Carbon Dioxide and the Greenhouse Effect: Possibilities for Legislative Action

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I. INTRODUCTION

Carbon dioxide, nitrogen, and oxygen comprise over 99% of the earth's atmosphere. Each of these gases is colorless, odorless and nontoxic. Therefore they are not the subject of any pollution control device or regulation. Carbon dioxide (CO_2), is also the most commonly occurring of all the so-called "greenhouse gases."[1] These gases trap infrared radiation or heat emanating from the earth's surface and prevent some of it from escaping into outer space.[2] The natural occurrence of the greenhouse gases in our atmosphere raises the mean temperature of the earth's surface by 35°K.[3]

This past century has witnessed a marked increase in the rate of human utilization of fossil fuels.[4] The atmospheric presence of carbon dioxide, the principal by-product of fossil fuel burning, has consequently climbed from 280 to 339 parts per billion.[5] This rapid emission of carbon dioxide has prompted concern among many environmentalists that the global temperature will rise during the next century to an extent sufficient to create a significant impact on precipitation and agricultural growing patterns.[6] Many climatologists believe that a doubling of atmospheric CO_2 levels could raise global average temperatures

1. NATIONAL RESEARCH COUNCIL, CARBON DIOXIDE AND CLIMATE: A SECOND ASSESSMENT, at xv (1982).

2. L. ORTLAND, ENVIRONMENTAL PLANNING AND DECISION MAKING 33, n. 8 (1984); THE COUNCIL ON ENVIRONMENTAL QUALITY 1983, at 207 (14th annual report); THE COUNCIL ON ENVIRONMENTAL QUALITY & THE DEPARTMENT OF STATE, THE GLOBAL 2000 REPORT TO THE PRESIDENT, VOLUME 2, at 260 (1980) [hereinafter cited as GLOBAL 2000 REPORT]. The term "greenhouse gas" is technically misleading since actual greenhouses used for the cultivation of and protection of plants are heated by convection, rather than radiative entrapment of infrared radiation. Chamberlain, *Climate Effects of Minor Atmospheric Contaminents*, in CARBON DIOXIDE REVIEW: 1982, at 255 (Clark ed.).

3. *Id.* For a nineteenth century landmark study on the effect of air generally and carbonic acid (the product of carbon dioxide reacted with water—H_2CO_3) upon the temperature of the earth's surface, see Arrhenius, *On the Influence of Carbonic Acid in the Air Upon the Temperature of the Ground*, 41 LONDON, EDIN, AND DUBLIN PHILOSOPHICAL MAGAZINE 237 (1896).

4. STEINBERG, AN ANALYSIS OF CONCEPT FOR CONTROLLING ATMOSPHERIC CARBON DIOXIDE, (1983) (prepared for the United States Department of Energy).

5. Kelling, *Measurement of the Concentration of Carbon Dioxide at Manna Lou Observatory, Hawaii*, in CARBON DIOXIDE REVIEW: 1982, at 377 (Clark ed.).

6. *See* J. NEWMANN, IMPACTS OF RISING ATMOSPHERIC CARBON DIOXIDE LEVELS ON AGRICULTURAL GROWING SEASONS AND CROP WATER EFFICIENCIES (1982) (prepared for the U.S. Department of Energy).

by .2°K to 4°K.[7] In polar regions, the average temperature rise could be as much as three or four times these estimates.[8] While these may not seem to be significant, in fact they might be, especially in areas where the local temperature increase is projected to exceed the average. Rises such as these may weaken the global wind systems, expand both tropical zones and dry belts, enhance melting of ice bodies, raise sea levels and decrease necessary variations in weather. Events such as these may cause vast changes in agricultural and living patterns, dislocation of major populations and possibly an overall decrease in arable land.

Unfortunately, greenhouse models suffer from multiple levels of uncertainty, which reduce the chances for effective legislative action. For example, uncertainty exists with respect to the relationship between CO_2 output and atmospheric build-up; between atmospheric CO_2 levels and global warming trends; between other factors, such as trace gas or particulate build-up and global temperature; and between global temperature and climatic changes.

Legislative action is generally premised on a rough calculation of "certainty of risk" multiplied by "magnitude of risk." The result is then compared to the costs of legislative action. A similar balancing process is brought to regulatory action as well. Once action is taken, it is often subject to judicial review, which can range from the deferential standard of the "rational basis test" (*i.e.*, is there a rational basis for the rule or law) to the stringent "substantial evidence test" (*i.e.*, is there substantial evidence in the entire record, taken as a whole, to support the action taken). The level of review for most new legislation is a sort of rational basis test, but regulations are reviewed according to the standard required by the underlying enabling legislation. In either case, where the costs of an action are significant, both political and judicial obstacles can forestall action until there is a reasonable cer-

7. See chart *infra* note 31.

8. GLOBAL 2000 REPORT, *supra* note 2, at 261. Another report estimates polar temperatures will increase by 7 to 10°K if atmospheric CO_2 doubles. Speth, *Global Energy Futures and the Carbon Dioxide Problem*, 9 B.C. ENVT'L AFFAIRS L. REV. 1, 2 (1980). Atmospheric CO_2 levels, according to many energy-use scenarios, are projected to increase beyond the arbitrary doubling in climate models studies, leading to steadily increasing temperatures after the doubling level is reached. S. SEIDAL & D. KEYENES, CAN WE DELAY A GREENHOUSE WARMING? 4-12, fig. 4-4 (1983) (prepared for the Environmental Protection Agency) [hereinafter cited as EPA STUDY].

tainty that a significant threat has been posed to the physical or economic welfare of the population.[9]

The result of these political and judicial obstacles is to make action with respect to CO_2 quite difficult.[10] Most proposals to reduce CO_2 output entail significant costs. Whenever the prevention of a risk entails significant costs, it is difficult to justify the cost of preventive action if the risk is uncertain and remote in time. Considering the inherent uncertainties of the greenhouse model, and the fact that global warming lies sometime in the future, it is one of the difficulties of the problem that the costs of preventive legislation will have to be incurred so far in advance.

This is not to say, however, that legislative action cannot be taken. First, a number of changes in energy policy that have the effect of reducing CO_2 output can be made. For example, conservation programs can be justified by their immediate benefits of reducing energy usage and increasing energy efficiency. The use of renewable energy sources is often less costly, less polluting and less depleting than the use of fossil fuels. Programs to reduce our dependence on fossil fuels and to increase energy efficiency can be justified by both their immediate economic and environmental benefits, and by their reduction of CO_2 output. The key here is that these proposals are not premised solely on their ability to reduce CO_2 output.

Second, some actions premised solely on reducing CO_2 output are politically viable, such as implementing low-cost preventive

9. *See e.g.*, Lead Industries Assoc. Inc. v. EPA, 647 F.2d 1130 (D.C. Cir. 1980), *cert. denied*, 449 U.S. 1042 (1980), upholding the national ambient air quality standards for lead, under the Clean Air Act, § 109, 42 U.S.C. § 7409 (1982).

10. The most direct method of control of emissions is through the Clean Air Act, which requires setting an ambient air quality standard for a particular substance, and then regulating emission control to achieve the ambient air quality standard. In the case of carbon dioxide this method of control is appropriate. Under the Clean Air Act, such regulatory controls are to be established for "emissions which [in the judgement of the Administrator] cause or contribute to air pollution which may reasonably be anticipated to endanger public health or welfare[.]" Clean Air Act § 108(a)(1)(A), 42 U.S.C. § 7408(a)(1)(A) (1982). While carbon dioxide specifically appears to meet the statutory language, it is clear that the kind of danger it poses is different in character from the danger posed by such criteria pollutants as sulfur dioxide, nitrogen oxide, carbon monoxide or lead. The controls of the Clean Air Act are inappropriate because the production of carbon dioxide is an integral part of virtually all natural and combustion processes. Thus, the emphasis, unlike the case of the other pollutants, is not on preventing the emission of carbon dioxide, but on making the combustion process more energy productive or finding alternative power sources so as to reduce the need for combustion processes—*i.e.*, to reduce the number of fires needed.

measures, or increasing research and development funding for specified purposes, such as data collection or developing more reliable models of the greenhouse effect.

Of course, atmospheric CO_2 increase is a global phenomenon stemming from fossil fuel use and a multitude of other combustion processes, including forest fires, all over the globe. This article will explore only national initiatives. While affirmative legislative action on a national scale can only make a small dent in the CO_2 problem, it can help to build the consensus necessary for international cooperative action.

II. The Greenhouse Effect and Global Climate

A. *Assumptions Underlying the Greenhouse Projections*

Greenhouse projections rest largely on two critical findings: first, that the atmospheric carbon dioxide concentration will increase at a rate proportional to the rate of combustion of fossil fuels; and second, that this increase will produce a significant increase in atmospheric temperature.[11]

The first of these findings is not well established in a quantitative sense. The atmospheric level of carbon dioxide increases at a rate reflecting only about 46% of the total carbon dioxide released annually.[12] The remaining amount of released carbon dioxide is either absorbed by the ocean or converted into oxygen by photosynthesizing plants and bacteria. Despite questions concerning the precise relationship between CO_2 output and atmospheric build-up, the relationship clearly is positive, *i.e.*, increased output leads to increased build up.

The task of quantifying this relationship is complicated because the rate of ocean absorption of carbon dioxide is difficult to determine. A report prepared by the Woods Hole Oceanographic Institution states that, "oceanographers have not nearly enough data to understand the dynamic processes of the global oceanic circulation in sufficient detail to predict its future states."[13] Furthermore, it is difficult to predict the future rate of storage of carbon compounds because it is likely to increase under future

11. G. Sewell, Environmental Quality Management 176 (1975).

12. The Global 2000 Report, *supra* note 2, at 261 (citing Siegenthaler & Oeschger, *Predicting Future Atmospheric Carbon Dioxide Levels*, 199 Science 388-95 (1978)).

13. M. McCartney & H. Lansford, Potential Effects on Ocean Dynamics of an Increase in Atmospheric Carbon Dioxide: Some Scientific Issues and Research Approaches 1 (1982).

conditions. For example, an increased concentration of carbon dioxide in the atmosphere may stimulate photosynthesis in plants and bacteria.[14] Moreover, the extent of surface water pollution in the future may affect photosynthesis levels, since it is within these waters that 70% of all photosynthesis occurs.[15]

The second assumption, that carbon dioxide build-up will cause a significant rise in the earth's atmospheric temperature, is equally difficult to document with precision. However, models do indicate some positive correlation between CO_2 concentration and surface temperature. The most pronounced consequences of temperature rise could be the effect on the polar regions. It has been anticipated that an increase in surface temperature could lead to the disappearance of floating ice in the Arctic and the disintegration of the West Antarctic Ice Sheet.[16] Reductions in surface ice would reduce the reflectivity of the earth's surface, further enhancing the warming trend. Of course, in the highly complex field of meteorology, the nature and extent of any additional climatic shifts which such a melting would instigate are extremely difficult to predict.

B. *Collateral Factors Influencing Global Climate*

1. Particulate Matter

It is possible that particulate matter suspended in the atmosphere may have a significant influence on the earth's heat balance. Suspended particles both reflect light energy before it enters the atmosphere and absorb it during passage to and from the earth's surface.[17] A vast array of particles occur naturally in the atmosphere such as dust, sea spray and volcanic ash.[18] Human activities produce additional particulate emissions in the form of automobile, airplane and smokestack exhausts and dust from wind blowing over barren soil;[19] and the Clean Air Act has extensive controls for such suspended particulates.[20] Particulate matter

14. SEWELL, *supra* note 11, at 176.

15. *Id.* at 43.

16. Weiss, *A Resource Management Approach to Carbon Dioxide During the Century of Transition*, 10 DENV. J. INT'L L. & POLICY 487, 488 (1981); Note, *Carbon Dioxide's Threat to Global Climate: An International Solution*, 17 STAND. J. INT'L L. 389, 391 (1981).

17. SEWELL, *supra* note 11, at 176; GLOBAL 2000 REPORT, *supra* note 2, at 263.

18. *Id.*

19. Note, *supra* note 16, at 390 n. 4.

20. Particulate matter (regulated as "TSP"—total suspended particulates) was on the original list of air pollutants for which the Administrator of EPA must issue criteria and

comes in an array of shapes and sizes, each having a distinctive ability to reflect incoming or outgoing radiation. While it is suspected that the overall climatic effect of these particulate emissions may be to cool the earth's atmosphere, experts have not been able to make clear findings.[21]

2. Other Greenhouse Gases

Possibly having nearly as significant an influence on global temperature as CO_2 is the compound effect of trace greenhouse gases such as nitrous oxide, methane and chlorofluorocarbons. The future emissions rates of these gases, however, and the precise mechanisms by which they will affect global climate, are each issues of great uncertainty.

a. Nitrous Oxide. Nitrous oxide (N_20) is released into the atmosphere primarily as a product of biological processes in the oceans and in the soil.[22] The use of nitrogen fertilizers and the addition of nitrogen-rich sewage to bodies of water result in a further release of nitrous oxide. In addition to its direct contribution to a greenhouse warming, nitrous oxide may react with other gases to produce more ozone in the atmosphere and troposphere. The creation of ozone, also a greenhouse gas, could aggravate the warming effect.[23]

b. Methane. Methane (CH_4), present in the atmosphere primarily as a product of fermentation, is another trace greenhouse gas.[24] While methane concentration in the atmosphere (measured as 1.65 ppm in 1980) is currently increasing by 1% per year,[25] this rate may accelerate dramatically if the earth undergoes a climatic warming. As much as 2000 gigatons of methane in the form of methane hydrate may presently be frozen in peat bogs in the northern latitudes. Were these peat bogs to thaw, immense

ambient air quality standards. These so-called "criteria pollutants" are air pollutants which, in the Administrator's view, have an adverse effect on health and welfare. Clean Air Act § 108(a)(1), 42 U.S.C. § 7408(a)(1), (b)(1) (1982), 36 Fed. Reg. 1502, 14 (1971). As defined, the effects on welfare include effects on "climate." Clean Air Act § 392(h), 42 U.S.C. § 7602(h), 1982). Detailed ambient air quality standards have been promulgated for TSP, and state that implementation plans must include emission limits for TSP.

21. GLOBAL 2000 REPORT, *supra* note 2, at 51, 263-64.

22. EPA STUDY, *supra* note 8, at 2-12.

23. *Id.* at 2-13.

24. *Id.*

25. Lacis, *Greenhouse Effect of Trace Gases, 1970-1980*, 8 GEOPHYSICAL RESEARCH LETTERS 1035 (1981).

quantities of methane could eventually escape into the atmosphere.[26]

c. Chloroflurocarbons. Chloroflurocarbons exist in the atmosphere solely as a result of their manufacture and use in items such as refrigerators, air conditioners, solvents and cleaning agents.[27] The presence of merely a few parts per billion of compounds such as CCl_3F (Freon 11) and CCl_2F (Freon 12) could produce an appreciable global warming.[28] Such compounds, however, may also promote the destruction of the stratosphere ozone layer and thereby promote a substantial cooling.

Due to the complexity of stratospheric photochemistry, scientists have been unable to make reliable projections regarding the net climatic effect of chloroflurocarbons.[29] In fact, according to EPA calculations, the uncertainties as to the rates of growth and effects of the trace greenhouse gases are so great that the overall result might be to advance a 2°K warming by fifteen years from the baseline projection, or to delay it by as much as thirty years.[30]

C. *The Results of the Climate Studies*

A wide array of studies have been conducted over the past thirty years to predict the surface and air temperature change to be expected from a doubling of the pre-industrial level of carbon dioxide. The results of these studies are inconsistent, ranging from Moller's 1963 projection of an enormous 9.6°K temperature rise down to Idso's 1980 projection of an insignificant tempera-

26. Once released into the atmosphere, the methane would oxidize to carbon dioxide over a period of four to ten years. Bell, *Methane Hydrate and the Carbon Dioxide Question* in CARBON DIOXIDE REVIEW: 1982, at 401 (Clark ed.).

The methane problem could be partially offset by eliminating carbon monoxide as a trace by-product of fossil fuel burning. A reduction in carbon monoxide would lead to an accumulation in the trophosphere of gases known to destroy methane. EPA STUDY, *supra* note 8, at 2.13.

27. Glantz, Robsinson, & Krenz, *Climate-Related Impact Studies: A Review of Past Experiences* in CARBON DIOXIDE REVIEW: 1982, at 77 (Clark ed.).

28. Wang & Pinto, *Climate Effects Due to Halogenated Compounds in the Earth's Atmosphere*, 37 JOURNAL OF ATMOSPHERIC SCIENCE 333 (1980).

29. *Id.* at 337.

30. EPA STUDY, *supra* note 8, at v.

ture rise of 0.10°K.[31] These inconsistencies reflect the complexity of the CO_2 problem and the limits of current climatological models. Such inconsistency does not necessarily indicate that the greenhouse effect is illusory or that it is benign. On the contrary, most climatologists agree that even minor changes in global average temperatures could cause significant changes in climate and therefore in land use patterns. The lack of a clear-cut model demonstrating precisely when these effects might occur, however, poses a challenge to legislators and regulators who seek to enact possibly costly restrictions on CO_2 output.

An often cited 1979 study by the National Academy of Sciences (NAS) reviewed results which were available at that time and concluded that the most likely temperature rise would amount to 3.0 ± 1.5°K.[32] A second panel convened three years later by the NAS acknowledged a far greater uncertainty to this interval than the original calculations had suggested.[33]

When other factors influencing global climate are considered, such as atmospheric dust concentration, trace greenhouse gases, increased use of the upper atmosphere by airplanes, expansion of the earth's desert regions, volcanic dust and sun spot activity, the net climatic effect is quite uncertain. On the one hand, a study by NASA has claimed that a greenhouse warming of 0.4°K occurred between the years 1880 and 1970[34] and that a warming of 0.24°K

31. The following are the results of a series of studies conducted between 1956 and 1981:

Source	Change in Temperature (°K)
Plass (1956)	3.7
Moller (1963)	9.6
Weave and Snell (1974)	0.7
Hansen (1978)	3.5
Ohring and Adler (1978)	0.8
Hansen (1979)	3.9
Ramathan *et al.* (1979)	3.0
Gates and Cook (1980)	0.2
Idso (1980)	0.1
Wetherald and Manable (1981)	2.4

See Clark, *The Carbon Dioxide Question: Perspectives for 1982*, in CARBON DIOXIDE REVIEW: 1982, at 24 (Clark ed.).

32. NATIONAL ACADEMY OF SCIENCES, CARBON DIOXIDE AND CLIMATE: A SCIENTIFIC ASSESSMENT (Charney, chairman, 1979).

33. NATIONAL ACADEMY OF SCIENCE, CARBON DIOXIDE AND CLIMATE: A SECOND ASSESSMENT 52 (Smagorinsky, chairman) (1982).

34. Shell, *Will the Changes be Unbearable?*, 84 TECHNOLOGY REVIEW 32 (1981).

occurred during the decade 1970-80.[35] On the other hand, some other scientists have been detecting periodic decreases in global temperature.[36] This may reflect natural or artificially induced cooling (for example, from added particulate matter).

In 1978, a detailed study was conducted by the Research Directorate of the National Defense University in Washington, DC.[37] The study employed twenty-four specialists chosen for their knowledge of climatology and their diversity of views. Each panelist was asked to assign probabilities to specific climatic changes over the next twenty-five years. The results of this study, diagrammed below, indicate that climatology experts cannot reach a consensus on the effect of fossil fuel use:

Temperature Category	Change in Mean Northern Hemisphere Temperature from Present by the Year 2000	Probability
Large Cooling	0.3°K - 1.2°K Cooler	0.10
Moderate Cooling	0.05°K - 0.3°K Cooler	0.25
Same as Last Thirty Years	0.05°K Cooler to 0.25°K Warmer	0.30
Moderate Warming	0.25°K to 0.6°K Warmer	0.25
Large Warming	0.6°K to 1.8°K Warmer	0.10[38]

Although a great deal of global climate research has been published since the 1978 poll was released, unanimity of views remains illusive.

Given the wide range of predictions that are available to date, it should come as no surprise that there are a variety of political responses, ranging from efforts to drastically reduce CO_2 output to suggestions that nothing be done at all.

35. Lacis, *supra* note 19.

36. EPA REPORT, *supra* note 8, at 2-23, fig. 2-4.

37. NATIONAL DEFENSE UNIVERSITY, CLIMATE CHANGE TO THE YEAR 2000: A SURVEY OF EXPERT OPINION (1978); *see also* GLOBAL 2000 REPORT, *supra* note 2, at 52-56.

38. These result of the National Defense University Study are reproduced in GLOBAL 2000 REPORT, *supra* note 2, at 541.

III. Three Available Avenues of Response

A. *The Wait-and-See Approach*

Wait-and-see theorists take very seriously those studies, such as that conducted by the National Defense University, which cast doubt as to whether a global warming is to be expected at all. Moreover, they contend that a global warming would not necessarily be harmful. For example, Norman Rosenberg, director of the Center for Agricultural Meteorology, and Charles Cooper, director of the Center for Regional Environmental Studies, have claimed that, "a doubling of atmospheric carbon dioxide is about as likely to increase global food, at least in the long run, as to decrease it."[39] Sylvan Wittwer, director of the Agricultural Experiment Station, has even suggested that in certain respects, an increase in carbon dioxide levels may even be desirable: "The primary conclusion from all the [relevant research] is that the present level of carbon dioxide is suboptimal, and the oxygen level is supraoptimal, for photosynthesis and primary productivity in the majority of plants."[40]

The creed of the wait-and-see theorists is therefore the following: countermeasures are inappropriate unless a large adverse climatic trend is conclusively established. However, even wait-and-see theorists generally advocate "extensive research . . . in numerical modeling, statistical analysis and measurement techniques in order to help detect first climate changes produced by the upward trend in carbon dioxide concentration."[41] If such research yields statistical verification of a large adverse effect, they agree, affirmative countermeasures should then be pursued.

B. *The Adaptation to Inevitable Changes Approach*

An unusual alternative response, articulated by economist Lester Lave,[42] is to accept climatic changes as inevitable, to dismiss

39. Cooper, *Food and Fiber in a World of Increasing Carbon Dioxide*, in Carbon Dioxide Review: 1982, at 249 (Clark ed.); Rosenberg, *Commentary* in Carbon Dioxide Review: 1982, at 324 (Clark ed.) (a response to Cooper's essay).

40. Wittwer, *Commentary*, in Carbon Dioxide Review: 1982, at 322 (Clark ed.) (a response to Cooper's essay, *supra* note 34).

41. Klein, *Detecting Carbon Dioxide Effects on Climate*, in Carbon Dioxide Review: 1982, at 236 (Clark ed.).

42. Lester Lave, Professor of Economics at Carnegie-Mellon University, served on the steering committee of the American Association for the Advancement of Science study to design a research agenda for carbon dioxide from 1977 to 1981.

attempts at prevention as futile, and to rely on mankind's inherent power of conscious and unconscious adaptation to changes in the environment.[43] This response is based on the premise that three time lags stand in the way of abating carbon dioxide emissions.

The first is a recognition lag. To verify current simulation models to the satisfaction of the wait-and-see theorists, scientists may have to wait until the year 2000 before they have accumulated sufficient data. By that time, new uncertainties may arise as climatic features which are currently of moderate importance gain greater significance with increased atmospheric levels of carbon dioxide.

The second lag will involve reaching an international agreement on the best means to rectify the problem. Obtaining worldwide agreement may take decades since the seriousness of the problem for each nation will vary depending on its location and economic condition. Moreover, great resistance is to be expected from those nations which continue to believe that they will stand the gain from a climatic change.

Finally, the international agreement reached may well involve the switching to alternative sources of fuel. Many decades may be required before any such plan can be fully implemented.

According to this reasoning, no substantial curtailment of the greenhouse process could conceivably be accomplished before the latter part of the twenty-first century. By that time, significant and possibly irreversible climatic changes may already have occurred. Therefore, argues Professor Lave, it is a waste of time and effort to attempt to mitigate the greenhouse effect. Mankind must rely on its innate ability "to adapt to and exploit a changing environment."[44]

C. *The Act-Now Approach*

Of the three possible responses to the carbon dioxide question, it is only the act-now approach which demands immediate formulation of national policies and prompt implementation of federal controls or regulations. This approach is premised on the fact that even in the absence of any conclusive scientific or mathematical verification that a global warming will take place, the mere

43. *See* Lave, *A More Feasible Social Response*, 84 TECHNOLOGY REVIEW 23 (1981).
44. *Id.* at 31.

threat of such an occurrence is sufficient to warrant taking preventive measures. Considering control of carbon dioxide as an insurance policy, proponents of this theory seek solutions now, while the "premiums" or net costs are low because they are "economically attractive, pose little environmental hazard, [or] reduce dependence on imported oil."[45]

Part IV of this article examines many of these options for their effectiveness and feasibility. It is arguably true that almost any sort of preventive action will be less expensive in human suffering, environmental degradation and dollar expenditures than a form of adaption or reaction sometime in the future. The problem, however, lies in the nature of our political and legal systems, which demand some degree of immediacy and certainty as a premise to action. Further, the more subtle and distant the problem to be addressed, the more unreasonable will appear the costs of preventive action, thus once again demanding a level of scientific certainty that may not be possible for many years to come.

IV. Alternatives for Immediate Action

A. *Non-energy Alternatives*

While most proposals for the prevention of global warming involve direct or indirect controls on fossil fuel consumption, others attack the problem from a variety of angles. Non-energy alternatives frequently suggested include forestation, tropospheric release of sulfer dioxide, and chemical scrubbing of carbon dioxide from smokestack emissions.

1. Forestation

It has long been recognized that forests absorb and sequester carbon dioxide during the process of tree growth.[46] It has therefore occasionally been advocated that the carbon dioxide problem be solved by planting new forest regions or expanding old ones. Proponents of this solution have argued that in addition to providing a sink for carbon dioxide, forestation would also undo the damaging effects of past deforestation by restoring nutrients to the soil and containing the spread of desert regions.[47] Attractive as this option may seem, the forestation alternative has lost many

45. Scroggin & Harris, *Reducation at the Source*, 84 Technology Review 22, 26 (1981).
46. EPA Study, *supra* note 8, at 6-5.
47. *Id.* at 6-6.

adherents because a series of studies have indicated its limited usefulness as a single strategy for reducing the rate of increase of atmospheric CO_2.[48]

a. Forestation with Sycamore Trees. The original forestation proposal, presented in 1976 by the physicist Freeman Dyson, recommended that American sycamores be planted on 6.7 million km^2 of land, or roughly an acreage corresponding to the land area of Europe.[49] Sycamores were selected since they grow well in temperate climates and require very little rainfall.[50]

Locating suitable land of this magnitude would present a formidable obstacle. Thirty-eight percent of the world's total land surface is already covered by trees. Much of the remaining unpopulated land area consists of sand, rock or ice or is used for food production.[51]

An additional impediment to the forestation of sycamore trees is that such a scheme would call for an estimated 17 million tons of nitrogen; roughly thirty percent of the world's current production of this fertilizer.[52] As was discussed earlier in this article,[53] if world production and use of nitrogen fertilizers were forced to increase, large quantities of nitrous oxide, another greenhouse gas, would consequently be released into the atmosphere.

b. Forestation with Leucaenus Trees. Far more effective in absorbing carbon dioxide than sycamores are leucaenus trees. Only one-fourth of the acreage required by sycamore trees is required by leucaenus trees to achieve the same effect.[54]

The problem with planting a leucaenus forest, however, is that these trees grow well only in tropical land areas and would require sixty inches of rain per year. Assuming the planting region to have a climate resembling that of Hawaii, an irrigation system would be necessary requiring a capital investment of up to $260 billion (in 1980 dollars) and annual operating expenses of up to $34 billion. Adding to this the initial cost of land, an investment

48. *See generally* D. GREENBERG, SEQUESTERING (1982) (draft report prepared for the EPA available in the office of the *Columbia Journal of Environmental Law*).

49. EPA STUDY, *supra* note 8, at 407 (citing F. DYSON, CAN WE CONTROL THE AMOUNT OF CARBON DIOXIDE IN THE ATMOSPHERE? (1976)).

50. *Id.* at 606.

51. *Id.* at 607.

52. *Id.* at 608.

53. *See supra* notes 22-23 and accompanying text.

54. EPA STUDY, *supra* note 8, at 6-10.

of at least $400 billion might be required.[55] This does not even consider the additional costs of pesticides and maintaining nurseries.

While leucaenus trees would not require any nitrogen fertilizers, they would require over 10 million tons of phosphate. The primary sources of phosphate rock are located in the United States and Morocco. At current rates of consumption, known reserves would last for approximately twenty years. If phosphate were needed to foster leucaenus forestation, reserves would be depleted many years sooner.[56]

There is an additional problem concerning any forestation scheme regardless of any tree species involved. Planting on fallow land could significantly reduce the earth's albedo or reflective characteristics if not offset by other factors, including increased transpiration. As a result, more of the sun's heat could be absorbed by the earth's surface. If the earth's albedo were reduced by 20% through forestation, the resulting global temperature rise could be as great as that caused by carbon dioxide over a seven year period at current rates of emission.[57] However, there is much further work to be done to determine if other species or other patterns of forestation can be used effectively, either alone or in conjunction with other strategies, to reduce net CO_2 output.

2. Tropospheric Release of Sulfur Dioxide

The Soviet meteorologist Budyko has suggested that as an alternative to reducing the output of carbon dioxide into the atmosphere, the greenhouse effect might be neutralized by the addition to the troposphere of an anti-greenhouse gas such as sulfur dioxide.[58] While carbon dioxide intercepts radiation which would otherwise have escaped into outer space, sulfur dioxide would absorb incoming radiation which would otherwise have passed to the earth's surface.

It has been estimated that to offset the effect of a carbon dioxide doubling, roughly thirty-five million tons per year of sulfur dioxide would have to be released into the troposphere. This

55. EPA STUDY, *supra* note 8, at 6-11 (citing HAWAII NATURAL ENERGY INSTITUTE, GRAINT LEUCAENA (KAO HAOLE) ENERGY TREE FARM (Brewbaker ed. 1980).

56. *Id.* at 6-9.

57. GREENBERG, *supra*, note 48.

58. EPA STUDY, *supra* note 8, at 6-13 (citing Budyko, *The Method of Climate Modification*, 2 METEOROLOGY AND HYDROLOGY 91 (1974) (in Russian).

would require 750-800 daily airplane flights at a total cost of approximately $21 billion per year (in 1983 dollars).[59]

Overall, this suggestion is quite troublesome because years of experience in environmental sciences have demonstrated that wholesale attempts to alter the environment almost inevitably create drastic and uncontrollable adverse effects. For example, this process may well stimulate increased acid rainfall, or affect chemical reactions in the stratosphere, resulting in a two- or three-fold increase in the atmospheric concentration of the greenhouse gas nitrous oxide.[60] Much more research, therefore, is needed before this approach could ever be considered to be safe or effective.

3. Scrubbing Carbon Dioxide from Gas Streams

With the use of liquid solvents or solid absorbents, carbon dioxide can be effectively removed from smokestack emissions. The recovered carbon dioxide can be converted into gas, liquid or solid blocks and then deposited deep into the ocean, where natural currents will carry it to the lower depths.[61]

The Brookhaven National Laboratory examined several alternatives for scrubbing and disposal of carbon dioxide from smokestack emissions. Among these, the control option which seemed the most feasible used the chemical solvent monoethanolamine.[62]

Even the monoethanolmine option, however, appears prohibitively expensive. In addition to the capital costs of a monoethanolamine control system (estimated at $50-300 million per plant in 1980 dollars), the Brookhaven National Laboratory has deter-

59. EPA STUDY, *supra* note 8, at 6-12 (citing Boccker, SO_2, Back Stop Against a Bad CO_2 Trip? (1983) (unpublished manuscripted).

60. *Id.*

61. For a broader discussion of carbon dioxide disposal schemes, *see* STEINBERG, *supra* note 4, at 49-50.

Rather than being discarded, the chemically scrubbed carbon dioxide might be put to use. For example, it has been suggested that the recovered carbon dioxide be pumped into depleted oil wells where the consequent added pressure would force untapped reserves to the surface. Shell, *supra* note 34, at 33.

Carbon dioxide in liquid form can be very useful as an aid to coal mining. Liquid carbon dioxide can be used both in the blasting process and as a medium in which to transport coal through pipelines. STEINBERG, *supra* note 4, at 55.

62. Other liquid solvents that the Brookhaven National Laboratories have considered are water, aqueous sodium carbonate, aqueous potassium carbonate, sodium hydroxide, diethanolamine, methanol, N-methyl-pyrolidine, propylene carbonate, amonia, alkazid and sulfinol. Solid absorbents which were considered included clays, zeolites, waste oil shale, silicon, molecular sieves, coal, charcoal and carbon. STEINBERG, *supra* note 4, at 18, 20.

mined that if fossil fuel is used to supply the necessary energy for the scrubbing process, the effective capacity of power plants would drop by up to one third to achieve 50% carbon dioxide control and by up to two thirds to achieve 70% control.[63] Since such a loss of power would be intolerable, non-fossil energy such as solar or nuclear power would be necessary to meet the energy requirements of such an operation. The cost of nuclear reactors sufficient to provide this energy need would amount to $200 billion (in 1981 dollars).[64]

4. CO_2 Recycling Power Plant

Another method of limiting the emission of carbon dioxide from fossil fuel plants would be to burn coal with oxygen and recycled CO_2. Prior to combustion, nitrogen would be separated from oxygen in an air liquification plant. Then, enough CO_2 would be recycled to maintain a combustion temperature equivalent to that of a normal air (oxygen and nitrogen) flame.[65]

A study conducted by Steinberg and Horn in 1981[66] indicated that the energy requirement for such a recycling operation would be much lower than that for monoethanolamine scrubbing. Further research on this option is necessary to determine both the best conditions for the combustion of coal in oxygen and carbon dioxide and the most efficient method of separating oxygen from nitrogen.

B. *Energy Policies*

The majority of proposed regulations to insure against a greenhouse warming directly or indirectly have an impact on fossil fuels. An indirect approach might consist of a general tax on fossil fuel consumption with the objective of reducing demand. Another possibility is reversing some of the tax incentive programs created during the world oil shortage crises that prompted the use of fossil fuels. The most direct method would involve en-

63. Costs would be even greater at plants far from large bodies of water. EPA STUDY, *supra* note 8, at 6-4 (citing ALBANESO & STEINBERG, ENVIRONMENTAL CONTROL TECHNOLOGY FOR ATMOSPHERIC CARBON DIOXIDE 44 (1980) (prepared for the U.S. Department of Energy)).

64. STEINBERG, *supra* note 4, at 19.

65. *Id.* at 33.

66. STEINBERG, *supra* note 4, at 33 (citing HORN AND STEINBERG, A CARBON DIOXIDE POWER PLANT FOR TOTAL EMISSION CONTROL AND ENHANCED OIL RECOVERY (Aug. 1981) (BNL 30046).

forced limitations or outright bans on the use of high carbon dioxide producing fuels.

1. Taxation of Fossil Fuels

It has occasionally been suggested that a reduction of carbon dioxide emissions be effected by taxing each type of fuel proportionately to its net carbon dioxide emissions per unit of energy. One such tax schedule, which has been analyzed by the Office of Policy Analysis of the U.S. Environmental Protection Agency, is substantially as follows:[67]

Fuel Type	Tax (Percent)
Unconventional (Shale) Oil	100%
Synthetic Gas	86
Synthetic Oil	81
Coal	52
Conventional Oil	41
Conventional Gas	29
Unconventional Gas	29
Others (solar, hydro, nuclear, etc.)	0

According to EPA calculations and projections, this tax schedule, specified to double the cost of the fuel releasing the greatest amount of carbon dioxide, would not have a sufficient effect on energy demand to delay a 2°K rise by any measurable length of time. Even if tax schedules of twice this severity were implemented in every country in the world, a 2°K warming might be delayed by a mere five years. The economic penalty for achieving this minor global effect[68] would be an average rise in regional energy prices of approximately 20% for solids, 40% for gas and 60% for liquids.[69] Further, more than a mere delay in temperature rise is needed if the greenhouse effect is to be avoided entirely.

2. Reversing Fossil Fuel Tax Incentives

In response to the world-wide oil shortage in the mid-1970's, a number of legislative programs to promote greater utilization of

67. EPA STUDY, *supra* note 8, at 4-27.
68. Before addition of the tripling taxes.
69. *See* EPA STUDY, *supra* note 8, at 4-27 to 4-31.

coal were created.[70] These included a variety of coal-gastification incentive schemes.[71] Reduction in coal usage mandates reversal of these programs. Acid rain control legislation furthers this same end by seeking to reduce coal consumption.[72]

Future incentive programs should be aimed at fuel technologies with minimal environmental impacts. The alternative fuel source research and development grants of the 1970s were certainly a positive movement along this line.[73] So too were tax credit programs encouraging conservation.[74]

3. Direct Methods of Control

The most direct method of setting a limit on global carbon dioxide emissions would consist of a ban on specified fossil fuels.[75] As indicated in the table above,[76] the fuel types which produce the greatest amount of carbon dioxide are shale oil, synthetic gas, synthetic oil and coal. The EPA has therefore analyzed four different scenarios for fossil fuels bans: a) shale oil only, b) coal

70. For example, the Energy Supply and Environmental Coordination Act of 1974, Pub. L. No. 93-319, 88 Stat. 246 (1974), gave the President the power to order coal conversion of any facility except powerplants and the power to waive compliance with stationary source requirements of the Clean Air Act where noncompliance was due to the unavailability of certain fuel types. In addition, Title III of the Energy Tax Act of 1978, Pub. L. No. 95-618, 92 Stat. 3174 (1978), gave tax credits for coal conversion of businesses.

71. *See, e.g.*, the Synthetic Fuels Act of 1980, 94 Stat. 66 (codified at 42 U.S.C. § 8701 (1982)) which established the Synthetic Fuel Corporation which was to have a production capacity of 2,000,000 barrels per day by 1992. However, in 1985 the House Committee on Energy and the Environment reported the Synthetic Fuels Fiscal Responsibility Act which would eliminate the Synthetic Fuels Corporation and reduce the size of the synthetic fuels program. H.R. 935, 99th Cong., 1st Sess. (1985).

72. *See, e.g.*, the following acid rain control bills introduced in the most recent session of Congress: S. 52, 99th Cong., 1st Sess. (1985) (by Stafford); S. 283, 99th Cong., 1st Sess. (1985) (by Mitchell); S. 503, 99th Cong., 1st Sess. (1985) (by Solomon); H.R. 1030, 99th Cong., 1st Sess. (1985) (by Conde); H.R. 1162, 99th Cong., 1st Sess. (1985) (by Conde).

73. *See, e.g.*, Geothermal Energy Research, Development, and Demonstration Act of 1974, Pub. L. No. 94-410, 88 Stat. 1079 (1974); Solar Energy Research, Development and Demonstration Act of 1974, Pub. L. No. 93-473, 88 Stat. 1437 (1974); Solar Heating and Cooling Demonstration Act of 1974, Pub. L. No. 93-409, 88 Stat. 1069 (1974); National Energy Conservation Act of 1978, 92 Stat. 3206 (1978) which promoted conservation and alternative energy utilization; Biomass Energy and Alcohol Fuels Act of 1980, 94 Stat. 683 (1980).

74. *See, e.g.*, Energy Tax Act of 1978, Pub. L. No. 95-618, 92 Stat. 3174 (1978). The Act provided residential tax credits for the use of wind, solar or geothermal energy production technologies in homes. It also gave businesses tax credits for oil and gas conservation.

75. With possible exemptions for plants with scrubbers.

76. *See supra* text accompanying note 67.

only, c) joint bans on coal and shale oil, d) joint bans on shale and synfuel.

a. Ban on Shale Oil. Even though shale oil releases a greater amount of carbon dioxide per unit of energy than any other fossil fuel, the EPA has determined that its ban would not significantly delay a 2°K warming. The increased demand for liquid fuels which would result from a shale oil ban could easily be satisfied by an increase in production of synthetic oil. The net effect of such a substitution on atmospheric temperature would be an extremely slight magnitude.[77]

b. Ban on Coal. The EPA has predicted that a ban on coal phased in effect over the next twenty years would delay a 2°K warming by fifteen years. Such a ban would also prohibit the production of synthetic fuels based on coal. As a consequence, synfuels would thereafter be limited by the availability of biomass.

Heavy biomass reliance may have some undesirable consequences. The cost of producing synfuels based on biomass may result in a substantial increase in the price of solid fuels.[78] Moreover, the burning of biomass would also release substantial quantities of carbon dioxide. In calculating the fifteen year global warming delay that would result from a ban on coal, the EPA completely ignored the carbon dioxide released in biomass burning,[79] making the unwritten assumption that such an effect would be entirely offset by a concurrent effort at forestation.[80]

In any event, much of the effectiveness of a coal ban would probably cease by the middle of the twenty-first century as shale oil production would expand to meet world energy demands.[81]

c. Joint Bans on Coal and Shale. According to EPA estimates, a joint ban on coal and shale oil could delay a 2°K warming by as much as twenty five years.[82] Such a joint ban would result in an early reduction in carbon dioxide emissions due to the immediate phasing out of coal. Carbon dioxide emission rates would remain

77. *See* EPA STUDY, *supra* note 8, at 4-37, fig. 4-14.

78. *See id.* at 4-35, 4-36.

79. *See id.* at 4-27.

80. Telephone interview with Steven Seidel of the United States Environmental Protection Agency (Feb. 1985).

81. EPA STUDY, *supra* note 8, at 4-36.

82. Once again, however, the EPA assumes that carbon dioxide emissions from biomass burning will be offset by forestation. Telephone interview with Steven Seidel, *supra* note 79.

low during the twenty-first century since a phasing in of the use of shale oil would also be prohibited.

While a joint ban on coal and shale would result in a significant delaying of the greenhouse effect, there are three reasons why any plan eliminating all use of coal would border on the politically impossible. First, coal-fired power plants have a relatively long life and those under construction may still be operative by the year 2050. It would be extremely difficult and costly to convert such a plant to non-fossil fuels.

Second, such a ban would create an unequal distribution of costs and benefits among the nations. Eighty-two percent of the world's coal reserves are concentrated in the United States, the Soviet Union and China. These countries would have to share a loss in coal revenue of $1-2.5 trillion (in 1980 dollars).[83]

Finally, an international agreement would be imperative. Since fifty-seven percent of the world's coal reserves are in the Soviet Union and China, a unilateral effort by the United States would be inadequate.[84]

d. Joint Bans on Shale and Synfuel. Far more feasible than a ban on coal would be a joint ban on shale oil and synfuels. The initial cost of such an undertaking would be very low, consisting merely of the loss of research and development costs. Regions with large deposits of shale and coal would be the most heavily "burdened" by the plan, but this lost revenue would not be incurred until the middle of the twenty-first century when these fuel resources might otherwise have come on line.[85]

EPA projections have indicated that a joint ban on shale and synfuels might have a significant effect in reducing carbon dioxide emissions by the year 2100. Short range climatic effects of such a plan, however, would be very slight. The EPA estimates that a total ban on shale oil and synfuels would only delay a 2°K warming by five years.[86] EPA's assessment that little can be done to halt a warming of about 2°K appears to be consistent with other studies. For instance, Goldemberg, in a study promoting the use

83. EPA STUDY, *supra* note 8, at 5-6.

84. *Id.* at 5-2 to 5-6.

85. A joint ban on shale and synfuel would not significantly affect fuel supply until the year 2050. By that time, some of the increased demand for fuel might be met by increased reliance on fuels which produce no carbon dioxide, such as nuclear, wind and solar energy. *See* COUNCIL ON ENVIRONMENTAL QUALITY, GLOBAL ENERGY FUTURES AND THE CARBON DIOXIDE PROBLEM 68-70 (1981).

86. EPA STUDY, *supra* note 8, at 5-14, 5-15.

of renewables and conservation, concludes that preventing a 1.5°K warming is impractical.[87] However, if an even greater warming trend were detected, it might be more economically or technically feasible to delay such a trend. In that case, the question would become "can we prevent a 2-4° warming?"

V. CONCLUSION

In light of the considerable uncertainties likely to remain for some years in greenhouse modeling, it is unlikely that any costly action specifically taken to inhibit CO_2 output could survive political and legislative review. In the alternative, then, the following actions are possible:

1. to consider low-cost actions to begin reducing CO_2 output or increase CO_2 uptake, such as banning shale oil and synfuels.
2. to embark on pilot projects for more expensive actions, such as pilot reforestation programs to better identify appropriate species and planting strategies.
3. to implement legislation reducing fossil fuel use and increasing energy efficiency, premised largely on the more apparent and immediate benefits of these programs, but incidentally, on their potential for reducing CO_2 output.
4. to increase funding for data collection and research in order to develop better models of the greenhouse effect, and to detect the nature and extent of climatic changes resulting from increasing levels of concentration of carbon dioxide in the atmosphere.

87. Goldemberg, Johansson, Reddy & Williams, *An End-Use Oriented Global Energy Strategy*, 10 ANN. REV. OF ENERGY 613, 678 (1985).