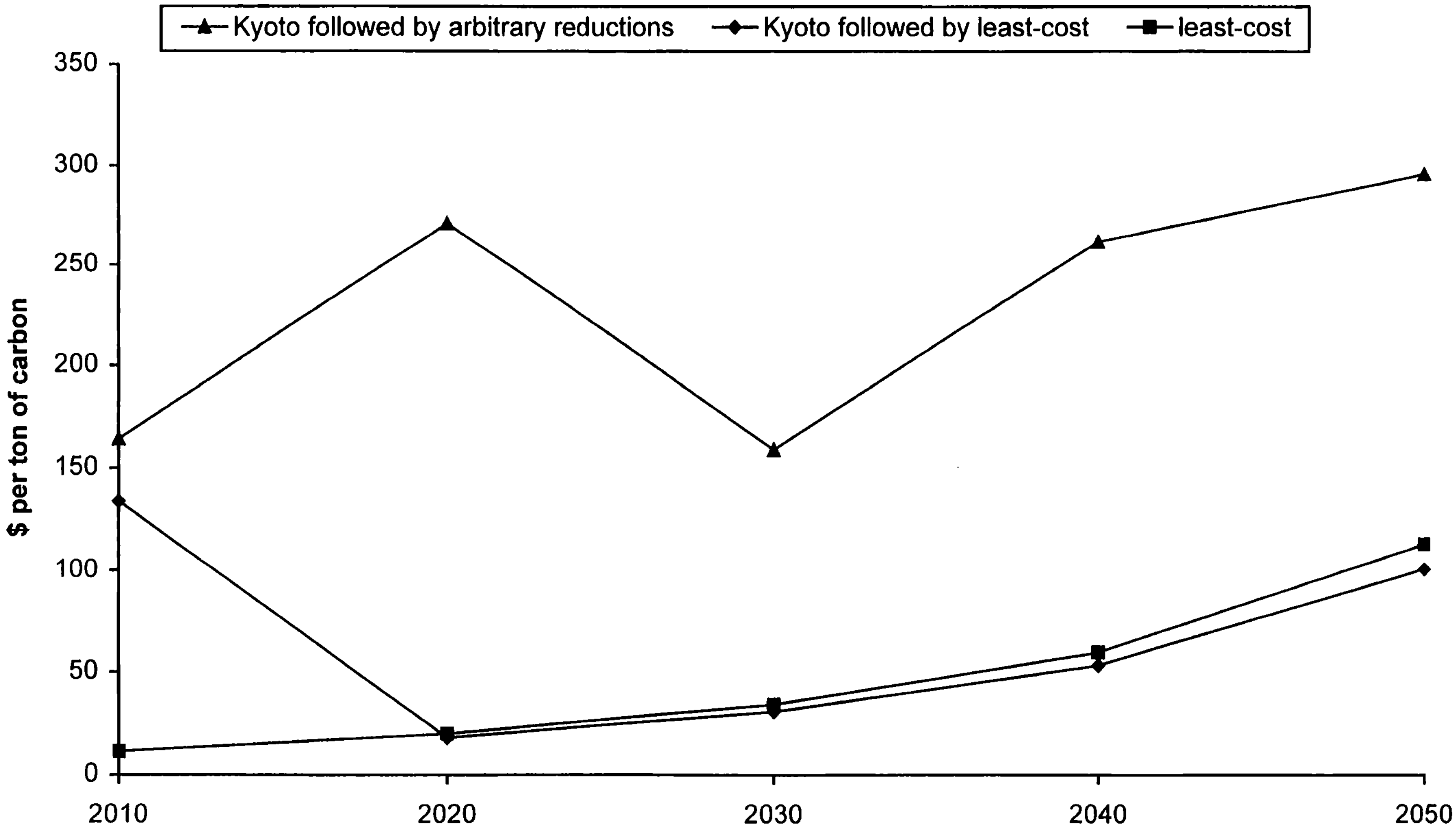


Figure 7.3 US GDP Losses Under Alternative 550ppmv Stabilization Scenarios

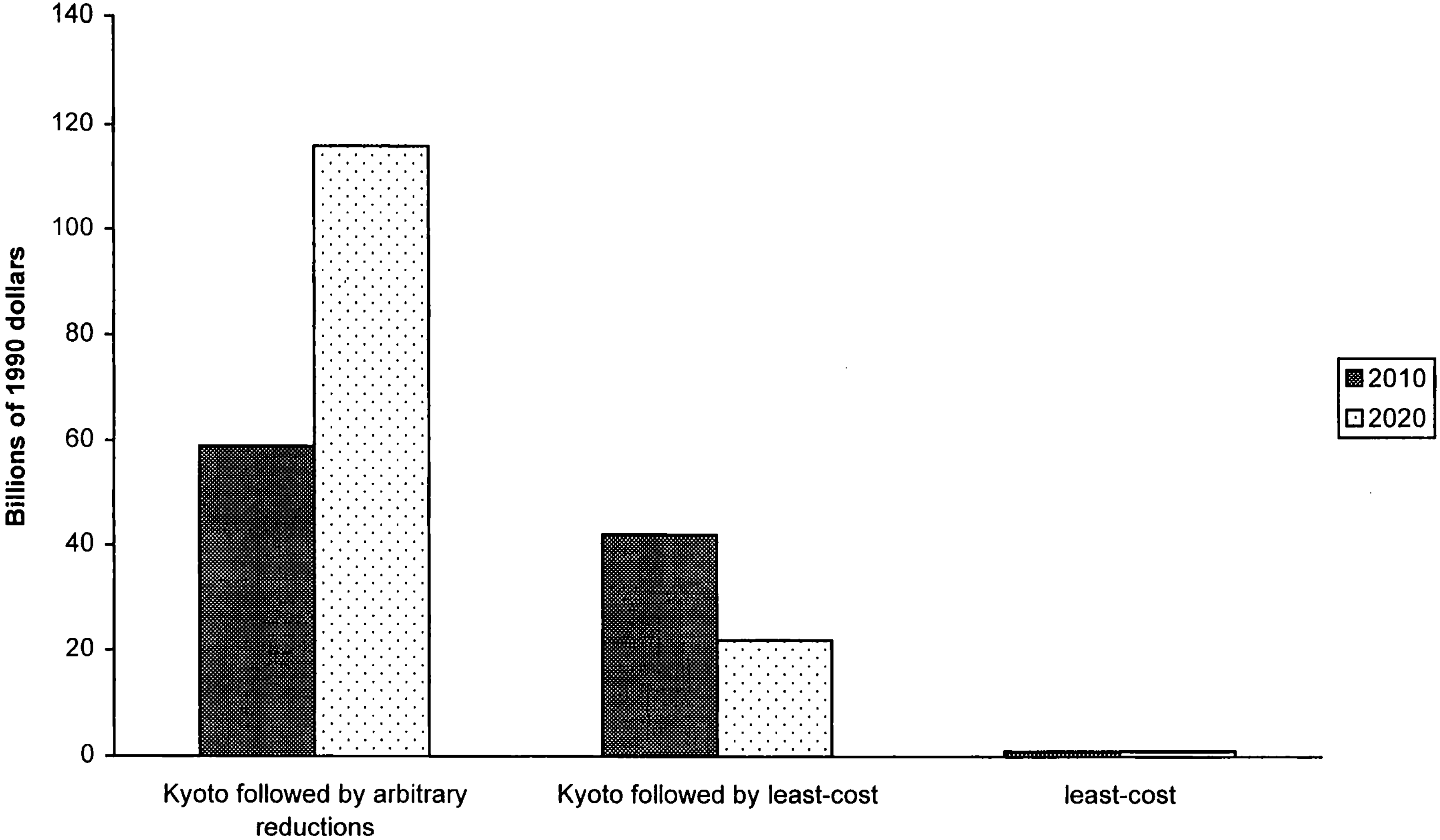
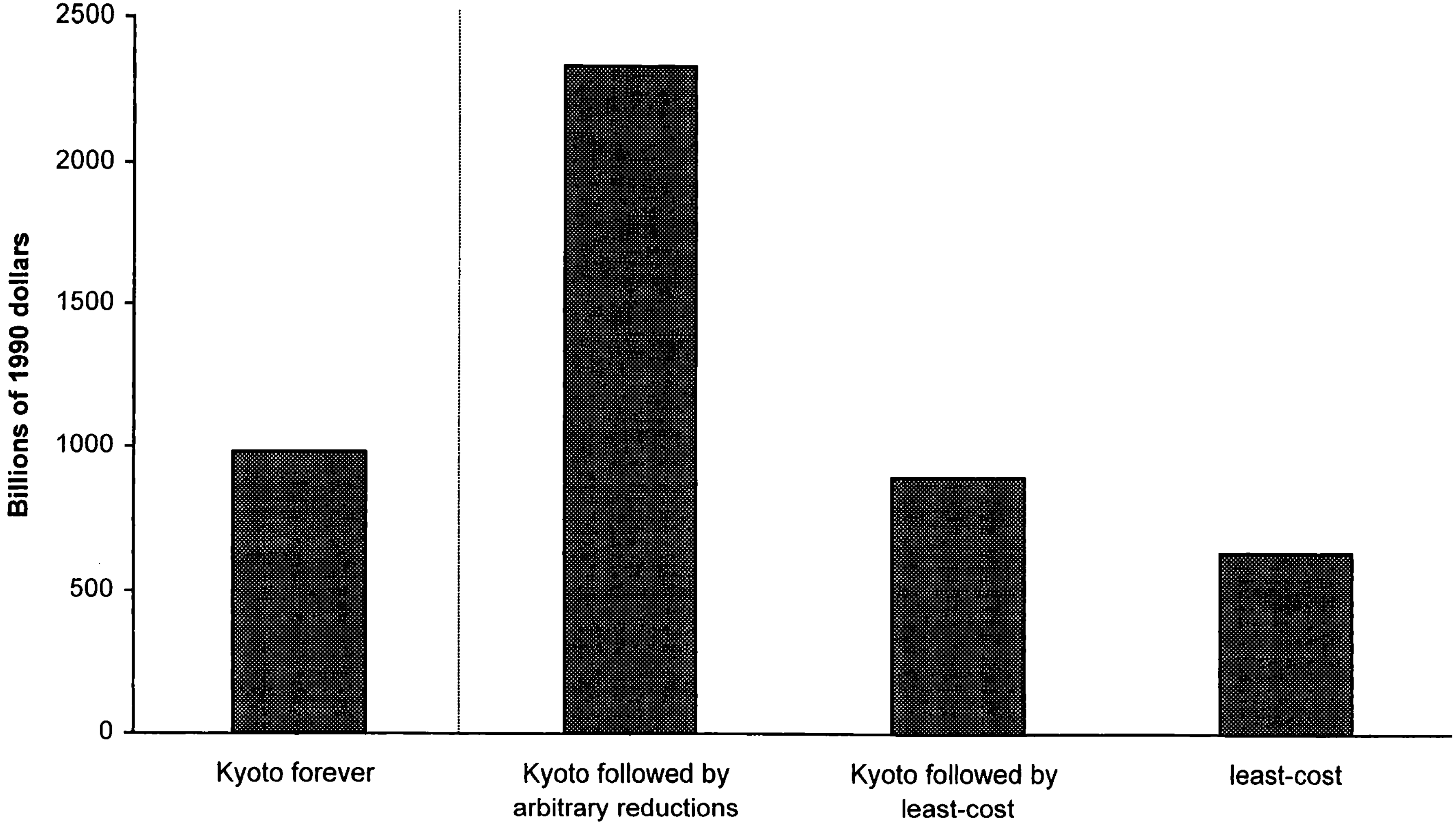


Figure 7.4 Global Consumption Losses through 2100 Discounted to 1990 at 5% -- Kyoto Forever vs. Three Scenarios for Stabilizing Concentrations at 550ppmv



improvement, but is still 40% more expensive than embarking on the most cost-effective mitigation pathway from the outset.

What is surprising is that "Kyoto Forever" turns out to be more expensive than "Kyoto followed by least cost" or "least cost". "Kyoto Forever" results in sharper global emission reductions during the early decades of the 21st century. It does not, however, succeed in stabilizing emissions, much less concentrations. By contrast, the other scenarios all lead to stabilization at 550ppmv. In other words, "Kyoto Forever" ends up costing more, and it buys less long-term protection.

8. Further comments

Some suggest that models such as MERGE tend to *overestimate* the costs of mitigation. They argue that, when prospects for technical progress are incorporated, the costs of a carbon constraint, even a sharp near-term constraint, will be minimal. We, too, are optimistic about the outlook for technical innovation. Indeed, such innovation is embedded both in our reference case and in the policy scenarios. The disagreement is over the rate at which such progress will occur. We do not believe that economically competitive substitutes will become available at such a rate as to trivialize the costs of a Kyoto-like Protocol.

A more valid concern may be that we are *underestimating* the costs of a carbon constraint. There are several reasons why this may be the case. To begin with, optimization models assume that decision makers have perfect foresight. That is, they assume that investors are fully informed about the nature of future constraints, and act accordingly. Given the present state of uncertainty, this is highly unlikely. Models such as MERGE also tend to ignore short-term macro shocks. For example, the higher energy prices brought about by a carbon constraint are likely to be inflationary. If this leads to higher interest rates, investment may be dampened. The result would be a slowdown in economic growth.

In addition, we assume that policies will be efficient. That is, market mechanisms will be chosen over "command and control" approaches to accomplishing environmental objectives. Whereas, in recent years, there has been an increasing trend toward market mechanisms, the approach to be taken with climate policy is by no means assured. Moreover, even if such a commitment were made, we have no assurances that the requisite international institutions will be available when needed.

Although it is easy to quibble over the numbers, the real value of analyses lies more in insights than in numerical values. And, indeed we believe that the current exercise has yielded several insights that may be of value to those charged with interpreting the current proposal. Here, we summarize what we have learned:

- First, it is extremely unlikely that a "Kyoto Forever" scenario will stabilize emissions -- much less concentrations. Non-Annex 1 emissions are quickly overtaking those of the OECD and the economies in transition. Hence, meeting the stabilization goal of the Framework Convention will eventually require the participation of developing countries.

- International cooperation through trade in emission rights is essential if we are to reduce mitigation costs. The magnitude of the savings will depend on several factors. These include the number of countries participating in the trading market, the shape of each country's marginal abatement cost curve, and the extent to which buyers can satisfy their obligation through the purchase of emission rights.

- With regard to the latter, limitations on the purchase of emission rights may be especially costly. In the example explored here, limiting purchases to one-third of a country's obligation increased GDP losses by a factor of at least two and one-half in the year 2010. If proponents of such limitations are successful, they may seriously reduce the benefits from "where" flexibility.

- The issue of monopoly power in markets for emission rights may turn out to be important. This is most likely to occur if trading is limited to Annex 1 and the majority of inexpensive emission rights are concentrated in a small number of countries. If these countries were successful in organizing a sellers' cartel, they might be able to extract sizable rents.

- The near-term costs of the Protocol will depend on expectations regarding the future. Energy investments are typically long-lived. Today's investment decisions are not only influenced by what happens during the next decade, but also by what happens thereafter. Hence, analyses which focus solely on 2010 may be underestimating the costs of Kyoto.

- Finally, and perhaps most importantly, unless the concentration target for CO2 is well below 550ppmv, the Protocol appears to be inconsistent with a cost-effective long-term strategy for stabilizing CO2 concentrations. Rather than requiring sharp near-term reductions, it appears that a more sensible strategy would be to make the transition at the point of capital stock turnover. This would eliminate the need for premature retirement of existing plant and equipment and would provide the time that is needed to develop low-cost, low-carbon substitutes.

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Appendix A. Modeling international trade in the energy-intensive sectors

MERGE 3.0 has recently been modified to include the possibility of trade in EIS (energy-intensive sectors). EIS is an aggregate including ferrous and non-ferrous metals, chemicals, nonmetallic minerals, paper, pulp and print. This aggregate does not include the energy-intensive industry of petroleum refining. The model may be run either with or without EIS trade.

The new feature is introduced in a way that preserves the basic simplifying characteristics of the ETA-MACRO submodel. That is, energy, capital and labor are substitutes that enter into an aggregate production function. They produce a numeraire good which may be used for consumption, investment and interindustry payments for energy costs.

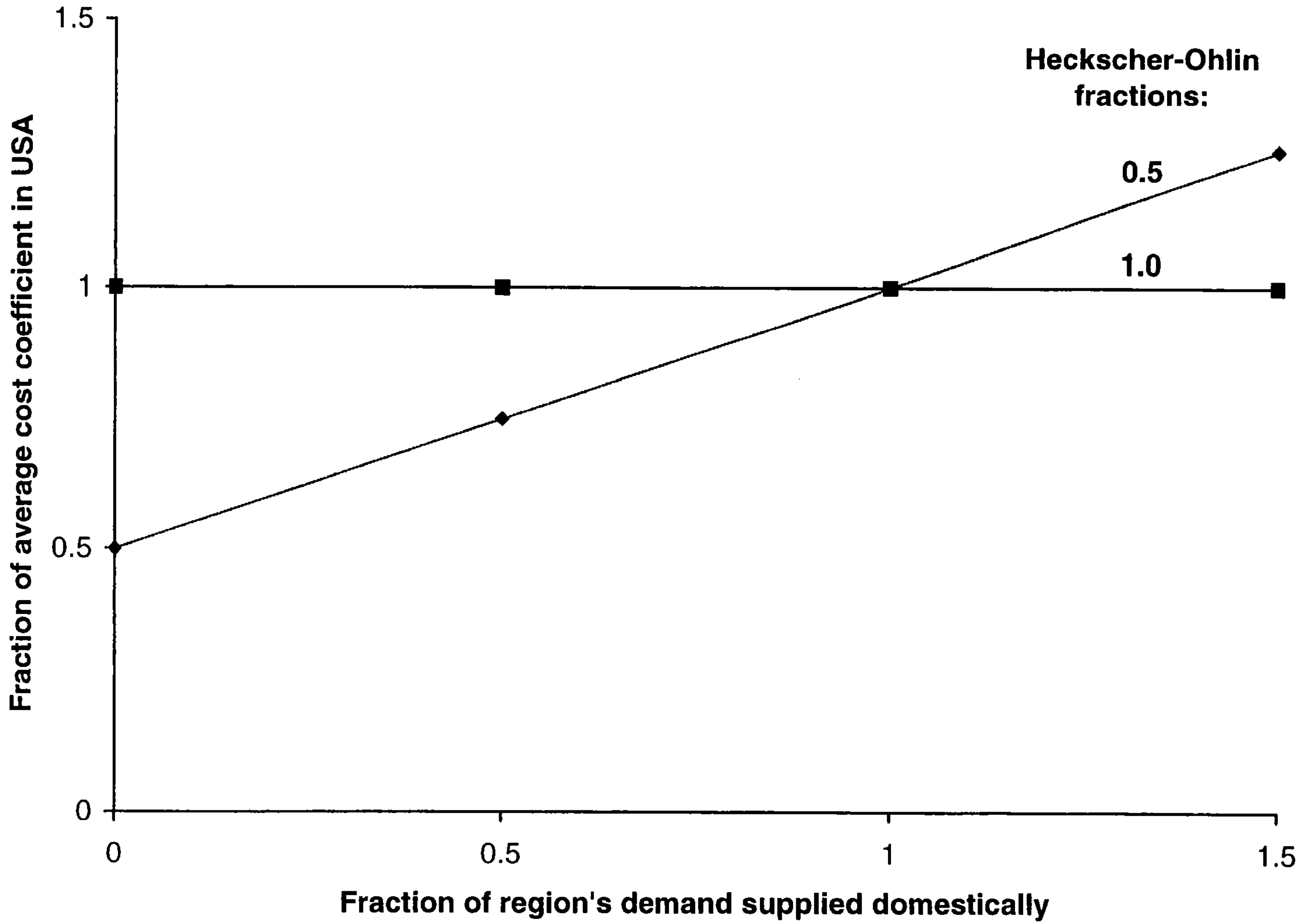
It is assumed that trade will continue to represent a relatively small amount of each region's total internal demand for EIS. The GTAP (General Trade Analysis Program, 1992) data base is employed to estimate each region's EIS demands. In all other respects, the model is the same as MERGE 3.0.

For projecting the impact of the Kyoto protocol, each region is taken to be self-sufficient at base year energy prices. Changes in the location of production are attributed primarily to changes in the cost of energy. At base year prices in the USA, 85% of the cost of EIS consisted of non-energy inputs (labor, shipping, capital, iron ore, etc.), and 15% of the cost consisted of energy inputs (half electric and half non-electric). Under these conditions, a doubling of energy prices would imply only a 15% increase in the cost of EIS. This is why it is assumed that the demand for EIS is inelastic with respect to the price of energy. For projecting future demands, the income elasticity is taken to be 0.5.

For modeling purposes, we have supposed that the marginal supplies of EIS in all regions are determined by the same international technology that prevails in the USA. Each region has the same energy-EIS production ratio. For non-energy inputs, each supply curve is linear. Its positive slope serves the same purpose as an Armington elasticity describing substitution between foreign and domestic goods. This is the way in which we avoid penny-switching as a characteristic solution mode.

The slope of the non-energy supply curve is described as a Heckscher-Ohlin fraction. If this fraction is unity, EIS is viewed as a perfectly homogeneous commodity. Small changes in energy costs will then lead to large changes in the international location of production. If this fraction is less than unity, the supply function is less elastic, and the changes in location will be less dramatic. (See Figure A.1.)

Figure A.1 EIS Supply Curves --
Marginal Cost of Non-Energy Inputs to EIS



Obstacles to Global CO_2 Trading: A Familiar Problem

Paper

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Obstacles to Global CO_2 Trading: A Familiar Problem

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Executive Summary*

There are many obstacles to the development of an international CO_2 emissions trading system, but the biggest is a feature that is often assumed: the existence of a single national system. Once a national system is in place, an international system will develop naturally more as a matter of self-interested trade than as a matter of international agreement.

Meeting the Kyoto targets will create a scarcity; and the scarcity requires that use and the associated rent be allocated somehow. This allocation—deciding who gets what—is a familiar problem and the largest impediment to the creation of a national system, and thus of an international regime of CO_2 emissions trading. This paper reviews the various instruments by which the Kyoto target might be met from the standpoint of the allocation of the scarce use and the associated rent. In particular, the paper emphasizes that existing users will largely continue to use the scarce resource and that they now actively exercise the incipient right to the proposed scarcity. Creation of the scarcity and the allocation of rights raise fundamental issues of equity that lie preeminently in the political realm. The author observes that the creation of the scarcity and the allocation of rights are fused and that agreement on one will occur only as there is agreement on the other. Nevertheless, such problems have been solved before—for land and for SO_2 permits—although in both cases the conditions were easier than what is now proposed for CO_2.

An international CO_2 trading system will develop from a national allowance system for the same reasons that trading can be expected to occur domestically. However, the unavoidable requirement of certification and verification will impede access to non-Annex B sources of emission reduction, and at the same time encourage countries with such sources to accept Annex B limits. The negotiation of such limits raises the same problems of allocation as faced at the national level, only on a global scale; and there is even less agreement here. Nevertheless, the discussion on global allocation will not begin in earnest until a national system creates the trade opportunities that will make an Annex B limit worth pursuing. The development of an international system for CO_2 emissions trading should not be expected to be either quick or easy, but to occur only by accretion and mostly as a matter of self-interested trade.

*Prepared for a symposium entitled *Climate Change Policy: Practical Strategies to Promote Economic Growth and Environmental Quality*, sponsored by the American Council for Capital Formation Center for Policy Research, September 23, 1998, at the National Press Club in Washington, D.C.

OBSTACLES TO GLOBAL CO_2 TRADING:

A FAMILIAR PROBLEM

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INTRODUCTION

Global trading in CO_2 emissions appeals to us for two reasons. Our experience with Title IV has demonstrated that tradable permits are an efficient means of meeting both environmental and economic goals.[1] We could drop the global, and we would still want to use tradable permits to meet any given CO_2 emissions target. But the global dimension makes the use of tradable permits doubly appealing. Cheaper emission reductions lie abroad so that the cost of meeting any domestic target would be much less if these cheaper reductions could be substituted for what would otherwise be required domestically.[2] Global emissions trading provides the mechanism to effect that substitution.

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[1] Schmalensee *et. al.* (1998) provide a quick summary of the essential features of the initial experience with emissions trading under the U.S. Acid Rain Program.

[2] This point was emphasized in the testimony of the chairman of the Council of Economic Advisors, Janet Yellen, and illustrated in the recently released supporting analysis (USG/EOB, 1998). Other models of global emissions and economic cost arrive at similar conclusions, when comparable assumptions are made.

Given the apparently large savings from global trading, it seems appropriate to examine what are the obstacles that stand in the way of realizing this potential. The temptation is to set to work on the details of an international regime for greenhouse gas (GHG) emissions trading, that would include CO_2. These details are, to use the words of my respondent, David Harrison, daunting. They are addressed very well in an earlier paper of his, as well as by an excellent UNCTAD draft that is now circulating. (Harrison, 1997; UNCTAD, 1998) I am not going to take issue with anything in these studies, because I agree very largely with the analysis presented therein.

Still, it is easy to overlook an important but unspoken assumption in these studies focused on the international details: an emissions trading system at the national level. As important as it is to get the details of an international regime right, the chief obstacle to the creation of a global system of tradable CO_2 permits is at least one functioning national system. To put the argument pithily, the greatest challenge lies at home; and, assuming that we are decided to implement such a system, the biggest obstacle is a crassly familiar one: deciding who gets the rent from the scarcity thus created.

In fact, the problems of creating a national system may be even more daunting than the details of an international trading system. For what has been heretofore free will be made scarce; and scarcity presents any society with a problem of how to allocate the use and the associated rent for the scarce thing. As I will attempt to explain, this problem of domestic allocation is a difficult but not impossible task. Some attempts are being made to address the issue openly, in particular the about-to-be-released Heinz Center study. It is one of those tasks that determine whether we are really serious or not.

A corollary proposition is that, once a national system is in place, an international system will develop more or less naturally, not so much as the result of global agreement, but as a matter of self-interested trade. Still, to realize the full potential of global trading, we will eventually have to confront the same problem, but on a grander scale, of determining who has a right to the rents created by this global scarcity.[3]

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[3] Heather Ross has recently published a feature on the RFF Weathervane emphasizing the centrality of this issue (Ross 1998).

In order to move the argument along, I am going to make two assumptions that I will not seek to justify, but which are necessary to focus on the main problem. The first is that the targets agreed to at Kyoto are more than aspirational goals toward which all parties will endeavor. A showing of sufficient good works or other manifestations of earnest and well-intentioned effort will not be enough to constitute compliance; achieving the target will be the only thing that counts. The second assumption is implied by the subject assigned to me, namely, that a cap-and-trade system will be put in place. Given the uncertainty of economic growth rates, fuel use trends and technological change, it hard to see how the quantitative goal established in Kyoto would be achieved otherwise, and how other Annex B parties could expect to meet their goals efficiently without such a system.

Two points will be discussed in the remainder of the paper. The first is a discussion of what is involved in allocating the use and the associated rent of the newly scarce resource. The second is how a national tradable permit system would evolve into global emissions trading.

THE PROBLEM OF ALLOCATION

A national cap, such as is suggested by the Kyoto targets for Annex B parties, is most usefully seen as each party's current allocation of the capacity of the earth's atmosphere to act as a repository for greenhouse gas emissions. We may debate whether there is a limit on that capacity, and if there is, what it is; but we should recognize that the underlying premise of all proposals to take action is that there is such a limit.

This capacity has become a concern, not because we have been heretofore morally obtuse, but because the scope of human activity has expanded so much. Defining the problem as one of emerging scarcity implicitly asserts that the problem is not one of limiting a socially undesirable activity, as is the case with tobacco, for example. This distinction is a subtle one, since both motivations seek to limit use, but it is fundamental. One needs only to ask whether the objective is to eliminate use of what is being limited. The impositions placed upon smokers do not reflect any underlying scarcity, and most people would not care if the strictures against tobacco were to lead to no smoking at all. On the whole, it would be hard to argue that society would be much changed. The argument is quite different with respect to energy. Aside from a few romantics, very few find the notion of a world without the forms of energy associated with the industrial age to be appealing. Society would be very different without these forms of energy, whereas the same cannot be said for tobacco.

Allocation of the rights to the scarce resource can be split into two aspects: the use of the resource and the receipt of the rent attached to that use. The two are often combined, but they need not be. One of the advantages of permit trading systems is that the two can be separated practically as well as analytically. In principle, all would agree that the newly limited sink should be reserved for the most highly valued uses, although there might be some disagreement about what those uses are. At an earlier time, we had sufficient faith in the government's ability to decide such issues that we rationed use administratively, as for example during the Second World War. Now, we trust markets so that the answer, particularly by economists, would be that the requisite number of rights to the use of the sink should be auctioned off as tradable permits. In this manner, those valuing continued use most highly, and only those, would have access.

An auction of these rights raises an issue that ought not to be one but is: what to do with the revenue. There is a rich literature on this subject, and some very appealing arguments on how the revenue might be recycled optimally. There are, however, two problems. First, belief in the government's ability to distribute the rents optimally is no greater than the belief in the government's ability to allocate use, which is the reason for the auction in the first place. As such, auctioning the permits takes on the appearance of a disguised tax. The second and more fundamental problem is the assumption that the government owns the rights that are to be auctioned. The inconvenient fact is that these incipient rights are possessed *de facto* by existing emitters and actively exercised by them. From their point of view, the auction is not just a tax in disguise, it is confiscation of rights established by time-hallowed use.

Now if our government were little more than some invading horde that took what it wanted by force and defined the terms by which nearly everything of value was used, none of this would be a problem. But that is not the case. Those who possess the incipient rights, the squatters if you will, are part of society and they have voice. They know that their interests will not necessarily be improved by the actions being proposed, and they can be expected to assert those interests. At the very least, in a society that seeks to be just and equitable in dealing with its citizens, they have a legitimate claim to compensation.

With respect to the use of the now scarce resource (and without yet addressing the rent), it is evident that those who will use the sink after limits are imposed are very largely those who were using it before, albeit in less quantity. Conventional command-and-control regulation allocates such use explicitly to existing users, and typically imposes a more stringent standard on new entrants. With grand-fathered permits, use is also allocated to existing users, but the recipients are not required to use all or only the permits distributed to them. With taxes and auctioned permits, those who pay the taxes or who bid successfully for the permits, and thereby earn the right to use the now limited sink, will be mostly existing users.

Turning now to the rent associated with use, it is also evident that, if there is strong sentiment to limit the right, and even if existing users are opposed to the limit, a deal can be and will be struck. The deal that can be struck is one in which the rights are limited, but given to the existing users, either through conventional command-and-control regulation or through grand-fathered permits. As a matter of political economy, taxes and auctioned permits lose out, unless there is overwhelming consensus to take action and the adversely affected existing users are poorly organized. When the right is allocated by grandfathered permits, the grant of the rent is very explicit, and for this reason there is often objection to this arrangement. In contrast, there appears to be no grant of the rent in the regulatory form, but that is not quite the case. It is not as explicit and it may not be as secure, but it is still there, just well-hidden. It shows up in the value of the asset that has been granted the right to use the now-limited resource.

Despite the political appeal of command-and-control regulation in hiding the rent, we seem to have come to the point where we regard this form of regulation as too inefficient to be considered seriously. It is inefficient precisely because the inseparability of use and rent impedes the mobility of resources. Thus, grand-fathered permits alone seem to combine efficient allocation of use to the highest value with the politically expedient granting of the rents to existing sources. The rent is obvious, however, and it will be charged to consumers. It is not clear that consumers are any more willing to pay equivalent charges to the local utilities or multinational oil companies than they are to pay taxes to Uncle Sam.

For one thing, payment of the rent to existing users lends itself easily to the demagoguery that already rich corporations will be further enriched. It is not at all clear that corporate profits would be higher since charging for the use of the permit will reduce demand. As such, the rent can be seen as compensation. Nevertheless, when compared to the effect of an equivalent tax, the rent from the permit will improve corporate profits, but from a societal standpoint, that is not the end of it. Since the corporation is a shell, the revenue will be recycled in some combination of taxes, investment and dividends. A third goes to the government in any case, hopefully to be optimally recycled. The new set of prices will create an incentive to retool the capital stock to be less carbon-using, and the increment of revenue will make the financing of such investment easier, perhaps reducing what would otherwise would likely be a demand for tax credits. Dividends and appreciated stock values will benefit stock-holders, but with the role of mutual funds, private retirement accounts, and pension funds in modern American society, such a distribution may not be as inequitable as it might first sound, or what the government might accomplish if it had all the rent. In fact, an interesting test suggests itself: will the government recycle its third as efficiently and equitably as the two-thirds that would remain with corporations?

Another charge that has always to be dealt with when allocating grand-fathered permits is that a barrier to entry is created. Potential new entrants are understandably upset that the existing parties with whom they must compete would enjoy any advantage, but the important issue is whether the grant affects decisions at the margin. Typically, it does not; it is a lump sum transfer that will be welcomed by any party and that will have little if any influence on the marginal decisions of existing users or new entrants. Nevertheless, potential new entrants are one of the political complications, even if their claims are nothing more than disguised entreaties for their share.

The seriousness with which the claims of new entrants are taken does indicate acceptance of the principle that private parties should receive the rent. It is however only an introduction to an even more difficult problem: who along the vertical chain of existing use has the superior claim to the right? Take the automobile for instance. Do the rights to the use of carbon reside in the fuel, or in the car? Or for that matter, with the driver? The same could be said of powerplants? Do coal producers have the right to produce carbon, or do electric utilities have the right to emit CO_2 ?

Where the carbon will be monitored along that vertical chain will have a strong influence on who gets the permits, but it need not be so. In the SO_2 program, the monitoring and the distribution of permits occur at the same point in the vertical chain, the powerplant. If transactions cost are negligible, then the permits could be distributed elsewhere and the powerplant operator would manage to acquire the requisite number of permits. The charge to the consumer would be the same, but the payments would be different. The owner of the powerplant whose value has been diminished by the limit has not been compensated, but the powerplant is not the only asset along the vertical chain of existing use that may have a claim. The assets of coal producers will be affected by the new set of prices; and the same claim could be made for downstream assets, even for any consumer assets that were premised on the former set of prices.

Although the problem of allocation is difficult, it is not insoluble. It has been done before; however, the conditions were easier. In the case of Title IV, the recipients of the rents, electric utilities, were presumed to be subject to cost-based regulation. Thus, the rent associated with the grand-fathered permits would be passed on to rate-payers. Since nearly everyone uses electricity, this was a pretty broadly defined group. Still, there were many deviations from the initial principles of Title IV allowance allocations, that can be seen as successful rent-seeking, but the cost-based regulation permitted the utilities to argue that they were acting as agents of rate-payers.[4] It will not be possible to make similar arguments for CO_2 allowances. The generation of electricity is being effectively deregulated, and the other prospective recipients, oil companies, natural gas

[4] Joskow and Schmalensee (1998) provide a good discussion of the departures.

pipelines, large industrial users are not regulated either. As a result, the rents will be as transparent as taxes are, but not necessarily any more politically acceptable.

The other precedent for allocation of the atmospheric sink is land. Land is a God-given resource made more scarce by increasing human and economic activity, not unlike the earth's atmosphere. It just became scarce a lot sooner. The history of establishing and perfecting the title to land is long and convoluted, but not an inappropriate one. Notably, in our society and most industrialized societies, no one today questions private ownership of this limited resource, even though all of us need a patch of land to call home; and any entitlement we may receive comes through private inheritance, not from the state. Although there surely was an original recipient of the right to this land, now lost in the shrouds of history, no one seems to care.

Although there was some controversy about the initial assignment of title in land, that controversy was damped by the gradual emergence of the scarcity. One might marvel today at the terms by which titles to mid-town Manhattan were distributed to some 17th century Dutchmen but the wonder arises from the value today, not then. It would be absolutely impossible to attempt to distribute such title today, but at the time, the value was such that there would have been little to no controversy, and probably active encouragement of assuming such title.

In contrast, the scarcity that is implied by the Kyoto targets is significant, on the order of 30% of 2010 emissions. Such bold action is appealing politically, but it gets in the way of practical solutions by creating sizeable rents that are worth fighting over. The allocation would be much less contentious if scarcity were to be created only gradually, so that discounting of future costs would dampen the present value of the rent.

My point in making these distinctions is not to argue for any particular way of allocating the rents, but to emphasize the complexity of the problem that will be faced in setting up one functioning national system of tradable permits. Creating a scarcity, such as is implied by the Kyoto targets, raises fundamental issues of equity and the definition of rights, which are pre-eminently of the political realm. In fact, creation of the scarcity and allocation of the rights and rents can be separated only analytically. In practice, the two are fused and there will likely be agreement on the creation of the scarcity only as there is agreement on the allocation of the rents thereby created.

EVOLVING INTO AN INTERNATIONAL SYSTEM

The evolution of a national system into a global system is most easily described as a matter of trade. When the thing being traded can be produced abroad as cheaply as it can be at home, we can anticipate that trade will develop across national boundaries for the same reasons that we expect emissions trading to operate within the country. Parties at home will seek cheaper supplies abroad, and parties abroad will seek to tap into this new market opportunity. Two types of international emissions trading can be anticipated: with other Annex B countries and with non-Annex B sources of emission reduction.

Trade among Annex B parties is not expected to bring the large benefits associated with global trading, but it is a useful point of departure. To take the simplest case, suppose that two Annex B countries, say, the U.S. and Norway, have solved the domestic allocation problem and adopted domestic emissions trading systems.[5] Each would have its own autarkic market price for the right to emit CO_2, and it is likely that the price would be higher in Norway than in the US. This difference in price indicates an opportunity to gain from trade, and an incentive for persons in Norway to import permits from the US. Similarly, there is an incentive for persons in the US to abate more in order to free up permits for sale to Norway at a higher price. Full trading between these two parties would lead to some equilibrium price, which would be higher than otherwise in the US and lower than otherwise in Norway to the mutual gain of both. As with any traded good, there will be groups in both countries who will object, alternatively, to the competition from cheap imports, or to the higher prices created by the exports. Nevertheless, we can assume that these problems will get resolved, as they do with other goods, and that trade will occur.

Such trading could be easily extended to other Annex B countries; all that would be required is faith in the validity of the permit, which would be provided by accurate

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[5] Norway has in fact decided to implement a system using grand-fathered permits to meet its Kyoto commitment. (GECR; July 10, 1998)

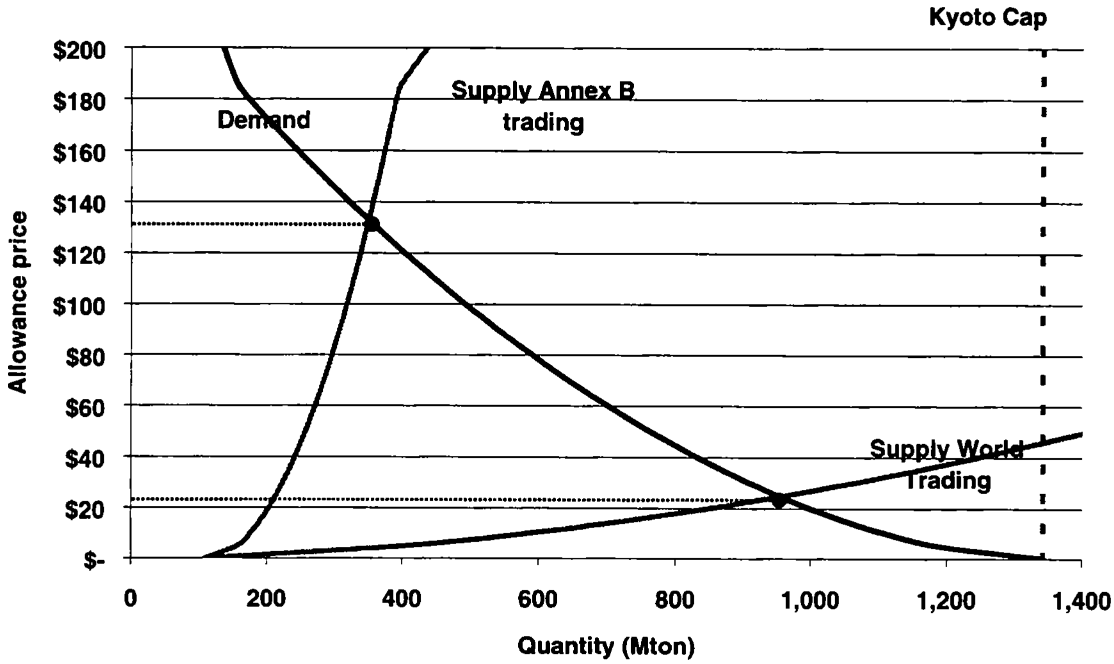
monitoring of emissions and effective enforcement of the domestic permit system by each trading party. This faith in the value of the permit is identical to what applies for any good or service that is exchanged in international trade. Moreover, the monitoring of emissions that will be required to ensure the value of the permits is that same as what would be put in place to determine compliance with the Kyoto targets, even if there were no trading.

Annex B trading would be desirable, but it does lead to really large reductions in the cost of meeting the Kyoto targets. Cheap abatement opportunities will be found in Eastern Europe and the former Soviet Union, both Annex B parties, but there will not be enough to bring about the really low price that is typically predicted by global emissions models. For instance, in the model we use at MIT, we get a market price of about $120 for Annex B trading but one of $25 with full global trading (Ellerman and Decaux, 1998).

Figure 1, which illustrates the demand and supply for emission permits, shows just how much difference the non-Annex B countries make in these models. The demand curve is the same for both the Annex B and the global markets, but the supply curves are very different. In the Annex B market, a significant amount of permits would be supplied by the former Soviet Union to the OECD countries, on the order of 350 million tons, or approximately 25% of the total reduction predicted to be required of these parties. But in this model, as in others, when the market is expanded to include non-Annex B countries much greater supply at lower costs becomes available. In this global market, Annex B countries would import about 70% of the total reduction requirement; and at such prices, the cost of meeting the Kyoto target for the US is less than a third of what it would be in the Annex B market.

The logic of non-Annex B involvement in emissions trading is fundamentally no different than that for Annex B trading. Trade is a response to opportunity, and emissions trading is the mechanism by which emission reductions outside Annex B would be made available. Also, the thing traded must not be counterfeit, but this requirement introduces a critical difference for Annex B trading. When there is no cap, it is much harder to establish that the permit represents a real reduction of emissions, or to use the jargon of the Kyoto Protocol, that it is "additional."

Fig. 1: Aggregated Supply and Demand Curves - Kyoto - 2010
Annex B Trading / World Trading



Establishing that an emission reduction is additional involves measuring a difference, that between observed emissions and what emissions would have been, if the emission reduction activity had not taken place. What would have been cannot be measured by its very nature; it can only be estimated. Consequently, the permit, and the reduction underlying it, is only as good as the estimate of this counterfactual, assuming of course that observable emissions are accurately measured. There are better and worse estimates, and the effort to make sure they are better will be costly, and always subject to challenge by anyone opposed to the proposed trade.

We can hope for the best in this process, but making these estimates, dealing with challenges to them, and getting them approved will limit the potential for this form of trading, as they have for all forms of credit-based emissions trading. These transactions cost will limit Annex B access to low-cost substitute emissions reductions, and they will frustrate would-be non-Annex B exporters; but the underlying requirement cannot be avoided. No Annex B party with a tight cap-and-trade system can tolerate ersatz goods. We can hope that the institutions can be established to reduce the transactions cost, but the experience so far with Activities Jointly Implemented has not been particularly encouraging.[6]

It will not take long for non-Annex B exporters to realize that these costs can be avoided, and that they are avoided in trading among Annex B countries, because the Annex B cap directly creates rights to emit. Parties without a cap have to engage in an additional step, demonstrating the *bona fide* of the emission reduction, in order to obtain a equivalent, tradable "right to emit." If the non-Annex B country were to accept a limit and implement the necessary monitoring and enforcement to ensure the integrity of its permits, this transactions cost would be avoided and export quantities and earnings increased. The necessary monitoring and enforcement would already be in place at the project level, and the apparatus would need only to be extended to the national level. There would also be a certain economy of scope in negotiating the baseline in one fell swoop, instead of in detail on a project by project basis.

The critical question would be: can an acceptable cap be negotiated? Within the framework of the Berlin Mandate as embodied in the Kyoto Protocol, the principle for determining the cap on a non-Annex I country in the first commitment period is clear: what emissions would be without the trading activity. The ideal would be an exactly-fitting but non-binding cap. In such an ideal, there would be no constraint on the non-Annex B country's growth and there would be no "hot air." All exported permits would reflect real emission reductions.

The reality is not so neat. No one will know what emissions would have been without emissions trading, and given the possibility that economic growth, and therefore counterfactual emissions, might be greater than expected, the prospective Annex B country is likely to want to assure itself of some "headroom." (Wiener, 1998) Unfortunately, granting "headroom" increases the probability of "hot air." On a practical level, both sides will have to compromise. The non-Annex B applicant must be prepared to accept a little upside constraint if it wishes to retain the permits created by any

[6] UNCTAD (1998) is unequivocal on this point. For instance, "Under the pilot program for AIJ, (the) verification process has led to the rejection of many proposed trades, and can take one to two years, creating high transaction costs and uncertainty." (p. 6) Or, "In general, past programs that impose emission

downside variation. Correspondingly, those on the other side of the table must recognize that a little hot air is the downside counterpart to the upside constraint on emissions. In the end, some element of enabling myth will be required, as it is in any project baseline.

Raising the negotiation from the project to the national level involves more than an all-encompassing, multi-project baseline for the first commitment period. These other considerations provide more flexibility, but they also raise issues of allocation on the international scale.

Taking a longer view, if atmospheric concentrations are to be stabilized, then limits on developing country emissions are necessary at some future time. The partial allocation of the use of the global sink adopted at Kyoto will have to be extended eventually to encompass all countries, or at least all major emitters (Yang and Jacoby, 1998; Jacoby *et. al.*, 1998). Accordingly, there is some advantage in having non-Annex B countries accept limits earlier, even if some headroom were involved.

For instance, if the ultimate allocative principle for global access to the atmospheric sink had been agreed to and were enforceable, and that principle allowed headroom now for some countries, then there should be no objection. The country would be free to bank or to sell currently according to its judgment of its interests, and cumulative emissions would be no greater. Even without such an ultimate principle, there would be a strategic interest in establishing the precedent and the procedures of monitoring and enforcement, even if at the price of some hot air, as is apparently the case with Russia and the Ukraine.

Moreover, if the concern about hot air is strong enough, nothing prevents any or several of the Annex B countries from transferring some of their limit to the non-Annex B applicant. There are even conditions under which Annex B countries might be better off by doing so, quite aside from the strategic interest. For instance, a very small part of the US limit of 1.27 Gton would provide comfortable headroom for Mexico. Under certain conditions—if the reduction of transactions cost associated with accepting an Annex B limit were to increase supply sufficiently—it would be possible for the US to

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caps coupled with allowance trading have performed well, whereas credit trading systems have generally not performed to expectations." (p. 1) gain by opening up these new supplies. Otherwise, the equilibrium price would be no different; and the US would simply have transferred some of the rent from domestic recipients to Mexico to serve the longer-term strategic interest.

The ability of Annex B parties to use Article 4 of the Kyoto Protocol to transfer a portion of their limit to others raises new possibilities of bringing non-Annex B countries to accept limits. But it also returns us to the very issue that will have to be solved at the national level first: how is the new scarcity to be allocated. As is the case at the national level, tradable permits allow the assignment and the actual use of the right to be separated; and the rents associated with the assignment of the right can serve a multiplicity of interests. Nevertheless, there is no more agreement on the allocation at the international level than at the national level, and perhaps less. The development of the full potential of global trading will depend on how quickly such agreement develops, but the discussion cannot be expected to become serious among non-Annex B parties until there is some advantage in accepting an Annex B limit.

In the discussing the evolution of a global emissions market, little has been said about the Clean Development Mechanism (CDM) or Joint Implementation (JI). The reason is that both are essentially transitional institutions. There will be no place for either in global emissions trading market in which all participate. This role may be transitional, but it is still very important. We can hope that these institutions will be reasonably efficient and that the transactions cost will not be too high. Whether called CDM or JI activities, the real role will be prospecting: finding cheap abatement possibilities and demonstrating the advantages of trade to both exporter and importer. In addition, these activities will provide the experience in measurement and enforcement that will make host countries feel more comfortable in making the transition to a cap, and that will assure Annex B countries of the capability to enforce the new Annex B limit.

The creation of the CDM as the sole intermediary between Annex B parties and non-Annex B emission reductions does raise some questions. At times, it appears as a means for effecting a North-South resource transfer. At other times, concern is expressed about avoiding price-reducing competition among host countries for projects, which language suggests an incipient cartel. And at still other times, the CDM is presented as a mechanism to facilitate trade by providing valuable recording, certification and verification services. (Aslam, 1998) It could also be very bureaucratic and costly, not least to the countries it is intended to serve. Of course, to the extent that it becomes more than a facilitator to trade, it will only raise the incentive for those who are more interested in trade to by pass it by becoming Annex B signatories.

CONCLUSION

As with so many things, the creation of an international system of global trading will start at home. There may be very large reserves of cheap carbon abatement lying abroad that could be developed into a flourishing international trade in emission permits to everyone's advantage; however, those reserves will remain untapped until demand is created somewhere and value thereby imparted to them. Given a functioning national system of emissions trading, there is every reason to believe that the trading would extend beyond national borders, particularly with other Annex B parties. Trade with non-Annex B parties will face unique problems that will inevitably raise costs and diminish prospects of abundant supply, but these problems create the incentive for these parties to accept Annex B limits and thus to participate more fully in the benefits of this trade. This expansion of the system will not come quickly, nor easily; but it is the way the system will develop, by accretion and as a matter of self-interested trade.

Recognizing that the main obstacle to global emissions trading lies at home does not make the creation of such a system any easier. The problem is not in the monitoring or the enforcement, which must occur in any case; but in the distribution of the rents, which is fundamentally a political and at times even a philosophical problem. And the issue is not just an issue of public vs. private; but also one of deciding among a number of private claimants with equally plausible claims. Unfortunately, the type of system that lends itself most easily to expansion abroad is also that which makes the rents most transparent; and transparency may not make agreement any easier.

Disagreement on such fundamental matters also reveals the lack of consensus on the nature of the problem and the need for action. Those who view the problem as one of allocating a scarce resource are typically not much concerned about the allocation of the rents, for it is really a matter of adapting to new circumstances and assignment of the rents to existing users is a convenient way of compensation. The opposing view is that we are not so much allocating a scarcity as limiting socially undesirable activity, for which there is no issue of pre-existing rights or of compensation, and no other place for the revenue generated than the government.

Quite evidently there is not a sufficient consensus to impose any single view, nor is there sufficient accommodation in the positions of parties to permit the sort of political solutions that will permit legislation to pass. In the meantime, it is worth working on the many details of an international system, because those details will facilitate the development of a market once national action has been taken. But nothing will happen until we are comfortable with some distribution of the rents that will be created by this new scarcity.

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Long-Term Energy Technology: Needs and Opportunities for Stabilizing Atmospheric CO_2 Concentrations

Paper

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Long-Term Energy Technology:
Needs and Opportunities for Stabilizing Atmospheric CO_2 Concentrations

by
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Executive Summary*

Technology plays a large role in answering the difficult questions about the desirable concentration level at which greenhouse gases should be stabilized, the means to achieve this level, and the associated costs. Real-world technologies do not spring into being, fully mature, but must evolve and compete in a world in which cost and performance matter. This study addresses two relevant questions: (1) What technologies are needed to achieve stabilization of greenhouse gas concentrations; and (2) Is the existing level of energy research and development (R&D) sufficient to produce the needed technologies?

We use the MiniCAM integrated assessment model to explore two future scenarios. The first scenario, Coal Bridge to the Future (CBF), assumes a transition from the present domination of oil and gas to a future dominated by coal. The second, Oil and Gas Forever (OGF), assumes that oil and gas can be economically attractive in the future, continuing their domination as fuels. These cases are realistic and interesting from a policy perspective.

When CO_2 concentration constraints are introduced, various technological possibilities come into play. The CBF case sees little change in the use of oil and gas, but coal use decreases. In the OGF case, the scale of change in the energy system is somewhat greater than in the CBF case. Energy conservation technologies play a large role in both scenarios. Renewable and nuclear technologies increase under concentrations ceilings. Biomass energy cropping is expanded to meet energy demands, leading to increased emissions from land-use changes. The value of carbon also increases over time, varying from $9 per tonne (CBF, 750 ppmv ceiling) to $105 per tonne (OGF, 450 ppmv). Carbon has consistently higher values in the OGF case than in the CBF case.

If we introduce technologies to capture and sequester carbon, both from energy production and in natural systems (soils and forests), and to implement fuel cells, one effect is to reduce by half the costs of stabilizing atmospheric concentrations of CO_2. The mix of technologies changes also; it is more evenly distributed between existing and new energy technologies. Notably, the use of biomass technologies decreases, reducing the pressure to expand agricultural production to unmanaged ecosystems.

Thus, a portfolio of technologies will be needed to address carbon mitigation as well as adaptation. The eventual large-scale deployment of technologies that are not presently part of the energy system requires energy R&D. A carbon constraint will raise the value of this R&D, justifying increased investment. However, energy R&D has been declining over the last decade in the OECD countries—a real decline of 34 percent in the United States and a real decline of 23 percent in the nine OECD countries that fund such R&D. Only Japan has experienced a modest 8 percent increase. This decline represents a major obstacle to the successful development of the energy technology foundations that will be needed if the concentration of greenhouse gases in the atmosphere is to be stabilized.

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DRAFT – COMMENTS WELCOME

LONG-TERM ENERGY TECHNOLOGY
Needs and Opportunities for Stabilizing Atmospheric CO_2 Concentrations

Jae Edmonds, Jim Dooley, and Sonny Kim

INTRODUCTION

The Framework Convention on Climate Change (FCCC; United Nations, 1992), signed by more than 155 nations, has as its ultimate objective, "*...stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.*" (p.5). The treaty and three subsequent conferences of the parties to the convention artfully dodged the most difficult and obvious questions. At what concentration should greenhouse gases be stabilized? How is this to be accomplished? And how much will this cost? These are not entirely unrelated questions.

It is not surprising that technology plays a large role in constructing the answers. In models technology can spring, fully mature, like Venus on the half-shell. But real-world technologies are grown from the seeds of research and development (R&D) and must evolve and compete in a world in which cost and performance matter. From the perspective of carbon, not all R&D activities are equal. Some R&D are more important than other R&D. But which R&D ultimately pay dividends and which lead to technological dead-ends is *a priori* unknowable. In this analysis we attempt to develop some information, which can help to shed light on potentially relevant opportunities. We will address two relevant questions:

1. What type of R&D are needed to develop carbon-free energy and more efficient technologies? and
2. Are there major barriers to the development of new technologies?

We begin by considering the problem of stabilizing the concentration of atmospheric carbon dioxide (CO_2). We then examine the implications for the global energy system of these goals. We will pay particular attention to technologies that capture and sequester carbon, as these newly emerging technologies can fundamentally change the nature of the technology response to climate change. We then consider the recent R&D experience and some of the reasons energy R&D has declined over the past decade.

STABILILZING THE ATMOSPHERE

There are a wide variety of gases, both natural and of human origin, that affect the radiative balance of the Earth. Carbon dioxide (CO_2) is the most important[1]. The relationship between its emission and concentration is also unique among greenhouse gases. Whereas there is a proportional relationship between steady-state emissions and steady-state concentrations for gases such as nitrous oxide and methane, the same cannot be said for carbon dioxide. Chemical

[1] Others radiatevely important gases include: methane, nitrous oxide, other nitrogen compounds, carbon monoxide, and sulfate aerosols. Important anthropogenic gases include the chlorofiuorocarbons (CFCs), hydrofluorocarbons (HFCs), and Perfluorocarbons (PFCs).

processes in the atmosphere do not remove CO_2. The concentration of CO_2 is determined by the distribution of carbon among three larger reservoirs—the atmosphere, oceans, and land. To a first approximation it is the sum of emissions over a long period of time that determines the CO_2 concentration at any future date.

The literature on the relationship between anthropogenic emissions and CO_2 concentrations in the atmosphere is relatively mature (IPCC, 1996), and numerous models have quantified the relationship. While it may be possible, with a given model, to predict the future concentration of CO_2 from a trajectory of emissions, the inverse problem has no unique solution. Several alternative trajectories have been created including, IPCC (1995) and Wigley et al. (1996). The specific choice of trajectory will depend on the concentration ceiling deemed desirable, the policy instruments employed to insure that the ceiling is maintained, and the suite of technologies available to provide energy services to future growing economies.

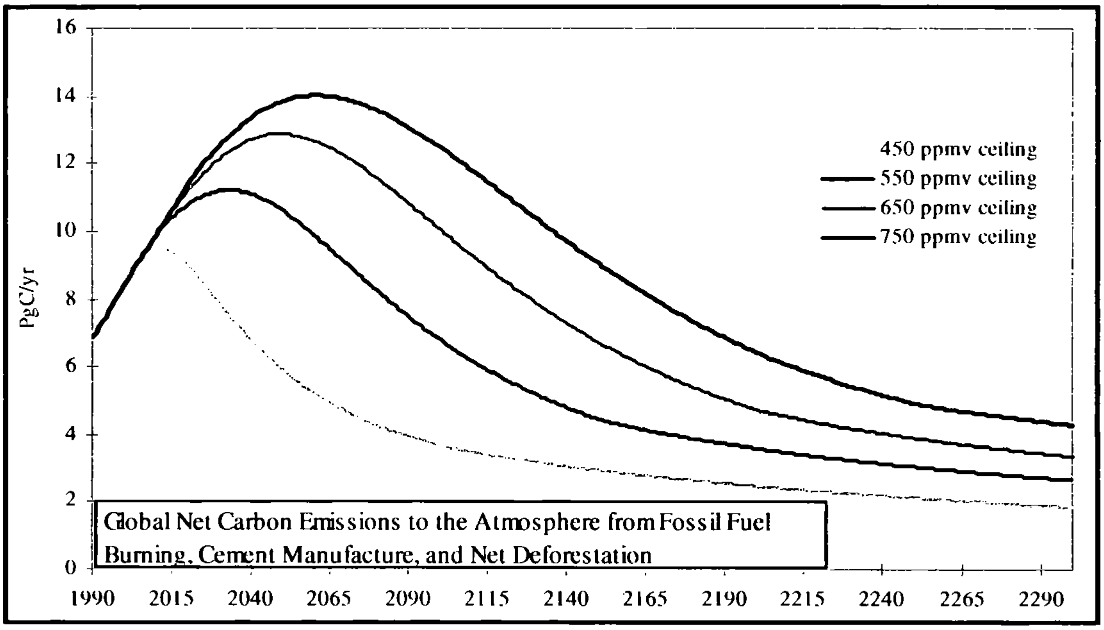

Figure 1: WRE Emissions Trajectories Consistent with Alternative CO_2 Concentration Ceilings

In this analysis we use the trajectories of Wigley et al. (1996, WRE) as they approximate a cost-effective emissions control path. These trajectories are shown in Figure 1 for concentration ceilings ranging from 450 ppmv to 750 ppmv.

THE ENERGY SYSTEM WITH AND WITHOUT AN EMISSIONS CEILING

Future technologies are anticipated to continue to improve. Scenarios of future are virtually unanimous in their anticipation of reductions in energy intensity during the course of the next century (IPCC, 1995). Power generating facilities in the future can be anticipated to be more efficient than at present. Similarly, changes in the composition and efficiency of future activities should provide a source of decreasing energy intensity. While models generally treat technological change as if it materialized by magic, in the real world it is energy R&D that provides the technological catalyst.

The relationship between R&D and technological change has proved difficult for researchers to predict.[2] This analysis does not attempt to develop a cause-and-effect representation for R&D and energy technology. Rather, we will consider changes in the global energy system that might be anticipated under alternative regimes to stabilize the atmosphere. We examine the changes in the energy system to indicate areas in which technical performance will be at a premium.

This approach compares a reference energy system over time to an alternative policy path. We have developed two alternative reference scenarios for global population, economy, energy, and agriculture. The first assumes a transition from the present conventional oil and gas based world to a future world dominated by coal. This is a standard vision of the future (IPCC, 1995). We refer to this reference case as, Coal Bridge to the Future (CBF). The second reference case assumes that oil and gas which is economically unattractive becomes available in the future implying a world which continues to be dominated by oil and gas. We refer to this reference case as Oil and Gas Forever (OGF).

Both of these energy worlds evolve against a background of continued productivity improvement in energy production, transformation and end-use. These two paths represent the two generic global energy system developments that are interesting from the perspective of climate policy. The world can either continue to develop using oil and gas as the core fuels, or it can transition to coal as the core fuel. Of course, in both of these cases other energy forms play important, and in some cases, such as solar energy, growing roles as the future unfolds. However, the backbone of the world's energy system remains fossil fuels.

A third, generic global energy system development path entails an evolution away from fossil fuels toward conservation, renewable, and nuclear energy forms (Shell, 1995). This reference case is uninteresting from the perspective of this paper as its accomplishment implies the stabilization of greenhouse gas concentrations in the reference case. There are no policy implications. The market takes care of everything.[3]

Our two reference cases, CBF and OGF, exhibit continued growth in fossil fuel emissions. This growth in turn is inconsistent with eventual stabilization of CO_2 concentrations.

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[2] Some authors have examined the effect of induced technological change on the timing of emissions mitigation. See for example, Goulder and Schneider (1998), Nordhaus (1997), and Grubb (1996). This literature breaks induced technological change into two types: learning-by-doing and induced R&D. The general conclusions reached by these researchers is that the presence of induced technological change tends to move mitigation activities from the near-term to the far-term when an optimal global tax policy is implemented (Goulder and Schneider, 1997; Nordhaus, 1997). The presence of learning-by-doing leads has an ambiguous effect on the timing of emissions abatement. Whether this effect shifts mitigation to the near-term or far-term depends on the particular parameterization chosen (Goulder and Schneider, 1998; Nordhaus, 1997; Grubb, 1996).

[3] While possible, we consider a self-stabilizing reference case unlikely. The continued decline in world oil prices and the continued extension of economically viable oil and gas resources lead us to conclude that the OGF scenario is at least as likely as the CBF scenario.

Because we do not know whether or at what level concentrations will eventually be stabilized, we explore constraints which include: 450 ppmv, 550 ppmv, 650 ppmv, 750 ppmv, as well as reference, that is unconstrained, carbon accumulation.

We compute the cost of achieving each of these alternative objectives under a specific policy regime. This policy regime assumes a coalition of **all** of the world's nations to mitigate emissions, though there may be compensating transfers of income among nations. At any point in time we show all economic agents in the model, in all regions, a common value of carbon[4] to be included in all economic decision making. This strategy minimizes the cost of emissions mitigation at each and every point in time.[5]

Costs of achieving stable carbon concentrations could be significantly greater if policy interventions undertake expensive emissions mitigation too early in the 21st century, or if significant portions of the world remain outside the coalition.[6]

Interactions between population, economy, energy, agriculture, land-use, greenhouse gas emissions, and atmospheric dispositions are modeled using MiniCAM 98.3. This is an updated version of the MiniCAM model described in Edmonds et al (1997), and Edmonds et al (1996). The energy component of the MiniCAM 98.3 has its origins in Edmonds and Reilly (1985). The energy module has been extended and upgraded on numerous occasions. The most recent enhancements are documented in Edmonds, et al. (1986), and Kinzey et al. (1998).

Population and Economic Drivers

The reference scenario is intended to reflect in large measure a continuation of many present trends. We assume that global population will eventually stabilize at approximately eleven billion people.

Economic growth is assumed to proceed in a heterogeneous manner. We assume that regions that are rapidly developing will continue to close the per capita income gap with developed nations and approach parity with the presently developed world over the course of the next century. Those presently growing less rapidly are assumed to begin the process of more rapid development some time during the next century.

These assumptions reflect an underlying theory of heterogeneous economic growth and development, with per capita income in developed regions continuing to grow steadily, but

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[4] The value of carbon is the premium associated with net carbon emissions that should be employed in all internal planning by energy producers and users to satisfy the associated carbon constraint.

[5] This is not precisely the minimum possible cost that could ever be encountered. That cost entails allowing the value of a tonne of carbon rise at the rate of interest plus the rate of carbon removal from the atmosphere by the natural system (Peck and Wan, 1996). The WRE trajectories provide a path that is similar in cost, however.

[6] Manne and Richels (1997) have shown that deviation from a cost-effective path can multiply the cost of complying with an atmospheric concentration ceiling, such as 550 ppmv. Richels et al. (1996) showed that if significant regions remain outside an emissions control regime, costs escalate.

slowly, and various developing regions joining the developed group through accelerated economic growth over sustained periods. We assume that some developing nations make the transition before others. That is, economic growth transitions occur in "waves." The order of the waves cannot be known *a priori*. Rapid economic growth is assumed to continue in China and South and East Asia, while other regions initiate the "catch-up" process subsequently. Other orders than those assumed here are, of course, also plausible.[7]

Oil, Gas and Coal Production

We use a common set of energy technology assumptions for both the CBF and OGF reference cases. Primary energy forms—oil, gas, and coal—are modeled as resource constrained technologies. Each of these energy forms has a set of resources that can be exploited. Resources are graded. It is assumed that less-expensive resources are developed before more-expensive resources. It is also assumed that the cost of production for each resource grade declines at an average annual rate of 0.5 percent per year. Resource estimates are taken from IPCC (1996), Rogner (1996), and Edmonds and Reilly (1985).

The principal difference between the CBF and OGF scenarios is the technology assumed for extracting unconventional oil and gas resources. In the OGF scenario unconventional oil and gas resources, including methane hydrates (clathrates) are initially available at oil prices of $20/barrel, with technological change lowering costs at 1%/year. In CBF these technologies are available at $50/barrel with technological progress proceeding at only 0.5%/year. While the same resources are available in all scenarios, differences in technology assumptions determine relative economic performance.

Commercial Biomass Energy: In MiniCAM 98.3 modern commercial biomass energy is produced in the context of overall agriculture and land-use management decision making. This modeling structure is described in Edmonds et al. 1996. The modeling structure includes an endogenous land-use emissions component. Land is partitioned between managed and unmanaged components. An expansion of the managed component typically has carbon emissions consequences. Thus the expansion of commercial biomass production implies that land-use patterns must change. Land must be acquired, with some of the land coming through competition with other activities within the managed land system and some coming at the expense of net intrusion into unmanaged ecosystems.

The cost of producing commercial biomass varies with the state of biomass technology, the level of production (land costs depend on overall demands for land), the technology for producing competing agricultural and sylvacultural products, and the demands for competing agricultural and sylvacultural products. Table 2 shows assumptions for the agriculture and land-use component of the model are used for all of the eleven regions.

[7] One could, for example, assume that the 1998 economic crisis in Asia leads to long-term, economic stagnation in that region such as occurred in Argentina.

Table 2: Agriculture-Land-Use Module Assumptions
All Cases

PARAMETER	Reference Case
Rate of Exogenous Productivity Improvement	
Crops	1.5%/yr
Livestock	1.5%/yr
Managed Forests	0.5%/yr
Fuelwood	0.5%/yr
	0.0%/yr
Initial Price Elasticities	
Crops	-0.2
Livestock	-0.2
Managed Forests	-0.4
Fuelwood	-0.4
Initial Income Elasticities	
Managed Forests	0.2
Fuelwood	-0.2
Asymptotic Demands	
Crops	0.95 Mg/cap/yr
Livestock	0.21 Mg/cap/yr
Biomass Productivity	
1990	6 Mg/ha/yr
2095	10 Mg/ha/yr

Electric Power Generation

Fossil fuel electric power generation is assumed to improve continuously between 2000 and 2095. It reaches an efficiency of transformation of 0.67 by the year 2095.

Other forms of power generation also improve. The cost of solar electricity is taken from EPRI-NREL (1997). The busbar cost of power declines rapidly between 1997 and 2035 but remains relatively stable thereafter. In 1997 the cost is assumed to be 52 c/kWh but has fallen to 6 c/kWh by 2035. Further decreases are modes with the final cost reaching 5 c/kWh in 2095.

Nuclear power is assumed to be phased out in Western Europe and North America, but remains an option in the remainder of the world. In regions where it is available, costs are assumed to decline at an average annual rate of 0.5 percent per year.

Fusion power is not considered in this exercise, but holds potential for contributing to a low-carbon emission future.

Hydro-electric power is resource limited and is modeled by a logistic penetration function given in Edmonds and Reilly (1985).

Reference Future Energy Systems

The two reference scenarios, Figure 2, paint alternative pictures of the overall energy system, though total primary energy and carbon emissions are similar. In CBF the transition from conventional oil and gas to coal is accompanied by an increase in the price of liquids and gases during the first half of the 21st century. This leads to a lower future energy in end-use applications, but the employment of more and more carbon-intensity primary energy implies relatively high primary energy demands and carbon emissions.

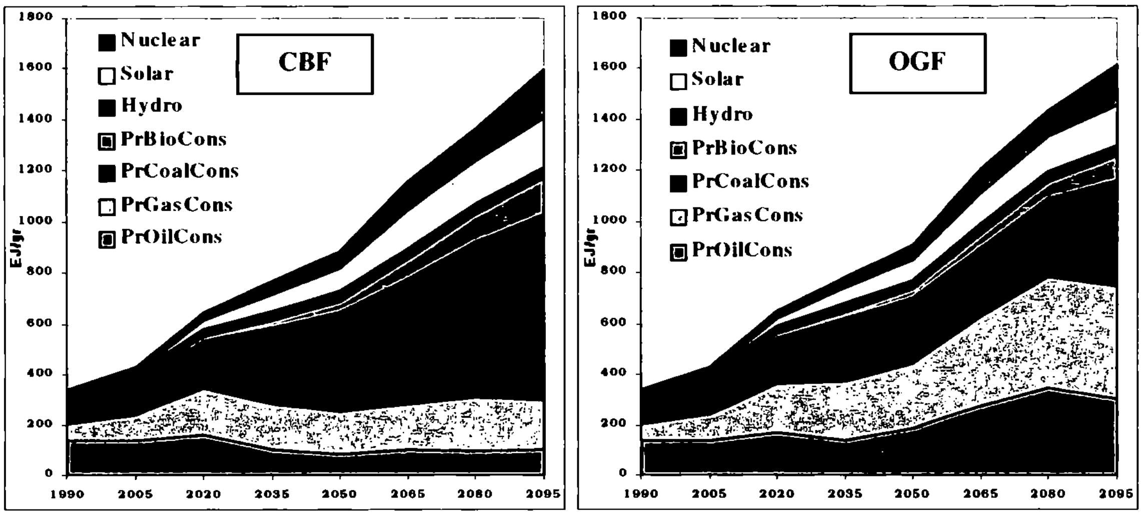

Figure 2: Reference Case Energy Emissions for the CBF and OGF Scenarios

In the OGF scenario, oil and gas prices remain low because usable resources are never exhausted. The lower energy prices imply a higher level of final energy consumption, but the lower carbon content of the primary energy inputs to the system leave carbon emissions similar to those of the CBF scenario. We also note that the lower energy prices imply a smaller contribution by renewable energy forms.

A Carbon Constrained World

The addition of the carbon emission constraints displayed in Figure 1 changes over time relative to the reference cases depicted in Figure 2. These changes are initially relatively modest, but over time the world's energy system relies more heavily on energy conservation and non-carbon energy forms. The pattern of these changes is shown in Figure 3. As the CO_2 concentration constraint tightens from 750 ppmv to 450 ppmv, the change in global energy system becomes increasingly pronounced.

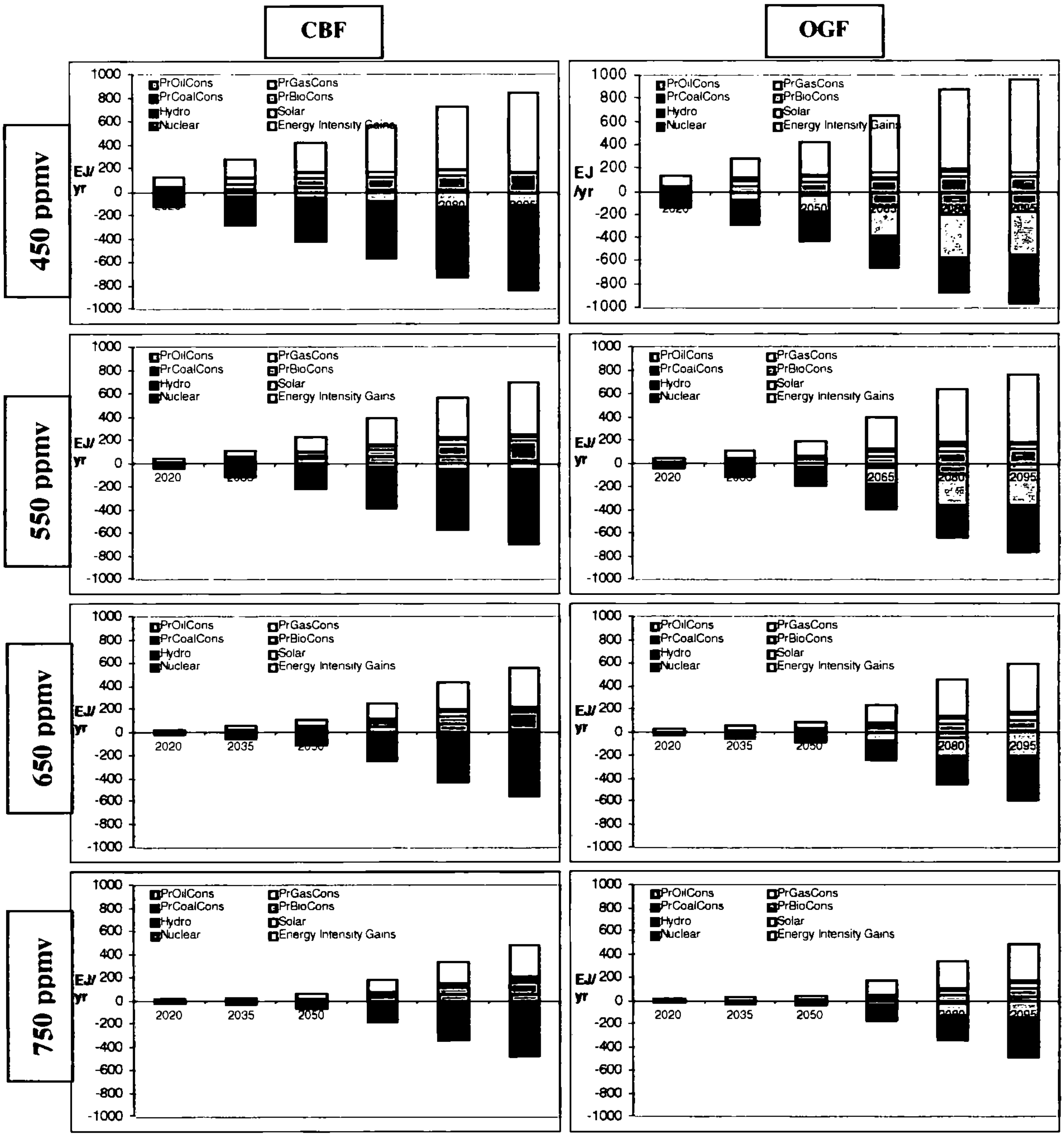

Figure 3: Changes in the Global Energy System Relative to Reference for Alternative CO_2 Concentration Ceilings

In the CBF case there is little change in the use of oil and gas. The scarce resources of conventional oil and gas are employed in all cases but the 450 ppmv ceiling, where a slight decrease in cumulative use is observed. Carbon mitigation means using less coal in the CBF scenario.

In the OGF case the scale of change in the energy system is somewhat greater than in the CBF case. More of the world's energy system is based on oil and gas in OGF than in CBF and less on coal, the changes that occur in the energy system required to satisfy a carbon concentration ceiling consequently require reductions in the scale of both the coal and gas production. Renewable, nuclear, and conservation (defined as the reduction in scale of the energy system relative to the reference case) all increase under CO_2 concentration ceiling cases.

Conservation provides about half of the change in the energy system is provided by a reduction in the total scale of the energy system.

The bulk of emissions mitigation occurs in the second half of the next century for all scenarios, Table 3. No mitigation is required at all before the year 2005. The lower the concentration constraint, the higher the cumulative emissions mitigation, and the greater the proportion of emissions mitigation that occurs in the first half of the next century. The difference between cumulative emissions mitigation in the first half of the 21st century with a 450 ppmv ceiling and a 750 ppmv ceiling is almost an order of magnitude.

We note that net carbon emissions from land use changes increase in the carbon-constrained scenarios. This increase is the direct consequence of the expansion of commercial biomass energy cropping. This expansion benefits farmers, by increasing the demand for crops, but simultaneously expands the demand for land relative to the reference cases. As a consequence, food prices rise under the carbon constrained cases and more of the unmanaged lands are brought into production. As the average carbon content of biomass crops is lower than the average carbon content of unmanaged ecosystems brought under cultivation, land-use change carbon emissions increase in all of the control scenarios.

Table 3: Cumulative Emission Mitigation for Alternative CO_2 Concentration Constraints—2000 to 2095 (PgC)

	450 ppmv	550 ppmv	650 ppmv	750 ppmv
2005-2050 CBF	211	87	43	25
2005-2050 OGF	208	84	40	22
2050-2095 CBF	668	480	344	264
2050-2095 OGF	652	464	328	248

The value of carbon also increases over time for all the carbon concentration ceilings. It starts modestly, but increases in all cases to the end of the century. The value of a tonne of carbon associated with meeting a carbon constraint between 450 ppmv and 750 ppmv in the year 2020 varies between $9 (CBF, 750 ppmv ceiling) and $105 (OGF, 450 ppmv), Table 4.

There is a consistent pattern of higher values of carbon for any concentration ceiling when OGF is the reference case than when the reference case is CBF. The difference is more pronounced later in the 21st century. The reason is the higher fossil fuel prices in the CBF case. These higher fossil fuel prices act as a "natural carbon tax." As there is little oil and gas toward the end of the century, conservation and renewable energy forms compete only against coal.

Table 4: Value of Carbon for Alternative Atmospheric CO_2 Constraints 2005 to 2095 ($/tonne C)

450 ppmv	CBF	OGF	550 ppmv	CBF	OGF
2005	0	0	*2005*	0	0
2020	97	105	*2020*	28	33
2035	195	231	*2035*	44	52
2050	323	432	*2050*	73	102
2065	491	720	*2065*	145	254
2080	635	960	*2080*	235	446
2095	727	1179	*2095*	303	663
650 ppmv	**CBF**	**OGF**	**750 ppmv**	**CBF**	**OGF**
2005	0	0	*2005*	0	0
2020	15	19	*2020*	9	13
2035	18	20	*2035*	10	10
2050	30	37	*2050*	16	16
2065	69	119	*2065*	44	72
2080	124	242	*2080*	83	159
2095	172	396	*2095*	125	265

Allowing Carbon Capture and Sequestration

To this point we have implicitly assumed that reducing carbon emissions meant reducing dependence on fossil fuels. This ignores the possibility that carbon from fossil fuels could be captured and sequestered. Introducing the possibility of large-scale carbon capture and sequestration radically changes both the cost and the character of carbon mitigation. We consider carbon capture from power plants and the production of hydrogen from fossil fuel feed stocks. Cost for these systems are broken down into energy and capital costs. In addition to the cost of carbon capture there are costs of transporting and sequestering the carbon.

Electric Power Production: The capture of CO_2 from the waste stream of a plant requires energy. We assume that the efficiency of carbon capture will increase with time, i.e., new and improved technologies and processes will come on-line that will reduce the energy penalty associated with powering the capture systems. Herzog, et. al. (1997) state that the eventual integration of these systems into the overall design of new fossil fueled power plants – such as integrated gasification combined cycle (IGCC) power plants– holds forth the promise of reducing the cost of CO_2 capture significantly. Further, recent research indicates that targeted basic science programs could lead to advancements that over time would improve the performance and reduce the costs of these systems (Dooley and Edmonds 1997). We will assume that the phasing in of these more efficient capture technologies will occur gradually and will be completed 50 years after the initiation of carbon capture.

In addition to the energy cost of capture there are additional capital investment requirements for a CO_2 capture system largely on the work of on Gottlicher and Pruschek (1997) and their comprehensive survey of over 300 studies of CO_2 removal systems from fossil-fueled power plants. Gottlicher and Pruschek's estimates of the performance of these CO_2 removal systems is based on the "present status of the technology," and therefore we will once again adopt the same assumption about costs decreasing over time. Given the wide range of cost reported by Gottlicher and Pruschek (1997) we adopt a midrange cost from their survey.

CO_2 Transport Costs: For the foreseeable future, the vast majority of research for disposal applications is likely to be focused on understanding and mitigating environmental concerns that arise from disposal and is unlikely to be directed at reducing the cost of disposal (Freund and Ormerod, 1997). Freund and Ormerod (1997) site estimates for transport and disposal cost that range from $4.7/ ton of C to $21/ ton of C depending upon whether the sequestration is to take place in a nearby depleted oil and gas well or a deep sea trench that is located some distance from an on-shore fossil-fueled power plant. In the absence of research that pairs current and future power plant sites with disposal sites on a global basis, we will assume an intermediate value of $15/ tonne C for all transport and disposal costs and hold this cost constant through out the time period under study.

CO_2 Capture and Disposal Costs for Fuel Transformation Technologies: CO_2 will also need to be captured from fuel conversion facilities such as plants for the conversion of coal to synthetic liquids and gases. Herzog, et. al. (1997) state that the cost of CO_2 capture from refineries will be comparable to or greater than the cost of capture from fossil fueled power plants. Therefore, we assume that all conversion facilities and refineries will have performance characteristics similar to those for coal-fired plants. We summarize our assumptions for capture and disposal in Table 5. The figures in Table 5 are not representative of any given capture and sequestration system configuration but rather are meant to be averages for the entire suite of carbon capture and disposal technologies and systems that could be deployed in any number of possible combinations.

Table 5: Assumed Cost and Performance of Carbon Capture and Disposal[8]

	Coal	Oil and Gas
Energy Penalty for Carbon Capture [(a)]	37% declining to 9%	24% declining to 10%
Additional Investment Costs for Capture System [(b)]	54% declining to 33%	54% declining to 33%
Transport and Disposal Cost [(c)]	$15/tonne of C	$15/tonne of C
Efficiency of Capture [(b)]	90%	90%

Sources: [(a)] Herzog, et. al. 1997, [(b)] Gottlicher and Pruschek, 1997, [(c)] Freund and Ormerod, 1997

Fuel Cell Technology: Fuel cells are a complementary technology to carbon capture and sequestration. They allow hydrogen to be employed as a fuel for transportation as well as disperse production of heat and power. In the absence of fuel cell technology, the transportation sector depends on batteries and fuels from biomass for emissions mitigation. Fuel cells are assumed to be capable of delivering electricity both to stationary and mobile applications. Our assumptions regarding fuel cell technology are given in Table 6.

[8] We note that the figures listed here for "Energy Penalty for Carbon Capture" and "Additional Investment Costs for Capture System" are largely consistent with midrange estimates for these parameters published by the IEA Greenhouse Gas Programme (1996).

Table 6: Assumed Performance of Various Hydrogen Production Methods

	Energy Input/Output Ratio	Levelized Cost for O&M and capital (\$/GJ H_2 produced)
Coal (a)	1.292	4.66
Natural Gas (a)	1.115	1.72
Oil (b)	1.2	3.0
Biomass (a)	1.3	4.44
Electrolysis (a)	1.1	2.36
Sources: (a) Williams (1995) and (b) Kaarstad and Audus, 1997.		

Soil Carbon: Finally, we consider the potential of carbon to be taken up by soils. Over the course of the next 50 to 100 years, according to the IPCC estimates (Cole et al, 1996), between 40 and 80 Pg of fossil fuel carbon emissions might be offset in croplands alone by applying soil carbon sequestration techniques (1 Pg=1 billion tonnes). The estimates for cropland assume the restitution of up to two thirds of the soil carbon released since the mid 19th century by the conversion of grasslands, wetlands and forests to agriculture. The experimental record confirms that carbon can actually be returned to soils in such quantities: carbon has been accumulating at rates exceeding 1 tonne/ha/yr in former crop lands planted to perennial grasses under the Conservation Reserve Program (CRP) (Gebhart et al, 1994). Soil carbon increases ranging from 1.3 to 2.5 tonne/ha/yr have been estimated in experiments on formerly cultivated land planted to switchgrass, a biomass crop (preliminary data, ORNL).

Managed forests, wetlands and rangelands provide further opportunity for significant carbon storage. For example, when agriculture is converted (or allowed to revert) to forest vegetation in systems with very little management to improve growth, soil carbon may accumulate at rates ranging from near zero to 7 tonne/ha/yr. In temperate regions gains range from 0.2 to 0.6 tonne/ha/yr and average about 0.3 tonne/ha/yr (Jenkinson, 1971). Gains in tropical and subtropical forests are greater, ranging from 1.0 to 7.4, with an average of 2.0 tonnes of carbon/ha/yr (Ramakrishnan and Toky, 1981).

Many soil carbon-conserving practices are currently being implemented for reasons other than CO_2 mitigation, such as erosion control or to reduce production costs or labor. However, impediments to more widespread adoption include costs of initial investment in equipment, fear/reluctance in adopting new technologies, and increased risks during the adoption transition phase. Financial incentives could substantially increase the rate of adoption of carbon sequestering practices and potentially provide a significant addition to farm income. We have made no attempt to estimate the net cost of these activities as initial estimates yield values for benefits, which are of a comparable magnitude to costs. Clearly, further work is required. In addition, we ignore the problem of institutional mechanisms to insure that the required change in agricultural practices is actually carried out. The purpose of this exercise is to examine the potential contribution of soil carbon capture to contribute to an overall strategy of global carbon management.

For the purposes of this analysis we assume that 40 to 80 PgC are available over the course of the next century. Given that the rate of carbon uptake by soils is highly non-linear, we assume that the rate of uptake is four times greater in the initial year of activity than 100 years later.

Afforestation and Reforestation: The forestry sector is modeled explicitly in MiniCAM. We have made no attempt to model policies to expand the stock of forest carbon, though the model can easily accommodate an increase in the demand for forests. The increase in the stock of carbon resulting from afforestation and reforestation policies represents a one-time removal of carbon from the atmosphere, and cannot be sustained unless the forests are harvested and the land replanted. In the latter case the problem of removing the harvested products from contact with the atmosphere arises. The problem can be overcome if the harvested materials are used as a commercial biomass feedstock and used as a substitute for fossil fuel energy.[9]

Filling the Emissions Gap: The introduction of the three carbon capture and sequestration technologies, which we have considered here, greatly changes the manner in which the energy system changes to satisfy the CO_2 concentration constraints, Figure 4. The global energy system relies much more heavily on fossil fuels than when carbon capture and sequestration are unavailable. Though the magnitude of the change in the mix of primary energy forms in the global energy system is much reduced by the presence of carbon capture and sequestration technologies, the global energy system, nonetheless, undergoes substantial changes by the end of the 21st century. Interestingly, those changes are delayed when carbon capture by soils is available. The time profile of the uptake of carbon by soils coupled with the net mitigation requirements implied by the WRE trajectories, means that no changes in the global energy system are required until after the year 2020.

It also greatly reduces the cost of meeting these constraints, Figure 5.[10] Soil carbon uptake alone could reduce the cost of meeting a 550 ppmv ceiling by about thirty percent. This is due primarily to the fact that carbon uptake in the initial years of the program is large compared to the total mitigation required. As a consequence, there is a significant delay in the time at which the energy system needs to depart significantly from reference trajectories.

The introduction of carbon capture and sequestration from central power facilities, and the introduction of hydrogen fuel cells as an option for both power generation and transport, enable the economy to rely less heavily on technologies, such as modern commercial biomass and solar power, which are at an early stage in their technological development. The combined effect of these two technologies alone cut the present discounted cost of satisfying the 550 ppmv constraint by more than 60 percent. The potential combined effect of all of the sequestration options taken together was a cost reduction of more than 70 percent for the 550 ppmv ceiling.

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[9] Forest products can also be used in a variety of applications which prevent their oxidization, such as building materials, railroad ties, telephone poles. However, the scale of carbon potentially available under a program which removed significant quantities of carbon from the atmosphere would quickly drop the price of these products to zero.

[10] Costs are computed as the present discounted value of annual costs over the period 1990 to 2095, computed using a 5% discount rate.

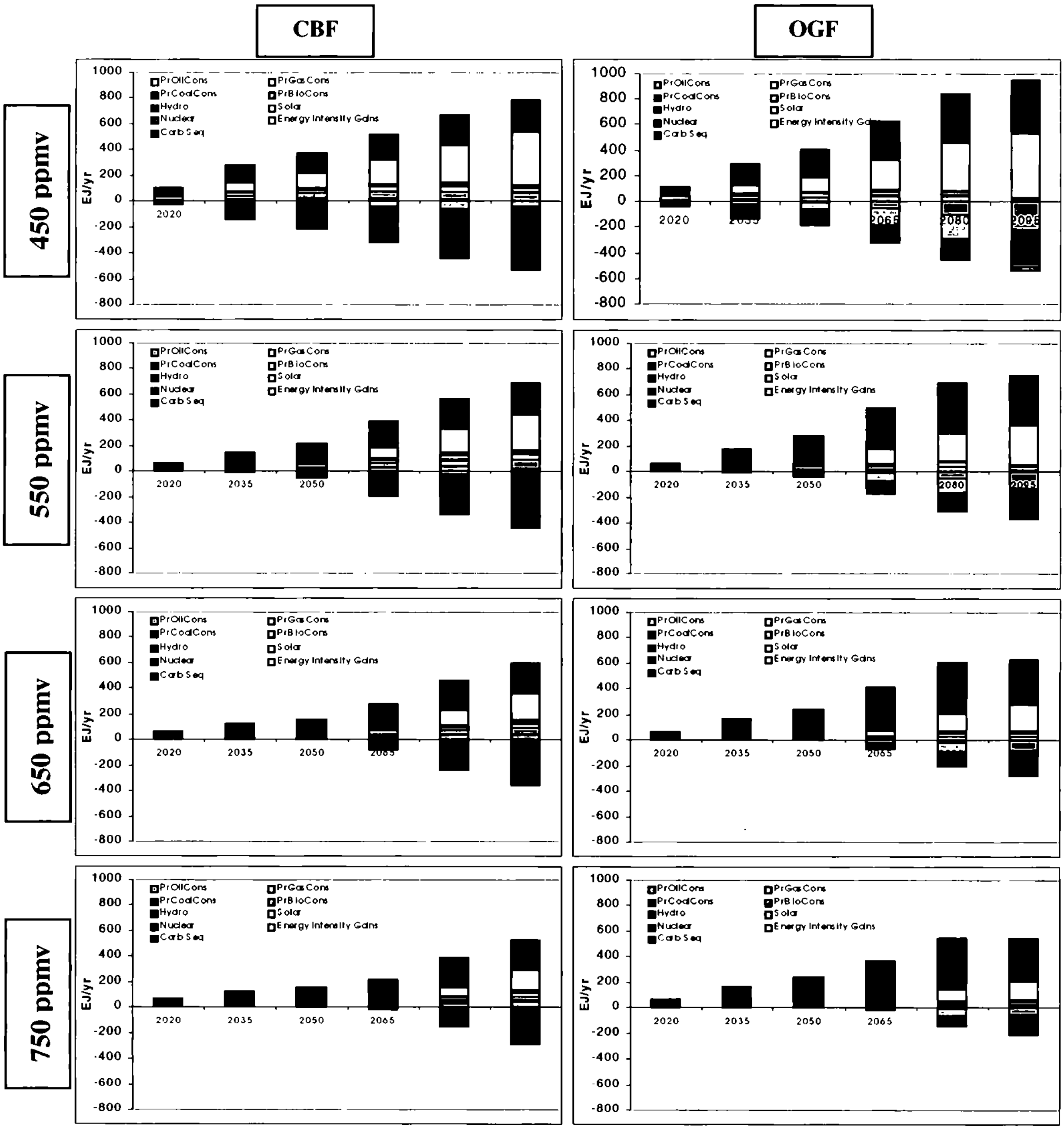


Figure 4: Changes in the Global Energy System Relative to Reference for Alternative CO_2 Concentration Ceilings

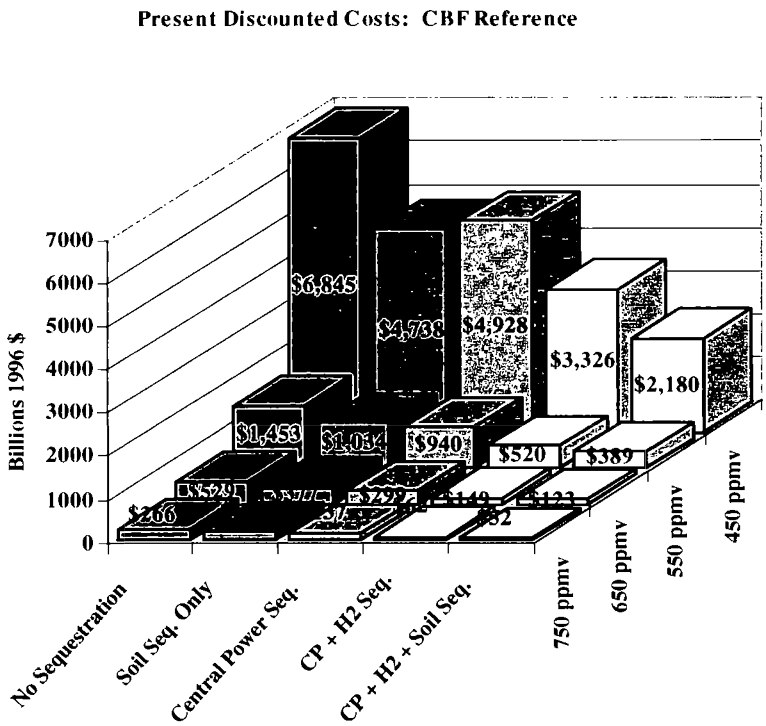


Figure 5: The Effect of Carbon Capture and Sequestration Technologies on the Cost of Meeting Alternative CO_2 Concentration Constraints—CBF, 550 ppmv Ceiling

The reduction in pressure on biomass technologies is important in that it reduces the pressure in land-use to expand into unmanaged ecosystems. The combined effect of introducing soil carbon and carbon capture and sequestration technologies to in an overall technology portfolio is to reduce net present costs by more than half.

The introduction of these technologies affects the composition of energy sector under carbon constraints. As a consequence, the mix of technologies which fill the gap between reference carbon emissions and the WRE constraint is more evenly distributed between existing and new energy technologies.

Sequestration: Over the course of the next century between 157 and 374 PgC of carbon are captured, Table 7.

Table 7: Cumulative Carbon Capture for Alternative CO_2 Concentration Constraints—2000 to 2095 (PgC)

	450 ppmv	550 ppmv	650 ppmv	750 ppmv
CBF	279	203	168	157
OGF	374	281	221	195

There are several types of carbon reservoirs, which could be employed for long-term storage. The most obvious are foil and gas wells—both active and depleted—but this reservoir is limited in capacity. Larger reservoirs are also potentially available including saline geological formations, caverns, salt domes, and deep oceans. Herzog et al. (1997) has estimated the capacity of various reservoirs, Table 8.

Table 8: Estimates of Global Carbon Storage Reservoirs

	Range (PgC)	
Carbon Storage Reservoir	**Low**	**High**
Deep Ocean	1,391	27,000
Deep Saline Geological Formations	87	2,727
Depleted Gas Reservoirs	136	300
Depleted Oil Reservoirs	41	191

Of these reservoirs, oil and gas reservoirs are the most attractive. Active oil and gas wells can utilize the CO_2 in tertiary recovery. Furthermore, the geological formation has already demonstrated its ability to hold oil and gas. There are no obvious environmental consequences to long-term storage in locations, which previously held oil and gas. The same cannot be said for deep oceans and deep saline geological formations. These sites, while promising, hold potential uncertainties in retention and environmental impacts. The quantities of carbon captured over the course of the next century in the carbon-constrained scenarios examined here do not strain the potential capacity of total reservoirs.

While we recognize the potential of carbon capture and sequestration technologies to add an important new element to the set of climate mitigation technologies, it is also important to point out that these technologies are part of a larger suite of technologies whose composition varies over time and space. The deployment of carbon capture and sequestration technologies may be limited by physical or technical considerations. It may also be limited by public acceptance, either locally or in general. Research can begin to address technical concerns, but experience will ultimately be needed to determine these technologies' acceptability.

ENERGY R&D TRENDS

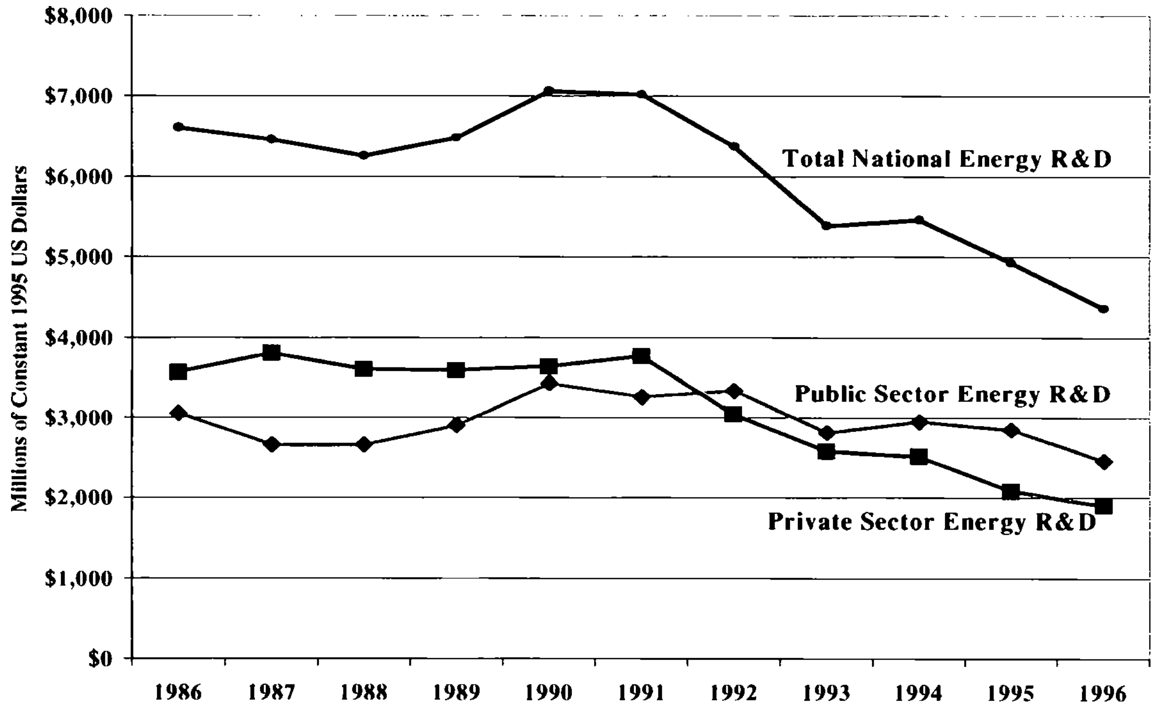
The eventual large-scale deployment of technologies that are not presently part of the energy system requires energy R&D. The presence of a carbon constraint raises the value of energy R&D compared with non-carbon mitigation cases. Increases in future energy R&D can be justified on climate grounds alone (Schock et al., 1997).

But, energy R&D has been declining over the last decade in many OECD nations (Dooley, 1997,1998). There are a variety of reasons that explain the decline. These include changes in productivity of investments, declining energy prices, and changes in institutions and markets. For whatever reasons, the trend is clear. These R&D trends reflect the present suite of private and public costs and benefit considerations about the continued development of these climate relevant technologies.

Decline in the Support for Energy R&D: United States investment in energy R&D has declined substantially over the last decade. Total (public and private) United States expenditures for energy R&D declined from $6.6 billion to $4.4 billion (expressed in constant 1995 dollars), a real decline of 34%. Furthermore as a percent of GDP, United States investments in energy R&D have declined 0.11% of GDP in 1986 to 0.06% of GDP in 1996. That is in the course of just the past decade, the US investment in energy R&D as a percentage of GDP, which can be taken as a measure of the relative importance placed on the continued development of these technologies was nearly halved (Dooley 1997).

Figure 6 presents data on total United States (public and private) investments in energy R&D in constant 1995 dollars. Public sector support for energy R&D declined from $3.0 billion in 1986 to $2.5 billion in 1996, a real decline of 19%. However the reductions in the private sector's support for energy R&D were far more dramatic. Private sector support for energy R&D declined in real terms by more than 46% over the past decade, falling from $3.6 billion in 1986 to $1.9 billion in 1996. (Dooley 1997).

Figure 6: United States Public and Private Sector Energy R&D—1986 to 1996

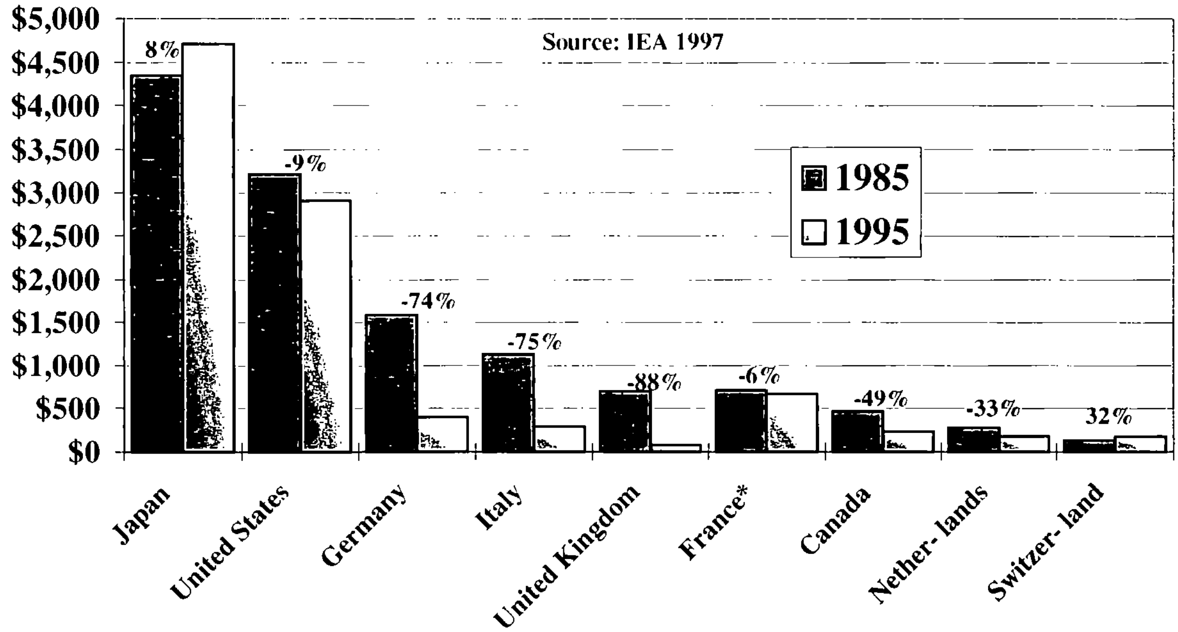


Decline in the Support for Energy R&D in the OECD: Similar reductions can be seen over the period 1985-1995 in public sector support for energy R&D[11] in the key countries known to perform such research. Approximately 96% of the industrialized world's public sector energy

[11] The following discussion of international "public energy R&D" is based on data from the International Energy Agency (IEA) as such it will often differ from accounts of energy R&D investment levels that are based upon country-specific data sources such as those presented above for trends in the US public sector's support for energy R&D.

R&D is carried out in only nine countries (number in parentheses shows country's rank in terms of public sector support for energy R&D in 1995): Canada (6), France (3), Germany (4), Italy (5), Japan (1), the Netherlands (7), Switzerland (8), the United Kingdom (9), and the United States (2) (International Energy Agency, 1997). All of these countries except Japan and Switzerland cut their public sector investments in energy R&D over this period. Many of these cuts have been substantial, with real reductions of 49-88% in support for energy R&D experienced in some nations. Figure 7 shows the public sector energy R&D funding of these nine nations for 1985 and 1995 and the real rate of increase (or decrease) from 1985 to 1995.[12]

Figure 7: Public Sector Support for Energy R&D in Selected Nations 1985-1995 in millions of constant 1995 US dollars (percentage indicates real growth from 1985 to 1995)



Taken as a whole, the changes in these nations' public energy R&D programs equates to a real decline of 23% in their combined energy R&D effort. These nations, the clear leaders in the industrialized world's search for new energy technologies, have reduced funding to support energy R&D; combined funding in 1995 was approximately $3 billion lower than the combined funding in 1985. Over this time period there have been particularly pronounced reductions in the R&D in support of energy supply options such as nuclear fission (-41%), fusion (-30%), and clean coal energy R&D (-47%). Even politically popular renewable energy R&D programs were unable to escape the reductions (-6%) targeted for energy supply technologies. For the most part, many of these energy supply R&D programs were simply ended, with the funding that have previously been allocated for the development of energy R&D technologies redirected towards meeting national priorities other than energy R&D, e.g., deficit reduction (Dooley 1998).

[12] Data for France's public sector energy R&D program for 1985 are unavailable. The number cited here for 1985 is actually the amount spent by the French government for energy R&D in 1990 and therefore the percentage shown indicates the rate of decrease in French funding for energy R&D from 1990-1995. It is known that French funding for energy R&D in 1985 was higher than the level in 1990 and that therefore the 6% reduction cited here actually understates the true rate of decline in the French government's support for energy R&D.

A further factor that compounds these reductions in energy supply R&D is the fact that many of these government energy R&D programs are now focusing on very near-term projects. Very little long-term, high-risk (and therefore presumably) high-reward energy R&D is being carried out in these nations (International Energy Agency, 1997). These reductions in OECD nation's support for energy R&D and the shift towards less risky research has led to concern that these changes have emasculated these nations' research capabilities to the point where they are unable to carry out energy supply R&D on a scale that is "commensurate in scope and scale with the challenges and opportunities of the twenty-first century" (Holdren et al., 1997).

Assessing the Impact of the Decline in the Support for Energy R&D: The changes in the level of public sector funding for energy R&D in these leading industrialized nations is significant because of how large a role these countries play in determining the rate of advancement in the world's search for new energy technologies. These changes are also significant because of the clear and well-established linkages between public and private sector research capabilities, i.e., it has been shown that public investments in energy R&D stimulate additional and complementary private sector investments in energy R&D (see, for example, Mansfield and Switzer, 1984).

Equally important are the changes in the nature of the energy R&D being conducted within these reduced budgets. Dooley (1998) has documented that a combination of factors most notably the push to deregulate and restructure energy industries has lead to a dramatic shortening in the time horizon deemed reasonable for private sector investments in energy R&D. Private sector firms in most of these OECD nations have substantially reduced their support for long-term, high-risk and therefore presumably high reward energy R&D programs. Private firms are instead redirecting their remaining energy R&D investments to focus on developing proprietary technologies that can be bundled with various energy services as a way to retain and attract customers in a deregulated market. Dooley (1998) concludes that given these trends "long-term energy R&D—and in particular cleaner, environmentally-preferred advanced energy supply R&D—is unlikely to be supported by individual utilities in a competitive, deregulated utility market." It also appears unlikely that national governments will support the development of these key energy technologies needed to deal with the challenge posed by climate change.

Because carbon management is not presently a direct financial consideration, there is presently no direct financial value to conducting R&D that would make it cheaper to control carbon emissions. The only motivations for conducting such R&D are philanthropic and to provide insurance against the contingency that carbon emissions might someday be managed. Some R&D focused on carbon management is already underway in both the public and private sectors. Numerous opportunities for basic research that could provide the foundation for lower cost carbon management also exist (Benson, et al., 1998). The potential value, of a successfully executed energy research program, changes dramatically if policies to stabilize carbon concentrations are implemented.

CONCLUSIONS

In this paper we have made a first attempt to consider the joint problems of energy technology needs for a carbon constrained world, and barriers to technology development. This analysis points to a number of conclusions.

First, a portfolio of technologies will be needed to address carbon mitigation as well as adaptation. We see no evidence that any single technology will provide the bulk of emissions mitigation that will be needed over the course of the next century.

The degree of emissions mitigation required in the near term, to meet all but the most stringent constraints, is relatively modest. The bulk of emissions mitigation in all of the scenarios we examined occurs in the second half of the 21st century. This in turn implies that the near-term value of a tonne of carbon is relatively small, but rises steadily.

The availability of carbon capture and sequestration technologies on a global scale can significantly reduce the long-term cost of emissions mitigation. These technologies can be an important part of a technology strategy to address climate change. However, it is important to recall that they reduce cost by expanding the set of options for mitigating emissions. They provide only a small fraction of total mitigation. The remainder is provided by nuclear, renewable, and conservation technologies.

The relative importance of technologies in the overall mix changes with time. Some opportunities, such as for example soil carbon uptake, are available for a limited period of time.

We note that the decline in energy R&D, and in particular the decline energy R&D that focuses on technologies which would contribute most prominently in a regime of long-term emissions mitigation. Funding for research in the area of carbon capture and sequestration technologies, for example, barely exists outside of Japan. Yet, the value of developing this option is denominated in hundreds of billions of present discounted dollars for the 550-ppmv constraint. This decline represents a major obstacle to the successful development of the energy technology foundations which will be needed in the decades ahead if the concentration of greenhouse gases in the atmosphere is to be stabilized.

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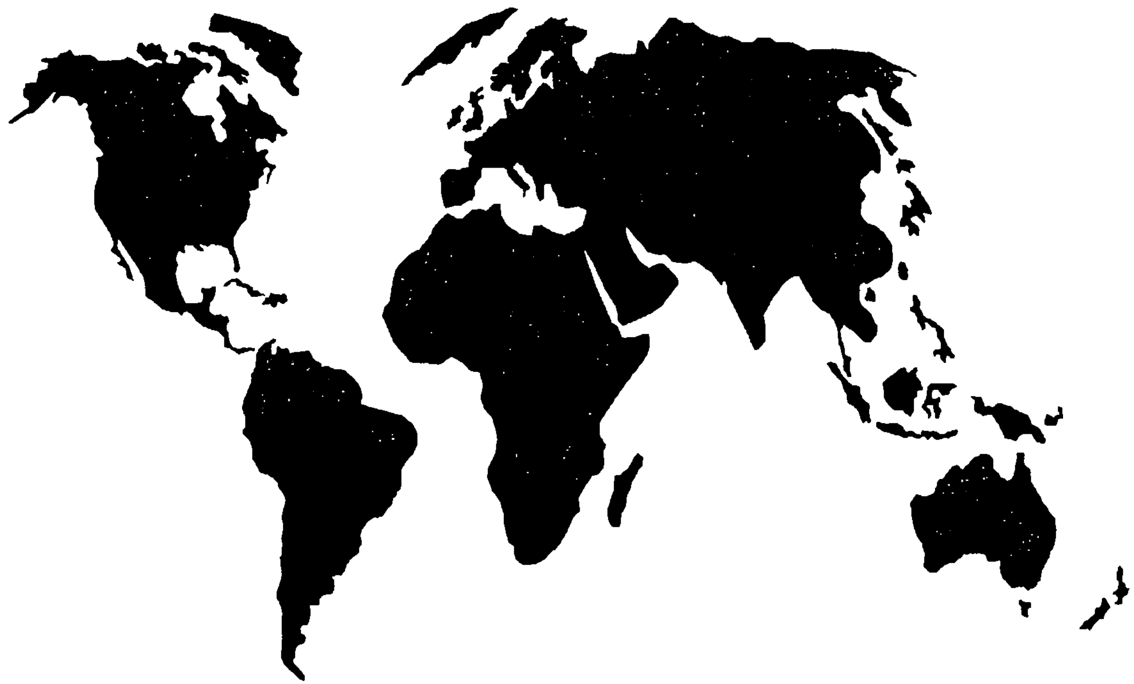
American Council for Capital Formation

The Impact of Meeting the Kyoto Protocol on Energy Markets and the Economy



September 23, 1998

Joyce Yanchar Brinner, Ph.D.

STANDARD & POOR'S
DRI

The Kyoto Protocol

On December 10, 1997 in Kyoto, Japan the Parties to the UN Framework Convention on Climate Change (160 nations) agreed to an historic Protocol to reduce greenhouse gas emissions by "harnessing the forces of the global marketplace."

Only 38 of the 160 nations are required to limit their emissions under the Protocol.

STANDARD & POOR'S DRI

The Kyoto Protocol and its Flexible Provisions

- Requires Annex I countries to limit emissions of 6 GHGs to 92-110% of 1990 (or 1995) levels between 2008-12.
- Emissions would be controlled through a system of country-allocated permits that can be traded among the Annex I countries.
- Project-based emission reductions would be credited toward the targets (JI and CDM).
- Certified emission reductions starting in 2000 in developing countries would count toward compliance in the first budget period.
- Activities that absorb carbon (sinks) could be used as offsets against emission targets.

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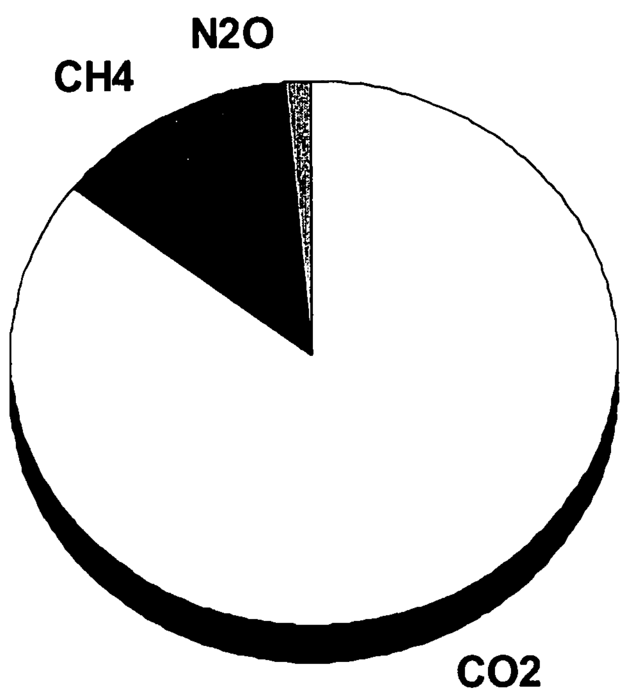
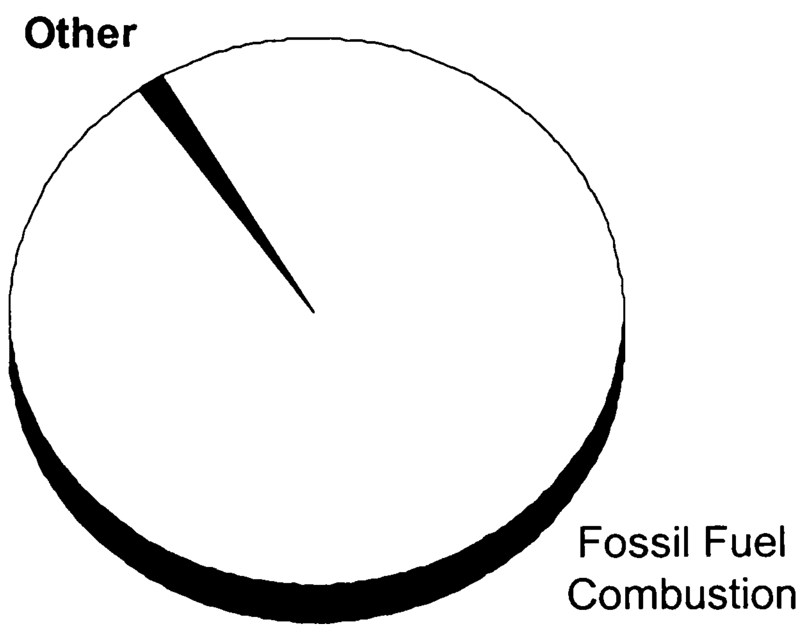
CO_2 is the Dominant Greenhouse Gas

Fossil Fuel Combustion is the Dominant Source of CO_2 Emissions



Greenhouse Gas Emissions



CO_2 Emissions

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Under the Flexible Mechanisms of the Protocol, the U.S. Can Achieve its Reductions At Home by...

- Shifting the mix of fuels it combusts,
- Curtailing its fossil fuel combustion,
- Making further reductions in other greenhouse gases, particularly those with higher global warming potentials,
- Expanding sinks.

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Or it Can Achieve the Reductions Abroad by...

- Purchasing emission credits from other Annex I countries,
- Investing in emission-reducing or sequestering projects in other Annex I countries (Joint Implementation),
- Investing in emission-reducing or sequestering projects in developing countries (Clean Development Mechanism).

U.S. Commitment Under the Kyoto Protocol

- U.S. Co_2 emissions are limited to 1243 million metric tons of carbon (93% of 1990 levels) between 2008-12.

- Under business-as-usual conditions, U.S. CO_2 emissions are projected to average 1740 million metric tons.

- The U.S. must reduce its CO_2 emissions 500 million metric tons, or 30% below business-as-usual levels.

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The Administration's Assessment

- 85% of the U.S. commitment can be met from abroad at a very low carbon permit price of $14-23 per metric ton.

- After accounting for offsets from sinks and other gases, the U.S. would only need to cut its fossil fuel use by 5% in the 2008-12 period.

- Consumer energy prices would only need to rise 3-5% to meet this reduction.

- GDP impacts would be negligible.

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The DRI Study Highlights Uncertainties

- Carbon emissions forecasts are uncertain. Forecasts for the Former Soviet Union countries are particularly questionable.

- The extent to which countries will be allowed to meet their emissions reductions from abroad is uncertain.

- The certification and scoring of projects by the CDM is uncertain.

- Offsets from sinks and other gases are uncertain.

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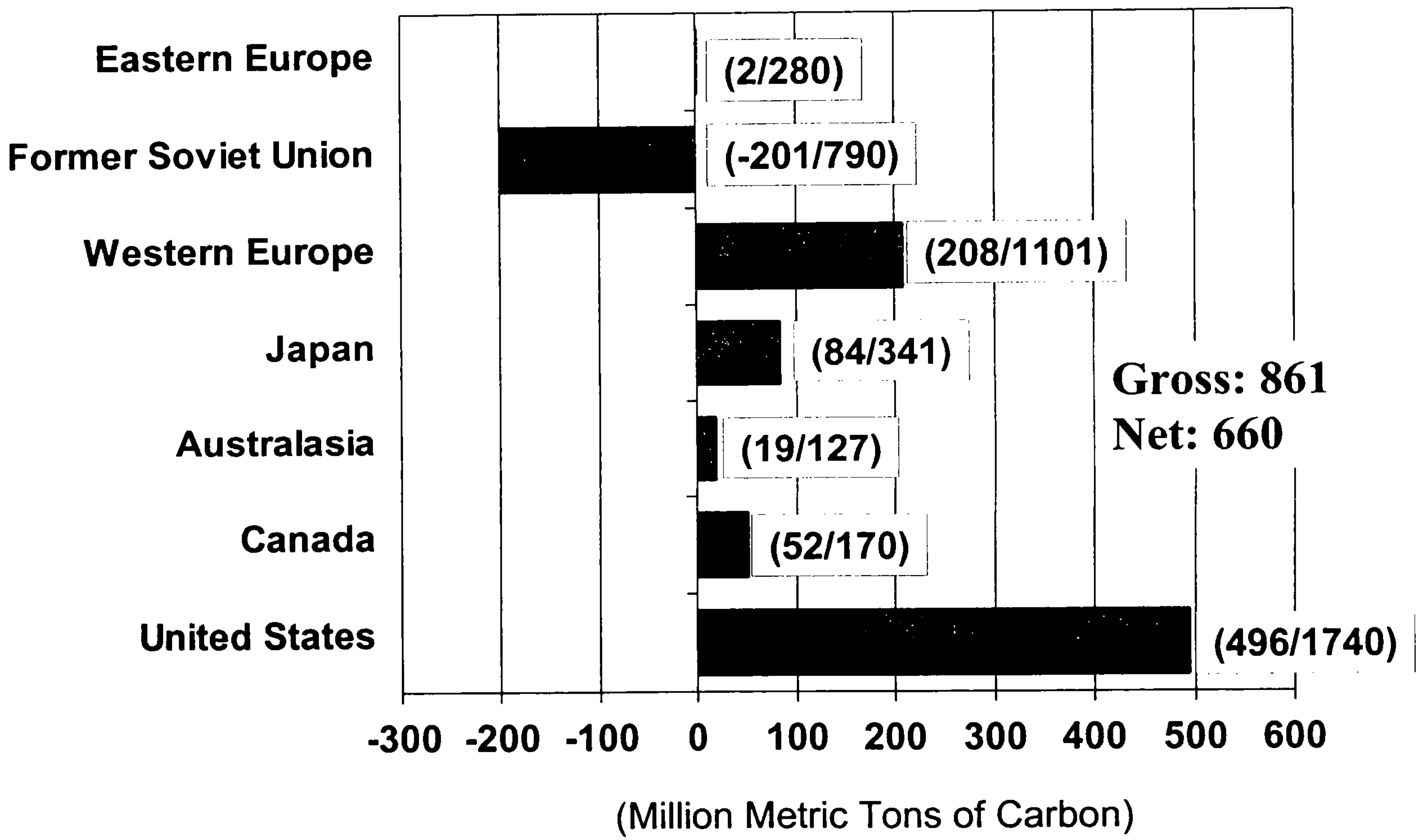
Required Reductions in CO_2 Emissions



(Required Reduction/Business-as-usual Projection)

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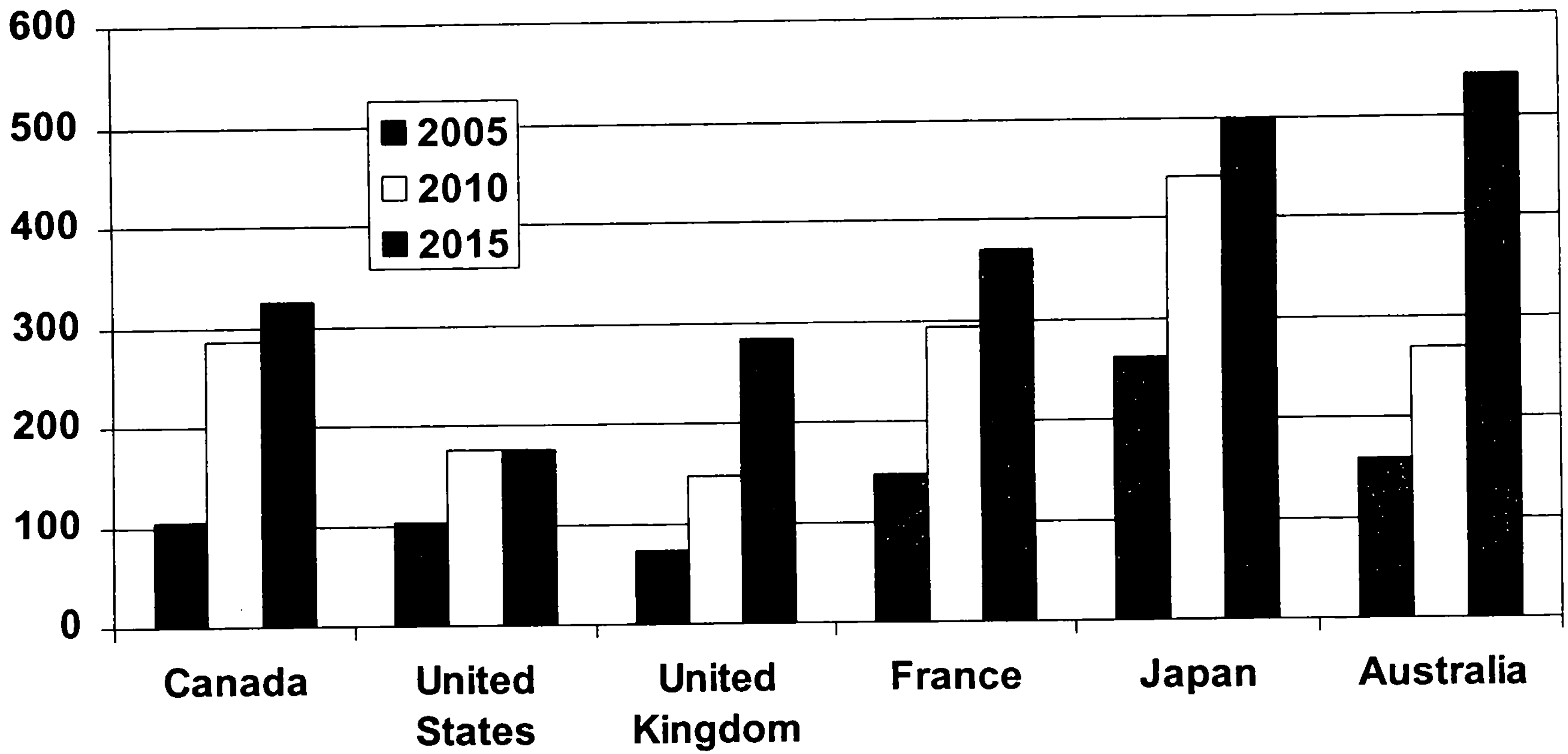
Other Countries Will Be Willing to Pay More for Available Carbon Permits

(International Carbon Permit Price Comparison, Stabilization Without International Trading, 1995 Dollars Per Metric Ton)



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Sources of U.S. Carbon Emission Reductions

2008-2012
(Percent of Required Reduction)

	CASE 1	CASE 2	CASE 3
Purchases from Abroad	15%	30%	55%
Sinks & Offsets from Other Gases	8%	12%	16%
Changes in Energy Use	77%	58%	29%

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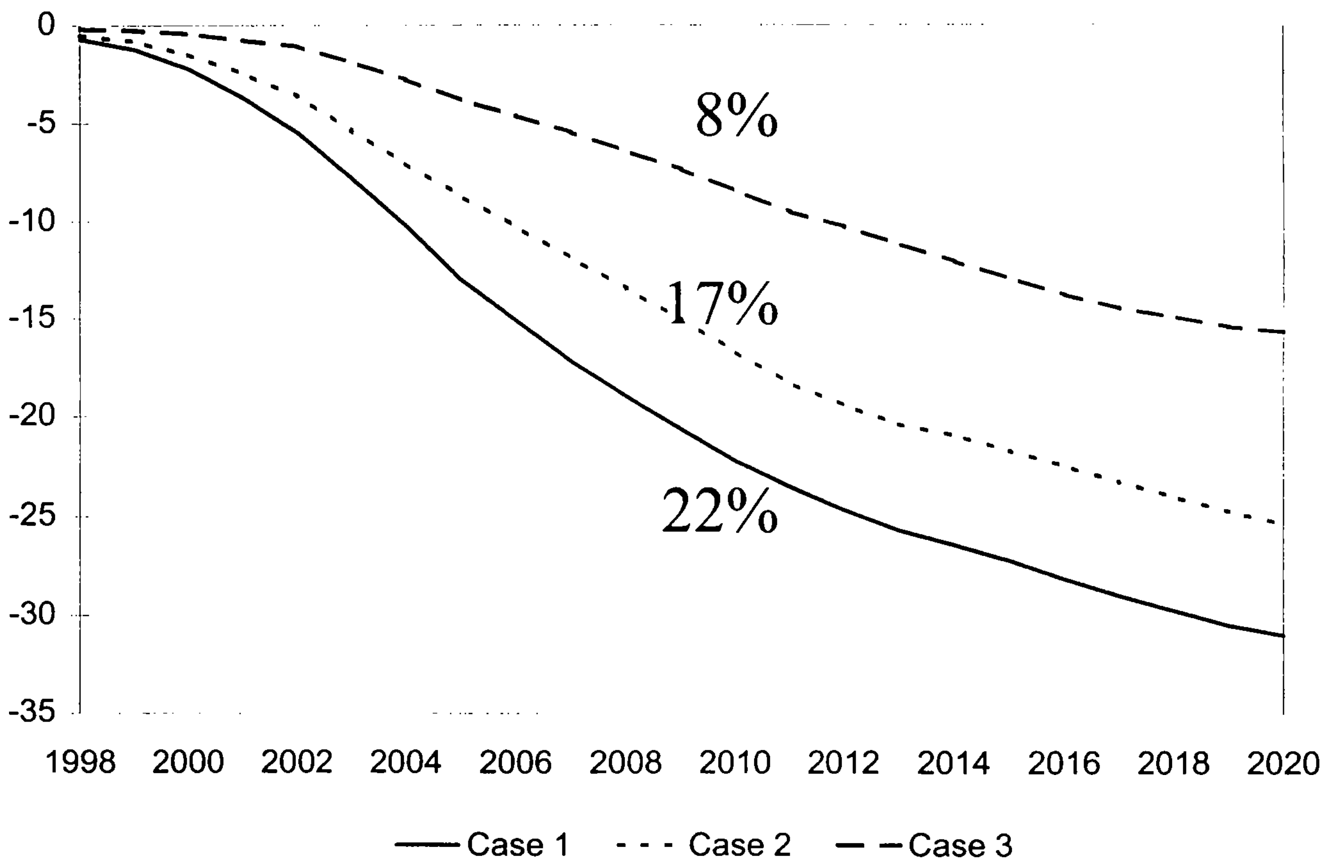
U.S. CO_2 Emissions from Fossil Fuel Combustion

(Percent Difference From Base Case)



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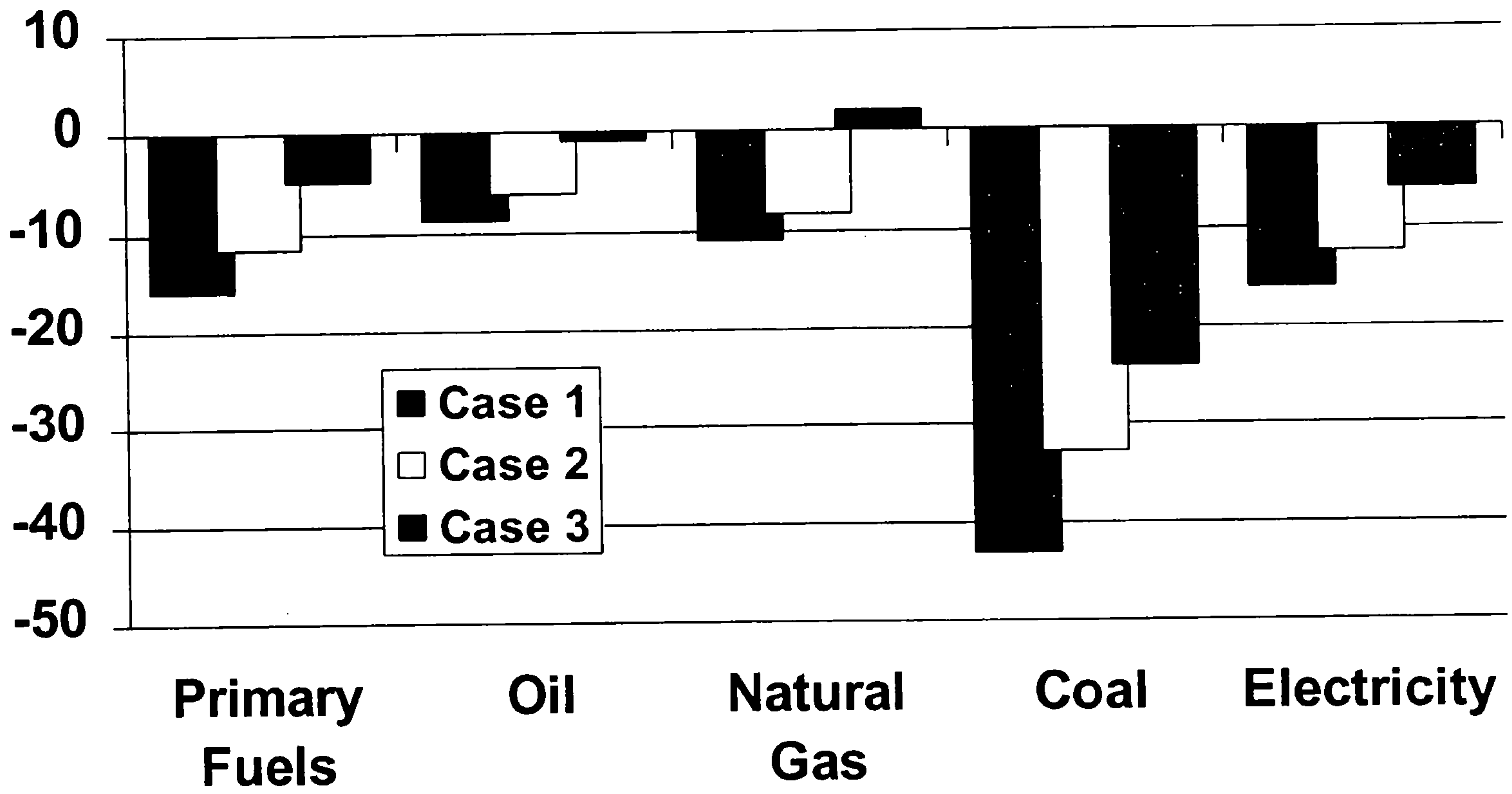
Energy Demand

(Percent Difference From Base Case, 2008-12)



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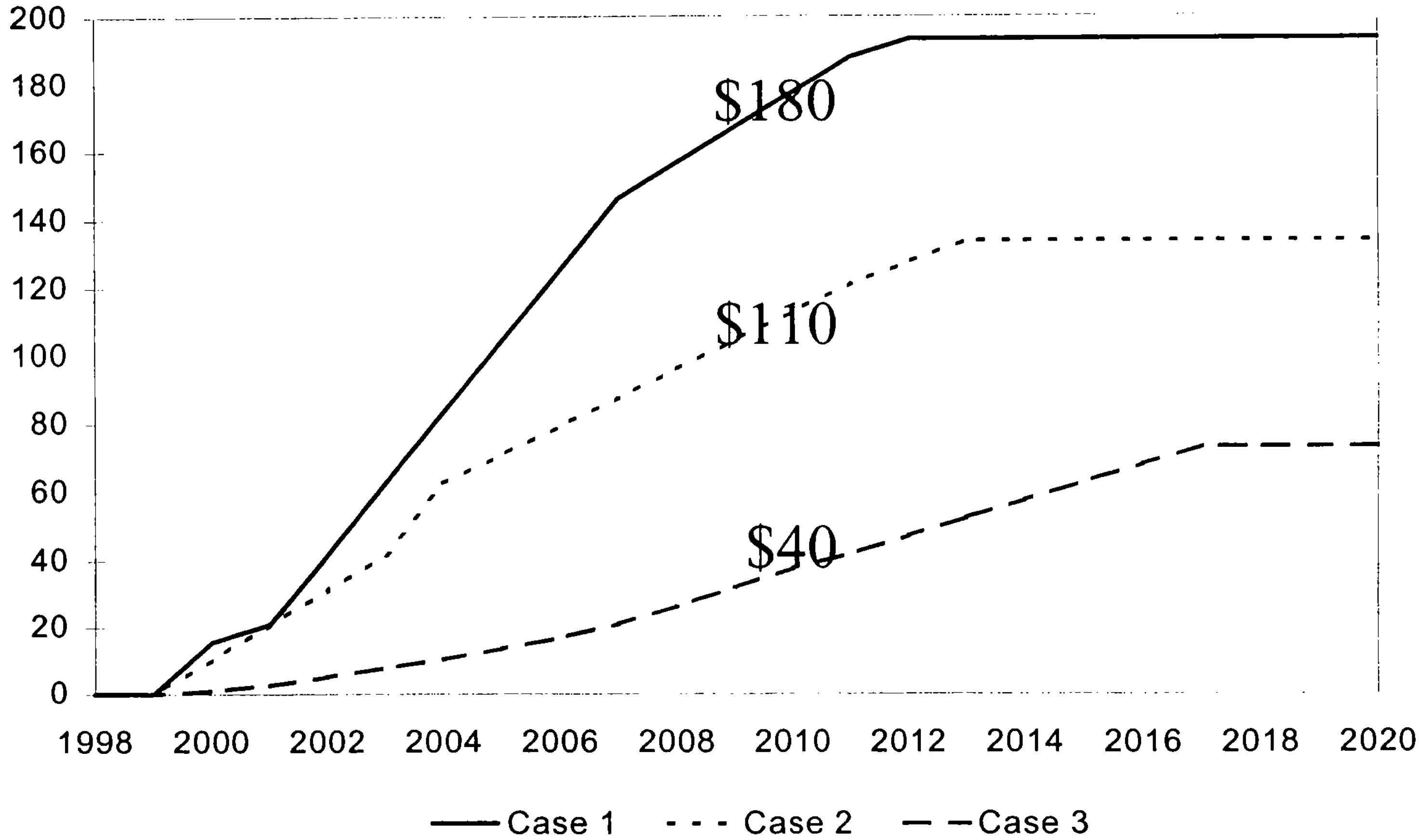
Carbon Permit Prices

(1997 Dollars Per Metric Ton)



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Real Energy Costs, 2010

(Percent Difference From Base Case)

	CASE 1	CASE 2	CASE 3
Gasoline - Retail	29	18	17
Residual Fuel	86	54	19
Electric Utility Coal	407	258	85
Electric Utility Natural Gas	111	69	26
Electricity Average	54	37	17
Producer Prices, Energy	77	49	18
Consumer Implicit Prices, Energy	36	24	9

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Output and Employment Losses Expected Over the Next Decade Under the Kyoto Protocol Because:

- Energy-using equipment and vehicles would be made prematurely obsolete;
- Consumers would be rattled by rapid increases in living costs;
- Net imports would be spurred by the competitive price advantage of non-Annex I countries.
- The Federal Reserve would most likely need to target more slack in the economy to deflate non-energy prices and stabilize the overall price environment.
- A large revenue stream would be diverted overseas.

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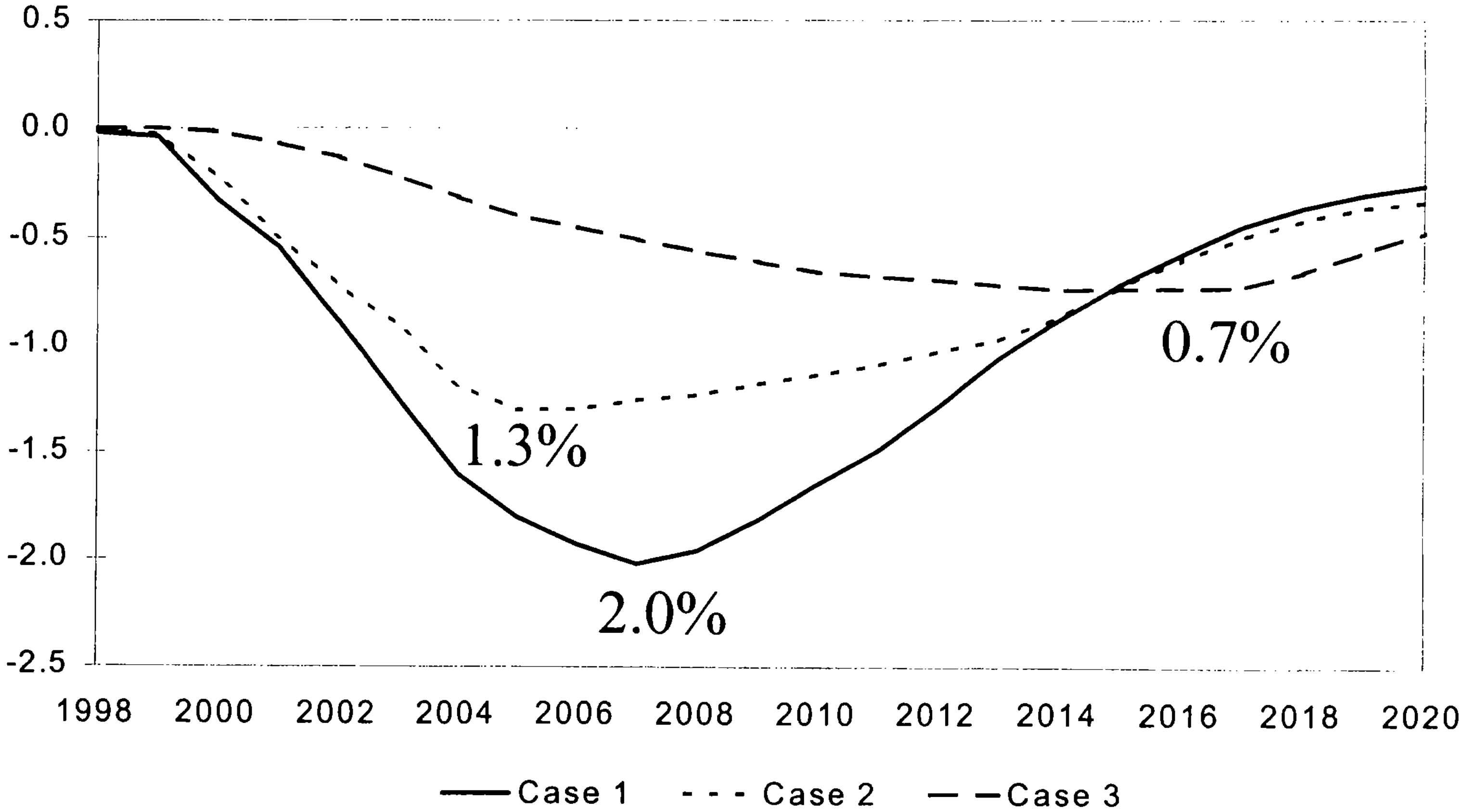
Real GDP

(Percent Difference From Base Case)



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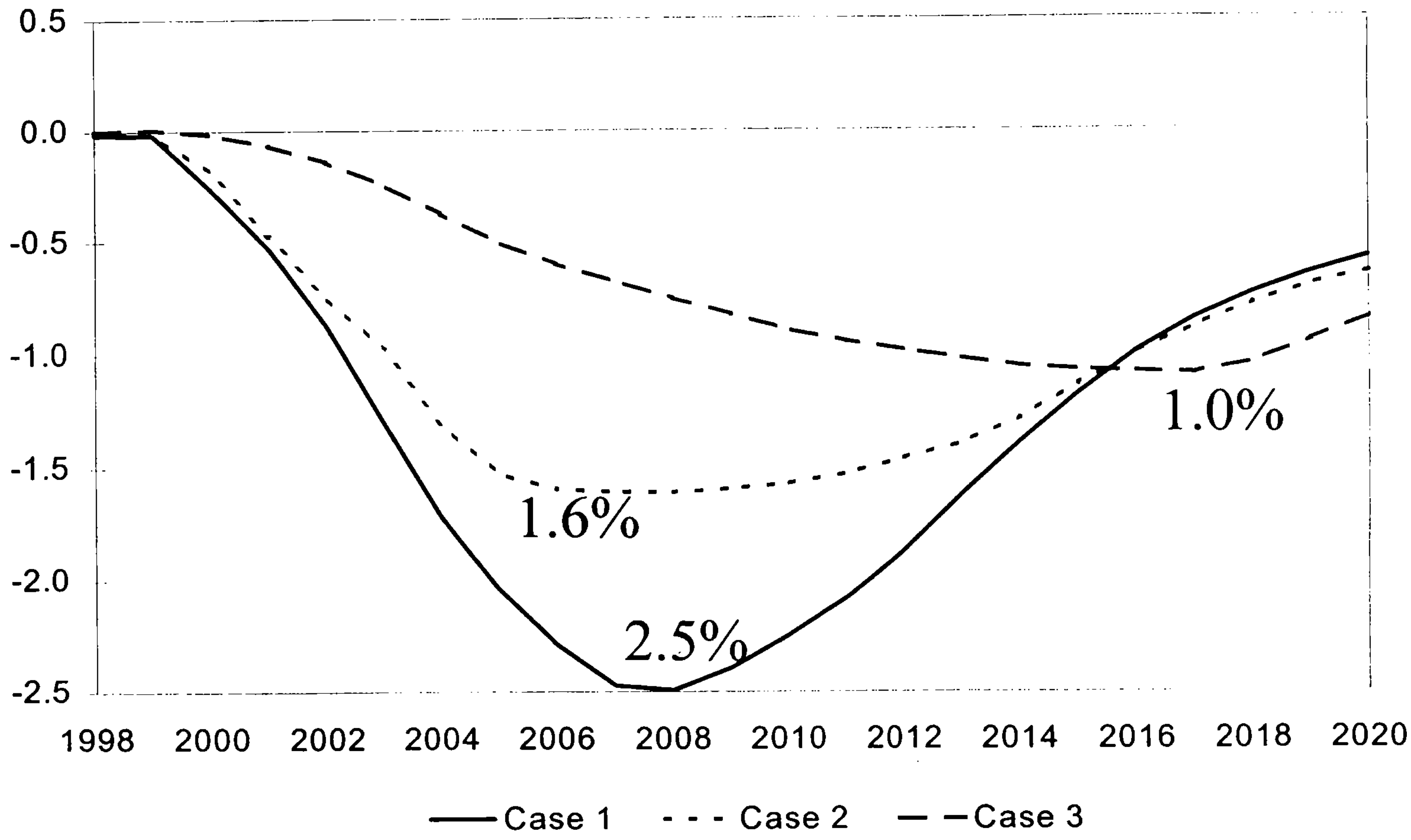
Real Consumption

(Percent Difference From Base Case)



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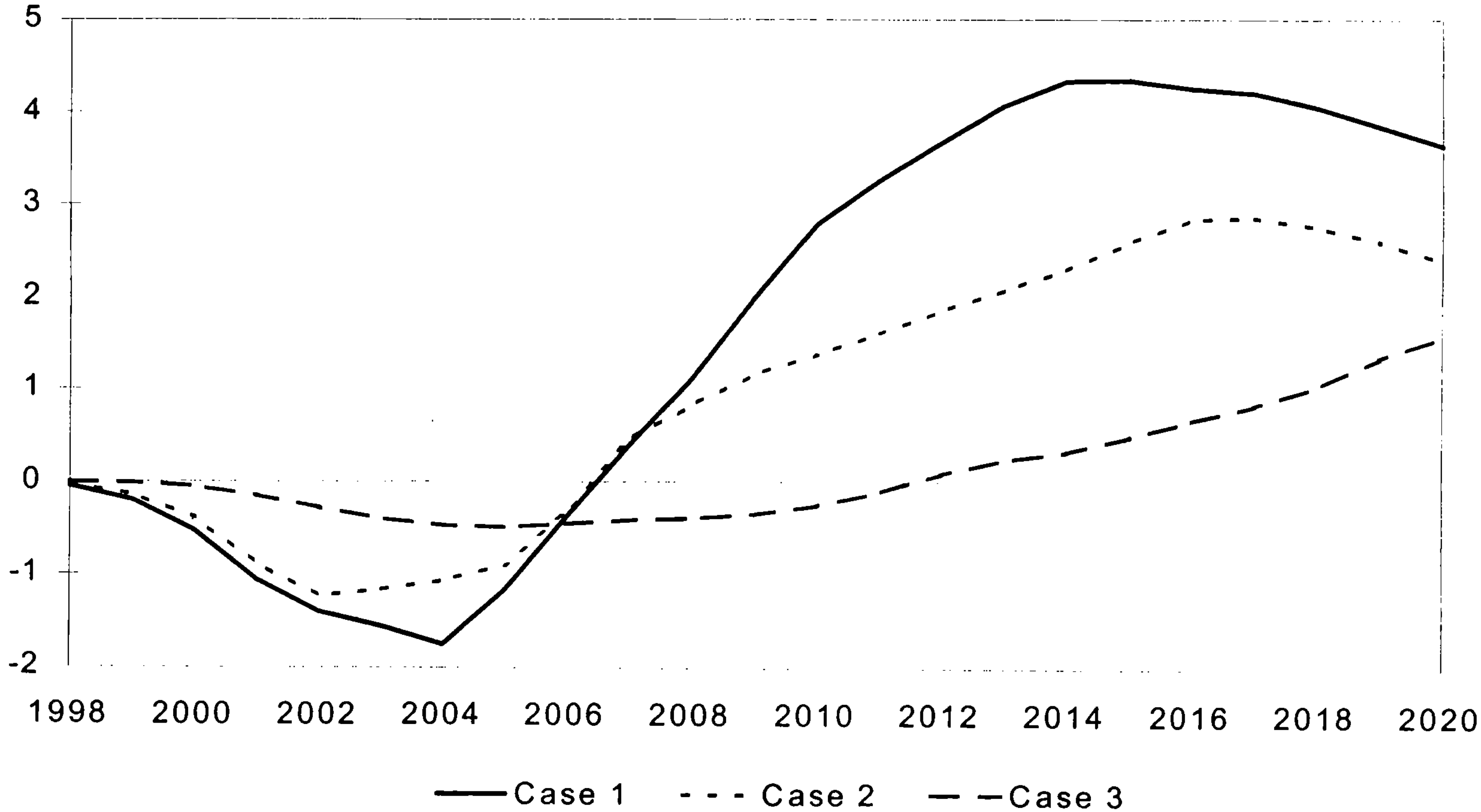
Real Business Fixed Investment

(Percent Difference From Base Case)



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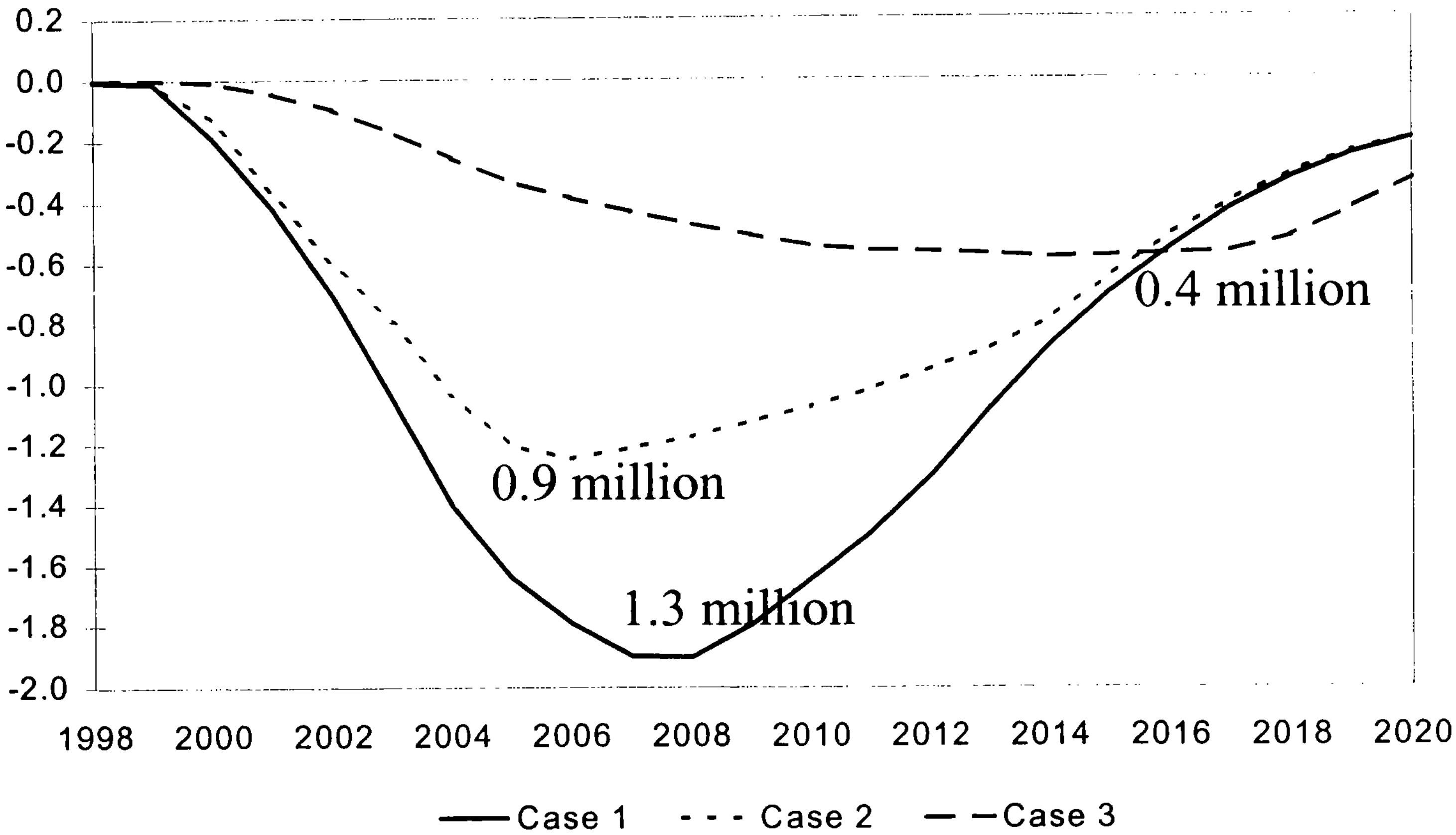
Civilian Employment

(Difference From Base Case, Millions)



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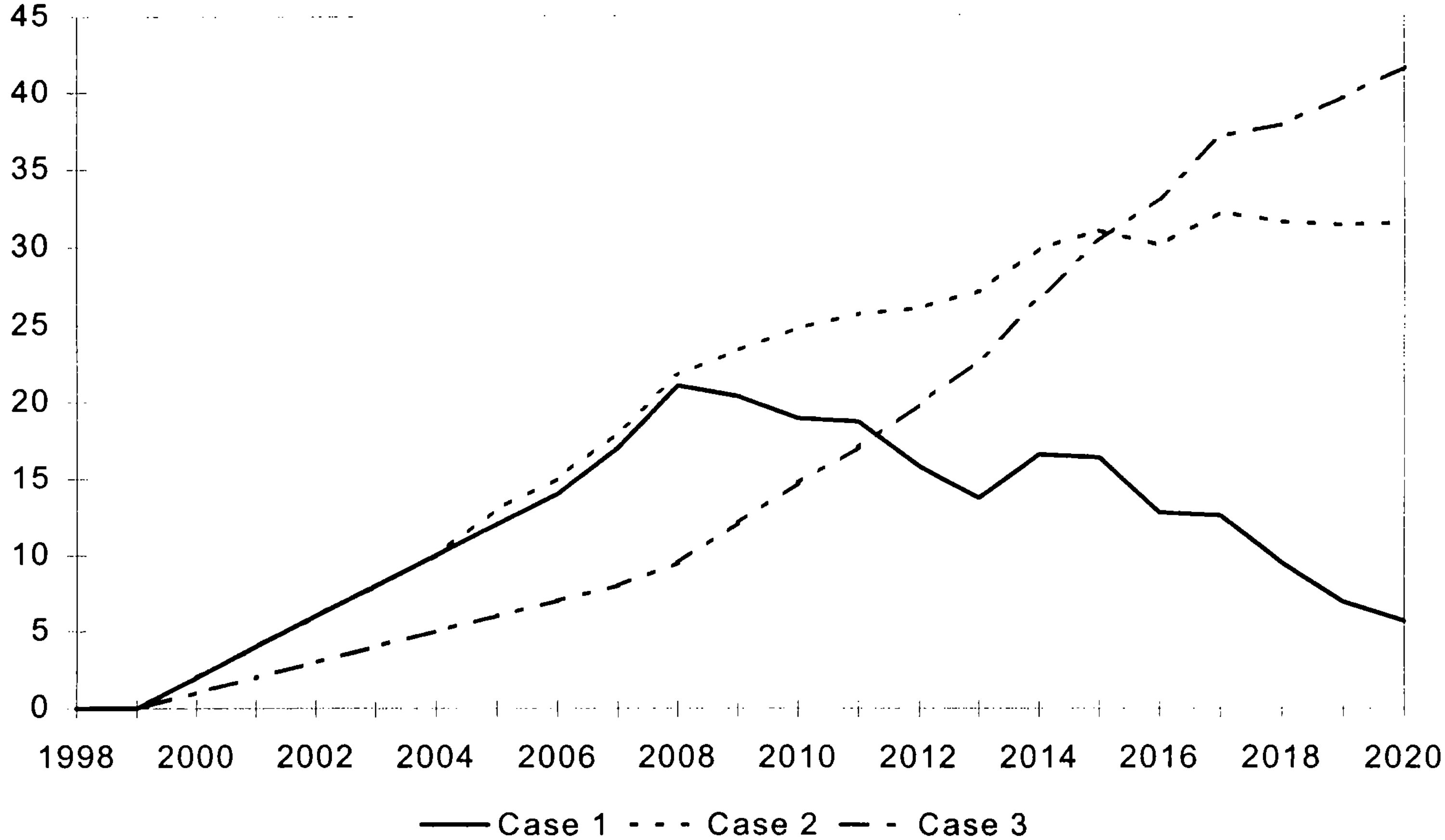
U.S. Payments for Purchases of Emissions Credits from Abroad

(Billions of Dollars)



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Impacts on U.S. Industry

- The energy producing and transformation industries suffer from a sharp decline in domestic demand. Coal mining is by far the hardest hit of the industries.
- Energy intensive industries experience significant price increases that depress domestic demand and encourage imports.
- Trade-sensitive industries suffer from an increase in import penetration.

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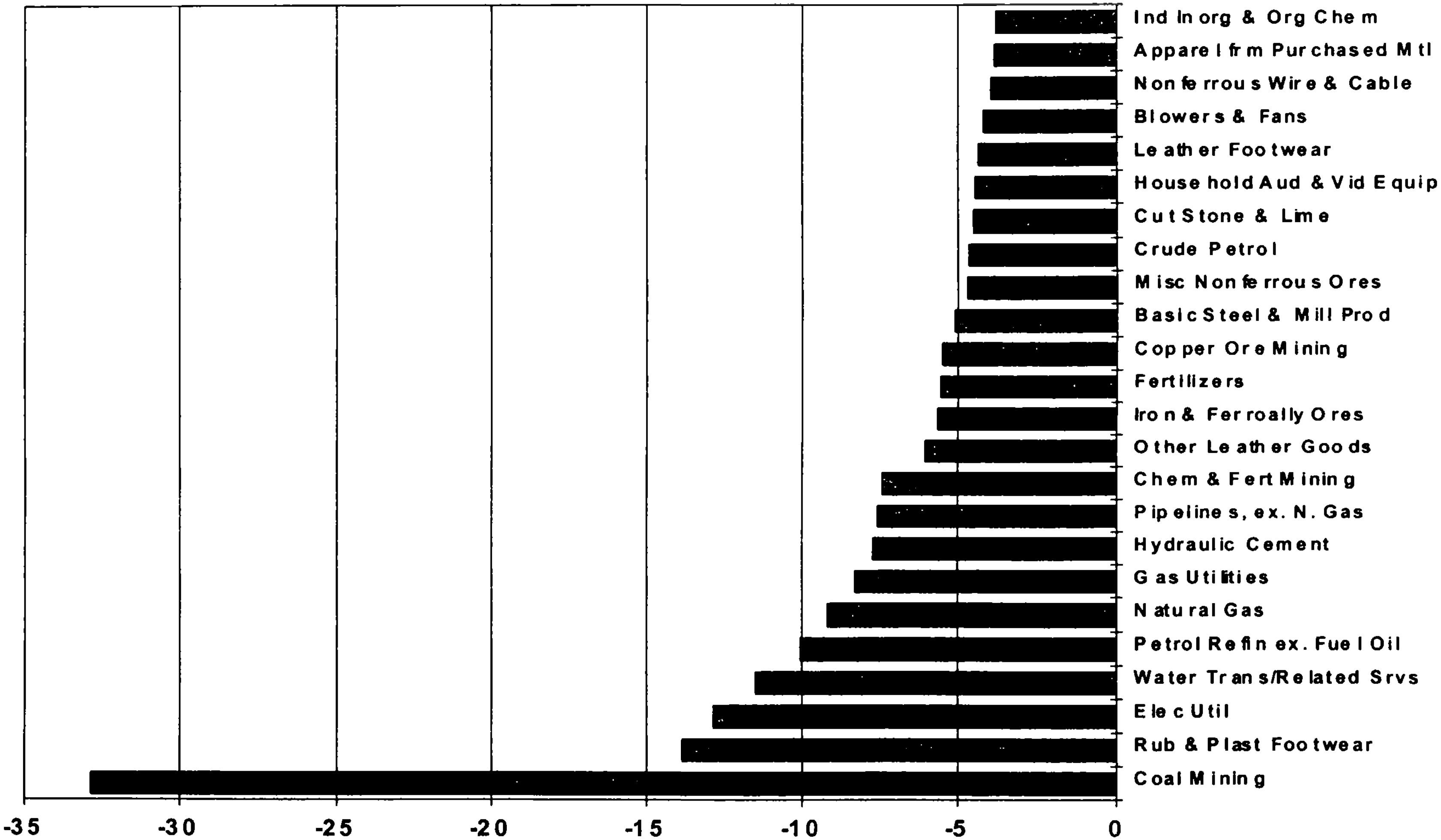
Impact of Carbon Permits on Industry Output, Top 25

(Case 2: Percent Difference From Base Case, 2010)



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The DRI Analysis

- Realistically, only 30% (15-55%) of the U.S. commitment can be met from abroad at a carbon permit price of $110 per metric ton ($180-40 per metric ton).
- After accounting for offsets from sinks and other gases, the U.S. would need to cut its coal use by 33% (43-24%) and its total fossil fuel use by 12% (16-5%) in the 2008-12 period.
- Producer energy prices would need to rise 49% (77-18%) to meet this reduction; consumer energy prices would rise 24% (36-9%).
- Real GDP would fall a maximum 1.3% (2.0-0.7%) below base case levels, with real consumption down 1.6% (2.5-1.0%).
- Annual employment losses would be as high as 0.9 million jobs (1.3-0.4 million).

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National Impacts of Alternative Emissions Reduction Cases, 2008-12

	Case 1	Case 2	Case 3
Reduction in Emissions from Domestic Energy Use (million tonnes difference from base)	385	290	150
Reduction in Domestic Energy Use (percent difference from base)	16%	12%	5%
Permit Price (1997 dollars)	$180	$110	$40
Producer Energy Prices (percent difference from base)	77%	49%	18%
Average Real GDP Impact (percent difference from base)	-1.6%	-1.1%	-0.6%
Average Real Consumption Impact (percent difference from base)	-2.2%	-1.6%	-0.9%
Employment Impact (percent difference from base)	-1.1%	-0.7%	-0.4%
Employment Impact (average annual difference from base, millions)	-1.6	-1.1	-0.5
Annual Payments for Emissions Credits from Abroad (billion dollars)	$19	$24	$15
Consumer Energy Prices (percent difference from base)	36%	24%	9%
Consumer Price Index (percent difference from base)	5.5%	3.5%	1.4%
Annual Household Energy Expenditures (price difference from base * base case demand levels, dollars)	$1,573	$1,012	$387
Real Household Income (difference from base, 1992 dollars)	-$1,403	-$1,021	-$598

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The Kyoto Protocol and U.S. Agriculture

Paper

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September 23, 1998

The Kyoto Protocol and U.S. Agriculture
by

Terry Francl, American Farm Bureau Federation
Richard Nadler, K.C. *Jones* and
Joseph Bast, The Heartland Institute

Executive Summary*

Farmers have a major stake in the debate taking place over global warming. Approximately one-fifth of greenhouse gas emissions in the United States come from agricultural activity. Agriculture, as it is practiced in the United States, is surprisingly energy intensive. As a result, proposals to tax fossil fuels or cap carbon dioxide emissions would raise the cost of many farm inputs, from fertilizer and other chemicals to fuel and motor oil.

This study is written for farmers and the businesses and institutions that benefit from their association with farmers. It identifies and quantifies what is at stake in the debate over global warming. It warns the agricultural community to participate in the public debate over the latest global warming treaty—the Kyoto Protocol—or else find itself under fierce assault by federal and state environmental agencies, and by international agencies with newly minted powers that supersede old notions of sovereignty.

How much is at stake? We estimate that compliance with the Protocol would increase U.S. farm production expenses between $10 billion and $20 billion per year and decrease farm income by 24 percent to 48 percent. The Kyoto Protocol, all by itself, could cost the average farmer between one-quarter and one-half of his or her annual income.

In Part 1 of this report, we describe the Kyoto Protocol and the events that led to its endorsement by the Clinton Administration. The complete text of the Protocol appears in the report's appendix. In Part 2, we examine in considerable detail the likely impact of the Protocol on U.S. agriculture. We walk the reader through the steps of our analysis so that he or she knows that we are presenting objective, solid evidence, not just opinion or alarmist speculation.

In Part 3, we step back from the debate over the Protocol to review briefly the science behind the global warming scare. If the evidence doesn't support the claim that human activities are having a harmful effect on the global climate, why should the United States participate in the Protocol? We find compelling evidence that global warming is not a scientific certainty, but an unproven theory supported by a small but politically influential minority in the scientific community. Moreover, we find that the concerns of this minority are consistently overblown by an alarmist press.

In Part 4 we describe a positive approach to the global warming issue. We believe people in the agricultural community can make a unique contribution to the public debate by describing the *positive* effects that rising carbon dioxide (CO_2) levels have on plant growth, and "win-win" activities that can reduce CO_2 emissions while also benefitting farmers and consumers. Part 5 consists of a brief summary and conclusion.

The positions and evidence presented here are seldom reported by newspapers or featured in television documentaries. This does not mean they represent minority views within the scientific or economic communities; in fact, we will present survey data showing the great majority of scientists do not believe global warming is a real threat to the environment or to human health. If the facts and scientific opinions we present are unfamiliar to the reader, it is because so many journalists and

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*Prepared for a symposium entitled *Climate Change Policy: Practical Strategies to Promote Economic Growth and Environmental Quality*, sponsored by the American Council for Capital Formation Center for Policy Research, September 23, 1998, at the National Press Club in Washington, D.C.

reporters lack the training and background needed to distinguish real science and economic facts from political and ideological "spin."

We hope this report will encourage some journalists to study the global warming issue more closely, and give other readers a source of reliable information on one of the most important issues of the day. Most of all, we hope farmers and their natural allies will use it to defend their farms, their homes, and their way of life.

Pre-Publication Release
This is a near-final copy of a *Heartland Policy Study* scheduled for release by The Heartland Institute, a Chicago-based public policy research group, on October 9. Single-copy price $10; bulk purchase discounts are available. To place an advance order, call 312/377-4000.

No. 87—October 9, 1998

The Kyoto Protocol and U.S. Agriculture

by Terry Francl, Richard Nadler, and Joseph Bast*

Farmers have a major stake in the debate taking place over global warming. Approximately one-fifth of greenhouse gas emissions in the U.S. come from agricultural activity. Agriculture, as it is practiced in the U.S., is surprisingly energy intensive. As a result, proposals to tax fossil fuels or cap carbon dioxide emissions would raise the cost of many farm inputs, from fertilizer and other chemicals to fuel and motor oil.

> The farm community may find itself under fierce assault by federal and state environmental agencies, and by international agencies with newly minted powers that supercede old notions of sovereignty.

This study is written for farmers and the businesses and institutions that benefit from their association with farmers. It identifies and quantifies what is at stake in the debate over global warming. It warns the agricultural community to participate in the public debate over the latest global warming treaty—the Kyoto Protocol—or else find itself under fierce assault by federal and state environmental agencies, and by international agencies with newly minted powers that supersede old notions of sovereignty.

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Any errors that remain are the authors' only.

How much is at stake? We estimate that compliance with the Protocol would increase U.S. farm production expenses between $10 and $20 billion per year and decrease farm income by 24 to 48 percent. The Kyoto Protocol, all by itself, could cost the average farmer between a quarter and one-half of his or her annual income.

In Part 1 of this report we describe the Kyoto Protocol and the events that led to its endorsement by the Clinton Administration. The complete text of the Protocol appears in the report's appendix. In Part 2, we examine in considerable detail the likely impact of the Protocol on U.S. agriculture. We walk the reader through the steps of our analysis so that he or she knows that we are presenting objective, solid evidence, not just opinion or alarmist speculation.

> The Kyoto Protocol, all by itself, could cost the average farmer between a quarter and nearly one-half of his or her annual income.

In Part 3, we step back from the debate over the Protocol to review briefly the science behind the global warming scare. If the evidence doesn't support the claim that human activities are having a harmful effect on the global climate, why should the U.S. participate in the Protocol? We find compelling evidence that global warming is not a scientific certainty, but an unproven theory supported by a small but politically influential minority in the scientific community. Moreover, we find that the concerns of this minority are consistently overblown by an alarmist press.

In Part 4 we describe a positive approach to the global warming issue. We believe people in the agricultural community can make a unique contribution to the public debate by describing the *positive* effects that rising carbon dioxide (CO_2) levels have on plant growth, and "win-win" activities that can reduce CO_2 emissions while also benefitting farmers and consumers. Part 5 consists of a brief summary and conclusion.

The positions and evidence presented here are seldom reported by newspapers or featured in television documentaries. This does not mean they represent minority views within the scientific or economic communities; in fact, we will present survey data showing the great majority of scientists do not believe global warming is a real threat to the environment or to human health. If the facts and scientific opinions we present are unfamiliar to the reader, it is because so many journalists and reporters lack the training and background needed to distinguish real science and economic facts from political and ideological "spin."

We hope this report will encourage some journalists to study the global warming issue more closely, and give other readers a source of reliable information on one of the most important issues of the day. Most of all, we hope farmers and their natural allies will use it to defend their farms, their homes, and their way of life.

PART 1

The Kyoto Protocol

Events Leading to the Kyoto Meeting

In 1992, representatives of the U.S. and 160 other nations met in Rio de Janeiro to negotiate and eventually endorse the United Nations Framework Convention on Global Climate Change, more popularly known as the Rio Treaty. That treaty endorsed voluntary, nonbinding measures "to achieve . . . stabilization of greenhouse gas concentrations . . . at a level that would prevent dangerous anthropogenic interference with the climate system"[1] and pledged to reduce emissions of greenhouse gases to 1990 levels by the year 2000.

In 1995, representatives of the Parties to the Rio Treaty met in Berlin. Discouraged by evidence indicating that few nations would reach their targets by 2000, they decided to pursue a new strategy: amend the original treaty to place mandatory, legally binding greenhouse emission caps on participating nations. Representatives for developing countries refused to allow negotiations to move forward unless they were exempted from the caps. Representatives for developed countries (including then-Undersecretary of State Timothy Wirth) agreed to their demands.

The bipartisan Byrd-Hagel Resolution (S.R. 98) required our negotiators to pursue options that would not seriously harm the U.S. economy.

On July 25, 1997, the U.S. Senate put the Clinton-Gore Administration on notice that it expected U.S. negotiators to uphold American interests in any agreement to limit greenhouse gas emissions. The bipartisan Byrd-Hagel Resolution (S.R. 98) required our negotiators to pursue options that would not seriously harm the U.S. economy. It also demanded that developed and developing nations follow the same compliance period—even if they set different emission goals. The resolution passed the Senate by a 95-0 vote.

On December 1, 1997, the Parties to the Rio Treaty met in Kyoto, Japan, to complete negotiations for a protocol, or amendment, to the treaty. At first, the U.S. negotiating team's positions were consistent with the Senate resolution. U.S. negotiators were prepared to commit the nation to cutting its greenhouse gas emissions to 1990 levels by 2010—a 30 percent reduction from the business-as-usual baseline, by Administration calculations. But five "hard" positions were supposedly in place to protect American competitiveness [NEEDS SOURCE].

1 United Nations Framework Convention on Climate Change, Article 2.

- Emission targets below 1990 levels are unacceptable.

- The 25 largest developing-world greenhouse gas producers must agree to emission targets.

- European nations must accept individual, not collective, emission standards, to prevent some European Union (EU) nations, such as Germany and England, from "shifting" emission reduction credits to other EU members.

- United Nations oversight of U.S. policy areas such as agriculture and forestry must not be allowed.

- Emission trading and joint implementation must be allowed. (Emission trading means allowing government and businesses in countries where it costs little to reduce emissions to do so in return for "credits" that could then be sold to countries where emission control costs are high. Joint implementation means giving companies in one country credits for investing in emission reduction projects in other countries.)

Gore "came to Kyoto wanting a deal very badly," said Rep. F. James Sensenbrenner (R-WI), "and America got a very bad deal."

A week after the bargaining began, it appeared as though negotiators would once again deadlock. Spokespersons for developing nations flatly refused to apply even voluntary emission caps to their own economies while demanding that developed nations cut their emissions more deeply than was called for by the Rio Treaty. They rejected emissions trading, saying such programs "exploit" poorer countries by allowing polluters in developed countries to take credit for investments in developing countries that would have been made anyway.

European countries also backed larger reductions in emissions than what U.S. negotiators wanted, partly to appease Green political movements back home and partly because they were secretly counting on the U.S. delegation to veto such unrealistic targets. Unfortunately, they overestimated the resolve of the Clinton-Gore Administration.

Vice President Al Gore traveled to Kyoto to personally break the deadlock. Gore "came to Kyoto wanting a deal very badly," said Rep. F. James Sensenbrenner (R-Wisconsin), "and America got a very bad deal."[2] Gore directed the U.S. team to adopt a "flexible" posture to ensure a deal. The result was a Protocol that sacrificed all five "hard positions" demanded by the U.S. Senate.

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2 Quoted in Angela Antonelli and Brett Schaefer, "From Fear to Folly: Why the Kyoto Agreement is 'A Very Bad Deal.'" *Backgrounder Update* No. 289, The Heritage Foundation , December 23, 1997.

What the Protocol Says

The key provisions of the Kyoto Protocol present a mirror image of the five "hard positions" the Clinton-Gore Administration was expected to defend:

- Developed countries are required to reduce their overall greenhouse gas emissions "by at least 5 percent below 1990 levels" by 2012,[3] with the U.S. required to reduce its emissions even further, to 7 percent below 1990's levels,[4] even though the U.S. population and economy are growing much faster than most other developed countries. Adjusting for projected U.S. population growth, this would constitute a 45 percent per-capita reduction in greenhouse gas emissions from business-as-usual baseline projections. [SOURCE?]

- Developing nations that are major sources of greenhouse gases, such as China, India, and Mexico, are excused from having to comply with any emission requirements—even one of their own choosing[5]—and are promised "the establishment of funding, insurance and transfer of technology mechanisms" to "minimize adverse social, environmental and economic impacts" that might result when *developed* countries reduce their emissions.[6]

> The Protocol requires the U.S. to reduce its greenhouse gas emissions to 7 percent below 1990's level by the year 2012.

- Countries belonging to the European Union agreed to reduce their emissions by 8 percent, but are allowed to "jointly fulfil their commitments," with each country getting a new emission cap to be set out in a separate agreement.[7]

- A permanent international body, the Framework Convention on Climate Change Secretariat, is created,[8] served by a Subsidiary Body for Implementation and a Subsidiary Body for Scientific and Technological Advice. It is to receive from each participating nation an "annual inventory of anthropogenic emissions by sources and removals by sinks of

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3 CITE WEB SITE SOURCE "Kyoto Protocol to the United Nations Framework Convention on Climate Change," Conference of the Parties, Third Session, Kyoto, Japan, December 1-10, 1997 (henceforth "Kyoto Protocol"), Article 3, §1.

4 Ibid., Annex B.

5 The reduction requirements in Article 3, §1 only apply to countries listed in Annex B. No developing countries appear in that list.

6 Ibid., Article 3, §14. See also Articles 10 and 11.

7 Ibid., Article 4, §1.

8 Ibid., Articles 13-15.

greenhouse gases . . . ."[9] and national "programmes containing measures to mitigate climate change and measures to facilitate adequate adaptation to climate change."[10]

- Emission trading appears in the Protocol but is restricted to buying and selling expensive credits among developed countries.[11] Joint implementation is endorsed in the Protocol but limited to specific projects. And a "clean development mechanism" is outlined in Article 12 that would transfer technology to developing nations—again, on a project-by-project basis. Since the Kyoto meeting, spokespersons for developing nations have disparaged both joint implementation and the clean development mechanism, suggesting they would be phased out or never developed.[12]

Developing Nations Do Not Have To Limit Emissions

> In 2015, developing nations will be generating 20 percent more carbon dioxide than industrialized nations produce now.

The decision to excuse developing nations from any responsibility to reduce their future emissions cripples the Kyoto Protocol. Developing countries accounted for 36 percent of the world's 6 billion tons of carbon dioxide emissions in 1990; by 2015, their share will rise to 57 percent of 8.453 billion tons.[13] In 2015, when the treaty targets are implemented, developing nations will be generating 20 percent more carbon dioxide than industrialized nations produce now. [SOURCE? JUST OECD, OR WHAT PROTOCOL CALLS "DEVELOPED NATIONS" — OECD + RUSSIA + FORMER SOVIET UNION?]

The major developing countries are unlikely to join the Kyoto emission-control regime at a later date. "China and India refused to approve the treaty," write Angela Antonelli and Brett Schaefer, "unless a provision allowing developing countries *voluntarily* to reduce emissions was stricken. Developing countries will not agree to participate—even voluntarily—in measures that result in lower economic growth."[14]

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9 Ibid., Article 7, § 1.

10 Ibid., Article 10.

11 Ibid., Article 6, §1 and Article 16 bis.

12 John J. Fialka, "Global-Warming Pact Negotiation May Phase Out Emissions Trading," *The Wall Street Journal*, March 17, 1998.

13 Intergovernmental Panel on Climate Change, ADD chapter and section.

14 Angela Antonelli and Brett Schaefer, supra note 2.

"We have a much higher and urgent priority," explained Indian Ambassador Naresh Chandra, "and that is eradication of poverty, and improving the level of living of our people. That is a much greater urgent necessity than the long-term aim of controlling greenhouse gas emissions."[15]

China, whose emissions will exceed those of the United States in 15 years, has demanded a *fifty-year moratorium* on any restrictions imposed on its own emissions.[16] Dr. Henry R. Linden, Director of the Department of Chemical and Environmental Engineering at the Illinois Institute of Technology, says "likely increases in CO_2 emissions by such large developing nations as the Peoples Republic of China (PRC) and India will overwhelm any conceivable cutbacks the industrialized world could make."[17] Linden notes that China plans to increase its annual coal production from 1.2 billion tons to 2 billion tons by 2010.

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Eugene Trisko, an attorney for the United Mine Workers of America, summarized the futility of the U.S. negotiating posture in Kyoto:

> We believe the parties to the Rio Treaty made a fundamental error when they agreed to negotiate legally binding carbon restrictions on the United States and other industrialized countries while simultaneously agreeing to exempt high growth developing countries like China, Mexico, Brazil, and Korea from any new carbon reduction commitments. As much as 60 percent of global carbon emissions are expected to come from such countries in the next few decades, with China becoming the single largest emitter in the near future. The exclusion of new commitments by developing nations . . . will create a powerful incentive for transnational corporations to export jobs, capital, and pollution, and will do little or nothing to stabilize atmospheric concentrations of carbon . . . .[18]

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15 Margaret Warner interview with Ambassador Naresh Chandra, NewsHour Transcript, December 9, 1997.

16 Ibid.

17 Dr. Henry Linden, "A Dissenting View on Global Climate Change," *The Electricity Journal*, July 1993, page 63.

18 Eugene Trisko, Remarks at a Briefing on Global Warming, sponsored by the Competitive Enterprise Institute and the National Center for Policy Analysis, Washington D.C., June 13, 1997.

Status of the Treaty Today

At the time of this writing, President Clinton has not revealed when he intends to submit the Kyoto Protocol to the U.S. Senate for approval. Since it so clearly fails to meet the requirements set forth by the Senate in S.R. 98, the treaty's chief negotiator admitted it might be "years" before the Administration submits the treaty to the Senate.[19]

Senate opposition may not prevent the Administration from attempting to meet the treaty's targets through other means. Possible avenues include altering government procurement policies, funding researchers and organizations that are wedded to the global warming issue, and influencing environmental education programs in the nation's schools. The Administration is also reportedly studying whether the Clean Air Act and other existing statutes give it authority to regulate carbon dioxide and other greenhouse gases as pollutants.[20]

On March 2, 1997, Rep. David McIntosh (R-Indiana), chairman of the House Government Reform and Oversight Subcommittee on Regulatory Affairs, called for hearings on whether the Administration is using "regulatory efforts to foist this treaty on the American people." "I will not allow the administration to circumvent the Senate through back-door regulations that hurt the economy and threaten jobs," said McIntosh.[21]

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>
> —*Rep. David McIntosh*

The Protocol becomes legally binding on the U.S. when two-thirds of the Senate approves it; the Protocol becomes effective when developed countries accounting for at least 55 percent of greenhouse gas emissions have approved it. Since the U.S. accounts for approximately 35 percent of all such emissions, it is unlikely the treaty will go into effect without Senate approval.

The Clinton Administration has said it will try to persuade developing countries to voluntarily limit their emissions and to agree to emission trading, thereby making the treaty more acceptable to the Senate. Many experts experienced in international negotiations think this unlikely. Economist Jim Johnston, who helped negotiate the Law of the Sea Treaty, says "the U.S. concessions at both Berlin in 1995 and Kyoto in 1997, after piously posturing against them

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19 Stuart E. Eizenstat, "Global Warming Pact: Let's Clear the Air," *The Wall Street Journal*, March 5, 1998.

20 "Administration Tries 'End-Run' on Kyoto," *Environment News*, April 1998, page 9.

21 Ibid.

before these meetings took place, only whets the appetite for more demands."[22] Moreover, "the emissions trading schemes developed thus far are government creations heavily laden with regulation. The international system proposed at Kyoto is unlikely to be better. Indeed, the nature of the international negotiations adds serious impediments to the process."[23]

In short, the Kyoto Protocol as it stands today is a deeply flawed document. Contrary to a unanimous resolution of the U.S. Senate, the Protocol calls for deep cuts in U.S. greenhouse gas emissions and excuses developing nations from any commitments. It is unlikely to provide for workable emission trading or joint implementation, and it creates a new international agency with power to interfere with U.S. domestic policy. While the Clinton-Gore Administration will campaign for public support of the Protocol and its approval by the Senate, it is unlikely to support the changes necessary to make the Protocol acceptable to either the public or its representatives in the Senate.

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22 Jim Johnston, "Emissions Trading: Getting It Wrong Again," *Intellectual Ammunition*, February/March 1998, page 16.

23 Ibid. ADD Jim Johnston's latest Regulation piece.

PART 2

Impact of the Kyoto Protocol on U.S. Agriculture

Spokespersons for the farm community in the U.S. have not been silent during the public debate over the Kyoto Protocol. On March 14, 1997, a bipartisan group of farm state senators wrote to Vice President Al Gore demanding to know the likely effects of the agreement on U.S. farmers and ranchers, and whether the competitive advantages that would be enjoyed by farmers in countries with less stringent controls were being taken into account.[24] The letter was signed by 13 members of the Senate.

> **Possible Greenhouse Gas Policies Affecting Agriculture**
>
> - Stricter fuel economy requirements
> - Reduction or phase out of the use of diesel fuel
> - Limitations on production per acre for some crops
> - Requirements for "plowless" soil preparation
> - Mandatory fallowing of crop land
> - Limits and restrictions on livestock production to reduce methane emissions
> - Restrictions on the use of fertilizer
> - Restrictions on timber harvesting
> - Restrictions on processing, manufacturing and transporting food products
>
> *Source: Open Letter to President Clinton, from organizations representing agriculture, dated November 8, 1996.*

On November 8, 1996, representatives from 18 farm and ranching trade groups and associations signed a letter to President Clinton expressing their "deep concern and surprise" that the Administration was excluding agricultural groups from treaty negotiations. They expressed concern over nine specific policies, listed in the box to the left, that the Administration was said to be considering as means to reduce greenhouse gas emissions.

The American Farm Bureau Federation has been outspoken in its criticism of both the science and the politics of the global warming debate. "Temperatures rise and fall," wrote Dean Kleckner, the organization's president, "on a time scale not conducive to today's 30-second sound bite mentality. Remember back to the 1950s and '60s and you will remember a similar, yet shorter lived, witch hunt. Then, consider the 1970s and '80s when there was talk of global cooling. This brought predictions of a new Ice Age. It should not surprise anyone that solutions proposed for both catastrophes are the same—greater international regulation and intrusion.[25]

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24 "Farm State Senators Caution Vice President on Global Climate Treaty," *Environment News*, June 1997, page 3.

25Dean Kleckner, "Global Warming Contention Is So Much Hot Air," president's column, American Farm Bureau, October 1997, available at www.fb.com/views/prescol/97/pres1097.htm.

What would happen to American farmers and ranchers if the Kyoto Protocol were adopted as written? Since farm income is affected by trends in other parts of the economy, we start by reviewing other estimates of the impact of the Kyoto Treaty on the entire U.S. economy.

Effect on the National Economy

Virtually every economic activity, and many purely recreational or consumptive activities, involve the use of energy and consequently the release of greenhouse gases. A treaty that proposes to limit greenhouse gases therefore is a license for United Nations officials to monitor, tax, regulate, or ban virtually any activity. "It would be the first time in history," said Sen. Larry Craig (R-ID), "that an American President has allowed foreign interests to control and limit the growth of the U.S. economy."[26]

WEFA, Inc. among the nation's leading economic forecasting and modeling firms, estimated the effects of stabilizing greenhouse emissions at 93 percent of their 1990 level by 2010.[27] WEFA analysts made the following predictions:

- Consumers would see price increases in excess of 55 percent for electricity and 70 percent for home heating oil by 2010.
- Commercial establishments would see electricity price increases of 60 percent.
- Gross Domestic Product (GDP) would fall over 3 percent by 2010, costing the average household $2,728 a year.
- Employment in 2010 would be 2,400,000 below baseline projections.
- Real wages in the manufacturing sector would fall 2.1 percent below the baseline in 2010.

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— *WEFA, Inc.*

In May 1998, Pittsburgh-based CONSAD Research Corporation estimated that 3.1 million fewer Americans will be employed in 2010 as a direct result of the treaty, and that Gross Domestic Product will fall by at least $177 billion and perhaps by as much as $318 billion by 2012.[28]

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26 Quoted in Angela Antonelli and Brent Schaefer, supra note 2.

27 WEFA, Inc., *Global Warming: The High Cost of the Kyoto Protocol. National and State Impacts*, 1998.

28CONSAD Research Corporation, *The Kyoto Protocol: A Flawed Treaty Impacts America. Sectoral and Regional Economic Impact Analysis*, May 1998.

Other researchers and commentators have reached similar conclusions. Eugene Trisko, a labor lawyer, projects American job losses of 1.7 million by 2010, 1 million coming from manufacturing.[29] "What we're looking at here," said Trisko, "is a range of loss of goods and services of approximately $500-$1,500 per capita in the United States."

Professors William Nordhaus of Yale and Robert Stavins of Harvard contend that meeting U.S. treaty commitments under the proposed Kyoto accord would reduce GDP by 3 percent.[30] Stavins puts the price tag at "approximately the cost of complying with all other environmental regulations combined."[31]

These are enormous costs. Later in this report we will ask whether they are justified by what we know about global climate change. But first, we focus on the costs likely to be borne by the agricultural community.

Effects of the Kyoto Protocol on U.S. Agriculture

> Fuel and oil costs represent only about 30 percent of the total energy bill farmers pay, while the remaining 70 percent is hidden in the prices of manufactured inputs, fertilizer, pesticides and other chemicals.

If the Kyoto Protocol is adopted, the U.S. government will have to undertake policies aimed at reducing the emissions of trace greenhouse gases. Water vapor, found in nature, accounts for between 66 and 95 percent of the greenhouse effect. The remaining greenhouse effect, targeted by the Kyoto protocol, results from atmospheric carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulphur hexafluoride. Carbon dioxide, a natural byproduct of the combustion of carbon-based fuels, accounts for approximately 70 percent of those gases. Methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, and sulphur hexafluoride are the remaining gases named in Annex A of the Protocol.

Nearly all analysts agree that the steep reduction in emissions called for by the Kyoto Protocol would require new taxes on fossil fuels to discourage consumption and promote the adoption of energy-efficient or alternative-energy technologies. Using the administration's initial greenhouse gas emission targets, 7 percent less restrictive than those adopted at Kyoto, the American Petroleum Institute estimates that such taxes would increase prices for gasoline, diesel

29 Eugene Trisko, Briefing on Global Warming. Sponsored by the Competitive Enterprise Institute and the National Center for Policy Analysis, June 13, 1997.

30 Cited in Jerry Taylor, "Global Warming: The Anatomy of a Debate." Presentation before the Johns Hopkins University Applied Physics Laboratory. January 16, 1998. [GET ORIGINAL SOURCE]

31 Ibid. [GET ORIGINAL SOURCE]

fuel, and electricity by 50 percent or more, the equivalent of a 50 cents per gallon tax on gasoline.[32]

The Clinton Administration claims a smaller tax hike would be sufficient to reduce energy consumption, but its methodologies assume a highly efficient international emissions trading regime and an economic boost from shifting taxes away from capital. Both assumptions have been heavily criticized.[33] Still, based on these assumptions, the U.S. Commerce Department recently agreed that capping carbon dioxide emissions at 1990 levels would require the equivalent of a 25 cents per gallon fuel tax.[34] These two conservative estimates can be used to indicate the high and low range of taxes likely to result from the Kyoto Protocol. Both describe an emissions regime 7 percent *less* restrictive than that to which American negotiators actually agreed.

Agricultural production is an energy-intensive process. The immediate focus is often on the cost of fuels and oils for farming equipment. However, this accounts for only about 30 percent of the total amount of energy consumed on a typical farm. Manufactured inputs [IS THIS tractors, plows, trailers, building materials, etc.], fertilizer, pesticides, and other chemicals are all extremely energy intensive. For example, energy (natural gas) typically accounts for 75 percent of the cash cost of manufacturing anhydrous ammonia, a basic feedstock or ingredient for all nitrogen fertilizer products. Energy accounts for half or more of the underlying cash production costs for nearly all the manufactured inputs..

Farmers are poorly positioned to simply pass through to consumers a sudden increase in their cost of production.

For farmers, then, fuel and oil costs represent only about 30 percent of the total energy bill they pay, while the remaining 70 percent is hidden in the prices of manufactured inputs, fertilizer, pesticides, and other chemicals.

Finally, farmers are poorly positioned to simply pass through to consumers a sudden increase in their cost of production. Mexico, China, Argentina, and Brazil, all major livestock and agricultural producers, would not be bound by the terms of the Kyoto Protocol, and would quickly step up their exports to capitalize on their new cost advantage. The gradual global

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32Angela Antonelli and Brett Schaefer, supra note 2, citing Mary H. Novak, "Economic and Energy Sector Implications of Adopting Global Climate Change Policies," WEFA Group, Pennsylvania, February 5, 1997. [GET ORIGINAL SOURCE]

33 See John J. Fialka, "Clinton Economist Defends Curbing Global Warming," *The Wall Street Journal*, March 5, 1998. For the "double dividend" assumption, see "Economic Effects of Global Climate Change Policies: Results of the Research Efforts of the Interagency Analytical Team," various drafts in May and June 1997.

34 ADD HERE

diffusion of agricultural technologies, such as high-yield hybrid plants and new pesticides, has enabled more countries to become net food exporters, and many of those countries are eager to establish a foothold in the huge U.S. marketplace. If the Kyoto Protocol slows economic growth in the U.S. as much as other experts predict, growth in demand for food in the U.S. will also be slow and consumers will be sensitive to price hikes.

Study Methodology

To better understand how farmers and ranchers would be affected by the Kyoto Protocol, we calculated the average expected cost increase per acre or per hundredweight, and the likely effect on the farmer's net profit. We then estimated the likely effects of energy taxes on agriculture as a whole industry. The first analysis is called a "micro" analysis, while the second is called a "macro" analysis.

Six representative commodities were chosen for the micro analysis. Four are field crops: wheat, soybeans, corn, and cotton. Two are livestock-related: hogs and milk. By looking at the different commodities, the range of effects can be measured. Some commodity production is very energy intensive, while other commodities are less affected by changes in energy prices. For example, corn and cotton crops use a lot of nitrogen fertilizer and pesticides, products that are very sensitive to changes in energy prices. Soybean production, on the other hand, is less sensitive to changes in energy costs.

Table 1
Effect of Energy Taxes on Agricultural Inputs

Inputs	*25¢ / gallon*	*50¢ / gallon*
Fuel and electricity prices	25%	50%
Pesticides/chemical	20%	40%
Fertilizer		
Corn/cotton	20%	40%
Wheat/soybean	15%	30%
Custom operations/hauling	15%	30%
Other expenses	5%	10%

The impact of energy price changes—increases of 25 cents or 50 cents per gallon in fuel costs and related energy products—on agricultural inputs, is calculated first. Since some inputs are more energy intensive than others, an increase in energy prices raises the price of some inputs more than others. The macro analysis utilizes U.S. farm production expenses for 1994 as the base. From there the impact of the change in energy prices, 25 cents per gallon or 50 cents per gallon increase in fuel prices and related energy products, is applied, the parameters established are shown in Table 1.

Impact of the Kyoto Protocol on Individual Farmers

The following tables show the impact of higher energy prices on four crops—corn, cotton, soybeans and wheat—and two livestock—hogs and dairy. The baseline year is 1994. The 1994 base year production cost figures come from the *ERS Farm Business Economics Report, 1994*, ECI-1995. They represent the average U.S. cash production cost per acre of crop or per hundredweight of pork and milk.

The information most relevant to this analysis is in two categories, total variable cash expenses and the gross value of production minus variable cash expense or net profit. Table 2 below summarizes that information.

Table 2
Impact of Higher Energy Costs on Agriculture
(dollars per acre/hundredweight)

	Base	Low	High	Base	Low	High
	Corn			Cotton		
Variable cash expenses	147.08	169.92	193.65	276.95	312.17	347.38
Change		15.5%	31.7%		12.7%	25.4%
Value of production less cash expense (net profit)	99.11	76.7	52.5	143.36	108.14	72.93
Change		-23.0%	-47.0%		-24.6%	-49.1%
	Soybeans			Wheat		
Variable cash expenses	75.76	86.11	96.45	54.58	61.87	69.15
Change		13.7%	27.3%		13.4%	26.7%
Value of production less cash expense (net profit)	100.91	90.56	80.22	25.48	18.19	10.91
Change		-10.0%	-20.5%		-28.6%	-57.2%
	Hogs			Milk		
Variable cash expenses	38.44	40.32	42.41	11.35	11.78	12.20
Change		4.9%	10.3%		3.8%	7.5%
Value of production less cash expense (net profit)	4.70	2.82	0.73	1.60	1.17	0.75
Change		-40.0%	-84.5%		-26.9%	-53.1%

The information of greatest interest to us is the percentage increase in the producer's operating costs (total variable cash expenses) and the percentage decrease in net profits (gross value of production minus variable cash expense). Those values are summarized in Table 3 below. (Tables 5 and 6 in the Appendix offer more detail.)

Table 3
Effect of Kyoto Protocol on Individual Farmer's Costs and Net Profit

Commodity	Effect on Costs		Effect on Profits	
	25¢ per gallon tax	50¢ per gallon tax	25¢ per gallon tax	50¢ per gallon tax
Corn	15.53%	31.66%	-23.05%	-46.99%
Soybeans	13.66%	27.31%	-10.26%	-20.50%
Cotton	12.72%	25.43%	-24.57%	-49.13%
Wheat	13.36%	26.69%	-28.61%	-57.18%
Hogs	4.89%	10.33%	-40.00%	-84.47%
Milk	3.79%	7.49%	-26.88%	-53.13%

The average farmer will see his or her operating expenses increase by between 3.79 percent (for milk) to 15.53 percent (for corn) if gasoline taxes are raised by 25 cents per gallon. A 50-cents-per-gallon price increase would increase expenses by between 7.49 percent (again for milk) and 31.66 percent (again for corn).

Although in percentage terms the change in operating expenses is nearly the same for the four field crops, when viewed in dollar terms there is a much greater difference. Under the lower energy price scenario, total variable cash expenses for wheat increase by only $7.29 per acre, whereas expenses for cotton increase more than $35 per acre. A similar difference occurs when gasoline taxes are hiked by 50 cents.

Turning to net profit, the 25 cents-per-gallon tax would reduce net profits by at least 10.26 percent (for soybeans) or as much as 40 percent (for hogs). A 50 cents-per-gallon tax reduces net profits on soybean production by 20.30 percent and net profits on hogs by a dramatic 84.47 percent. Milk producers would also see their net profits fall by over half. These numbers reflect the fact that livestock feeders and dairy farmers operate on very thin margins. Relatively small changes in the cost of production can result in very significant changes in their profits.

It should be noted that in all cases the gross value of production or price received by farmers is based on the 1994 year. Commodity prices vary from year to year. For example, milk prices declined rather significantly in late 1996 and early 1997. In the case of milk, the higher variable cash expenses would have simply exacerbated the losses producers were already experiencing.

Looking at costs per acre and per hundredweight of hogs or milk produces a farmer's eye view of what would happen if the Kyoto Protocol were approved. The view is frightening.

The average farmer could see net profits fall by about one-fourth if gasoline taxes were raised by 25 cents a gallon, the *minimum* amount of increase required, according to the Clinton Administration, to meet the requirements of the Kyoto Protocol. If taxes were raised by 50 cents a gallon, as is more likely the case, then the average farmer loses half his net profits.

The average farmer could see his net profits fall by about one-fourth if gasoline taxes were raised by 25 cents a gallon, and by more than half if taxes were raised by 50 cents a gallon.

Impact of the Kyoto Protocol on the Agricultural Community

Table 4 presents the results of a "macro" analysis of the effects of higher energy taxes on the total agricultural sector. Whereas the previous analysis may be of most interest to individual farmers and ranchers, this "big picture" analysis should interest people in businesses that serve as suppliers to or buyers from farmers and ranchers. What would happen to *the size of your market* if the Kyoto Protocol were adopted?

The cells in the bottom right-hand corner of Table 4 show total U.S. farm production expenses would rise by over $10 billion if gasoline taxes were raised 25 cents a gallon, and by more than $20 billion if taxes were raised 50 cents a gallon. Those figures represent 5.8 percent and 11.7 percent, respectively, of total 1995 production expenses of $175.5 billion. If you are in a business that sells production inputs to farmers, those figures mean the buying power of your customers would shrink by either $10 billion or $20 billion as a result of the Kyoto Protocol.

Table 4 Total U.S. Farm Production Expenses (millions of dollars)					
	Base Year 1995	Estimated expenses with higher energy prices		Difference between base year and adjusted expenses	
		25¢ per gallon tax	50¢ per gallon tax	25¢ per gallon tax	50¢ per gallon tax
Feed purchased	24,528	26,000	27,471	1,472	2,943
Livestock & poultry purchased	12,557	11,929	11,301	(628)	(1,256)
Seed purchased	5,463	5,791	6,119	328	656
Total farm-origin inputs	42,548	43,720	44,891	1,172	2,343
Fertilizer & lime	10,034	11,790	13,545	1,756	3,511
Fuels & Oils	5,687	7,109	8,531	1,422	2,844
Pesticides	7,719	9,263	10,807	1,544	3,088
Total manufactured inputs	23,440	28,162	32,883	4,722	9,443
Total interest charges	12,757	13,395	14,033	638	1,276
Other operating expenses	59,964	62,962	65,960	2,998	5,996
Capital consumption	19,107	20,062	21,018	955	1,911
Taxes	6,891	7,236	7,580	345	689
Net rent to nonoperator landlords	10,873	10,295	9,753	(578)	(1,120)
Other overhead expenses	36,871	37,593	38,351	722	1,480
Total production expenses	175,580	185,832	196,118	10,252	20,538
Percent change		5.8%	11.7%		

The loss of total net income to the agricultural community that would result from higher energy taxes can also be calculated. Annual U.S. net farm income averaged $42.7 billion over the 1991 to 1995 period. The increased expense of a 25 cents-per-gallon gasoline tax would equal 24 percent of net farm income, while a 50 cents-per-gallon tax would equal 48 percent of net farm income. Those figures are close to the estimates we obtained through the earlier micro analysis. If you are in a business that sells finished goods to farm families, your customers would have either three-fourths or just one-half as much to spend on your products as they would if the Kyoto Protocol were not implemented.

Higher energy taxes have the potential for causing an economic downturn in the agricultural sector that could parallel the experience of the mid-1980s. Not only would net farm income fall in the short term, but a downturn in land prices would shrink asset values and, most likely, result in another mini-depression in the farm sector. The increased production costs are expected to reduce farm profits and farm income, invariably slowing farm loan and mortgage repayments. Consequently, this scenario bodes poorly for lenders who extend credit to farmers.

Another outcome of either scenario would be the increased consolidation of agricultural production. Many small farmers, who typically have a higher average cost of production, would be forced to sell to large farmers. Young farmers just starting or those who have recently taken on increased debt to expand their operations could find themselves in an unprofitable situation that might force them to abandon agriculture. Not only would this hurt lenders, but it would also have an adverse economic impact on small towns and rural America in general.

The increased production costs are expected to reduce profits and farm income, invariably slowing farm loan and mortgage repayments.

It should be noted that Table 4 shows two categories of expenses that are expected to *fall* if the Kyoto Protocol were put into effect. First is the livestock and poultry purchase category under farm-origin inputs. When farmers who feed livestock bid on the feeder animals—calves, pigs, or chicks—their bids are predicated on the potential profit of feeding that animal. When feed prices increase they compensate by lowering their bids for these young animals. While that reduces production expenses, it also is an overall negative to gross farm revenues. For the agricultural sector as a whole, it is a net loss.

The other expense expected to fall is net rent to non-operator landlords. This, too, has some rather ominous implications. Lower rents are a reflection of the higher cost of production, which means that farmers renting land will reduce their bid or the rental rate. (It may be a rather heroic assumption that this occurs in year one, but it will happen over time if higher expenses reduce profits in successive years.) Associated with this reduction is the fact that land prices in general will also come under downward pressures. So this would also be viewed as a negative impact on assets and the farm sector financial balance sheet.

How Agriculture Influences Other Parts of the Economy

No single study can capture the ripple effect that a decline in farm income would have on other aspects of the agricultural and non-agricultural economy. However, a study by DRI and McGraw Hill for the Sparks Companies, Inc., released in October 1997, lists some of the probable consequences, based again on an emission-control regime stabilized at 1990 levels—a protocol less rigorous than that which U.S. negotiators accepted in Kyoto.[35] Here is a brief summary of the study's findings:

- **Consumer food prices would rise.** A 2 percent decline in gross domestic product would result in a 0.7 percent decline in domestic demand for food. This would create a mild, short-term downward pressure on food prices, counterbalanced by the inflationary pressures of higher energy costs. On net, food consumption expenditures would rise 2.6 percent. This would have only minor effects on the average U.S. consumer, whose food costs account for 11.9 percent of disposable income. But the impact on poor families would be considerable. The 37.4 percent of U.S. households earning under $20,000 after-tax spend between 21.4 and 100 percent of their income on food.

> By increasing the energy costs of farm production in America while leaving them unchanged in many countries that are emerging agricultural producers, Kyoto will cause U.S. food exports to decline and U.S. food imports to increase.

- **Public assistance costs would rise.** The U.S. Department of Agriculture allocates more than $38 billion annually to six food programs, most notably the Child Nutrition Programs and Food Stamps. The emission-control regime, by reducing employment, could add roughly 700,000 to the food stamp rolls. This would increase the cost of USDA food programs between 4 and 5.5 percent, or between $1.5 billion to $2.1 billion annually.

- **Agricultural exports would fall.** By increasing the energy costs of farm production in America while leaving them unchanged in many countries that are emerging agricultural producers, the Kyoto Protocol would cause U.S. food exports to decline and U.S. food imports to increase. The rising cost of U.S. food abroad would also encourage developing nations to produce their own, immediately in fruits and vegetables, more gradually in major grain crops. The reduced efficiency of the world food system could add to a political backlash against free trade policies both at home and abroad.

- **Agricultural investment would fall.** Kyoto would trigger a wave of farm consolidations, accompanied by a reduction of net farm investment. "The higher energy costs," wrote the Sparks Companies researchers, "together with the reduced domestic and export demand, could lead to a very severe decline in investment in agriculture, and a sharp increase in farm consolidation. Small farm numbers likely would decline much more rapidly than under baseline conditions, while investment in even larger commercial farms likely would stagnate or decline."[36]

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35 DRI Inc. and McGraw Hill, *Carbon Emission Constraints: Potential Impacts on US Agriculture*, for Sparks Companies, Inc., October 1997.

36 Ibid.

Summary

This analysis suggests that higher energy prices would have a significant negative impact on the U.S. agricultural sector. Farmers stand to see their net profits fall by as much as 84 percent, and typically 50 percent, if gasoline taxes are raised by 50 cents per gallon. Even a 25 cents-per-gallon tax would likely lower net profits for hog producers by 40 percent and 25 percent for farmers raising field crops.

Total annual U.S. farm production expenses would rise over $10 billion under the 25-cents-per-gallon scenario and by more than $20 billion dollars under the 50-cents-per-gallon scenario. This would represent a 24 or 48 percent decrease in net farm income, respectively. Many farmers, especially those who are just getting started or who are already operating on small margins, would be unable to cope with these declines in income and would be forced off the land.

It is no exaggeration to say the Kyoto Protocol is the biggest single public policy threat to the agricultural community today.

Farmers and their allies in the agricultural community have a big stake in how the debate over global warming ends. Millions of jobs and thousands of family farms hang in the balance. It is no exaggeration to say the Kyoto Protocol is the biggest single public policy threat to the agricultural community today. It will continue to be a threat so long as the Clinton-Gore Administration refuses to renegotiate either the targets or the exemption from such targets for developing nations.

PART 3

The Questionable Science Behind the Global Warming Scare

Seven Things You Should Know About Global Warming

1. Most scientists do not believe human activities threaten to harm or disrupt the Earth's climate.
2. Our most reliable sources of temperature data show no global warming trend.
3. Global computer models are too crude to predict future climate changes.
4. The IPCC did *not* prove that human activities are causing global warming.
5. A modest amount of global warming, should it occur, would be beneficial to the natural world and to human civilization.
6. Efforts to quickly reduce human greenhouse gas emissions are costly and will not stop Earth's climate from changing.
7. Based on available information, "no regrets" actions are the best "insurance" policy against human disruptions of climate.

America's farmers and ranchers should participate in the public debate over global warming because policies adopted in the name of "stopping global warming" would increase their costs by billions of dollars each year. But once in the public arena, what should farmers say? For starters, farmers need to know whether global warming is a fact, a theory, or a fraud. We find that it has aspects of each.

Science has confirmed that concentrations of minor greenhouse gases[38] in the atmosphere, particularly carbon dioxide, have increased in tandem with the rise in human industrial activity. Theoretically, these gases could trap more heat in the atmosphere, leading to a gradual warming of the Earth's atmosphere. But what appears to be happening is excess heat in the atmosphere finds other ways to escape; other processes counteract or overwhelm whatever effects these gases have; and whatever warming might occur would be small, probably around 1 degree Celsius over the next 100 years.

The discussion that follows has the goal of imparting a good, basic understanding of the issues related to global warming. Believe it or not, it is possible for a person who is not trained in physics or climatology to reach an informed opinion about the science behind the global warming debate. On issues where the science is too complicated or the jargon too dense, there are reliable sources to turn to for an objective and fully informed opinion.

[38] Carbon dioxide, methane, and the other gases that would be regulated under the Kyoto Protocol are called "minor" greenhouse gases because water vapor, the "major" greenhouse gas, is responsible for over 95 percent of the natural greenhouse effect. [PRIMARY SOURCE?]

1. Most scientists do not believe human activities threaten to disrupt the Earth's climate.

Well over 15,000 scientists have signed a petition saying, in part, "there is no convincing scientific evidence that human release of carbon dioxide, methane, or other greenhouse gases is causing or will, in the foreseeable future, cause catastrophic heating of the Earth's atmosphere and disruption of the Earth's climate."[39]

The petition is being circulated by the Oregon Institute of Science and Medicine, an independent research organization that receives no funding from industry.

Among the signers of the petition are over 2,100 physicists, geophysicists, climatologists, meteorologists, and environmental scientists who are especially well-qualified to evaluate the effects of carbon dioxide on the Earth's atmosphere. Another 4,400 signers are scientists qualified to comment on carbon dioxide's effects on plant and animal life. Nearly all of the signers have some sort of advanced technical training.

The Oregon Institute Petition

"We urge the United States government to reject the global warming agreement that was written in Kyoto, Japan in December 1997, and any other similar proposals. The proposed limits on greenhouse gases would harm the environment, hinder the advance of science and technology, and damage the health and welfare of mankind.

"There is no convincing scientific evidence that human release of carbon dioxide, methane, or other greenhouse gases is causing or will, in the foreseeable future, cause catastrophic heating of the Earth's atmosphere and disruption of the Earth's climate. Moreover, there is substantial scientific evidence that increases in atmospheric carbon dioxide produce many beneficial effects upon the natural plant and animal environments of the Earth."

— Signed by over 15,000 scientists

The qualifications of the signers of the Oregon Institute Petition are dramatically better than the 2,600 "scientists" who have signed a competing petition, circulated by Ozone Action, calling for immediate action to counter global warming. An investigation by Citizens for a Sound Economy found that more than 90 percent of that petition's signers lacked credentials to speak with authority on the issue.[40] The entire list included just *one* climatologist.

Over one hundred climate scientists signed the 1996 Leipzig Declaration, which stated in part, "there does not exist today a general scientific consensus about the importance of greenhouse warming from rising levels of carbon dioxide. On the contrary, most scientists now accept the fact that actual observations from earth satellites show no climate warming whatsoever."[41]

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39 "15,000 Scientists Urge Congress to Reject Kyoto Global Warming Treaty," *Environment News*, Vol. 1, No. 9, May 1998, page 1, 5.

40 Ibid.

41 Dr. S. Fred Singer, *Hot Talk, Cold Science: Global Warming's Unfinished Debate* (Oakland, CA: The Independent Institute, 1997) pages 40-43.

A survey of 36 state climatologists—scientists retained by state governments to monitor and research climate issues—conducted in September and October 1997[42] found that 58 percent disagreed with the statement, "global warming is for real," while only 36 percent agreed. A remarkable 89 percent agreed that "current science is unable to isolate and measure variations in global temperatures caused only by man-made factors." None of the climatologists strongly agreed, and only 11 percent "somewhat agreed," with this statement: "Reducing anthropogenic or man-made carbon dioxide emissions among developed nations such as the United States to 1990 levels will prevent global temperatures from rising." Eighty-six percent disagreed with the statement.

A remarkable 89 percent of state climatologists agreed that "current science is unable to isolate and measure variations in global temperatures caused only by man-made factors."

Advocates of immediate action to "stop global warming" have sought to silence their critics by calling them a small group of industry-funded dissenters from the "scientific consensus."[43] The Oregon Institute Petition, the Leipzig Declaration, and the survey of practicing climatologists prove these claims are false. We should keep in mind, however, that scientific truths are not found by polling scientists, but through rigorous debate recorded in peer-reviewed journals. As the following points show, global warming skeptics can win that debate, too.

2. Our most reliable sources of temperature data show no global warming trend.

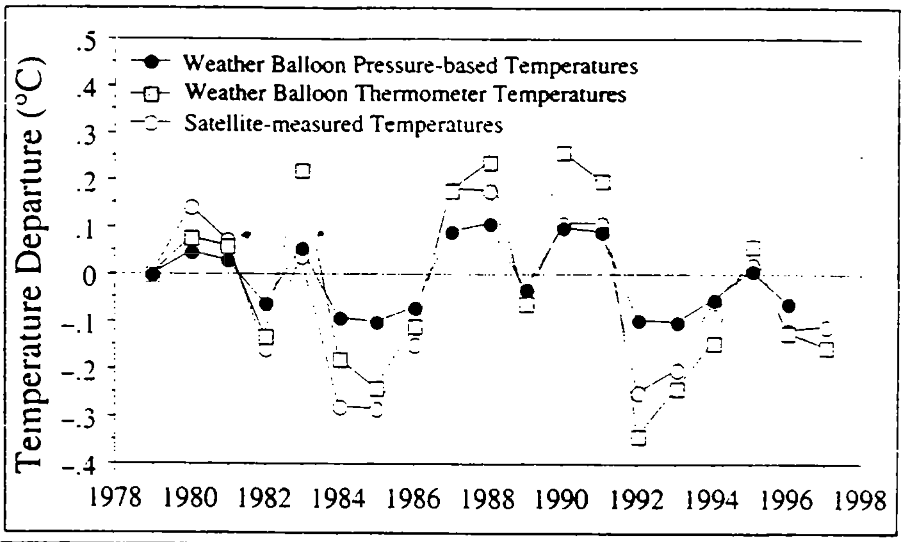
It is an article of faith among those who warn of catastrophic global warming that temperatures are already rising. They point to surface-based measurements produced by the National Oceanic and Atmospheric Administration to declare 1997 the warmest year on record.[44] But U.S. weather satellites and radiosonde (weather) balloons, which are far more accurate, ranked 1997 as the seventh *coolest* year since satellite measurements began in 1978.[45] The actual balloon and satellite record, provided by NASA, is shown below.

42 "Survey of State & Regional Climatologists, September-October 1997, Annotated Questionnaire," Citizens for a Sound Economy Foundation, from web site, December 9, 1997.

43 Ross Gelbspan, *The Heat is On: The High Stakes Battle Over Earth's Threatened Climate* (New York, NY: Addison-Wesley Publishing company, 1997).

44Paul Georgia, "The Warmest Year on Record?" *CEI Update*, February 1998. Available at www.cei.org/update/1998/0298-pg.html.

45 Ibid. See also Dr. Roy Spencer, "Truth and Consequences: In Defense of the Satellite Data," in Dr. Patrick J. Michaels, ed., *State of the Climate Report, 1998*, New Hope Environmental Services, Inc.



Modern surface-based temperature records began in 1880. Although useful for compiling regional data, such measurements are too few in number and too unevenly spaced to generate global temperature maps that are useful. Only 30 percent of the world's surface is land, so land-based temperature measurements account for less than 1/3 of the Earth's climate. Arctic and oceanic temperatures are under-represented. Data collected outside of the United States and Europe are poorly distributed. Urban stations, which are influenced by city heat anomalies, are over-represented; deserts, mountains, and forests are under-represented. The result is a set of measurements that understate some global trends, and overstate others.

Orbiting satellites cover 99 percent of the Earth's surface. The temperature data collected by satellites agree almost exactly with those recorded by weather balloons. They agree closely with the best surface-based data as well. "A look at the trends in the satellite data—our only truly global record of lower atmosphere temperature—is remarkably revealing," said Virginia State Climatologist Dr. Patrick J. Michaels in testimony before Congress. "There is a statistically significant global *cooling* trend over the entire 18.8 year period."[46] Since Michaels testified, El Niño (a weather phenomenon not caused by global warming) has raised global temperatures in 1997 and 1998, so the most recent data show no change.

Dr. Vincent Gray, a New Zealand scientist and member of the peer review board of the Intergovernmental Panel on Climate Change, agrees with Michaels. "There is no evidence of a global warming trend over the past 37 years if the radiosonde [weather balloon] measurements

46 Dr. Patrick Michaels, "The Effects of Proposals for Greenhouse Gas Emission Reduction." Testimony before the Subcommittee on Energy and Environment of the Committee on Science, U.S. House of Representatives. November 6, 1997.

are considered, or over 18 years if the satellite measurements only are considered."[47] Dr. Robert Balling, Director of the Office of Climatology at Arizona State University, summarizes the temperature data of the past two decades as follows: "The trend is statistically significant, and it's downward . . . Two of the three methods we use to measure planetary temperature show cooling, and one shows nothing at all . . . ."[48]

3. Global computer models are too crude to predict future climate changes.

> The ability to explain historical data is a critical test for any theory or model. GCMs flunk that test.

Predictions that rising concentrations of carbon dioxide in the atmosphere will cause global climate change are based on global climate models (GCMs), complex computer models of the Earth's atmosphere. GCMs were created to help scientists learn more about atmospheric physics, not to predict future climates.[49] When put to such an unintended use, they are unreliable. For example:

- **GCMs are unable to replicate past climate trends.** While global temperatures have risen between 0.3 and 0.6 degrees Celsius over the past one hundred years,[50] computer models predict that global temperatures should have gone up between 0.7 and 1.4 degrees by 1990. The two ranges do not even overlap![51] The ability to explain historical data is a critical test for any theory or computer model. GCMs flunk that test.

- **GCMs use "fudge factors" that are larger than the variables they are supposed to be measuring.** In order to get their models to produce predictions that are close to their designers' expectations, modelers resort to "flux adjustments" that can be 25 times larger

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47 Dr. Vincent Gray, "Climate Change 95: An Appraisal." Heartland Policy Study (Chicago, IL: The Heartland Institute, September 10, 1997).

48 Dr. Robert Balling, Jr., Briefing on Global Warming. Sponsored by the Competitive Enterprise Institute and the National Center for Policy Analysis, June 13, 1997.

49 "General Circulation Model outputs should be treated, at best, as broad-scale sets of possible future climatic conditions and should not be regarded as predictions." Intergovernmental Panel on PCC, *Climate Change 1995*, Working Group II, Full Supporting Material, 1996, Chapter 26, Section 6.5.3.

50 IPCC, *Climate Change 1995*, Policymakers' Summary, 1996. Note that all of this warming occurred prior to the more recent cooling trends documented by weather balloons since 1960 and by satellites since 1978.

51 Dr. Hugh W. Ellsaesser, "The Misuse of Science in Environmental Management," Heartland Policy Study (Chicago, IL: The Heartland Institute: December 8, 1995).

than the effect of doubling carbon dioxide concentrations.[52] Dr. Richard Lindzen, a meteorologist at MIT, notes that "one cannot even calculate the temperature of the Earth without models that accurately reproduce the motions of the atmosphere," yet "present models have large errors here—on the order of 50 percent."[53] Richard A. Kerr, a writer for *Science*, says "climate modelers have been 'cheating' for so long it's almost become respectable."[54]

Climate modelers resort to "flux adjustments" that can be 25 times larger than the effect of doubling carbon dioxide concentrations.

- **GCMs inaccurately model the effects of clouds.** The Intergovernmental Panel on Climate Change calls the impact of clouds "the single largest uncertainty in determining the climate sensitivity to either natural or anthropogenic [human-induced] changes" in greenhouse gases.[55] Most climate models assume that clouds absorb roughly 3 percent of the sun's radiation, but more recent estimates, published in *Science* in 1994 and 1995, indicate that the absorption rate may be closer to 19 percent, meaning past predictions could be wildly off target.[56]

- **GCMs do not take into account fluctuations in solar energy.** Scientists can only estimate the amount of solar energy that enters the Earth's atmosphere (an amount called the "solar constant") as well as the amount of sunlight reflected back into space by the Earth's surface and atmosphere (called the "reflectivity of the Earth"). Estimates for these values vary considerably over time, and some experts believe natural variations are closely related to changes in climate.[57]

- **GCMs are only as good as the data fed into them.** The GCMs used by the Intergovernmental Panel on Climate Change were programmed to assume an increase in greenhouse gas concentrations of 1 percent per year, even though the historical data show an annual increase of only 0.3 - 0.4 percent. Population growth and coal production figures

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52 Dr. Sally Baliunas, "Uncertainties in Climate Modeling: Solar Variability and Other Factors," testimony before the Committee on Energy and Natural Resources of the U.S. Senate, 1996.

53 Dr. Richard Lindzen, "Global Warming: The Origin and Nature of the Alleged Scientific Consensus." *Regulation: The Cato Review of Business and Government*, Spring 1992.

54 Richard A. Kerr, "Greenhouse Forecasting Still Cloudy," *Science*, May 16, 1997, page 1041.

55Jerry Taylor, *Global Warming: The Anatomy of a Debate*, speech presented before the Johns Hopkins University Applied Physics Laboratory, January 16, 1998.

56 Dr. Patrick Michaels, "Watts Wrong With the Models: How New Observations Invalidate Earlier Forecasts," *World Climate Report*, December 4, 1995.

57 Dr. Robert Jastrow, Dr. William Nierenberg, and Dr. Frederick Seitz, *Scientific Perspectives on the Greenhouse Problem* (Washington, DC: The George C. Marshall Institute, 1990), pages 49-59.

were similarly exaggerated. After correcting for these and other errors, Dr. Vincent Gray concludes "we can expect the *maximum* temperature rise between 1900 and 2100 to be 1°C." [58]

Global Climate Models have become more complex over time, but this doesn't mean they are becoming more accurate. Richard Kerr quotes an anonymous senior climate modeler as saying "the more you learn, the more you understand that you don't understand very much."[59] Kerr reports that "most modelers now agree that the climate models will not be able to link greenhouse warming unambiguously to human actions for a decade or more."[60]

4. The IPCC did *not* prove that human action is causing global warming.

The Intergovernmental Panel on Climate Change (IPCC) was created by the United Nations to act as a source of scientific advice on global warming. Its latest assessment, *Climate Change 1995: The Science of Climate Change*, published in 1996, was the scientific basis of the Kyoto meeting in 1997. In that report, the IPCC predicts a global temperature increase of between 1.5° C and 4.5° C by the year 2100, with a "best estimate" of 2.5° C.

> "Most modelers now agree that the climate models will not be able to link greenhouse warming unambiguously to human actions for a decade or more."
>
> — *Richard Kerr*

Climate Change 1995 is the source of perhaps the most often quoted sentence in the global warming debate: "The balance of evidence suggests a discernible human influence on the global climate." Upon this slender reed is hung nearly the entire scientific case of those advocating immediate action to "stop global warming." Yet, how meaningful is this sentence?

"Balance of evidence" is a phrase used by scientists when evidence of a cause-and-effect relationship is unavailable. It is an admission that genuine proof is not possible. The word "suggests" indicates that different people looking at the same data can disagree on its meaning. And "discernible" means detectible but by no means large or significant. It certainly does *not* mean "major," "troubling," or even "bad."

Climate Change 1995 is controversial for a second reason: Many revisions to the report were made *after* peer review was completed. Dr. Frederick Seitz, president emeritus of Rockefeller University and past president of the National Academy of Sciences, has publicly

58 Dr. Vincent Gray, supra note 47.

59 Richard A. Kerr, supra note 54, page 1040.

60 Ibid.

denounced the published document, writing "I have never witnessed a more disturbing corruption of the peer-review process than the events that led to this IPCC report."[61] Here are two passages *left out* of the final published report that directly contradict the claim made in the Policymakers' Summary that the authors found a "discernible human influence on the global climate":

> While some of the pattern-based studies discussed here have claimed a significant climate change, no study to date has positively attributed all or part of that change to anthropogenic [human-induced] causes. Nor has any study quantified the magnitude of a greenhouse-gas effect or aerosol effect in the observed data—an issue that is of primary relevance to policymakers.[62]

> When will an anthropogenic effect on the climate be identified? The best answer is 'we do not know.'[63]

> "I have never witnessed a more disturbing corruption of the peer-review process than the events that led to this IPCC report."
>
> — *Dr. Frederick Seitz*

Recent comments made by spokespersons for the IPCC suggest concern that their findings are being misrepresented. Dr. Benjamin Santer, lead author of the chapter of *Climate Change 1995* addressing climate science, has said "It's unfortunate that many people read the media hype before they read the chapter. . . . I think the caveats are there. We say quite clearly that few scientists would say the attribution issue was a done deal."[64] In a June 2, 1997 debate, IPCC chairman Bert Bolin said, "the climate issue is not 'settled'; it is both uncertain and incomplete."[65]

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61 Dr. Frederick Seitz, "A Major deception on 'Global Warming'," *The Wall Street Journal*, June 12, 1996.

62Cited in National Association of Manufacturers White Paper on Global Climate Change, June 1997, pages 9-10.

63 Dr. Vincent Gray, supra note 47, page 21.

64 Richard Kerr, supra note __, page 1040.

65 Jerry Taylor, "The Heated Rhetoric of Global Warming," *This Just In*, Cato Institute, September 15, 1997.

5. **A modest amount of global warming, should it occur, would be beneficial to the natural world and to human civilization.**

Because so little is known about how the atmosphere functions, it is impossible to rule out the possibility that man-made greenhouse gas emissions might cause some amount of warming (or cooling). Would some degree of warming be bad for most societies and natural environments? Probably not.

> "We say quite clearly that few scientists would say the attribution issue was a done deal."
> — *Dr. Benjamin Santer*

"During the 20th century," writes Dr. Patrick Michaels, "we have already proceeded more than half way to radioactively??? doubling the natural carbon dioxide greenhouse effect. Here is what resulted: Life expectancy doubled in the free and developed world. The developing world is catching up as their emissions rise. Corn production per acre increased five-fold. The growing season in the coldest latitudes increased slightly, but enough to increase greenness by 10 percent."[66]

The small amount of warming that occurred during the past century consisted primarily of increased minimum temperatures at night and during winters.[67] This means higher *average* temperatures, should they occur, would not result in more daytime evaporation, which some claim would lead to droughts and desertification. Warmer winters would mean longer growing seasons and less stress on most plants and wildlife, producing a substantial benefit for the global ecosystem. Finally, past warming has been accompanied by increased cloudiness, a phenomenon also predicted by most global climate models. This means a warmer world would probably be a wetter world, which once again is beneficial to most plant and animal life.[68]

Not everyone believes a warmer world would be benign. In his book, *Earth in the Balance*, Vice President Al Gore predicted that "the climate changes that we are now bringing about by modifying the global atmosphere are likely to dwarf completely the ones that caused the great subsistence crisis of 1816-19, for example, or those that set the stage for the Black Death. . . . [H]undreds of millions of people may well become even more susceptible to the

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66 Dr. Patrick Michaels, "U.N. Global Climate Treaty," Testimony before the Subcommittee on International Economic Policy, Export and Trade Promotion of the Senate Foreign Relations Committee, June 26, 1997.

67 ". . . most simulations show . . . a widespread reduction in diurnal range of temperature." IPCC, "Summary for Policymakers," Section 5. See also Dr. P.J. Michaels and Dr. D.E. Stooksbury, "Global Warming: A Reduced Threat?" *Bulletin of the American Meteorological Society*, Vol. 73 (1992), pages 1563-1577.

68 Dr. Robert C. Balling, Jr., "Global Warming: Messy Models, Decent Data, Pointless Policy," Competitive Enterprise Institute, November 1994, pages 13-14.

spread of diseases when populations of pests, germs, and viruses migrate with the changing climate patterns."[69]

Later in his book, Gore warns, "every coastal country will suffer adverse effects" from rising sea levels caused by melting polar ice.[70] Gore and others also claim that global warming will cause more floods, more droughts, more "torrential" rainfalls, and heavier snowfall.[71]

Warmer winters would mean longer growing seasons and less stress on most plants and wildlife, a substantial benefit for the global ecosystem.

Gore's claims are at odds with much scientific research. The bacterium responsible for the epidemic episode called the Black Death was transmitted by rats, which flourish in cool as well as warm climates. Cholera, another disease mentioned as a potential threat, is readily brought under control by treating water supplies with chlorine. Like most other bacteria-based diseases, the problem is not a difference in average temperatures of one or two degrees, but a lack of sanitary living conditions, food, and water.[72]

The latest research suggests that sea levels would decline, not rise, if temperatures rise, due to increased evaporation from the oceans and subsequent precipitation.[73] Increasing polar temperatures by a few degrees would not cause ice or snow to melt because the original temperatures are so low the new temperatures would still be well below freezing. However, the slightly warmer air *would* be able to retain more moisture, meaning more snowfall in polar regions and *more*, not less, water locked up in snow and ice.[74]

The "torrential" rainfalls turn out to be any rainfall of 2 inches or more in a 24-hour period, something every farmer knows would likely be a blessing rather than a curse.[75] The number and intensity of hurricanes occurring in the Atlantic (the ocean basin with the highest

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69 Al Gore, *Earth in the Balance* (New York, NY: Houghton Mifflin Company, 1993), page 74.

70 Ibid., page 104.

71 William K. Stevens, "More Extremes Found in Weather, Pointing to Greenhouse Gas Effect," *The New York Times*, May 23, 1995, page B7.

72 Dr. Sidney Shindell, M.D., and Jack Raso, M.S., R.D., *Global Climate Change and Human Health* (New York, NY: American Council on Science and Health, October 1997); Gary Taubes, "Apocalypse Not," *Science*, Vol. 278, No. 7 (November 1997), pages 1004-1006.

73 Dr. S. Fred Singer, supra note 41. See also H. Sterling Burnett, "Myths of Global Warming," *Brief Analysis*, National Center for Policy Analysis, May 23, 1997.

74 Dr. K.W. Nicholls, "Predicted reduction in basal melt rates of an Antarctic ice shelf in a warmer climate," *Nature*, vol. 388, July 31, 1997, pages 460-461.

75 Dr. Patrick Michaels, "'Torrential' Rains Increase!" *World Climate Report*, Vol. 1, No. 4, n.d., page 1.

quality data) has steadily fallen since aircraft reconnaissance began in 1944.[76] The Intergovernmental Panel on Climate Change found "inadequate data to determine whether consistent global changes in climate variability or weather extremes have occurred over the 20th century," with some regions exhibiting greater variability and others less.[77]

> The latest research suggests that sea levels would decline, not rise, if temperatures rise, due to increased evaporation from the oceans and subsequent precipitation.

In short, a slightly warmer world would probably be greener and a little cloudier than our world today, but otherwise not much different. As Dr. Patrick Michaels asked members of Congress during his 1997 testimony, "How much of the money of the citizens of this nation are you willing to spend to stop this? How much to stop a slight amelioration of the coldest temperatures, in the air-masses most inhospitable to unprotected life? How much to stop making the Earth greener, more productive, and human life increasingly long over the mass of the planet that still finds us the envy of history?"[78]

6. Efforts to quickly reduce human greenhouse gas emissions are costly and would not stop Earth's climate from changing.

What if the greenhouse emissions produced by developed countries were so small, relative to natural sources and the emissions of developing countries, that reducing them would have almost no effect on global concentrations of greenhouse gases in the atmosphere? Obviously, a reasonable person would stop and reconsider the wisdom of making the many sacrifices necessary to meet the caps contained in the Kyoto Protocol.

The most commonly discussed targets involve stabilizing global atmospheric concentrations of CO_2 at levels in the range of 450ppm (parts per million) to 650ppm. Current levels are roughly 360ppm. "Actions by the industrial countries alone," says Eugene Trisko, "cannot achieve any of the target concentrations that are now frequently discussed within the scientific community . . . [I]n order to approach those targets, emissions from the industrial countries have to go below zero. We have to more than disappear from the map to achieve any of them."[79]

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76 Dr. C.W. Landsea et al., "Downward Trends in the Frequency of Intense Atlantic Hurricanes During the Past Five Decades." *Geophysical Research Letters*, Vol. 23 (1996), pages 1697-1700.

77 IPCC, supra note 13, Section 3. See also Jerry Taylor, supra note 55.

78Dr. Patrick J. Michaels, "U.N. Global Climate Treaty," testimony before the Subcommittee on International Economic Policy, Export and Trade Promotion of the Senate Foreign Relations Committee, June 26, 1997.

79 Ibid.

"Actually stopping any further global warming from occurring (assuming the median predictions of present climate models) would require a 70 percent reduction of present emissions," writes environmental analyst Jerry Taylor, "roughly the equivalent of completely abandoning the use of fossil fuels."[80]

The Kyoto controls could actually *increase* concentrations of greenhouse gases. If manufacturers are required by the treaty to invest in expensive new emission control equipment for their U.S.-located plants, for example, they may abandon the country instead, building new facilities overseas in countries not bound by the Kyoto controls. The drag on the economy caused by carbon taxes or other policies designed to reduce emissions would result in less investment in research and development and slower turnover of existing capital. This means older and less efficient machinery would be kept in service longer. Energy taxes would also slow the gradual process whereby fuel-based technologies are being gradually replaced with electrotechnologies. Since the latter are cleaner and more efficient than the former, the result would be a net increase in greenhouse gas emissions.[81]

> "[I]n order to approach those targets, emissions from the industrial countries have to go below zero. We have to more than disappear from the map to achieve any of them."
>
> — *Eugene Trisko*

Moreover, forcing developing countries to participate would level the competitive field but not significantly alter likely human impacts on climate, because that impact is so small. For example, Dr. Michaels recently computed the "temperature saving" if the *entire world* reduced greenhouse emissions to 1990 levels by 2010. He used the U.S. National Center for Atmospheric Research (NCAR) model, and the latest IPCC estimates of CO_2 increase rates. Under this scenario, the global temperature *increase* will be just 0.017° C less than baseline in 2010, and 0.146° C less in 2040.[82] Even using a higher figure for CO_2 accumulation, as NCAR prefers, the emission controls would reduce global warming by only 0.18° C. over the next 50 years—a mere 7 percent of the IPCC's "best estimate" temperature increase.

80 Jerry Taylor, "Global Warming: The Anatomy of a Debate." Presentation before the Johns Hopkins University Applied Physics Laboratory. January 16, 1998.

81 Dr. Henry R. Linden, "Electrification Will Enable Sustained Prosperity," *Power Engineering*, October 1996, page 26-28.

82Dr. Patrick J. Michaels, "The Consequences of Kyoto," *Policy Analysis*, Cato Institute, May 7, 1998.

7. **Based on available information, the best strategy to pursue is one of "no regrets."**

Some environmentalists call for a "save-the-day" strategy to "stop global warming," saying it is better to be safe than sorry. Such a position seems logical until we stop to think: Immediate action wouldn't make us any safer, but it would surely make us poorer. And being poorer would make us *less* safe.

> The best strategy is to invest in research to determine whether a genuine threat exists, and to invest in reducing emissions only when such investments make economic sense.

CO_2 stays in the atmosphere for decades, meaning each year's emissions are only a small percentage of the total amount of CO_2 in the atmosphere. Consequently, immediate large reductions in emissions have relatively small effects on concentrations of greenhouse gases.

Whether emission reductions occur now or thirty years from now, they will have the same overall impact. If it proves necessary to make reductions, the *cost* of making reductions later, after new technologies now under development become available commercially and after current capital stock has come up for replacement, is likely to be much less than the cost of making reductions today.

Researchers have found a close relationship between a nation's standard of living (its wealth) and many measures of public health and safety. Wealthier societies are able to invest more in things that ensure safety, such as guardrails on highways, vaccines against diseases, and safe drinking water. Simply put, wealthier is healthier.

The "save-the-day" strategy will definitely make us poorer, to the tune of hundreds of billions of dollars each year. If that money is no longer available to purchase safety-enhancing devices, plainly we will be less safe as a result of our efforts to "stop global warming."

The best strategy is to invest in atmospheric research to determine whether a genuine threat exists, and to invest in reducing emissions only when such investments make economic sense in their own right, and reduce emissions as an added benefit.

This strategy is called "no regrets." It positions us to respond quickly to bad news while avoiding the mistake of spending too much, too soon, preparing for a threat that never materializes.

Some of the activities that would form part of a no-regrets strategy include:

- Fund research on the effects of higher CO_2 concentrations on plants and agriculture.
- Break the federal monopoly over global warming research, which currently has the effect of funding only those researchers who support the catastrophist view of global warming.

- Lower capital gains taxes and make other changes to tax policies and regulations to encourage new investments in capital and technology, thereby speeding up the process of phasing out inefficient machinery.

- Focus attention on ways to accommodate, rather than prevent, climate change. For example, higher sea levels, should they occur, could be addressed by modest improvements to dikes and seawalls in some areas, and by relocating homes and businesses in other areas. This cost—spread out over the course of a century—would surely be less than the cost of attempting to prevent climate change through energy taxes or emission caps.

- Repeal regulations that stand in the way of energy efficiency, such as restrictions on operating small businesses at home and zoning ordinances that lead to urban sprawl.

- Replace "command and control" regulations, which tell businesses what they must do to reduce emissions, with flexible and incentive-based rules that allow the use of lowest-cost options. This would end the pure waste of billions of dollars a year, allowing some part of that savings to be invested in research or ways to accommodate climate change.

The alternative to radical environmentalist demands for immediate action to "stop global warming" is not to do nothing. Much that can be done that would produce real social and economic benefits while also positioning us to respond if a genuine threat is ever proven to exist.

PART 4

The Agriculture Industry's Positive Message on Global Warming

As the final point of Part 3 makes clear, the alternative to the Kyoto Protocol does not have to be a "do nothing" strategy. Skeptics of the science behind the global warming scare should advocate affordable "win-win" activities in the short term while scientists continue their search for more reliable ways to predict future climate changes. Farmers are uniquely positioned to deliver this message because their crops *store* carbon dioxide, the leading minor greenhouse gas.

Farmers are a key part of the solution to global warming.

> Farmers, who specialize in promoting plant growth and turning plant tissue into consumer goods, could be said to be in the business of removing CO_2 from the air and sequestering it.

Many farmers in the U.S., aware of the beneficial effects of higher levels of carbon dioxide on plants, pump CO_2 into their greenhouses or buy from nurseries that do. An extensive body of scientific literature has documented the positive effects of higher concentrations of CO_2 on plant growth.[83] By boosting photosynthesis and the efficiency with which plants use water, a double of CO_2 concentration increases plant growth by about a third. "Of over a thousand experiments, detailed in 324 peer-reviewed scientific reports, 93 percent reported an increase in plant productivity averaging 52 percent."[84]

Dr. Sylvan Wittwer, a distinguished professor of horticulture at Michigan State University, writes that "the effects of an enriched CO_2 atmosphere on crop productivity, in large measure, are positive, leaving little doubt as to the benefits for global food security. . . . The rising level of atmospheric CO_2 is a universally free premium, gaining in magnitude with time on which we can all reckon for the foreseeable future."[85]

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83 For an extensive survey of this literature, see Dr. Sherwood Idso, *CO_2 and the Biosphere: The Incredible Legacy of the Industrial Revolution* (St. Paul, MN: Department of Soil, Water and Climate, University of Minnesota, October 1995).

84 Dr. Sylvan Wittwer, *Food, Climate and Carbon Dioxide* (Boca Ratan, FL: CRC Press, 1995).

85 Ibid., pages 189-190.

Plants benefit from exposure to CO_2 because they absorb and store the gas in their tissues. This means farmers, who specialize in promoting plant growth and turning plant tissue into consumer goods, could be said to be in the business of removing CO_2 from the air and temporarily sequestering it.

"The simplest way to remove carbon dioxide," says Dr. Gregory Benford, a physics professor at the University of California in Irvine, "... is to grow plants—preferably trees, since they tie up more of the gas in cellulose."[86] Land plants contain roughly three times as much CO_2 as the atmosphere. Roughly half of U.S. carbon dioxide emissions could be captured by planting tree crops on economically marginal lands for a sum of $5 billion per year—still a large sum but vastly less than the economic costs of the Kyoto regulatory regime.

> "The simplest way to remove carbon dioxide . . . is to grow plants—preferably trees, since they tie up more of the gas in cellulose."
> — *Dr. Gregory Benford*

Dr. Sherwood B. Idso, a research physicist for the U.S. Department of Agriculture, believes that this solution may occur *spontaneously*. "[T]he rising CO_2 content of Earth's atmosphere would eventually stimulate the productivity of woody plants to such an extent that the increase in their growth rates would be great enough to reduce the rate at which the CO_2 content of the air was then rising, and ultimately lead to a stabilized CO_2 concentration considerably less than what is typically projected under most 'business as usual' scenarios."[87] Other researchers have confirmed that the increase in atmospheric CO_2 concentrations slowed during the 1980s and 1990s.[88]

Plants absorb and hold carbon dioxide while they grow, but release it during the natural process of decay. Farmers prevent CO_2 from returning to the atmosphere when they harvest field crops and send them to processors to be turned into food products; harvest older trees before they die and replant sufficient quantities of new trees to provide a perpetual supply of wood fiber (sustained yield forest management); plant fast-growing trees in high densities and harvest them after a few short years for paper fiber; and collect straw left over from rice and other crops for use, once again, in papermaking. Each of these practices is already taking place, is profitable, and sequesters CO_2.

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86 Dr. Gregory Benford, "Climate Controls," *Reason Magazine*, November 1997.

87 Dr. Sherwood Idso, supra note 88, page 28.

88 Conway, T.J., Tans, P.P., Waterman, L.S. and Thoning, K.W. "Evidence for interannual variability of the carbon cycle from the National Oceanic and Atmospheric Administration/Climate Monitoring and Diagnostics Laboratory Global Air Sampling Network," *Journal of Geophysical Research*, Vol. 99, No. D11 (1994), pages 22, 831-832, 855. See also C.D. Keeling, "A study of the abundance and 13C/12C ratio of atmospheric carbon dioxide and oceanic carbon in relation to the global carbon cycle," in Riches, M.R. (Ed.), *Global Change Research: Summaries of Research in FY 1994* (Washington, DC: U.S. Dept. Of Energy, 1994), pages 109-110.

Farmers can change their practices to reduce emissions.

Besides sequestering more carbon dioxide from the atmosphere, farmers can act voluntarily to limit their own emissions. According to the IPCC, agriculture accounts for 25 percent of anthropogenic greenhouse gases. The agricultural techniques and technologies that would reduce emissions include practices many farmers already use routinely:[89]

During the past ten years, farmers helped restore 690,000 acres of American wetlands.

- **Control soil erosion**. Erosion reduces biomass per acre and below-ground carbon sequestration. It also costs farmers money by removing land from productive use. Farmers are making significant progress against soil erosion, reducing by 24 percent the amount of erosion per farm acre in the last 15 years.[90]

- **Preserve natural wetlands**. Wetlands contain unusually high levels of carbon and retain it longer than most soils. While farmers have historically drained wetlands to plant field crops, they now are leading the nation in restoring wetlands for flood control, recreation, and wildlife habitat. During the past ten years, farmers helped restore 690,000 acres of American wetlands.[91]

- **Reforestation**. Trees and woody shrubs sequester CO_2 both above and below ground, and are particularly useful for improving the carbon content of depleted soils.

- **Conservation tillage.** Tillage for fallowing increases oxidation rates of organic carbon. Conservation tillage, by contrast, fixes more carbon in the soil than other method by retaining crop residues and minimizing oxidation. In 1997, American farmers cultivated more than half of the nation's 294.6 million acres of crop land with conservation-till or reduced-till techniques.[92]

- **Retain forest slash on site**. The retained water and nutrients reestablish carbon-fixing vegetation rapidly.

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89 Council for Agriculture and Technology (CAST), *Preparing U.S. Agriculture for Global Climate Change*, Task Force Report No. 119. June 1992.

90American Farm Bureau Federation, "Farm Facts: Cropland Erosion on the Decline," www.fb.com/today/farmfacts/ffacts10.html, citing Conservation Technology Information Center, National Crop Reside RESIDUAL? Management Survey.

91C.D. Kelly, "How Farmers Mark Earth Day," *Focus on Agriculture*, American Farm Bureau Federation, April 20, 1998. Available at www.fb.com/views/focus/fo98/fo0420.html.

92 Ibid.

- **Mulching**. By decreasing extremes of soil surface temperature, mulching slows organic decomposition, retaining more carbon in the soil.

- **Leave crop residue**. Besides acting as mulch, such residues are a direct carbon source for new plants.

- **Maintain/Improve Soil Fertility.** Fertile soil, with appropriate levels of nitrogen, phosphorus, and potassium, sequesters more CO_2 than depleted soil.

Farmers cannot play a helpful role if they are taxed and regulated.

U.S. farmers lead the world in the use of progressive agricultural practices that minimize erosion, enhance soil fertility, and in other ways sequester carbon while minimizing emissions. If left unhampered by energy taxes or burdensome regulations, they will make further progress in limiting unnecessary emissions, as it is in their long-term self-interest to do so.

Adoption of the Kyoto Protocol, however, would lead to the imposition of taxes and regulations on U.S. farmers, but not on farmers in many other countries. As a result, a growing share of the world's food would be produced outside the U.S. with less progressive practices. At the extreme are situations, as in Brazil, where hundreds of thousands of acres of carbon-rich rainforests are burned each year to make way for low-yield field crops, a practice that releases tremendous amounts of carbon dioxide into the atmosphere.

> By making U.S. farm products less competitive in domestic and international markets, the Kyoto Protocol is likely to reduce the amount of carbon dioxide that is sequestered and cause more carbon dioxide to be emitted.

U.S. farmers and ranchers presently export $69.7 billion in produce and meat to consumers in other nations each year. American farmers produce 12 percent of the world's wheat, 19 percent of its cotton, 36 percent of its corn, and 47 percent of its soybeans. By making U.S. farm products less competitive in domestic and international markets, the Kyoto Protocol is likely to reduce farm exports, thereby reducing the amount of carbon dioxide sequestered by agricultural and forestry activities.

Summary

Farmers are better positioned than any other group to comment with natural authority on the global warming debate. On a day-to-day basis they experience the effects of rising CO_2 concentrations and changes in climate. *Their business is finding ways to capture carbon dioxide from the air and turn it into consumer goods.* If climates suddenly change, they will be on the forefront of efforts to adapt to change with new strains of seeds, different planting and harvesting technologies, and other innovations.

Farmers already capture and sequester more CO_2 than any other industry. If removing CO_2 from the atmosphere at higher rates is required or prudent, policymakers must eventually come to farmers to find the most cost-effective means. And farmers, because so many of the practices that reduce CO_2 emissions also enhance farm productivity and therefore net profits, are eager to help.

The Kyoto Protocol is exactly the *wrong* way to go about making the agricultural community in the U.S. a larger part of the *solution* to the possible problem of global warming.

But this is not the direction that public policy, represented by the Kyoto Protocol, is headed. Instead of encouraging farmers to do more to sequester CO_2, the Kyoto Protocol would *take away billions of dollars of net income*, causing a new exodus from the land and to urban centers. Rather than reward American farmers for their successful fight against erosion and other challenges that increase CO_2 emissions, the treaty would *reduce the American farmer's competitive advantage over farmers in other countries*, resulting in more investment in farming abroad and less here at home.

In short, the Kyoto Protocol is exactly the *wrong* way to go about making the agricultural community in the U.S. a larger part of the *solution* to the possible problem of global warming. For this reason, people who are sincerely concerned about the possibility of global warming should oppose, rather than embrace, the Kyoto Protocol. Farmers, obviously, have an added reason to oppose the Protocol.

PART 5

Summary and Conclusion

While the typical farm or ranch in the U.S. doesn't have a smoke stack, it nevertheless produces prodigious amounts of carbon dioxide and other minor greenhouse gases. Those gases are not "pollution," in the sense that they pose a direct threat to human health. Indeed, since carbon dioxide makes plant photosynthesis possible, one can accurately say these gases are life-creating and life-saving. Nevertheless, some environmental advocates believe these emissions, together with those from many other sources, may eventually destabilize the global climate. Those ideas have led to a proposed treaty, the Kyoto Protocol, that would have sweeping implications for farmers.

If the Kyoto Protocol is implemented, American farmers will find themselves subject to ruinous taxes and regulations. Unable to pass along to consumers the billions of dollars in higher operating expenses, farmers will lose markets both at home and abroad to producers in other countries who are not asked to bear the same financial burdens. Small family-owned farms will be forced out of business, and with them will go countless businesses, both small and large, that rely on the farmer to buy their products.

The science behind the global warming scare is too weak to support the draconian policies that would follow approval of the Kyoto Protocol. If a "consensus of scientific opinion" exists on the subject, it almost surely is that too little is known about the world's atmosphere to predict either warming or cooling in the coming years. The world's leading experts ask us to wait ten years or longer for new tools to be invented to help them model and analyze the impact of anthropogenic greenhouse gases. Unfortunately, politicians seems all too eager to jump ahead of sound science, regardless of reasonable doubts, and regardless of the costs that would be incurred.

Farmers can be much more than naysayers in the debate over global warming. If the prophets of global catastrophe are correct, farmers hold the key to reducing greenhouse gases quickly and affordably. By turning eroded areas into forests and fields, and by better managing their fields and wetlands, farmers can dramatically increase the amount of carbon that is removed from the atmosphere and safely sequestered in consumer products or underground. By increasing their use of progressive practices that are already well established and profitable, farmers can reduce their own emissions of carbon dioxide and other greenhouse gases as well, perhaps buying scientists more time to learn how the global climate works.

If you are a farmer, and if you have read this far, then you now have all the information you need to be an effective communicator on the global warming issue. We hope you will speak out in conversations with family and friends, with the reporters and editors of your local newspapers, and with your local, state, and national elected officials. Let them know that you understand the issues concerning global warming, and that you have a "win-win" alternative to the Kyoto Protocol.

Appendix

Table 5
U.S. Production Cash Costs, Field Crops

Table 6
U.S. Production Cash Costs, Hogs and Milk

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Table 5
U.S. Production Cash Costs, Field Crops
(dollars per acre)

	Corn			Soybeans			Cotton			Wheat		
		Impact of Higher Energy Prices			Impact of Higher Energy Prices			Impact of Higher Energy Prices			Impact of Higher Energy Prices	
	1994	Low	High	1994	Low	High	1994	Low	High	1994	Low	High
Gross Value of Production	296.32			219.56			477.39 [2]			104.95 [3]		
Cash Expenses												
Fertilizer, lime & gypsum	46.07	55.28	65.38	9.25	10.65	12.03	38.16	45.79	53.42	15.21	17.49	19.77
Pesticides	25.22	30.26	35.30	24.45	29.34	34.23	49.87	59.84	69.82	6.18	7.42	8.65
Custom Operations	10.05	11.56	13.07	3.73	4.29	4.85	19.59	22.53	25.47	4.87	5.60	6.33
Fuel, lube and electricity	18.96	23.70	28.44	7.93	9.91	11.90	31.03	38.79	46.54	8.12	10.15	12.18
Other [1]	46.78	49.12	51.46	30.40	31.92	33.44	138.30	145.22	152.13	20.20	21.21	22.22
Total, Variable Cash Expenses	147.08	169.92	193.65	75.76	86.11	96.45	276.95	312.17	347.38	54.58	61.87	69.15
Percent Change in Expenses		15.5%	31.7%		13.7%	27.3%		12.7%	25.4%		13.4%	26.7%
Total, Fixed Cash Expenses	50.13	50.13	50.13	42.89	42.89	42.89	57.08	57.08	57.08	24.89	24.89	24.89
Total, Cash Expenses	197.21	220.05	243.78	118.65	129.00	139.34	334.03	369.25	404.46	79.47	86.76	94.04
Gross Value of Production Less Cash Expenses	99.11	76.27	52.54	100.91	90.56	80.22	143.36	108.14	72.93	25.48	18.19	10.91
Percent Change in Net Profit		-23.0%	-47.0%		-10.3%	-20.5%		-24.6%	-49.1%		-28.6%	-57.2%

[1] Includes seed, repairs, hired labor, other variable cash expenses and ginning for cotton.
[2] Total for Cotton (421.04) and Cottonseed (56.35).
[3] Total for Wheat (103.64) and Wheat Straw (1.31).

Table 6
U.S. Production Cash Costs, Hogs and Milk
(dollars per hundredweight)

Hogs

	1994	Impact of Higher Energy Prices: Low	Impact of Higher Energy Prices: High
Hog Production			
Market Hogs	36.29		
Feeder Pigs	4.52		
Cull Stock	2.31		
Breeding Stock	2.11		
Inventory Change	0.44		
Other Income	1.13		
Gross Value of Production	46.80		
Cash Expenses			
Grain	11.54	12.35	13.16
Protein Sources	9.35	9.72	10.10
Complete Mixes	5.69	6.06	6.43
Other Feed Items	0.59	0.63	0.67
Total Feed Costs	27.17	28.76	30.36
Other Variable Cash Expenses	11.27	11.56	12.05
Total, Variable Cash Expenses	38.44	40.32	42.41
Percent Change in Expenses		**4.9%**	**10.3%**
Total, Fixed Cash Expenses	3.66	3.66	3.66
Total, Cash Expenses	42.10	43.98	46.07
Gross Value of Production Less Cash Expenses	4.70	2.82	0.73
Percent Change in Net Profit		**-40.0%**	**-84.6%**

Milk

	1994	Impact of Higher Energy Prices: Low	Impact of Higher Energy Prices: High
Milk Production			
Milk	12.99		
Cattle	1.00		
Other Income	0.51		
	14.50		
Cash Expenses			
Concentrates	3.69	3.84	3.95
Silage	1.41	1.51	1.61
Other Feed	2.07	2.07	2.07
Total Feed Costs	7.17	7.42	7.63
Other Variable Cash Expenses	4.18	4.36	4.57
Total, Variable Cash Expenses	11.35	11.78	12.20
Percent Change in Expenses		**3.8%**	**7.6%**
Total, Fixed Cash Expenses	1.55	1.55	1.55
Total, Cash Expenses	12.90	13.33	13.75
Grass Value of Production Less Cash Expenses	1.60	1.17	0.75
Percent Change in Net Profit		**-26.9%**	**-53.1%**