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NORTH AMERICAN AGRICULTURE AND THE GREENHOUSE PROBLEM

REPORT OF THE HUMPHREY INSTITUTE SYMPOSIUM ON THE RESPONSE OF THE NORTH AMERICAN GRANARY TO GREENHOUSE CLIMATE CHANGE

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PREFACE

The recent National Academy of Sciences' reviews of the carbon dioxide or greenhouse problem have confirmed the understanding of most scientists investigating the greenhouse effect — there does indeed exist a high probability of future climatic change, and that such change will exceed any other such change heretofore experienced by human society. All the evidence is not yet in, and uncertainties continue to cloud our understanding of the climate. However, nearly all the evidence indicates that the the greenhouse problem is real, that it is coming, and that the results could be momentous for humanity.

The work of the climate modellers should and will continue, as they attempt to refine their models and estimates. However, human society is faced with time constraints with regard to the greenhouse problem. The time is fast approaching when preventive measures must be taken if they are to be successful in averting significant warming. It is, therefore, time that the greenhouse problem be evaluated for its potential risks to human activities and human society.

For this reason, the Hubert H. Humphrey Institute of Public Affairs, a multidisciplinary institution for the education of public decisionmakers and for research into important public policy questions, sponsored a symposium on November 12, 1982 to investigate the response of one of the human activities most likely impacted by impending global climate change — agriculture and more specifically North American agriculture. Participants were asked to begin the process of sorting through the potential impacts of regional warming and other climatic changes on the North American Granary. The following is a draft summary of the conclusions of this symposium, augmented by background information supplied by the staff of the Humphrey Institute. The conclusions are solely the responsibility of its authors. Comments would be appreciated. They should be sent to Project Director, Dean Abrahamson, Humphrey Institute of Public Affairs, 909 Social Sciences Building, 267 19th Avenue South, Minneapolis, Minnesota 55455.

INTRODUCTION

The carbon dioxide-greenhouse problem has received increased review by those involved in the scientific and agricultural community in recent years. The most accepted estimates suggest that atmospheric concentrations of carbon dioxide and the other trace gases will increase to at least 150% of pre-industrial levels, and perhaps even double sometime in the next century. Present understanding of the heat balance of the planet indicates that this will result in a average global surface warming of 1.5-4.0 degrees Celsius within the next 70 years. The resulting redistribution of heat across the planetary surface will alter the mechanisms and the pathways through which the atmosphere seeks to reach thermal equilibrium across latitudes, thereby altering regional climates. Climatic changes expected to result in the continental United States from projected global warming include significant summer and winter temperature increases, decreased spring and summer soil moisture, decreased length and intensity of cold seasons, poleward movement of storm tracks and precipitation, the occurrence of more extreme spring-summer weather events (drought, heat waves etc.) and more erratic weather patterns over the first several decades of significant warming.

These climatic changes have significant implications for United States agriculture, especially Midwestern and Great Plains agriculture. Studies over the last decades show that Midwestern and Great Plains agriculture has been and remains sensitive to interannual weather variation, with fluctuations of yield of perhaps 15-25% recorded over the historic range of weather fluctuations this last fifty years. The center of the country also has been and remains subject to intense droughts. Ongoing environmental pressures, such as wind erosion on the Great Plains and aquifer depletion, have compounded the sensitivity of United States agriculture to interannual weather variability and are likely to be accelerated by the regional climatic changes expected for the center of the United States. We would expect, therefore, as a first estimate, that projected regional climatic changes could have significant implications for American agriculture.

The Humphrey Institute symposium assembled a group of University of Minnesota specialists in agricultural and related disciplines to offer informed comment on the likely impacts of climatic change, the information that remains lacking, and the approach that an impact analysis for climatic change and American agriculture should take. The participants offered informed speculation on the areas in which greenhouse gas-induced climatic change might represent a significant challenge to society. Nine areas were cited for special concern and study, including: generalized reductions in yield due to stress of heightened average temperature and decreased average available moisture; greater interannual variability of yields as compared to the present due to more extreme spring-summer climatic events and greater climatic variability throughout the first decades of significant warming; reductions in available surface and subsurface waters for irrigation; accelerated wind erosion of soils; forced relocations of existing crop belts to less favorable soil and topographical regions; impacts on the unmanaged biosphere; impacts on the transportation system, especially that part dependent upon surface waterways; impacts upon the forestry industry from heightened temperatures and increased pest damage; and impacts on the agricultural sectors of other nations with which the United States trades. In addition, concern was expressed that pest damage, which at present destroys about one-third of agricultural production, might increase. This, however, is uncertain.

The symposium participants also stressed the uncertainty involved in the projections of impacts of future climatic changes. Such projections are based upon assumptions about the rate and degree of warming and attendant climate change. They also are based upon projections of the future mix of agricultural technologies and the economic context in which climatic change will progess. These make projection of impacts incomplete at best.

THE GREENHOUSE PROBLEM

Climate on any part of the earth results from the the heat balance of the planet at each point on the surface and the unequal distribution of heat across the earth's surface. The earth receives short wave solar radiation from the sun which warms the surface. The spheroid shape of the planet tends to grade the energy distribution across different latitudes. The earth's albedo tends to reinforce this gradient by reflecting very large percentages of received short wave solar radiation back to space at the polar regions. Relatively high atmospheric concentrations of water vapor in the tropics reinforce this uneven distribution by increasing atmospheric resistance to radiative cooling, thereby warming the lower tropical atmosphere. The atmosphere redresses these imbalances through transports of heat from warm to cool regions, thereby forming the large-scale motions of the atmosphere that help to produce what we know as climate.

The distribution of energy across the planet's surface is acutely dependent upon the chemical composition of the atmosphere. The atmosphere contains gases and particles, some of which reflect short-wave solar radiation to space, thereby reducing the heating of the earth below them, others that absorb and radiate escaping long-wave radiation downward, thereby warming the surface below. Aerosols are important in the former case. Atmospheric carbon dioxide, water vapor, ozone, and various other greenhouse gases, notably nitrous oxide, methane, and tropospheric ozone, ammonia, nitric acid and the chlorofluorocarbons, are important in the latter regard. The atmospheric burden of the aerosols is not expected to increase beyond the normal burden for the last century. Significant increases in the atmospheric concentrations of carbon dioxide, water vapor and the other greenhouse gases are expected in the future. This would warm the surface at all latitudes above the present norm. In addition, significant warming due to increased ambient greenhouse gases would decrease snow and ice cover and radiation loss in more northern regions and increase the amount of water vapor borne by polar air, leading to disproportionate warming at the poles. Transports of ocean heat also would be drastically altered.

The atmospheric concentrations of these gases have been increasing for decades. Very accurate measurements from Mauna Loa and around the world reveal that atmospheric carbon dioxide concentrations have increased 17-21 percent above preindustrial 1880 concentrations. Total atmospheric carbon dioxide would approximately double by about 2025 should these trends continue. Atmospheric concentrations of most of the other greenhouse gases are likewise projected to double sometime in the next century. Atmospheric concentrations of carbon dioxide, the chlorofluorocarbons and perhaps nitrous oxide are expected to decay very slowly, with the process of decay to 50 percent of the initially added concentrations taking in excess of fifty years, and in the case of carbon dioxide many hundreds of years, which makes warming from these gases essentially irreversible once initiated.

The results of numerous planetary heat-balance studies have converged upon the conclusion, as confirmed by two National Academy of Science Panels, that average global temperatures will increase 2.0-3.0 degrees Celsius as a result of a doubling of atmospheric carbon dioxide and 150 to 200 percent of that when all the trace gases are considered. The atmospheric modellers project a warming from the present of 8-12 degrees Celsius at the poles and 2-3 degrees Celsius at the equator for this type of average global temperature change. A global warming of about 0.5 degrees Celsius above the preindustrial average has been detected by several independent investigators and an apparent consensus reached within recent months among the involved scientific community that the temperature signal associated with historic increases of the greenhouse gases has been detected. No countervailing factors have been identified to compensate for such a warming, although the large thermal capacity of the oceans may delay the anticipated warming by several decades.

The most thermally important of the added greenhouse gases are produced in direct proportion to the combustion of fossil fuel and the denitrification of agricultural fertilizers, with tropical deforestation also involved in the disturbed cycles of some of these gases. The rate of growth in fossil-fuel use has been significantly reduced from 4.5 percent per year to about 2.25 percent per year in recent years. However, it seems unlikely that the total concentrations of greenhouse gases related to the fossil fuels will remain below 150 percent of present levels in the next century, or about 430 parts per million, given the total amount of oil and gas reserves and existing investments in the solid hydrocarbons. This would raise global temperatures from the present by about 0.75-1.2 degrees Celsius and a total of 1.5-2.5 degrees Celsius should concentrations of the other trace gases double, as is predicted.

There may be, however, a series of feedback processes involving the carbon cycle through which the warming could, in the words of a symposium participant, "get out of hand." Net storage or net loss of carbon from the terrestrial biosphere, a carbon reserve three to four times the size of the carbon reserve of the atmosphere, is dependent upon a hierarchy of factors, the most important of which appears to be temperature. A significant global warming would alter the rate of respiration of the global forest biota, with higher global temperatures, all other factors held constant, stimulating the rate of release of carbon to the atmosphere through respiration and decay of organic material. The same process holds true for large reserves of carbon tied up in northern polar regions in peat deposits and in off-shore Arctic sediments. Annual releases from the the Arctic sediments, according to preliminary estimates, might be equal in amount to the present annual anthropogenic release of carbon, should a future warming of 2.5 degrees or more melt the permanent Arctic ice pack.

In addition, present understanding suggests that the oceanic sink capacity for carbon dioxide may decrease in the future. Modelling efforts have shown that the fraction of carbon dioxide remaining in the atmosphere after release might rise 5-10 percent over the next seventy years as a result of progressive saturation of the surface layers of the ocean with carbon dioxide. The atmospheric fraction might further increase, according to one symposium participant, should warming increase the thermal stability of the ocean's layers, leading to decreased upward supply of nutrients to oceanic plankton, and in turn to decreased productivity of the ocean's surface waters and reduced downward removal of carbon to ocean depths. These processes, along with feedback processes involving the biota, might increase total atmospheric carbon dioxide well above the projected 430 ppmv ceiling, and, in conjunction with the the effect of the other trace gases and natural warming trends, might move the range of predicted global temperature increase above 1.5-2.5 degrees Celsius.

Such a global warming has implications for large systems of the planet, especially the cryosphere. Such a warming would expand the water column and melt the fringes of the continental ice sheets and many temperate zone glaciers, raising sea level at least 50 cm, an event imminent over the next seventy years and an event with important implications for many millions that inhabit the world's great river deltas. In addition, it would threaten the planet's great continental ice sheets over the long run, leading to large transgressions of the oceans into coastal plains and even deeply into Siberia. It also would melt the permanent Arctic pack ice, which has been modelled to melt upon an average global temperature increase as small as 2.5 degrees Celsius.

One can expect the climate of the middle United States, Western Europe and the Central Russian Plain to be significantly warmer and drier under a regime of global warming and attendant climate change.* The latest modelling efforts suggest reductions in Midwestern and Great Plains summer soil moisture on the order of 20-30 percent and summer temperature increases of 5-6 degrees Celsius, should average global temperatures increase 4 degrees Celsius. Presumably soil moisture and temperature would respond in the same direction, though with smaller magnitude of change, from an average global temperature increase of 1.5-2.5 degrees Celsius. Regional summer temperatures are expected to be

* The general circulation of the atmosphere would be changed as a result of the greenhouse effect. It is expected that the middle latitude rainbelt will shift poleward, following the northern displacement of the region of maximum thermal contrast. It is also expected that the hot, dry anticyclonic regimes that exist at the equatorial side of the middle latitudes will shift somewhat poleward as the tropical circulation intensifies. The overall precipitation budget of the globe should increase slightly in intensity. This increase, however, will be outweighed in all latitudes but the equatorial and boreal latitudes by increased evaporation, leading to reduced summer or dry season soil moisture. The monsoonal circulation might be more regular.

on average 2 degrees Celsius warmer within several decades, with summer soil moisture decreased with increasing temperatures. The level of surface waters and stream flow would decrease as summer run-off decreases.

These conditions would be accentuated should the Arctic pack ice melt. The Arctic pack ice acts somewhat as a climatic anchor, balancing the cold source at the southern pole and maintaining relative climatic symmetry between hemispheres. Climatological theory projects that destruction of the pack ice, leading to an asymmetrical climatic arrangement, would bias Northern Hemispheric climatic zones northward, moving the climatic equator 5 degrees further north and, in our latitudes, relocating the area of anticyclonic influence 200 and 800 km north in summer and winter respectively. Flohn suggests that this would be accompanied by a much greater frequency of drought on the American plains and serious contraction of the belt of winter rains in the far American west. Flohn suggests that this also will greatly strengthen the southern hemispheric circulation and produce widespread aridization in the carbon-rich equatorial regions at 0-20 degrees South. The accompanying ecological revolutions in the polar reaches, the tropics, and other regions of shifting climate would be, in this case, unprecedented in the experience of humanity.

Overall, the projected climatic changes in these and subtropical latitudes were disturbing to symposium participants. Global climatic change would alter the normal ranges of temperature and soil moisture values for these latitudes, with the upward moving average temperatures and declining average available moisture, increasing the frequency of temperature and moisture events in the crisis parts of those ranges. The new equilibrium, the movement to which itself will be highly erratic due to the transient response of the oceans to the warming, therefore will be characterized in these latitudes by higher average temperatures, decreased average available moisture, and much greater frequency of extreme spring-summer events, in the words of a symposium participant, sequences of catastrophic droughts and heat waves.

This situation raises questions regarding global abliities to adapt both managed human systems and unmanaged natural systems to climatic and attendant environmental changes without serious damage to important resources. Climate defense strategies and technologies, techniques used to insulate human and other activities from the effects of variable climate, do appear to exist at present with regard to managed human systems. However, their application even in the rich developed world seems to be limited by economic pressures, and in this regard they appear to resemble other unutilized or underutilized environmental protection strategies and technologies. Climate defense strategies applicable to unmanaged environmental systems, on the other hand, appear to be non-existent, the cost of protecting such resources from the present vagaries of weather variability precluding consideration. Given this situation, some symposium participants questioned whether adaptive measures sufficient to protect both agricultural and ecological, economic and natural resources would be deployed even in the developed world, whether efficacious adaptive measures with respect to the unmanaged biosphere might be applied at all, and whether more than small-scale application of any such measures in the developing world was, as a symposium participant noted, even conceivable.

Ultimately, the greenhouse problem is embedded in a context of uncertainty and high risk. We are not entirely certain of the basic science of the problem, nor probably can we be certain; uncertainties are inherent in all models and projections, militating against full understanding of the involved systems of the planet. Nor can we be so clairvoyant as to describe the global economic context in which the greenhouse problem will be embedded or how each individual system will respond. However, we can be reasonably certain of a number of things. Global population is unlikely to remain below 8-10 billion by 2025; ongoing environmental and natural resource stresses will continue and intensify, and new stresses will develop, over the next fifty or so years; and the numbers of people living near the margin of existence, and therefore under conditions terribly sensitive to environmental change, will increase. The world will live nearer to the limits of survival with such pressures on population and natural resources. In this case, the global environmental situation in which climatic change will be embedded may be, as symposium participants noted, one of high risk, probably in terms of "acceptable" loss of life resulting from greenhouse disruptions, begging the question: how much risk is too much?

THE NORTH AMERICAN AGRICULTURAL RESPONSE

The response of North American agriculture to the greenhouse problem is difficult to forecast. Impacts on the Granary will take three forms: the direct effect of temperature and available moisture on crop yields; the effects of climatic changes on non-climatic agricultural resources, such as soils, water availability, etc., and the resultant impacts on crop yields; and the impacts of climatic changes on world food supply and demand, as these relate to the North American trade in agricultural products. Some of these impacts might be estimated from past granary response to medium-term and short-term changes in climate and weather. However, the long time scales involved in the problem, as they allow for technological and managerial adaptation and for changes in the economic and environmental context into which impacts will be fitted, complicate this effort. Most symposium participants seemed to indicate that impacts would nonetheless be important, in that they might impose high costs of adaptation and high natural resource costs.

The direct effects of warming and decreased available moisture are perhaps the most difficult of impacts to estimate. On the one hand, the North American Granary is <u>the</u> granary in part because of the optimal American climate for the cultivation of cereals and coarse grains. The climate of the Granary, if anything, might be on average slightly too warm and slightly too dry for the historic forms of cultivation in this region.

The Granary, ceteris paribus, will respond to higher average temperatures and decreased available moisture with decreased yields, crop-weather regression models showing reductions on the order of 20-25% under seasonal temperature increases of 2 degrees Celsius and moisture reductions of 20%. These models, according to symposium participants, seem accurately to predict crop response per temperature and moisture conditions at present, especially in areas where certain types of cultivation are already close to their agroclimatological limits, such as on the southern and western boundaries of the corn belt.

On the other hand, there is some question about the applicability of these models to the greenhouse issue. The global climatic models, for instance the Manabe-Stouffer-Wetherald model, show significant temperature increases for these latitudes in all seasons, with model reductions in soil moisture based upon these summer temperature values. However, questions exist regarding the reliability of these model results under conditions of limited warming, as small historic warming trends sometimes are dominated by winter warmings. The models also do not speak with defensible evidence to the timing of seasonal change or regional or areal precipitation changes. These problems make application of crop-weather results uncertain under conditions of limited greenhouse warming, where a small warming might be confined to the winter season, and therefore where other non-temperature growing season factors can be important.

More important, the crop-weather models indicate the historic response of yields to short term fluctuations in weather. Also, they are based upon present agricultural technology and management practices. Therefore, these models may fail to allow sufficient scope for longer-term adaptive processes, the agricultural system responding over the course of time with advances in plant breeding, new technologies and more appropriate management techniques to slowly changing average conditions. Symposium participants noted the historic record of the American agricultural system, which appears to have responded well in the past to some limited climatic changes through greater use of irrigation, chemicals, and improved varieties of cultivars. In addition, they noted potential new management strategies, such as earlier planting and harvesting to avoid some of the impacts of increased summer heating and decreased available moisture.

Symposium participants also made clear, however, that not all climatic changes can be technologically ameliorated. Agricultural geneticists, crop breeders, and other agricultural technologists probably can adapt crops slightly at the margin to greater average heat stress and can supply more available moisture locally through irrigation. However, the extent to which this technological fix has succeeded in the past has been limited by technological obstacles, such as an a inability to breed corn to produce economically with below 20 inches of moisture, and more important by economic obstacles, notably the sheer economic cost of modifying the crop environment of the entire Granary. Adaptive capability in this regard has been limited by income constraints, and, given current trends, these appear likely to intensify in the future.

Failure of the technological fix in the past to insulate American agriculture from the influences of climate is instructive with regard to the future. The agricultural system remains constrained by climate, to which the estimated 15-25% interannual variability of yields attests. Temperature and moisture limitations continue to exist on the Great Plains with respect to economical production of corn, and further west with respect to wheat, with for instance the western and southern boundaries of the corn belt defined by moisture and temperature limitations respectively. To date, modern technology has had little success in overcoming these limitations. Success has been harder to come by in other regions of the Western Hemisphere where yields show a wide departure from the North American norm in response to climatic conditions. Thus, while the economic imperative to adapt has existed and continues to exist, the sheer cost of, for instance, irrigating the entire Great Plains so as to sustain Plains corn production, has militated and continues to militate against such an enterprise.

Establishing the future economic context of the Granary is difficult. Current projections into the next decade suggest that the economic potential for large-scale adaptation will not be significantly greater than at present. These offer little instruction on the condition of the Granary on a longer timescale, such as is involved in the greenhouse problem. We can be sure, however, that the economic costs of those aspects of adaptation that depend upon exploitation of the free goods of the natural environment, for instance irrigation water, will increase substantially in the future as resource depletion progresses. It will be increasingly difficult in the future to envisage adaptation centered upon increased irrigation, given the rapid rates of depletion of acquifers, the rising costs of energy, and the full commitments of many western rivers.

A similar situation exists with regards Granary soils. One means of compensating for reduced soil moisture in the Granary would involve intensified management of the soils, for instance maintaining a cover on the soils throughout the planting and growing season in order to conserve moisture. This managerial fix, however, stands opposed to the reality of soil management in the United States where, according to one symposium participant, at least 15 percent of the agricultural soils are being irremediably degraded, and where nearly one-half of the nation's lands are undergoing moderate to extreme desertification. Moreover, there is the danger that significant regional warming may accelerate these trends in soil erosion and desertification, and have another, though indirect, effect on agricultural yields.

Similarly, impacts of the greenhouse problem on other non-climatic agricultural resources, for instance pest resistance, compound the problem of adaptation. Pest populations presently destroy about 25-30% of American agricultural production per year, despite application of mitigating technologies and management practices. Warmer conditions and longer frost free seasons may increase the aggregate size of this pest population, leading to greater, though as yet unestimated, agricultural losses. However, drier conditions may limit increased pest losses.

Given these circumstances, it is difficult to avoid the conclusion that adaptive processes may not be successful in mitigating the impacts of the greenhouse problem on North American agriculture. Conversely, the crop-weather models, rather than being meaningless, may indicate the direction and broad magnitude of crop response under average conditions of greenhouse climatic change. The response under extreme conditions of drought or heat wave, the frequency of which probably will increase, is relatively certain, given the unlikelihood that future North American agriculture will be able to sustain such random events without serious episodic losses of production.

Two types of adaptation most often discussed - relocation of agricultural production northward to follow storm tracks and optimal temperatures, and alteration of the crop mix of the North American Granary - are suggestive of the costs involved in a change of climatic conditions. Northward relocation of corn belt into northern Minnesota, Michigan, Wisconsin or Ontario would be accompanied by large reductions in yields, given the poor thin soils of these areas. Similarly, forced relocation of the Canadian wheat belt northward would be followed with large reductions in yields, with soil formation in these regions taking centuries. In addition, there would be large capital costs associated with such relocations. Changing the crop mix, for instance planting the corn belt or parts of it in wheat, and the wheat belt in more drought resistant cultivars like barley or sorghum, on the other hand, might involve little actual loss of agricultural tonnage. However, the mere necessity of such an action highlights the potential costs of the greenhouse problem, in this case in terms of forced transition to less desirable grains.

As one participant nicely summarized, the impacts of the greenhouse problem on the North American Granary are best defined by economic and environmental costs, increased economic costs of adaptation, and implicit costs associated with an undesirable crop and resource mix. Technological intervention may ameliorate the problem, but only at a certain cost. Thus, the issue again resolves into a question: are the costs to the Granary sufficient in themselves to warrant preventive action with regard to the greenhouse problem?

RESEARCH ISSUES

The symposium discussion, in its structure and focus, revealed the central role of the crop-weather models in an impact analysis of the effects of greenhouse climate change on the North American Granary. Climate, essentially an agricultural resource, must be understood as such a resource, the crop-weather models being the best, although by no means the optimum, tool through which to do so. The foremost priority as regards research on the agricultural impacts must be a thorough analysis of the crop-weather models, the goal being to establish better means by which to adapt them to the prediction of Granary impacts. Such a review, incorporating the problem of technological innovation and economic feasibility, would establish part of the groundwork on which any case, either for preventing the greenhouse problem, adapting to it, or simply ignoring it, will rest.

The symposium discussion also revealed the importance of impacts on non-climatic resources, especially surface and subsurface waters and soils. It also revealed the possible though yet uncertain effects of regional warming on pest populations. These impacts would affect yields in the short-term, and, in the case of soils and aquifers, in the long-term. These impacts also would transcend the Granary, affecting other important activities of society, such as industrial uses of water, recreation, water planning, urban planning, water pollution control and health maintenance. They might also affect non-cultivation sectors of the American agricultural system, such as transportation and grain storage, through water and pest impacts respectively.

Another important area for investigation involves the issue of cost, and more specifically the costs of forced relocation of the agriculture sector poleward, the costs associated with large-scale mitigation of the impacts of climatic changes through, for instance, heightened irrigation on the Great Plains and in the Corn Belt, or greater use of herbicides and pesticides, or any economic costs associated with altering the existing crop mix. Policy decisions, if any are to be made, must be based upon reasonable estimates of the economic costs of adaptation.

Lastly, the symposium discussion revealed the necessity for analysis of the impacts of climate change on the unmanaged biosphere of North America, and on the free goods that the unmanaged biosphere supplies to agriculture and society as a whole. Remarkably little appears to be known of possible impacts on the forests, the vast northern peatlands, the Arctic tundra, or diverse other aspects of the natural biota. These are the least managed of all systems that supply services to human societies, and for that reason probably the most subject to disruption as a result of changing environmental conditions. Large but poorly understood economic costs may be associated with these potential disruptions, costs that must be estimated prior to any public policy decision on the greenhouse problem.

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