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GLOBAL WARMING: THE GREENHOUSE, WHITE HOUSE, AND POORHOUSE EFFECTS

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EXECUTIVE SUMMARY

The potential for global warming presents policy issues of unprecedented proportions. The entire debate pivots on assessing large-scale risks without adequate information. For the past decade, environmentalists and some scientists have claimed that human-induced emissions of carbon dioxide (CO_2) (and other "greenhouse" gases) could lead to substantial changes in global temperatures. Some scientists, however, dispute these claims. Controversies over the potential implications of global climate change have ignited political debate—and in some cases, policy action—throughout the world.

Estimates of the annual impact on U.S. agriculture of temperature increases range from a *cost* of $10 billion to a *benefit* of $10 billion. Estimates of impacts on the total U.S. economy of strategies to reduce greenhouse gas emissions range from net benefits to losses in the U.S. gross national product ranging from 0.3 percent to 1.6 percent, depending on the reduction levels sought.

Despite these uncertainties and potentially high costs of significantly reducing greenhouse gas emissions, President Clinton has stated he would "stabilize" U.S. CO_2 emissions at 1990 levels by the year 2000. Like other approaches to directly reduce greenhouse gas emissions by specific amounts, this approach is likely to be costly.

Instead, "no-regrets" or "no-regrets-plus" strategy offers the best prospect for developing policies in which the benefits will outweigh the costs. Under these approaches, policies would focus on improving energy efficiency and reducing previously identified air emissions. These strategies would aim to achieve benefits *regardless* of whether climate changes occur. Reductions in greenhouse gases would be a side-effect of these efforts.

The no-regrets-plus option provides an additional level of flexibility to address future risk by encouraging greater investment in energy-related research, demonstration, and development (RD&D). While direct government funding of RD&D could be pursued under this approach, encouraging competitive RD&D markets is generally preferable to a public-investment strategy that "picks winners."

The only rationale for a strategy aimed at direct and aggressive reductions of greenhouse gas emissions would be the presence of clear indications that global temperatures are rising and that they will cause massive economic, environmental, and political upheavals. On the other hand, both the no-regrets and no-regrets-plus strategies articulate a set of goals that make sense given the high degree of uncertainty of global warming risks and the large potential costs of any strategy aimed directly at reducing greenhouse gas emissions.

I.INTRODUCTION

The November 3, 1992 presidential election transformed the "greenhouse effect" from a scientific concern requiring more study to a global threat necessitating immediate and concerted action. With Clinton's election, global warming is sure to rise to the top of the nation's environmental—and perhaps even national security—agenda.

Former President Bush's administration viewed the potential for global warming as uncertain, and, in any event, believed that the environmental consequences of any worldwide temperature increases were likely to be manageable. As a result, the Bush administration preferred a cautious approach toward implementation of any potentially expensive policies directed at reducing emissions of the "greenhouse gases"—principally carbon dioxide (CO_2), methane, and chloroflurocarbons (CFCs)—linked with global warming.

During the 1992 presidential campaign President Clinton stated he would "stabilize" U.S. CO_2 emissions at 1990 levels by the year 2000.[1] In addition, Vice President Al Gore has consistently pointed to global warming as one of the most critical problems facing the world today. In his 1992 book, the Vice President claimed that the potential for global warming puts the very "survival of civilization" at risk.[2] Given this backdrop, it is not surprising that Clinton, just months after his inauguration, reconfirmed his goal of reducing CO_2 emissions to 1990 levels by the turn of the century.

The potential for global warming presents policy issues of unprecedented proportions. The entire debate pivots on assessing large-scale risks without adequate information. On the one hand, global warming poses the risk that by doing nothing (i.e., maintaining the status quo) the earth's climate will change in ways that could engender dramatic political, economic, and social instability throughout the world. On the other hand, global warming presents the risk that any effective action to counter potential temperature increases would necessitate economic investment at a level that could severely disrupt the global economy, likewise leading to political instability. A previous treaty to counter ozone depletion has demonstrated that international mechanisms exist with which to address global environmental problems.[3] However, the actions to reduce the risk of ozone depletion require economic changes that are a fraction of the size and scope that would be needed to reduce greenhouse gases.

Proposed policies to address global warming range along a continuum that moves from inaction to draconian immediate measures to dramatically reduce human-induced greenhouse gases. Along this continuum are four main conceptual approaches. First is the "wait-and-see" strategy, in which no immediate action other than further scientific investigation is taken. Second is a "no-regrets" strategy that aims at improving energy efficiency and reducing currently targeted air pollutants, with reductions in greenhouse gases resulting as a side effect of these actions. Third is a "no-regrets-plus" approach, which adds to the no-regrets strategy an alternative energy research and development component. Finally is the "save-the-day" strategy designed to bring about rapid reductions in human-induced greenhouse gas emissions.

While global warming may present some risk to humankind, the costs associated with reducing this risk create important trade-off decisions. For example, fully eliminating the risks of human-induced global temperature increases could require massive investment in nonfossil fuel-based electricity generation and transportation systems. This investment level, in turn, would imply forgoing expenditures on other goods, such as expanded health care delivery, or new scientific ventures, or increased funding for education.

In this context of highly uncertain risks and potentially high costs to reduce these risks, either a "no-regrets" or "no-regrets-plus" strategy likely offers the best prospects for policies in which the benefits will outweigh the costs. In both strategies, policies focus on improving energy efficiency and reducing previously identified air emissions. Reductions in greenhouse gases would be a side-effect of these efforts, since most human-induced greenhouse gases result from fuel consumption. Both policies thus are designed to generate benefits *regardless* of whether human-induced greenhouse gas emissions contribute to climate changes with significant adverse consequences, with the "no-regrets-plus" alternative providing an additional level of flexibility to address future risk by expanding technological options.

II.GLOBAL UNCERTAINTY

The natural greenhouse effect, which contributes to the world's moderate temperatures, is responsible for the planet's abundance of plant and animal life. That is, "natural" emissions of various greenhouse gases early in the earth's development created an atmosphere capable of producing the range of temperature conditions that enables life to flourish throughout the globe.
Although the great majority of atmospheric greenhouse gases result from nonhuman processes, humankind is responsible for small but steady emission increases that some scientists have alleged could lead to global warming. While cooking, heating, and brush-clearing fires have generated greenhouse gases since the beginning of civilization, large-scale human contribution to greenhouse gases did not begin until the age of industrialization in the nineteenth century.

Today, human-induced emissions of greenhouse gases are dominated by CO_2, which accounts for approximately half of humankind's emissions. CFCs, the use of which will eventually be eliminated as a result of existing international treaties, are responsible for one-fifth of greenhouse gas emissions. In addition, methane contributes 16 percent; ozone, or O_3, 8 percent; and nitrogen oxides (NOx) 6 percent, to human-induced greenhouse gas emissions.[4] In total, human activities account for 4 percent of worldwide carbon dioxide emissions; the remaining 96 percent result from natural phenomena.[5]

Global warming theory holds that human-induced increases in total greenhouse gases in the atmosphere may lead to a significant rise in worldwide temperatures, with some analysts estimating possible temperature increases of three to nine degrees fahrenheit (F) over the next century.[6] Such large temperature changes could result from the adverse consequences engendered by a failure in the earth's natural "feedback" effects.

Under this scenario scientists postulate that the planet's biosphere has mechanisms that maintain climatic stability. For example, when CO_2 levels in the atmosphere rise, plant growth increases, thereby absorbing the additional greenhouse gases. However, if the level of greenhouse gases exceeds the boundary within which the feedback effects operate, some scientists fear that these effects would become reinforcing rather than offsetting: as CO_2 emissions rise, global temperatures would increase, thereby changing rainfall patterns, which would lead to reductions in plant growth, a decline in absorption of greenhouse gases, and a further increase in atmospheric CO_2 and global temperatures. Absent this type of feedback effect, most current global warming estimates cluster around temperature increases of two to four degrees F by the middle of the 21st century, with some scientists suggesting that even these changes appear unlikely.

In the more apocalyptic scenarios, the world's glaciers would melt. Rising sea levels could flood coastal areas, and geographic rainfall patterns could be significantly altered, thereby affecting patterns of worldwide agricultural productivity. More important than these potential aggregate impacts, regional climate changes could create economic and political instability in specific areas of the globe. For example, increased regional water scarcity induced by global warming-induced changes in weather patterns could act to encourage a repeat of the mass migrations and starvation currently taking place in the Horn of Africa.[7]

Whether or not global temperatures will actually rise as a result of human-engendered increases in greenhouse gas emissions, and what the consequences of such temperature increases would be, are a matter of debate among scientists. Strong evidence suggests that there is a correlation between global temperature changes and CO_2 levels, though scientists are uncertain whether increased CO_2 levels cause warming, or the warming causes increases in CO_2 levels.[8] Likewise, human activities appear to have increased the amount of greenhouse gases in the atmosphere.[9] However, beyond these facts there is considerable uncertainty surrounding the timing and magnitude of any potential warming, or whether human activity is responsible for any statistically significant temperature changes.

While two studies of temperature records found temperature increases of one degree F over the last century,[10] an undisputed period of cooling occurred between 1940 and 1970, leading to scientific speculation at the time that another ice age was imminent.[11] The findings of the global warming computer models are also highly uncertain. In 1989 most climate modelers, with the notable exception of James Hansen of the National Aeronautic and Space Administration's (NASA) Goddard Institute, halved their estimates of temperature increases.[12] Essentially, it is very difficult to forecast the outcome of small changes in the scheme of massive and complex systems. For example, despite the use of advanced climate-modeling computers, scientists have been unable to predict the intensity or duration of El Nino conditions in the Pacific Ocean. As one climatologist stated, until scientists can predict El Nino accurately, “we have no hope of predicting long-term events.”[13]

Potential behavioral responses to perceived global warming—such as voluntary reductions in energy use—add to the uncertainty of the ultimate outcome of climate change. Changes in human behavior could fundamentally alter the path of CO_2 increases and overwhelm any technological or political response to the problem. Projections of greenhouse gas emissions have recently been criticized by the U.S. National Research Council (NRC) for omitting potential lifestyle changes in the forecasts, changes which, if accurately accounted for, could result in significant reductions in current projections of future emissions.[14]

A.Political Science and Global Warming

Any substantial degree of uncertainty surrounding scientific phenomena renders policymaking and political leadership difficult. Political action directed at global warming requires an uncomfortable dependence on and faith in science. Not since the first experimental explosion of atomic weapons—when the nuclear scientists present made bets as to whether or not the atmosphere itself would catch on fire—have politicians had to depend so completely on the insights and findings of a small handful of sophisticated weathermen.

The politics of global warming increases the nation's reliance on “big” science as the messenger of change.[15] Investigations into global warming have consumed millions of dollars spent on scientific explorations and computer models. The magnitude of these research projects alone acts to push aside the single scientist with a microscope, thereby creating a reliance on an elite group of specialists capable of laying claim to being global warming “experts.”

Yet, despite the millions of dollars already spent attempting to trace human-induced climate changes—and regardless of the millions more likely to be spent over the next decade—scientists will not soon be able to predict global temperature changes with any certainty. Residual uncertainty, in turn, will act to block scientific consensus on the issue and force politicians to weigh the competing expert opinions and to respond to various interest-group pressures and perceptions.

The magnitude of the response necessary to fully counter any potential risks of global warming—and the intangible nature of the problem—likewise raise the political stakes of global warming. Implementing costly changes in political and public behavior is always difficult. Failed attempts at altering driving behavior in smoggy Los Angeles attest to this fact. Regulations directed at potential environmental problems that are barely visible particularly tax the public's patience. Should these onerous regulations be imposed and then be subsequently removed as more information indicates that climate change risks are not as large as previously believed, a furious public is much less likely to tolerate similar, even cost-effective, environmental policies in the future.

Additional challenges are created by the fact that the public does not always correctly perceive environmental improvements. In one case, San Francisco Bay Area public opinion polls indicated that between 1984 and 1992 the percentage of citizens who believed that air quality was worsening rose from 40 to 60 percent.[16] Yet during that same period a key indicator of air quality improved by approximately 60 percent.

Regardless of the strategy ultimately adopted to address potential risks associated with global warming, the issue is ushering in a new phase of policymaking. Political leaders and citizens-at-large must increasingly cope with risk and uncertainty as part of policymaking. For example, debate over the risks associated with pesticides, electromagnetic fields (EMFs), and asbestos used for building insulation involve much the same issues of scientific uncertainty and economic trade-offs as does global warming.

Such issues necessitate a more sophisticated political debate and an increased sensitivity to the limitations of science and the importance of economics.

One lesson from the ongoing debates over risk and uncertainty is that, in general, policies to address risks posed by potential environmental changes should not be developed in isolation. Although it is politically tempting to respond to a particular crisis—whether it be the energy crisis, the toxic crisis, or the EMF crisis—policies oriented towards "solving" a single environmental problem tend to be expensive and ineffective. A good case in point is the federal Superfund program, which, despite targeting billions of dollars on a limited number of toxic sites, has probably purchased less environmental health and safety than a broader-based program to reduce ongoing toxic emissions would have achieved.

The need to develop a broad policy strategy is particularly relevant in addressing the threat posed by global warming. Any policy to address potential climate change will achieve the greatest results if it is implemented as part of a general energy and environmental strategy where benefits are clear. Alternatively, policies solely directed at addressing global warming will tend to be costly. The four approaches examined below are presented with this in mind.

B.Four Potential Strategies

Most existing global warming proposals are based on obtaining some percentage reduction in greenhouse gases over a limited period. For example, Clinton has proposed stabilizing greenhouse gas emissions at 1990 levels by the year 2000. Other proposals would reduce emissions by 40 percent over a twenty-year period or halve emissions over a thirty-year period. In general, current proposals represent variations on a recommendation developed at an environmental conference held in Canada, which called for a 20 percent reduction in greenhouse gas emissions from 1990 levels by 2005, and further reductions to 50 percent by an unspecified time.[17] Regardless of the precise target, percentage-reduction proposals have not generally had an analytical basis; they are simply a convenient method of establishing a global-warming policy.

Conceptually, there are essentially four potential policy approaches to global warming. While the implementation of each of these approaches implies particular emission-reduction levels, each is based on an evaluation of the risks of global warming and the costs associated with countering it.

The first approach—"wait-and-see"—which was followed by the Bush administration, is based on amassing additional evidence of the potential patterns and implications of human-induced temperature increases before taking tangible action. The wait-and-see approach assumes that over the next several years a sufficient number of such natural experiments will occur to significantly expand scientific knowledge of the probability and implications of climate change. Scientists are currently using data from the Mount Pinatubo eruption in the Philippines to validate their initial estimates of the relationship between greenhouse gases and temperature changes that are used in the global climate-change models. In addition, the wait-and-see approach assumes that any adjustment from the status quo is costly and must be justified by a certain and imminent threat.

Second, the "no-regrets" approach is based on taking actions which, while reducing greenhouse gas emissions, would result in other direct environmental benefits and potentially result in improved energy efficiency. Under this strategy, benefits engendered by reductions in aggregate fossil fuel use per unit of output would, for example, reduce ambient air pollution *and* decrease CO_2 emissions. Proponents of this policy argue that its implementation, as a result of other benefits, would result in no net cost to society whether or not global warming occurs. That is, these policies generate benefits independent of any uncertain benefits achieved by reducing CO_2 emissions.

Third, the "no-regrets-plus" approach is based on investing greater amounts of resources than can be defended based on a no-regrets policy alone. This approach reflects two distinguishable elements: an effort to purchase greater insurance to protect against the risks associated with global warming; and an expanded energy-related research, development, and demonstration (RD&D) investment strategy. There is insufficient knowledge to implement an insurance-based scheme. However, an RD&D investment policy could generate benefits separate and apart from any benefits associated with countering the affects of global warming and keep open the "option" for a more-aggressive strategy should that ultimately prove desirable.

Finally, the "save-the-day" approach to global warming is based on establishing targets to reduce greenhouse gas emissions by the maximum extent possible in the shortest time period. One such proposal was embodied in Proposition 128, which appeared on the California electoral ballot in 1990. The ballot measure would have required the state to reduce CO_2 emissions by 20 percent from 1988 levels by the year 2000, and by 40 percent by 2010.[18] Some environmentalists have argued for even more aggressive approaches—cutting greenhouse gas emissions by more than 50 percent over a two-decade period. The save-the-day approach is based on the assumption that global warming presents catastrophic risks to humankind and must be addressed as a crisis of unparalleled dimensions.

C.Risks: The Steeper the Slope, the Harder the Climb

Figure 1 illustrates the range of potential risks and strategies associated with global warming. As indicated in the figure, the chosen strategy is dependent on an assessment of the risk of environmental, economic, and political damage likely to be imposed by human-induced global temperature increases. Since the Bush administration viewed the scientific evidence as inconclusive, it determined that global warming did not present a clear risk, and chose to follow the wait-and-see strategy.

Figure 1

Global Warming Strategies on the Risk Continuum

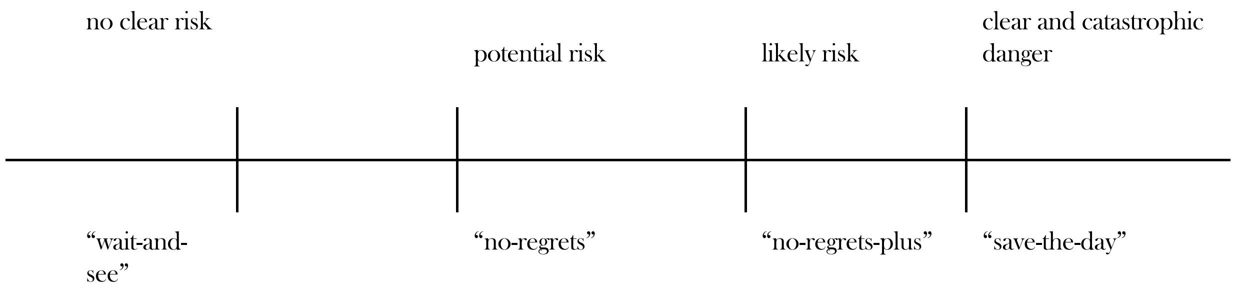


Figure 1 suggests that the risks associated with global warming are linear. However, some scientists believe that global warming risks are more likely to follow a threshold pattern, with the risks of adverse impacts growing rapidly at some point. In addition to the risks associated with whether global warming will actually occur, there is also a great deal of uncertainty associated with the impacts of higher temperatures should global warming become a reality.

Figure 2

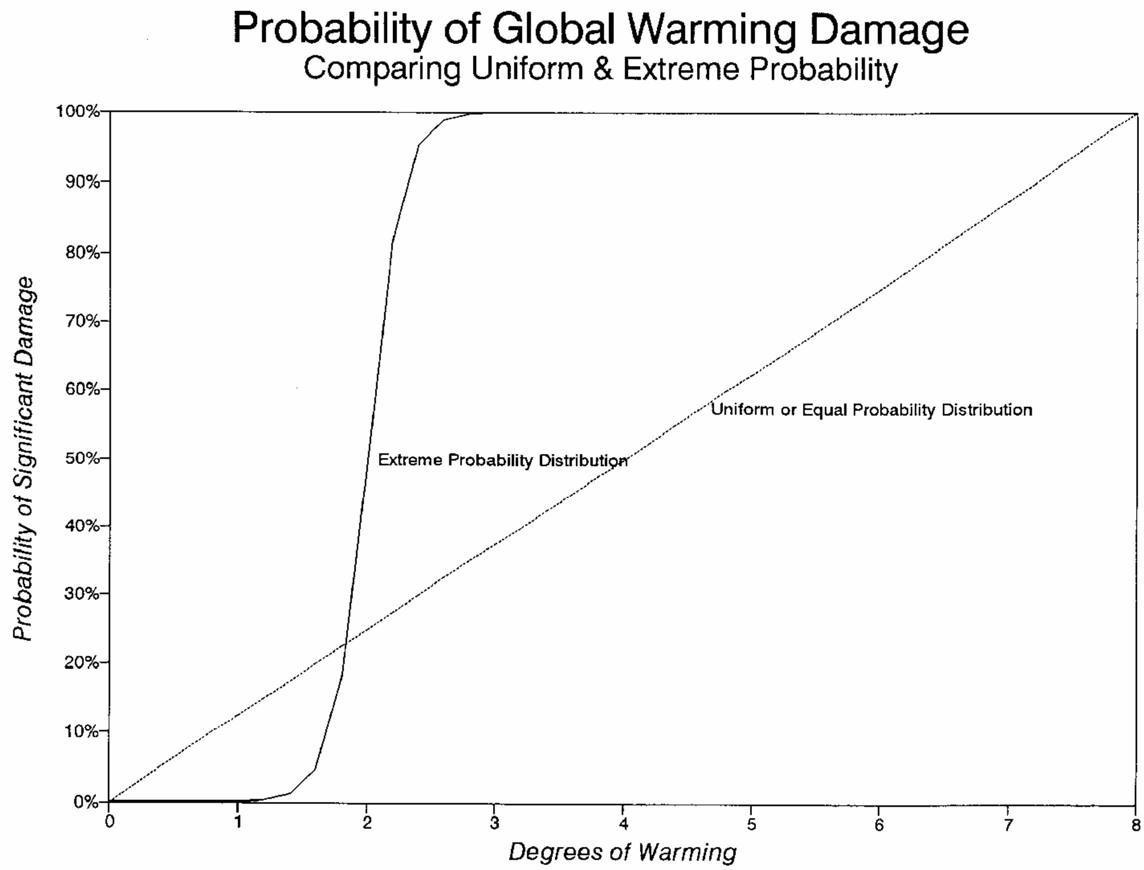


Figure 2 shows two ways of viewing the probability of significant damages associated with human-induced temperature increases. A uniform distribution is predicated on the assumption that damage levels follow a linear path with temperature increases. An extreme or bimodal distribution is based on the assumption that damages will be minimal until temperatures reach a certain threshold. Should global warming risks follow an extreme probability distribution, policymakers would be encouraged to purchase additional "insurance" against the risks of human-induced temperature increases.

The level of damage wreaked by global climate change is likely to depend on the speed at which it occurs. Over geological time average temperatures continually fluctuate, creating a steady, though slow, need for planetary life to evolve and adapt. Short-term temperature shocks, however, can create the need for rapid— and disruptive—responses.

Uncertainty surrounding the impacts of global warming has given rise to estimates that the annual impact on U.S. agriculture of temperature increases could range from a *cost* of $10 billion to a *benefit* of $10 billion.[19]

The risk of *whether* and *when* global climate change may occur represents a temporal risk of the kind addressed by insurance markets. This type of risk is similar to well-known human and natural disasters, such as house fires, floods, and hurricanes. Insurance for these types of risk is generally addressed through collecting funds from a wide range of participants, with the individual premiums based on a probability assessment of the incidence and timing of the event.

Insurance against temporal risk is viable only when two conditions are met: 1) the pool will not be drawn on by all participants simultaneously; and 2) the ultimate costs of the event can be gauged with some accuracy. In the case of global warming, the first condition could only be met if all, or most, of the earth's nations participated in the fund. Should global warming become a reality, the globe's various climate zones would face different benefits and costs, creating a potential mechanism to share risks. However, the current atomization in policymaking at the national and international level would inhibit the ability to adequately spread risks. In addition, the existing inability to accurately evaluate risks and costs—the second condition—virtually eliminates any real basis from which to construct an effective insurance scheme.

As a result of the dual risks created by the potential for global climate change (i.e., the potential incidence and implications of global warming), "quasi-option value" (rather than classic insurance schemes) offers a better model with which to approach the issue. This concept is similar to financial option instruments, which enable the gains garnered from additional information to be weighed against the losses that could be incurred as a result of deferred investment. When the investment choice may cause irreversible damage to the environment, and the uncertainty is primarily related to the level of the damage, the quasi-option value is always positive and leads to an implicit deferral of the investment through higher initial costs.[20]

However, the timing and parameters of the probability distribution for the possible outcomes are usually well-understood in financial option markets. In the case of climate change, the timing and likelihood of significant changes are unknown, and the outcome could lie at two extremes, depending on the scale of the temperature increase. As a result, while quasi-option values could be theorized, it would be difficult to effectively apply these concepts.

III.ASSESSING THE ALTERNATIVES

A.The Bush Administration: Wait and See

As previously indicated, the Bush administration chose to follow the wait-and-see strategy to the global warming issue. This strategy was predicated on the belief that the scientific jury had not reached a verdict on whether or not global warming actually posed a threat to humankind. In addition, the Bush administration was cautious in the face of preliminary evidence from economists that any effective action to counter global warming would require massive changes in energy usage, which would result in significantly slower economic growth.[21]

The wait-and-see strategy also reflects a good deal of optimism about the U.S. ability to extemporaneously cope with global temperature increases and the associated political and economic changes should they ever actually emerge. For example, sea level changes resulting from global warming could be countered through break-walls and levees; agricultural productivity could be protected with new technologies.

The wait-and-see approach has several drawbacks. During the later part of the 1980s, the international community began to coalesce around the notion that the potential for temperature increases warranted a policy response. For example, in 1991 the United Nations issued a report concluding that global warming posed a significant threat to the earth. International opinion reached its zenith at the 1992 "Earth Summit" conference in Brazil,[22] during which the United States was loudly and frequently lambasted for inadequate attention to the issue.[23]

U.S. policymakers should *not* adopt environmental policies simply because other nations choose to do so. However, the collective actions of a significant number of nations—particularly members of the European Community and Japan—are difficult to ignore. A continuing reliance on the wait-and-see approach to global warming may make it difficult for the United States to obtain consensus on cross-border resource issues it does care about, such as marine mammal protection.

Another drawback of the wait-and-see approach is that it does very little to address the risk of temperature increases and related economic and political disruption. Should hard evidence be uncovered during the next several years that global warming *is* becoming a reality, the United States would be in a poor position to take preventative action. Any effective response to global warming will require a "ramping-up" of technology—at least a decade or more of increased investment in alternative energy technologies as well as changes in individual behavior. This implies that if any significant risk related to global warming is present, some action should be taken to address this risk. Moreover, the wait-and-see approach ignores potential benefits that could accompany a systematic policy effort directed at promoting cost-effective improvements in energy efficiency and air quality.

Regardless of the appropriateness of a wait-and-see strategy during the Bush administration, this approach will not be acceptable to the Clinton administration. At a minimum, President Clinton is likely to substantially increase funding for climate research and establish a timeline for action.[24] Unless substantial evidence is uncovered that indicates little likelihood of temperature changes or a minimal risk of significant adverse global changes as a result of temperature increases, the new administration is likely to follow one of three strategies, as discussed below.

B.Save the Day: Social Restructuring

On the other end of the risk continuum from the wait-and-see strategy is the save-the-day approach. Under this approach the Clinton administration would implement an aggressive strategy to reduce greenhouse gas emissions to levels at which they would no longer pose a threat of global warming. A save-the-day approach would require a substantial investment of political and economic capital, broad changes in societal behavior, and unparalleled international cooperation. The only rationale for such a strategy would be clear indications that rising global temperatures will cause massive economic and political upheaval.

Under a save-the-day strategy, the Clinton administration would have to make global warming one of its top domestic and international policy concerns. To push through the policies necessary to fully counter global warming, the administration would likely have to appoint a global warming "czar," with cross-agency authority to propose legislation, promulgate regulations, and direct staff efforts.[25] Since President Clinton has already announced his intention to aggressively address a number of issues, including acquired immune deficiency syndrome (AIDS), health-care financing, education, technology investment, and the health of the economy, at some point the administration will likely have to narrow its focus and forgo pursuit of some issues. It is unlikely that the administration could muster sufficient political capital and bureaucratic wherewithal to appoint more than one or two such policy "czars."

The save-the-day strategy would likewise require an international alliance on the scale of a world war, without a Hitler to galvanize such cooperation. It also implies the development of global regulation to implement and enforce the necessary changes. A single nation's actions to reduce greenhouse gases would be futile absent action by other major greenhouse gas-producing countries. In addition, if a single nation attempted to address global warming through such policies as a carbon tax, the resulting production-cost increases could simply act to drive fossil fuel-intensive industries to other countries that did not impose the tax, with little or no net change in worldwide greenhouse gas emissions.[26] As a result, most of the world would have to agree to the changes necessary to reduce their emissions to obtain meaningful worldwide reductions and avoid country-specific economic disruption.

While similar action is being pursued to protect the earth against ozone depletion, the actions necessary to reduce CFC emissions are far less dramatic than those required to substantially reduce greenhouse gas emissions, and the ozone threat is more clear and defined.[27] Since nations that pursued less-aggressive actions to reduce emissions would have an economic advantage over those following more-expensive paths, sanctions would have to be imposed on those nations that did not perform according to their commitments. Under these circumstances it seems likely that a global-warming treaty would have to be coordinated with international trade agreements, such as the General Agreement on Tariffs and Trade (GATT), to provide a mechanism for potential trade sanctions.

Although existing economic studies do not provide uniform estimates of the economic cost of implementing a save-the-day strategy, they all agree that to achieve significant reductions in greenhouse gas emissions, status quo energy-use patterns would have to be dramatically altered. Massive adjustments in energy use could create disequilibrium in the U.S. economy and induce significant adjustment costs.[28] For example, switching to new technologies at an accelerated rate would result in premature obsolescence of existing investment.[29] The increased need to replace existing infrastructure, in turn, could act to crowd out investment in new growth. The impact of defense-industry cuts on Southern California is a real-world example of these types of adjustment costs.

Various studies indicate different economic costs associated with greenhouse gas emission-reduction targets. Three recently completed economic analyses provide good examples of the range of estimated costs. These studies were conducted by Darwin Hall;[30] Alan Manne and Richard Richels;[31] and Dale Jorgensen and Peter Wilcoxen.[32]

Figure 3

Figure 4

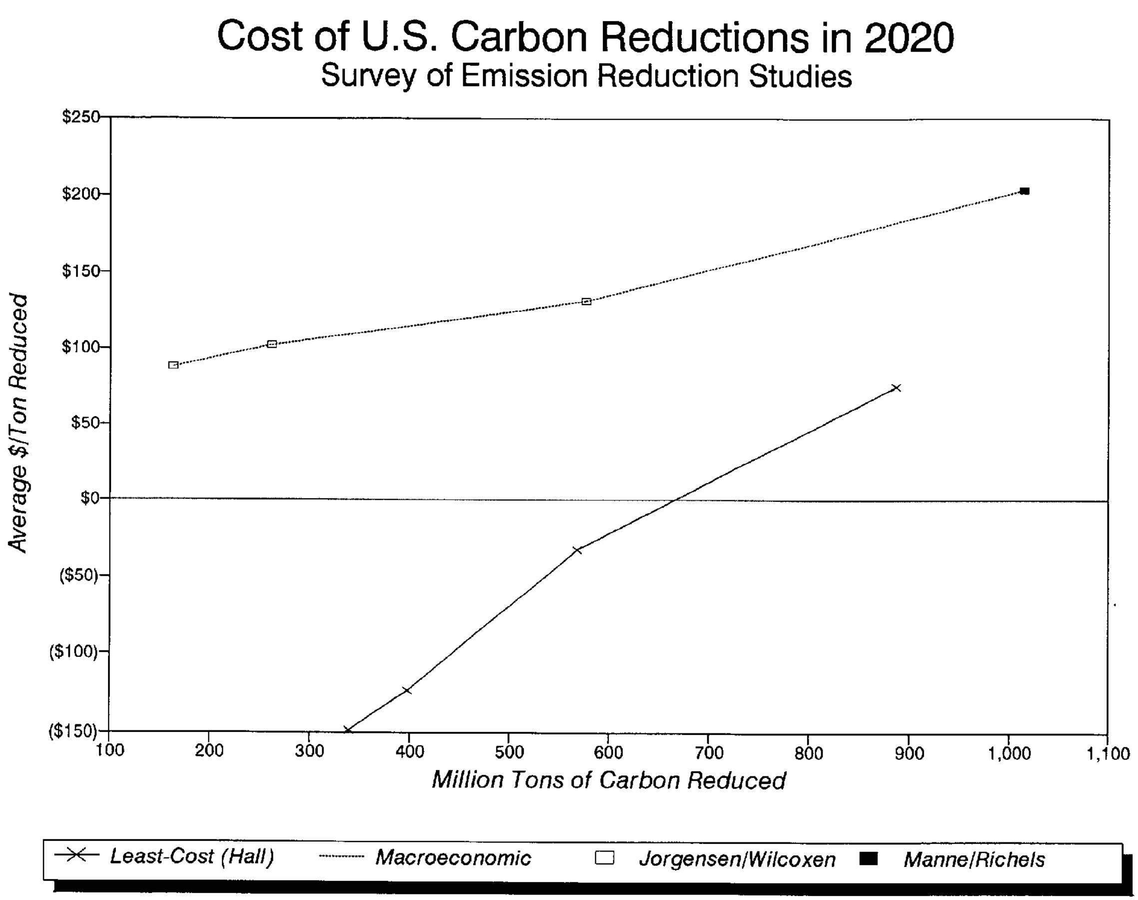


Figure 3 shows the different levels of forecasted carbon emissions used for the base-case analyses in the different studies.[33] Figure 4 compares the average cost for each ton of reduced carbon emissions in the year 2020 from the three studies. The bottom line tracks Hall's cost estimates. In the top line, the first three observations are from Jorgensen and Wilcoxen and the fourth from Manne and Richels. The relative linearity of the macroeconomic studies reveals their common assumptions about future economic performance.

Hall drew his "least-cost" estimates from a range of existing studies on conservation and alternative generating technologies for both the transportation and electricity sectors.[34] His calculations indicate some benefits from modest reductions in carbon emissions, but significant costs to achieving large-scale, or "save-the-day," emission-reduction levels. For example, Hall estimates that a 16-percent reduction from forecasted levels of CO_2 emissions by the year 2000 would generate net societal benefits of $46 billion a year, or $136 per ton of reduced carbon emissions. Likewise, meeting a 16-percent reduction target by the year 2020 would create $18.5 billion in societal benefits, or $33 per ton of carbon. However, to meet a more stringent 29 percent emission-reduction goal by the year 2000 would reduce the estimated benefits to $4.3 billion, or $9 per ton of carbon. And achieving a 50.7 percent reduction by the year 2020 is estimated to cost $66.9 billion, or $75 per ton.[35]

Manne and Richels use a general equilibrium model, Global 2100, that incorporates an array of generic energy technology choices and a production function that trades off investment in capital, labor, and energy in a "putty-clay" formulation (i.e., changing current practices are difficult in the near term—clay—but become easier over time—putty). Their approach is a "top-down" calculation that assumes a certain degree of responsiveness to price effects through carbon taxes. Energy conservation is induced in two ways, either through the elasticity of price-induced substitution (ESUB) or through autonomous energy-efficiency improvements (AEEI) from technical change or government standards that are not related to price effects.[36]

Manne and Richels examine two emission-reduction scenarios. The first scenario is based on stabilizing CO_2 emissions at 1990 levels by the year 2000 (the Clinton proposal) and on reducing emissions by 20 percent by the year 2010. The estimated loss in U.S. gross domestic product (GDP) induced by this policy is one percent by the year 2000 and 2.5 percent by the year 2030. At a 5 percent discount rate, the losses total $1.4 trillion through 2100. The long-run carbon tax necessary to achieve the targets is estimated to be approximately $208 per metric ton, ranging between less than $100 per ton for the case where technology is assumed to be readily available and increasing to $600 per ton when the capital stock is assumed to be relatively rigid.

In the second scenario, emissions would be reduced by 50 percent from 1990 levels by 2010 to stabilize world CO_2 levels. The resulting net present value cost to the U.S. GDP is estimated at $2.9 trillion through 2100.[37]

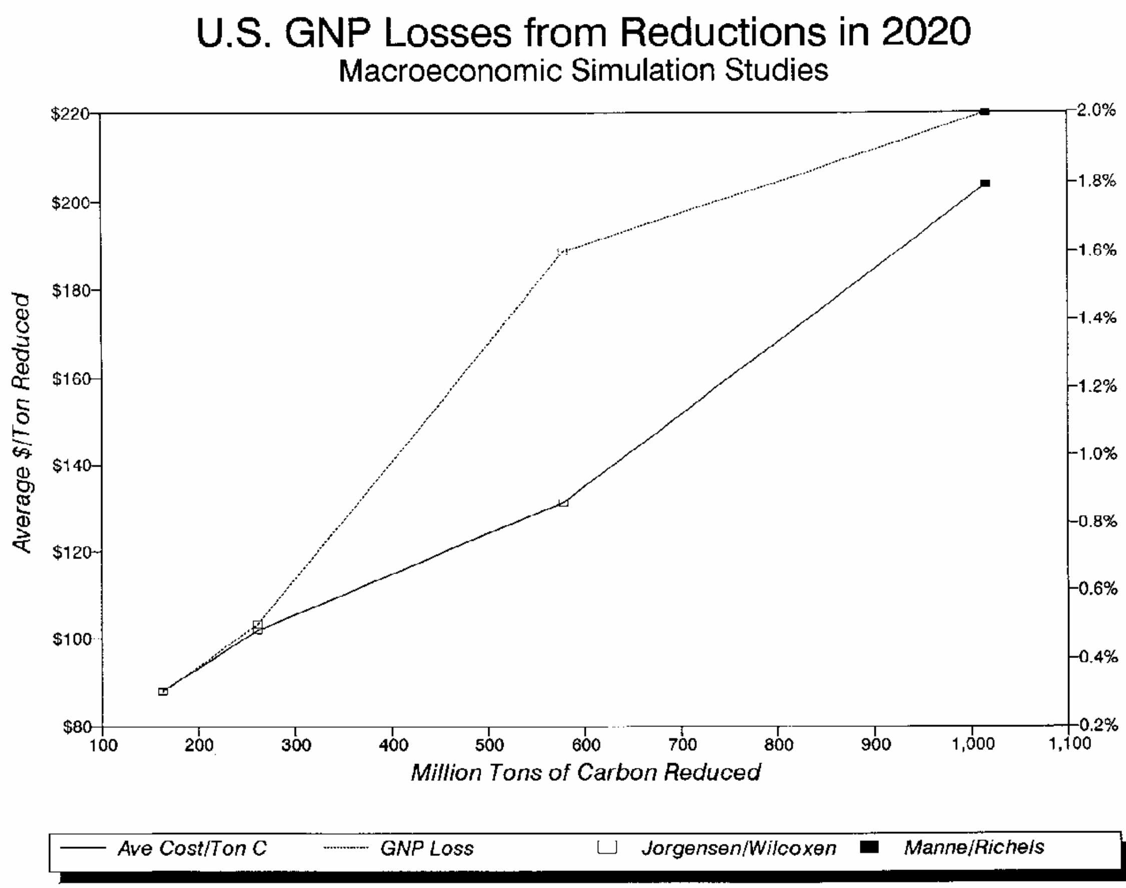
Jorgensen and Wilcoxen use a general equilibrium model that incorporates 35 industrial sectors and uses parameters estimated from 1947 to 1985 data. Their approach is "top-down" with all effects measured through a carbon tax and no technological changes actually specified. The model assumes no adjustment costs for investment and exogenous government spending and export levels. The population is projected to stabilize in 2020 based on Social Security Administration forecasts. Energy use is projected to 2050, and the model is run to 2100 to achieve a steady-state equilibrium.

Three scenarios are modeled, each calling for less-severe reductions than in most other studies. The first is based on a policy to stabilize emissions at 1990 levels immediately. The second is based on decreasing emissions by 20 percent from 1990 levels by the year 2005. The third policy is based on stabilizing emissions at year 2000 levels by 2010. Jorgensen and Wilcoxen did not model the more-severe reductions called for by the save-the-day strategy.

For scenario one, by 2020, CO_2 emissions are 14 percent below the base-case level, and the carbon tax reaches $16.96 per ton, causing a drop of 0.5 percent in the GNP from the base-case projections.[38] Tax revenues equal $26.7 billion and electricity rates are 5.6 percent higher. In the second scenario, the carbon tax increases to $60.09 per ton as emissions fall 32 percent below the base case in 2020. The GNP is 1.6 percent lower, tax revenues are $75.8 billion and electricity rates are 17.9 percent higher. For the third scenario, an 8 percent decrease in emissions requires a carbon tax of $8.55 per ton, generating $14.4 billion in taxes. The GNP is 0.3 percent lower and electricity rates 2.9 percent higher.

The two macroeconomic simulations can be combined to estimate the potential impacts from reduction targets on the U.S. GNP. Figure 5 shows the relationship in these two models of emission reductions, average costs for tons of reduced carbon, and losses from the GNP base case. The first three observations are from Jorgensen and Wilcoxen, the last from Manne and Richels. As expected, GNP losses increase faster than average direct reduction costs. This is the case because obtaining additional reductions becomes increasingly difficult, and the economic ramifications quickly multiply.

Figure 5



Given the difficulties associated with the save-the-day strategy, it is important to point out that this approach has been advocated both on a philosophical basis, and as means to fundamentally alter the way in which humans live in the world. That is, it is being advocated on nonscientific and noneconomic grounds. Some environmentalists view global warming as a moral issue. From this perspective human-engendered environmental changes should generally be viewed adversely. Since humans are presumed to be the cause of any temperature increases, they should take responsibility for them and act in ways that encourage the environment back towards the state it would experience absent human activity. Based on this philosophy, the possibility of global warming necessitates maximum counteraction regardless of its precise environmental and economic implications.

Alternatively, some environmental groups appear to advocate a save-the-day strategy as a means of forcing Americans into broad lifestyle changes. To achieve a 40-percent reduction in CO_2 emissions in California over a twenty-year period, the Natural Resources Defense Council (NRDC) has advocated dramatic changes in statewide transportation and housing patterns. For example, NRDC's proposals include doubling housing density over a twenty-year period.[39] Such policies can best be viewed as a general attempt to recreate the modern world to meet a particular vision of environmental "sustainability," rather than analytically based proposals oriented towards addressing the risks of human-induced temperature increases.

The economics of the save-the-day strategy exclude it from consideration in the near future, or at least until a better understanding of the scientific evidence has been developed. This analysis suggests that the debate should not be about "halting" global warming. Instead, the question is whether or not to invest in strategies to reduce the risk of global warming, and if so, the investment level to adopt.

C.No Regrets: Addressing the Possibility of Risk

A more-cautious approach to the risks of global warming is embodied in the no-regrets strategy. Under this approach the level of action to be taken to reduce greenhouse gas emissions would be dictated by the *nonglobal warming* benefits the policy generates. That is, action would be taken on the basis of the benefits associated with reducing ambient air pollution and decreasing energy expenditures in production and transportation, policies which would also produce the side-effect of reducing greenhouse gas emissions.

As previously indicated, CO_2 emissions are responsible for approximately half of human-induced greenhouse gas emissions. CO_2 is predominately created by fossil fuel used in transportation and to generate electricity for commercial, industrial, and domestic use. However, fossil fuel-burning emits other polluting gases, including nitrogen oxides (NOx), sulfur oxide (SOx), and reactive organic gases (ROG), gases considered pollutants under the Clean Air Act and other federal, state, and local laws. As a result, while more-efficient fossil fuel use would lessen greenhouse gas emissions, it would create benefits related to reductions in other air pollutants. For example, a decline in total vehicle miles traveled (VMT) in the United States engendered by a policy to raise the federal gasoline tax or price highway use through congestion charges would result in reduced NOx and ROG emissions. In the Southern California region, the California Energy Commission (CEC) places a value of between $14,000 and $26,000 for each ton of NOx that is eliminated.[40]

A no-regrets policy does *not* imply unlimited investment in strategies to reduce polluting air emissions. Rather, the no-regrets approach is based on comparing the costs of reducing polluting air emissions and fossil fuel use with the benefits derived from this reduction. In theory, when the costs of obtaining further emission reductions and increased energy efficiency exceed the benefits, no further action would be taken.

Developing the analytical basis for the no-regrets strategy is not a trivial task. For example, the harmful polluting emissions must be identified. A large body of evidence exists with which to evaluate the harmful impacts of various gases. However, uncertainty remains as to the precise mixture of gases which create smog.[41]

Likewise, estimating the health, environmental, and economic benefits of emission reductions is difficult and yields imprecise results. Various studies sponsored by the U.S. Environmental Protection

Agency and regional air-quality agencies have resulted in widely different benefit estimates. In addition, the benefits and costs of pollution reduction vary widely by region. While Los Angeles citizens may be willing to pay substantial sums to eliminate one ton of NOx, the citizens of Las Vegas are unlikely to be willing to pay as much.

In addition to developing a basis with which to weigh benefits and costs in a no-regrets approach, this strategy would also require coordination between regional, state, and federal agencies responsible for pollution reduction. Currently, there are as many global warming strategies as there are public utility commissions, energy agencies, and air pollution districts. For example, the California Public Utility Commission (CPUC) has placed a value on CO_2 emission reductions as part of its new-generation purchasing requirements. Likewise, Oregon is in the process of developing a strategy to reduce CO_2 emissions by 20 percent from 1988 levels by the year 2005.[42]

While individual localities may want to play a more activist role in countering the risks of global warming, these efforts will have negligible impacts without coordinated national action and can result in adverse economic impacts. For example, businesses and individuals can simply move from a locality with strict global warming regulations to one with no regulations whatsoever.

This type of shifting of economic and polluting activity can occur in jurisdictions as large as the State of California. For example, if the California Energy Commission mandates that the state's electric utilities halt their purchases of coal-fired power from surrounding states, these utilities would be forced to sell their shares of out-of-state facilities at “fire-sale” prices, resulting in higher electricity rates for Californians. This action, in turn, would reduce the cost of coal-fired power for surrounding states—such as Nevada and Arizona—and act to encourage these states to increase coal-related CO_2 emissions.[43] In addition, the fastest-growing source of greenhouse gas emissions is developing countries that are unable to exploit existing energy-efficient technologies. Prudent investment in enhancing energy efficiency in developing countries represents a much more effective response than investing substantial funds in state efforts to achieve small emission reductions.[44]

A no-regrets policy could also include the elimination of public subsidies for resource use. For example, existing federal subsidies for commercial timber harvesting act to encourage uneconomical removal of trees.[45] Since trees sequester carbon, wasteful timber practices potentially augment greenhouse gas accumulation in the atmosphere.[46] Likewise, federal agricultural subsidies encourage the production of rice and livestock, both of which contribute to methane emissions.[47,48]

Although a no-regrets policy would not be directly targeted at countering global warming, it would result in reductions in greenhouse gas emissions.[49] However, a no-regrets strategy would result in nationwide benefits *regardless* of whether or not global temperatures ultimately rise, since the target of such policies would be more-efficient energy use and reductions in known air pollutants.

The no-regrets concept does not guarantee low-cost solutions. Even policies that might fall under this conceptual framework are likely to have widely varying potential costs. For example, such policies could range from “command-and-control” measures that dictate changes in driving patterns or mandate use of specific fuels, to market-based policies such as highway tolls or deregulation of power-generation. Thus, the no-regrets concept establishes a conceptual framework with which to make global warming concerns part of a broader energy efficiency and air pollution-reduction effort. Such a conceptual framework does not, however, distinguish among the widely varying policy tools that might advance these goals.

The no-regrets policy attempts to strike a balance between an awareness of risks associated with both action and inaction on the global warming issue. Regardless of whether or not global temperature increases actually rise, this strategy would reduce greenhouse gas emissions while simultaneously garnering dollar-for-dollar benefits related to reductions in ambient air pollution and improved energy efficiency.

D.No-Regrets-Plus: Adding a Technology Strategy

A no-regrets-plus strategy places a greater probability on the likelihood that the risks of global warming will ultimately be realized, but continues to hedge against investment in a problem which may never develop. Under this policy, in addition to following the no-regrets approach, investment would be promoted in energy-related research. Although the no-regrets-plus approach would not act as an "insurance policy" against global warming—as previously indicated, insufficient information is available to craft such a policy, it would be similar to purchasing an option for more-aggressive emission-reduction action in the future.

It is important to note that the no-regrets strategy alone would act to induce increased *private-sector* investment in low-polluting energy technology. That is, by creating a market incentive to reduce pollution—either through direct-incentive approaches (e.g., pollution charges) or command-and-control regulations—energy companies will be encouraged to develop lower-cost, lower-polluting energy sources. Under the no-regrets-plus approach, however, additional incentives would be provided to develop lower-polluting technology more rapidly. These incentives could be developed through direct government funding of research, development, and demonstration (RD&D) programs or by providing even greater market-based incentives for private-sector funding of technological innovation.

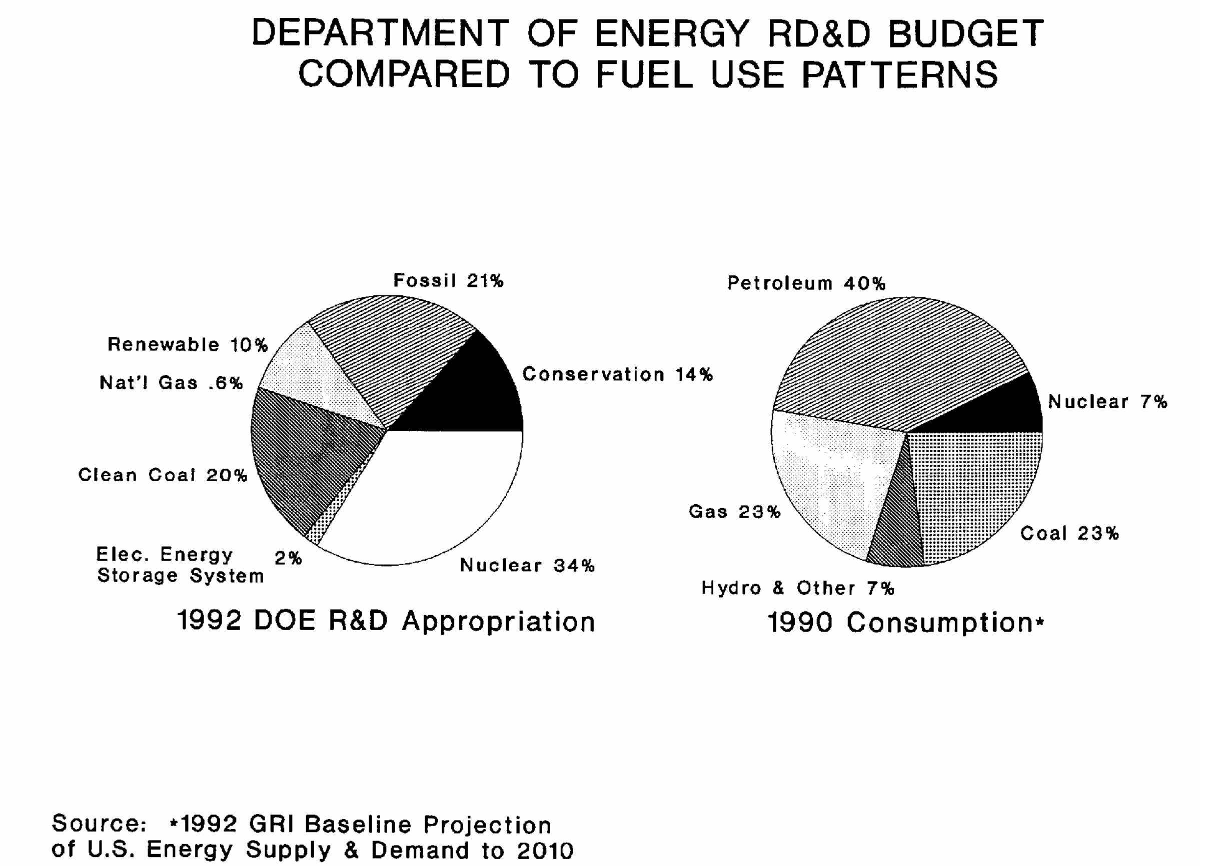
Increased investment in energy technology—and RD&D programs in general—may result in economic benefits apart from global warming. One recent examination of increased federal investment in natural gas RD&D concluded that modest additional expenditures could result in annualized social rates of return of between 30 and 50 percent. Energy-related RD&D benefits include reductions in fossil fuel use per unit of output, increased electric-generation efficiency, and reductions in polluting air emissions. One study found that an increased reliance on a free-market approach to energy use, coupled with a repriortization of RD&D to emphasize efficiency and clean fuels, could reduce CO2 emissions by 12 percent by 2010.

The "plus" could be added to no-regrets either by adding a technology "kicker" to no-regrets policies or by direct public-sector funding of energy-related RD&D. Under the former approach, for example, if it were determined that carbon monoxide (CO) emissions resulted in the equivalent of 10 cents per gallon in "external" social costs, in addition to a 10 cents per gallon tax on gasoline, a small additional sum could be added to further encourage the development of low-polluting technologies.

Under an approach that embraced direct government funding of RD&D, the additional gasoline charge collected by the government could be directly invested in energy-related RD&D programs. However, encouraging competitive RD&D markets is generally preferable to a public-investment strategy that "picks winners." Without technological competition—for example, natural gas vehicles versus electric cars—increasing returns to scale can act to rapidly induce acceptance of the first available technology, blocking (at least for some mid-term timeframe) future innovations. This is particularly true when the new technology is dependent on networks (e.g., communications equipment or computers) or substantial infrastructure (e.g., roads).[50] Moreover, private-sector applied RD&D investment is more likely to result in cost-effective research.

It should be noted, however, that the existing federal budget already includes substantial funding of energy-related RD&D. At a minimum, it would be prudent under a no-regrets-plus strategy to reorder current energy-related RD&D spending priorities. In fiscal year 1993, the federal government will spend slightly over $4 billion on energy-related RD&D. As indicated in Figure 6, two-fifths of this amount will be spent on coal and petroleum-related technologies, the burning of which generates both greenhouse gases and polluting air emissions. Only one-fifth of the budget will be invested in natural gas—which emits less CO_2 than other conventional fossil fuels—and conservation-related technologies. By reallocating a portion of the funds spent on coal and nuclear power to natural gas and conservation efforts the federal government could raise its investment in lower-polluting technology with no increase in the federal budget.[51]

Figure 6



The no-regrets-plus strategy does not amount to the purchase of "insurance" against global warming. As previously discussed, uncertainty related to the cost implications of global climate change makes it impossible to effectively spread climate change risk. However, RD&D investment can be seen as a means of purchasing an "option" for future action.

Most existing alternative electricity-generating technologies (e.g., wind, solar, geothermal, and biomass) are substantially more costly than fossil fuels.[52] Simply adding these resources to the electrical grid as a means of purchasing climate change insurance would increase electricity rates, without any indication that they would alter estimated paths of temperature increases. On the other hand, if RD&D investment in promising technologies—such as solar power (photovoltaics) or natural gas fuel cells that emit primarily oxygen and hydrogen—result in economically and environmentally attractive energy sources, there will be a basis apart from addressing global warming risks to adopt them. The no-regrets-plus strategy, then, is aimed at generating social returns on technology investment that can be justified whether or not the climate changes, since the focus is not on technologies that reduce greenhouse gas emissions per se, but on policies that result in more energy efficiency and RD&D activity in less-polluting technologies generally.

E.Weighing Risks Across Time and Space

The choice of which policy path to follow to address the risks of global warming necessitates a multi-dimensional assessment. First, the risks associated with global warming must be evaluated, to determine what level of action, if any, is warranted. Second, these risks must be weighed against other risks facing the United States and the world, including other environmental risks. Expenditures on global warming-related investments represent funds that would not be available to pay for other public services, such as health-care research, education, or infrastructure improvements, a full assessment of which is beyond the scope of this paper. Finally, any global warming policy should make sense within the broader context of U.S. environmental and energy policy.

Given existing knowledge, it appears prudent to follow either the no-regrets or no-regrets-plus approach to the risks of global climate change. In both cases, policies would be focused toward achieving benefits that would exceed or equal the cost *regardless of climatic changes*. However, neither strategy would be free. Both strategies would require increased investment today in order to garner future benefits. Likewise, both strategies are likely to take both attention and resources way from other national and international problems, including, for example, water-quality and supply problems throughout the world. Essentially, implementation of either the no-regrets or no-regrets-plus strategies would imply that the risks associated with global warming, and the benefits derived from reductions in ambient air pollution and greater energy efficiency, have a higher priority than other needs.

Adapting a no-regrets or no-regrets-plus strategy still leaves many important issues unanswered, particularly the detailed implementation questions that must be addressed under either approach. These strategies are aimed at determining what the *policy goal* should be. In both cases, the policy goal is improved energy efficiency and reductions in previously identified air pollution for which there is clear evidence of some harm. Reductions in greenhouse gas emissions are simply indirect results of achieving these other goals. However, establishing the goals does not determine the nature of policies designed to achieve those goals. Like the "save-the-day" approach, both the no-regrets and no-regrets-plus strategies could be pursued by market-oriented measures (e.g., congestion pricing of roads, deregulation of electricity generating capacity, air emission charges) and private-sector investment, or through command-and-control and public-investment measures. The choice of these policy measures can have a significant impact on overall policy costs (and effectiveness). However, either a no-regrets or no-regrets-plus strategy articulates a set of goals that make sense given the high degree of uncertainty of global warming risks and the large potential costs of *any* strategy aimed directly at reducing greenhouse gas emissions.

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Mr. McCann has completed numerous analyses on a variety of resource issues, including evaluating the socio-economic impacts of an air quality permit-trading program and developing a guidebook to analytical methods of environmental decision-making. Mr. McCann is currently writing his doctoral dissertation on institutional barriers to water markets. He has a Masters in Public Policy from the University of Michigan and a B.A. in Political Economy of Natural Resources from the University of California, Berkeley.

ENDNOTES

1.This proposal was widely promoted by western nations at the Earth Summit in Brazil, and has been proposed for adoption by the European Community by the Commission of the European Communities. "Clinton Win Portends Shift in U.S. Environmental Policy," *Global Environmental Change Report*, November 6, 1992.

2.Albert Gore, Jr. *Earth in the Balance,* Houghton Mifflin Company, Boston, 1992.

3.Through the "Montreal Protocol" the U.S. agreed to dramatically reduce CFC use by the turn-of-the-century. Under this treaty new supplies of CFCs, carbon tetrachloride, and methyl chloroform in developed countries will be prohibited by 1996, and production of new halon supplies banned by 1994. Op. cit., *Global Environmental Change Report.*

4.*World Resources 1990–1991*, World Resources Institute, New York, 1990, page 24. The estimated contributions of gases and activities to global warming vary widely, adding uncertainty to the choice of appropriate policy responses.

5.*Energy Policy in the Greenhouse*, International Project for a Sustainable Energy Path. El Cerrito, California, September, 1989.

6.Robert Balling, Jr., *The Heated Debate*, Pacific Research Institute for Public Policy, San Francisco, California 1992.

7.As noted by *The Economist*, "[g]lobal change offers a wealth of possibilities for the apocalyptically minded." For example, in addition to massive agricultural failures, regional temperature changes could alter the spread and pattern of diseases, particularly those borne by insects. By effectively increasing the range of insects, regional temperature changes could increase the incidence of malaria, sleeping sickness, leishmaniasis, elephantiasis, and other diseases endemic in Africa. "The Deadly Hitch-Hikers," *The Economist*, October 31, 1992.

8.See for example J.M. Barnola, et. al., "Vostok Ice Core Provides 160,000 Year Record of Atmospheric CO_2," *Nature* 329, October, 1987, page 408; Martin I. Hoffert and Curt Corey, "Deriving Global Climate Sensitivity from Paleoclimate Reconstructions," *Nature* 360, December 10, 1992, page 573.

9.C. D. Kelling; in ed. Daniel Lashof and Dennis Tirpak, *Policy Options for Stabilizing Global Climate: Draft Report to Congress*, U.S. Environmental Protection Agency, February, 1989.

10.James Hansen, et al., Goddard Institute of Space Studies; and Tom Wigley, et al., University of East Anglia, Climate Research Unit; in Michael Oppenheimer and Robert Boyle, *Dead Heat: The Race Against the Greenhouse Effect* (New Republic Books, 1990), p. 53.

11.Oppenheimer and Boyle, op. cit; and Warren Brookes, "The Global Warming Panic," *Forbes*, December 25, 1989.

12.Brookes, op. cit. and “Researchers Turning Cool on How Hot Climate Will Get,” *San Francisco Chronicle*, January 30, 1990.

13.John D. Cox, “Scientists Seek El Nino Secrets,” *Sacramento Bee*, November 23, 1992.

14.“Confronting Climate Change,” NRC, 1990, Washington, D.C.

15.This is part of a general trend towards an increased reliance on science to help guide society. As stated by the novelist Saul Bellow in an interview in *Bostonia*, “We have persuaded ourselves that if we had the time to apply ourselves to these scientific marvels we would understand them. But of course that's an illusion. It couldn't happen. Even among people who have had careers in science. They know no more about how it works than we do. So we are in the position of savage men who, however, have been educated into believing that they are capable of understanding everything.”

16.Association of Bay Area Governments, “Perception vs. Reality,” *Service Matters*, Number 3, January/February 1993, p. 6.

17.Environment Canada, *Conference Statement*, *The Changing Atmosphere: Implications for Global Security*, Toronto, Canada, 1988.

18.“California Environmental Protection Act of 1990,” otherwise known as “Big Green,” or the “Hayden Initiative.”

19.William Nordhaus, “To Slow or Not to Slow: The Economics of the Greenhouse Effect” *Economic Journal* 101: 920–937, (1991).

20.Anthony C. Fisher and W. Michael Hanemann, “Quasi-Option Value: Some Misconceptions Dispelled,” *Journal of Environmental Economics and Management*, 14: 183–190 (1987).

21.This preliminary consensus was reached in the late 1980s with the publication of a number of economic studies of global warming. See for example DRI International, “Proposed Reduction in Carbon Dioxide Emissions: Consequences for the California Economy,” October 1990; Alan Manne and Richard Richels, “CO_2 Emission Limits: An Economic Cost Analysis for the USA,” Stanford University and the Electric Power Research Institute (EPRI), Palo Alto, California, November, 1989; Richard McCann, Steven Moss, et al., “Economic Impacts of Greenhouse Gas Reduction Plan,” for the California Coordinating Council, August 1990; William D. Nordhaus, “The Economics of the Greenhouse Effect,” Yale University, June, 1989; U.S. Congressional Budget Office, “Carbon Charges as a Response to Global Warming: the Effects of Taxing Fossil Fuels,” August 1990; and U.S. Environmental Protection Agency, “Policy Options for Stabilizing Global Climate,” Draft

Report to Congress, February, 1989.

22.Officially known as the United Nations Conference on Development and the Environment.

23.The U.S. ultimately joined with 153 nations to ratify a treaty calling for “significant” efforts to control greenhouse gas emissions. See “Earth Summit Ends on Optimistic Note,” *Los Angeles Times*, June 15, 1992.

24.The federal government intends to spend $1.4 billion on climate research in 1993, “Bush Will Urge Prompt OK for Climate Treaty,” *Los Angeles Times*, June 12, 1992.

25.This authority could be vested in the Office of the Vice President, just as former Vice President Quayle led the Council on Competitiveness. Shortly after taking office, President Clinton delegated much of the responsibility for this issue to Vice President Gore, without providing the Vice President with any significantly expanded authority.

26.Other, less endowed, countries would have greater difficulty coping with temperature increases. Presumably, if global warming ever does damage nations which do not significantly contribute to greenhouse gas emissions, these nations will demand “reparations” from those nations responsible for the disruption.

27.For a limited economic analysis of the economics of ozone depletion, see Spectrum Economics, Inc., “Initiative Impact: Ozone Layer Protection,” for the California Coordinating Council, July, 1990.

28.Some economists argue that the economy is always in disequilibrium because people are constantly adapting to changing conditions and an uncertain future.

29.Fisher and Hanemann (1992), *op.cit.*

30.Darwin C. Hall, “Preliminary Estimates of Cumulative Private and External Vosts of Energy,” *Contemporary Policy Issues*, 8:3 (July 1990).

31.Alan S. Manne and Richard G. Richels, *Buying Greenhouse Insurance: The Economic Costs of Carbon Dioxide Emission Limits*, MIT Press, Cambridge, Massachusetts, 1992.

32.Dale W. Jorgensen and Peter Wilcoxen, “Reducing U.S. Carbon Dioxide Emissions: The Cost of Different Goals,” *Energy, Growth and the Environment. Advances in the Economics of Energy and Resources*, 7, pp. 125–158 (1992).

33.Hall assumes a relatively low starting point and low future growth rates. This makes achieving reductions from 1990 levels inexpensive compared to the higher emission levels assumed in the other two studies. Along this line, it should be noted that establishing a baseline from which percentage reductions can be calculated is not a trivial task. For example, estimating fuel usage for a large number of decentralized consumers can be difficult. In California, a state with a substantial capability to compile energy statistics, petroleum consumption estimates vary by more than tenfold. Likewise, the U.S. Department of Energy (DOE) estimates 1989 fuel oil sales to commercial and industrial customers of 74 trillion Btus (TBtu), while the California Energy Commission (CEC) estimates sales of between 227 and 868 TBtus.

In addition to the challenges associated with estimating emissions, depending on the adopted global warming policy, there may be an incentive to under- or overestimate. If an emission source is costly to reduce, the incentive would be to underestimate emissions, and pass emission-reduction responsibility to another locality. If near-term reductions are likely whether a greenhouse gas reduction policy is implemented or not, a local agency may overestimate emissions to demonstrate large savings in the future.

34.Hall did not explicitly calculate the total costs and benefits for meeting the reduction targets, but enough information has been provided to make an estimate.

35.Hall's analysis by his own admission is "back of the envelope," and relies on partial equilibrium analysis to calculate total direct costs. The analysis does account for the ripple effects engendered by the increased energy-related investments, a necessity given the significant effects likely to be induced by such large-scale shifts in fuel use. Other problems likewise make Hall's analysis problematical. First, he adopts the energy conservation costs and potential penetration rates derived by researchers at Lawrence Berkeley Laboratory's (LBL) Energy Division. These estimates show substantial cost savings from greater conservation, and drive Hall's result towards positive benefits. However, the LBL analysis overestimates the potential for conservation. In addition, Hall does not account for the "rebound" effect of increased demand induced by the lower costs associated with more efficient technologies.

36.The model has five regions in the world—the United States, the remaining member nations (Western Europe, Canada, Australia and Japan) of the Organization of Economic Cooperation and Development (OECD), the former U.S.S.R, the People's Republic of China, and the Rest of the World (ROW)—and estimates differences in costs between fixed and tradeable emission quota systems.

37.The Manne and Richels results are driven in a large part by exogenous assumptions about the availability and competitiveness of new technologies and relative fossil fuel prices. If fuel prices are lower and technology maturity is delayed, then total costs would increase. While Manne and Richels do incorporate some capital fixity, they generally do not fully incorporate adjustment costs throughout the economy.

In calibrating the model, Manne and Richels examined their assumptions about the price-induced and non-price-induced conservation effects in the U.S. economy. In the simulation model, they assumed that the ESUB was 0.4 for the U.S. (i.e., that a 10 percent increase in energy prices caused a 4 percent decrease in energy use) and the AEEI was 0.5 percent per year (i.e., energy efficiency improves 0.5 percent each year regardless of changing energy prices). However, looking at the performance of the U.S. economy over the 1960 to 1990 period, the energy use path is better captured by an ESUB parameter of 0.5 and an AEEI of less than 0.25 percent, implying that price effects are more substantial and government standards less than half as effective as presumed in the model.

38.Jorgensen and Wilcoxen assumed that revenue from a carbon tax would be used to offset the existing labor taxes i.e., income and Social Security.

39.Daniel Lashof and Eric Washburn, *The Statehouse Effect: State Policies to Cool the Greenhouse*, NRDC, July 26, 1990.

40.CEC, *The 1992–1993 California Energy Plan*, December, 1991.

41.For example, the National Academy of Sciences has recently critiqued the value of existing strategies to reduce NOx emissions. See Alexander Cockburn, "A Kind Word for the Clunker," *Los Angeles Times*, March 15, 1992.

42.Some of the strategies adopted by the states involve simple accounting tricks in which emissions are credited to another region (e.g., the emissions from coal burning the Southwest allocated to California since that is the state that utilizes the generated electricity).

43.Restrictions on product composition can have similar effects. For example, stringent U.S. regulations on pesticides has acted to increase sales of these toxic substances to developing countries which do not have the same regulations.

44.In testimony before the U.S. Senate at the end of June 1993, Energy Secretary Hazel O'Leary noted that "I believe we have made a commitment as an Administration to achieve the (greenhouse gas emission reduction) goal using U.S. activity." This statement would seem to preclude emissions offsets obtained by improvements in energy efficiency in Third World nations, for example.

45.For example, "the national forests surrounding Yellowstone National Park had losses from their timber programs ranging from $241,000 to $2.2 million per year from 1979 through 1984." Terry L. Anderson and Donald R. Leal, "Free Market Environmentalism," Pacific Research Institute for Public Policy, San Francisco, 1991.

46.Forests sequester between two to four tons of carbon per acre. Ralph Cavanagh, "Global Warming and Least-Cost Energy Planning," *Annual Review of Energy*, Volume 14, Palo Alto, California, 1989, p. 366; Lashof and Washburn; *op. cit.*, p. 32.

47.In addition to fossil fuel burning, rice and livestock production are the principal source of

methane emissions. According to Christopher Flavin, "Slowing Global Warming: A Worldwide Strategy," *Worldwatch Paper 91*, October 1989.

48. In addition to eliminating direct agricultural subsidies, efforts should continue to "close" crop residue disposal systems. For example, rice straw residue burning—which produces greenhouse gases—is being phased-out in California. Alternatives to burning, such as soil incorporation or biomass-based energy production will act to significantly reduce these emissions.

49. "U.S. Says It Can Cut Output of Carbon Dioxide Further," *Los Angeles Times*, April 25, 1992.

50. W.B. Arthur, "Competing Technologies, Increasing Returns and Lock-in by Historical Events," *Economics Journal* 99: 116–131 (1989).

51. Nuclear power consumes more than one-third of the federal energy budget. Although with no air emissions nuclear power is an obvious means of reducing the risks associated with global warming, there is no indication that this energy source will be acceptable to the public in the near future.

52. CEC, "Technology Characterization - Final Report" Energy Report 92 Resource Planning Assumptions, Sacramento, November 22, 1991.