NOW, THINK OF ADAPTATION

Paul E. Waggoner*

I. INTRODUCTION

Once upon a time an opponent challenged Abraham Lincoln to a duel. As a lawyer acquainted with many fine points, the Rail Splitter recalled that the challengee had the right to choose the weapons. He chose axes. The challenger withdrew.[1] So at a law school, I recall that the challengee, in this case the keynote speaker, can also choose the ground for the duel. The ground I choose is,

RESOLVED:
THE TIME HAS COME TO THINK OF ADAPTATION.

If we were to argue whether it is more prudent to concentrate on effects than causes of global warming, the discourse would be a predictable confrontation among disciplines, all giving fair representation to their specialties. On the other hand, the disciplinarians—biologists, social scientists and lawyers—can all think of adaptations. If my argument succeeds and my resolution is adopted, the outcome will be more tangible than the hollow word victory awarded to scholars debating the causes and impacts of global warming. Hence, I submit by my resolution that the time has come to think of adaptation.

II. DEFINITIONS

I begin with definitions, aided by Figure 1. I have written yield on the vertical axis and show it rising with time, as in fact crop yields have for more than half a century. A similar figure has been drawn by economist Richard Cooper[2] with the vertical axis Real Income, and most will want to think of Figure 1 as showing rising Real Income. Figure 1 envisions four paths of change in Yield or Income during the Time of a climate change. The top curve represents changes when climate is *UNCHANGED*, and the bottom curve represents changes when climate *SUFFERS* a harmful change. One of

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*Distinguished Scientist, Connecticut Agricultural Experiment Station, and Chairman, Adaptation Panel, National Academy of Sciences, National Academy of Engineering and Institute of Medicine.

1. Apocryphal.

2. Richard Cooper's chart is reproduced in Comm. on Sci., Eng'g, and Pub. Pol'y, Nat. Acad. of Sci., Policy Implications of Greenhouse Warming—Synthesis Panel 29 (1991) [hereinafter "Synthesis Panel Report"].

the intermediate curves depicts the outcome of measures to *MITIGATE* the climate change, and the other intermediate curve (*ADAPT*) depicts the outcome of adaptation.

Putting the curve for *UNCHANGED* climate at the top assumes the present climate is a good one. As time passes in this good climate, the impacts of other factors raise Yield or Income. The impact of all factors but climate is the difference (long and jointed arrow T) from the start on the left to the top of the *UNCHANGED* curve on the right at the longest Time. One mnemonic for impact T is 'technology,' but another is 'total,' signifying the impact of all the factors but climate that raise either Yield or Income as time passes.

Assuming climate change is harmful, I show *SUFFER* as the lowest curve. On the right at the longest Time, the difference in Yield between the top and bottom curves shows the integral over years of (climate change in °C per year) times (the sensitivity of the crop in Yield T/ha per °C). The distance in Yield from the top *UNCHANGED* curve down to *SUFFER* climate change is the impact C of climate change. Sensitivity is defined as the change-ability T/ha per °C of a crop or $ per °C of income. Therefore, the impact is the integral of the sensitivity multiplied by the climate change, year by year; or in other words, *impact is sensitivity times change.* In the end, the size of the sensitivities and changes in the other factors will make the impact C of climate change either small or large on the scale of all issues confronting humanity.

Mitigate means we emit no more greenhouse gases. To depict the hobbling of farmers by restricting fertilizer to slow emission of the greenhouse gas nitrous oxide, I draw the Xs of *MITIGATE* rising slowly at first. But I assume that, in the end and in net, mitigation of climate change is beneficial, and I have drawn *MITIGATE* rising until the impact M of mitigation measured from the base of *SUFFER* is a positive one. For income, the hobble might be the cost of eliminating coal. However, if I set aside the hobbles by mitigation, I can draw *MITIGATE* coinciding with *UNCHANGED* at the top of the graph, which makes impact M exactly as large a positive as impact C is negative. If instead mitigation measures do hobble Yield and mitigation is not needed because climate change does not occur, the impact M should be measured down from *UNCHANGED* and be negative.

Adaptation means we change sensitivity. Visualize adaptation modifying the T/ha per °C or the $ per °C during the half century while climate is changing °C per year. Then curve *ADAPT* lies between *UNCHANGED* and *SUFFER*. By the middle of the next century, adaptation may make the T/ha impact on Yield by the °C climate change either a smaller loss or a bigger gain. Adaptation may make the $ per °C a smaller loss or a bigger gain. *For the harmful change of climate depicted in Figure 1, the integral of adaptations in sensitivity integrated over Time is the impact A of adaptation.*

Finally, I have placed impact I in the lower left, which is measured down from the present level. For yields, impact I would be the impact on a farmer dumbly suffering climate change and missing all the other changes raising neighbor's yields. This is the impact calculated from the implausible dumb farmer scenario.[3] In other words, I is the impact on income of scenarios of harmful climate change and dumb people. Impact I matters if among all factors, climate is the limiting one. It also matters if we hold the world steady for a laboratory experiment allowing only the climate to change. In the unlikely event that only climate limits affairs or that we devote the planet to a controlled climate experiment, the impact I will represent the blow of climate change. *Impact I is the harm calculated for the imposition of future climate on dumb farmer's crops or on dumb people's income.* The doubling of food production during the past half century proves farmers are not dumb, and the rise in income since the Stock Market Crash of 1929 proves people are not dumb. Impact I doesn't matter.

Note that I have drawn curves for yield, not impact as Ralph d'Arge has done.[4] d'Arge shows how impact would be first positive and then negative if the climate changed through a beneficial realm into a harmful one. My Figure 1 deals only with a harmful change. If the change were first beneficial and then harmful, the *SUFFER* curve for example would first rise above and then fall below the *UNCHANGED*. On the other hand, if the climate change were *always beneficial*, the *SUFFER* curve would always be *above UNCHANGED*. In addition, profitable adaptation to an *unmitigated change* in a salutary climate would move the *ADAPT* curve higher still. Of course, saying *an unmitigated change* to a better climate is paradoxical because mitigate connotes moderating the severity of that which is distressing. Thus, the expression mitigation of climate change, like the curves on Figure 1, implies that climate change will harm when, in fact it may help. Nevertheless, the implications of the graph and saying *mitigation* are reasonable to people who are averse to risk.

III. TWO CONSEQUENCES OF DEFINITIONS

The definitions permit two conclusions. First, the relative importance of climate change to an activity depends on its sensitivity to climate and other factors, and on the rates of change of climate and other factors. Big changes in other factors and high sensitivities to those other factors lower the relative impact of climate change.

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3. Comm. on Sci., Eng'g and Pub. Pol'y, Nat. Acad. of Sci., Policy Implications of Greenhouse Warming—Adaptation Panel 16 (1991) [hereinafter "Adaptation Panel Report"].

4. Ralph C. d'Arge et al., *Carbon Dioxide and Intergenerational Choice*, 72 Am. Econ. Rev. 251, 253 (1982).

Second, if the sensitivity to climate remains unchanged by adaptation or passing into a new realm of climate, the impact of climate change is simply the constant sensitivity times the change in climate from the beginning to the end of a period.[5] In this last case, studies of sensitivity can be separated from scenarios. While meteorologists are perfecting climate models, this separation of studies of sensitivity from scenarios allows other scientists to get on with the work of investigating sensitivities to be multiplied by future, more definite scenarios of change.

VI. SIDESTEPPING SCENARIOS

Before I can sidestep scenarios by separating studies of sensitivities and adaptation, I must deal with the proviso that climate not pass into a new realm, rendering the studies irrelevant. After all, the sensitivity of a tomato to a degree cooling at 5°C is irrelevant at 0°C, where it freezes. The sensitivity of a 1 meter wall to a sea rising 90 cm up the wall is irrelevant when the sea rises 110 cm and it floods over.

So while I can sidestep precise climate scenarios, I cannot dodge the sort or order, which I call the realm, of climate change. Three realms are enough to judge whether climate change is negligible, considerable or impossible to cope with. Three realms are enough for people to decide whether they should ignore climate change, think of adaptation, or fear all is lost. One realm is inconsequential change, another is cataclysmic change, and the third is a degree or two warming with accompanying changes in precipitation.[6]

The realm of inconsequential change seems unlikely. Uncertainties about global warming include a mismatch of the rising greenhouse gases with the warming since the 19th century, the possibility that other forces oppose a warming, and the imperfection of complex models of global circulation. Against these qualifications stand the irresistible rise of greenhouse gases and their sure absorption of infrared. I pass by the realm of inconsequential change.

Cataclysmic change is possible. Warming could melt ice beneath the tundra, release methane, and amplify greenhouse warming. More fresh water running into the polar oceans and a smaller difference between polar and equatorial regions could change ocean currents and a polar ice sheet could

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5. More formally, if the sensitivity to climate is unchanged by adaptation or passing into a new realm of climate, for example, the impact of climate change is simply the constant sensitivity A (climate) times the change in climate, which is the integral of d(climate)/dt.

6. By the way, a scenario of climate cooling was proposed during the 1970s during examination of supersonic transport. Because cooling was then figured more harmful than warming, citizens may be grateful that the scenario of cooling can now be neglected. Ralph C. d'Arge, *Climate and Economic Activity*, *in* Proceedings of the World Climate Conference WMO No. 537, 654 (1979).

melt. While being alert for these events is sensible, "[n]o credible claim can be made that any of these events is imminent."[7] Mixing the merely possible with the probable depreciates the probable because if all things are possible nothing is probable. Similarly, forecasting a storm every day protects a forecaster's rear but devalues his currency fast. I do not enter the realm of cataclysmic events.

The realm of a degree or two warming with accompanying changes in precipitation remains. It lies within the range of scenarios put forth for more than a decade (e.g. 1 to 5 °C)[8] although at the lower end. Warming of a degree or two would be reached on the way to a warmer climate. Rather than investigating a hotter climate that may never be reached, I find it more worthwhile to explore the realm of warmer by a degree or two.

To compare impact and adaptation I can sidestep scenarios, but I must pin-point the realm I am considering. I am thinking of a degree or two warming, a realm that the planet is likely to enter, even though it may eventually pass on to another, either warmer or cooler.

V. PREDILECTION FOR PREVENTION

Before I can convince the reader to think about adaptation, I must face up to the inclination to avoid the risk inherent in change and think only of mitigation. Humanity, of course, has nowhere else to go and hence fears whatever puts the planet at risk. Climate change is easily seen as putting the planet at risk.

First, climate change by degrees Celsius is unknown in historical times, and the unknown is especially frightening. Second, people fear any change will take what they have. Andreas Teuber illustrates the change in attitude to risk with the example of insurance.[9] Insurance began as a short-term bet on the life of a third party, like the pope. Matters changed with the arrival of a new group with newly acquired wealth who had something to lose if their fortunes reversed. For example, the prospectus of an eighteenth century society for the assurance of lives advertised insurance by playing upon the anxieties of family members. The prospectus made much of the "catastrophe of being catapulted out of the middle ranks of society," which they had struggled hard to attain by "dint of their own industry and thrift."[10]

In this century the physical well being of people has improved, and they naturally fear being catapulted out of that prosperity by any change on the planet. This apprehension about any change helps explain why in the 1970s

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7. Synthesis Panel Report, *supra* note 2, at 24.

8. *See, e.g.*, Nat. Acad. of Sci., Changing Climate 266 (1983); Synthesis Panel Report, *supra* note 2, at 17-20.

9. Andreas Teuber, *Justifying Risk*, 119(4) Daedalus 235 (1990).

10. *Id.* at 235.

we feared a climate cooled by supersonic transports, and in the 1980s we feared a climate warmed by greenhouse gases. People easily see any climate change as putting the planet at risk.

Historically, once people decide that climate change puts the planet at risk, their actions are dictated by their perception of the concept of risk.

> [I]n the eighteenth century the analysis of risk had important uses in marine insurance. The chances of a ship coming safely home and making the fortune of its owner were set against the chances of its being lost at sea, bringing ruin. The idea of risk in itself was neutral; it took account of the probability of losses and gains.
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> [Now], however, the risk that is a central concept for our policy debates has not got much to do with probability calculations. The original connection is only indicated by arm waving in the direction of possible science: the word *risk* now means danger; *high risk* means a lot of danger.
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> Whereas originally a high risk meant a game in which a throw of the die had a strong probability of bringing great pain or great loss, now *risk* refers only to negative outcomes. The word has been preempted to mean bad risks.[11]

Mary Douglas concludes that risk is now a forensic resource, something that can be referenced for help in the forum. Thus, no one should be surprised that 20th Century people are predisposed to see change as risk, equate risk with bad, and thus concentrate on preventing change rather than on its effects.

VI. ENCOURAGING PREVENTION IS HARD

Although people have a predilection for prevention, no one should be surprised that down-right, premeditated prevention is hard to achieve. No one should be surprised at a national panel sensing the difficulty and writing that their "recommendations are generally based on low-cost, currently available technologies."[12]

Mitigation is anticipatory. It is premeditated. The need to prevent the change *before* it happens and before it is seen and suffered makes it a chancy investment and raises an obstacle. Helen Ingram, Hanna Cortner and Marc Landy[13] wrote that only issues that were serious, certain, soon, caused by a

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11. Mary Douglas, *Risk as a Forensic Resource*, 119(4) Daedalus 2-3 (1990).

12. Synthesis Panel Report, *supra* note 2, at 72.

13. Helen M. Ingram, Hanna J. Cortner and Marc K. Landy, *The Political Agenda, in* Climate Change and U.S. Water Resources 421 (Paul E. Waggoner ed., 1990).

sinner, and soluble won places on the agenda for action. If climate change will be harmful, it is serious. Although I choose the realm of a degree or two warming, the change is still not certain. The conventional forecast of warming by the middle or late twenty-first century is not soon. Singling out a sinner is hard. Although CFCs can be blamed on an industry, the greater greenhouse gas, CO_2, is emitted by good people enriching their nations and warming their nests.[14] The emission of the preeminent greenhouse gas, CO_2, is entwined with economic well-being.

> [P]erhaps the best measure of a nation's industrialization is its energy consumption from modern forms (that is, coal, petroleum, natural gas, and hydroelectricity, but not wood), since it is an indication both of a country's technical ability to exploit inanimate forms of energy and of its economic pulse rate.[15]

The headline "Heavy Energy Tax is Proposed to Curb Emissions in Europe"[16] runs counter to the theory of things not soon or certain winning a place on the agenda, and counter to the reality of national competition. Nevertheless, the subhead goes on to state "Industries are Strongly Against the Surcharge," and the story reports the fears of industries fleeing to countries without the heavy tax.[17]

One can hope humanity will lessen the emission of greenhouse gases. For example, premeditated prevention of climate change didn't slow the growth of the burning of coal and oil or speed the greater use of natural gas and nuclear plants.[18] Neither did it spur weather stripping and insulation during the late 1970s to save money, the banning of CFCs to protect stratospheric ozone, the promotion of mass transit to clean air in cities. Nor did it collapse the economies in Eastern Europe and the former USSR.[19] Nevertheless, all of the above acted to mitigate the emission of greenhouse gases. Therefore, while hoping that other factors will mitigate the emission of greenhouse

14. Business and industry are frequently blamed for problems, making them the sinners. Exemplifying the search for sinners, a panel of 402 citizens was examined by the Public Agenda Foundation of New York. Their conclusion, in an August 15, 1991 letter by Deborah Wadsworth of the Foundation, is that "[t]here is strong resistance to measures which would require people to change their driving habits or pay more for gas to help reduce carbon dioxide. Citizens support only 4 out of 10 proposals involving gasoline consumption, preferring to shift much of the burden of dealing with this issue to business and industry." (on file with the Author).

15. P. M. Kennedy, The Rise and Fall of the Great Powers (1987).

16. P. L. Montgomery, *Heavy Energy Tax is Proposed to Curb Emissions in Europe*, N.Y. Times, Sept. 26, 1991, at D3.

17. *Id.*

18. Thomas H. Lee, *Advanced Fossil Fuel Systems and Beyond, in Technology and Environment* 114 (Jesse H. Ausubel & Hedy E. Sladovich eds., 1989) *citing* A. Grübler and N. Nakicenovic, *The Dynamic Evolution of Methane Technologies, in* The Methane Age, (Thomas H. Lee, H.R. Linden, D.A. Dreyfus and T. Vasko eds., 1988).

19. Matthew L. Wald, *Carbon Dioxide Emissions Dropped in 1990, Ecologists Say*, N.Y. Times, Dec. 8, 1991, at A17.

gases, and while urging still more mitigation, no one should be surprised that down-right, premeditated prevention is hard to achieve.

VII. FIGURING EFFECTS TO JUSTIFY MITIGATION

If readers will now consider the effects of climate change, their first step will be figuring impacts sans adaptation. Even with a predilection for prevention, they will still want to know what harm or impact to themselves and their surroundings mitigation might avert.

Many mitigations may be justified only partly on the basis of climate change. One might not turn off a light to prevent climate change in the year 2050. But in 1991, turning off the light saves money and may diminish acid rain as well as mitigate the emission of a greenhouse gas. In this example, the prospect of climate change partially justifies turning off the light, and it might provide the boost that lifts people over the hurdle of apathy.

Despite the attractiveness of partial justifications, including climate change, they still must add up to a full justification. One could argue that people should turn off a light today for reasons ranging from more efficiency in energy through clearing the air to banning CFCs. But, if these reasons are not convincing enough, does climate change genuinely lift solutions over the existing investment or indifference hurdles? If not, what reasons are convincing enough and what are the real obstacles to them? Like suitors, solutions court problems,[20] and the risk of climatic change could help justify numerous solutions. Winning approval for an unaccepted solution may require the removal of a fundamental obstacle such as cost, convenience, or ignorance rather than formulating an additional justification.[21] Regardless of whether the partial justifications add up to a whole, an impact must be figured to weigh the justification of climate with all other partial justifications.

VIII. SOME HAZARDS OF FIGURING IMPACTS TO ENCOURAGE MITIGATION

Some hazards lie in the path of the person with an eye on mitigation: emphasizing bad over good things; and, overlooking common sense. To his dismay, Jesse Ausubel found the theme that there are only losers from climate change to be sounded again and again as conventional wisdom.[22] An

20. For more on solutions courting problems see Ingram, Cortner and Landy, *supra* note 13.

21. Adaptation Panel Report, *supra* note 3, at 32.

22. Jesse H. Ausubel, *A Second Look at the Impacts of Climate Change*, 79(3) Am. Sci. 210 (1991).

international report on climate change and human health shows the emphasis on bad over good.[23] Its introductory paragraph says humans adapt to climate but warns that adaptation took thousands of years. The other paragraphs on human health are introduced by statements on risk of death from heat waves; risk of more ultraviolet and cancer; poleward movement of disease vectors; changes in water quality and availability, drought and famine; and scarcity of biomass for cooking. After mentioning deaths avoided by warmer winters, the report qualifies that good news by stating that more deaths and illness in the summer would likely exceed the lives saved by warmer winters. The international report does not delve into adaptation, which seems the reason for the surprising fact that fewer die during heat waves in cities in the southern United States than in the North.[24]

A U.S. report on the impact of climate change on agricultural pests also emphasizes bad effects.[25] It predicts climate change will increase survival of insects, extend their range, increase species with more than one generation per year, allow establishment earlier in the year, and substantially raise pesticide use. This and related reports do not mention pests like the fungi that blight potatoes and scab apples that are discouraged by warm, dry weather.

The hazard of overlooking common sense is accepting a "dumb folks scenario."[26] That is, after all the work to anticipate the future climate, an analyst figures impacts on current affairs. For example, he imposes the climate of the year 2050 on 1990 crops. Doing this, the analyst assumes climate changing while also assuming that people dumbly suffer the change without altering their ways.

The unlikelihood of people dumbly suffering without change is shown, for example, by the burgeoning of yield per acre of corn from 16 to 30 bushels during the 1930s up to 80 to 120 during the 1980s.[27] Lest this smart farming should be thought an attribute of industrial nations only, I note that during the same period, rice yields in India and the Philippines more than doubled.

In terms of Figure 1, the impact of climate change is the difference between the heights of the curves on the right side or end of the graph—not on the left or beginning. The impact must be reckoned from the changing sensitivities to climate during the half century, and it must be related to the other impacts. A dumb folks scenario is wrong.

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23. Intergovernmental Panel on Climate Change, World Meteorological Organization, Policymaker's Summary of the Potential Impacts of Climate Change 31 (1990).

24. Laurence S. Kalkstein, *The Impact of CO_2 and Trace Gas-Induced Climate Changes Upon Human Mortality, in* The Potential Effects of Global Climate Change on the United States 535-37 (Joel B. Smith and Dennis A. Tirpak eds., 1990).

25. Benjamin R. Stinner, et al., *Potential Effects of Climate Change on Plan-Pest Interactions, in* The Potential Effects of Global Climate Change on the United States 397-400 (Joel B. Smith and Dennis A. Tirpak eds., 1990).

26. Adaptation Panel Report, *supra* note 3, at 16.

27. United States Department of Agriculture, Agricultural Statistics 1988, 45 (1990).

In the enthusiasm to reach the worthy goal of mitigation lie hazards of emphasizing bad over good things and overlooking common sense. But "science is the great antidote to the poison of enthusiasm and superstition."[28] Therefore, as the study of the outcome of climate change progresses, analyses will surely become more objective and even incorporate adaptations to match climate scenarios for the year 2050 with smart farmer scenarios.

IX. HURDLING THE FIRST OBSTACLE TO ADAPTATION

The path to adaptation is not smooth. The first obstacle to adaptation is reluctance to contemplate it. Steve Rayner pointed out that from the standpoint of those who advocate prevention, "discussion of adaptation to climate change is viewed with the same distaste that the religious right reserves for sex education in schools. Both [adaptation to climate change and sex education] are seen as ethical compromises that will in any case only encourage dangerous experimentation with the undesired behavior."[29]

Indirect costs of adaptations emerging from interactions among activities and from the adaptations themselves are invoked to discourage adaptation. Reasoning from past experience is said to be risky and adaptation adds additional difficulties for developing nations.[30] Since such objections to adaptation are supported by "moral imperatives,"[31] they will not easily be abandoned. If stanching the flow of greenhouse gases proves impractical and climate change grows more likely or becomes manifest and is felt, the hurdle of these imperatives will surely lower. Just as surely, the enrichment of the air with greenhouse gases since the year 1800, its acceleration, and the certainty that the gases absorb the radiation that cools the earth will in the meantime encourage some people to search for adaptations.

X. HOW TO DISCOVER ADAPTATIONS

After seeing some hazards of figuring impacts to encourage mitigation and after hurdling the obstacle of contemplating adaptation, I come face to face with the hard job—actually finding effective adaptations. A panel commissioned by the Council on Agricultural Science and Technology stuffed their ears against distractions and focused on adaptation by asking themselves the question:

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28. Adam Smith, *An Inquiry into the Nature and Causes of the Wealth of Nations V*, pt. 3.3 (1776)(C.J. Bullock ed., 1909).

29. Steve Rayner, *The Greenhouse Effect in the U.S.: The Legacy of Energy Abundance*, *in* Energy Policies and the Greenhouse Effect, II 265 (M. Grubb et al. eds., 1991).

30. Jane Lubchenco, Note, *in* Adaptation Panel Report, *supra* note 3, at 5; *see also* Jessica Mathews, *in* Synthesis Panel Report, *supra* note 2, at 45-46.

31. Rayner, *supra* note 29.

> For a warmer planet with more people, more trade, and more CO_2 in the air, can U.S. farming and forestry prepare within a few decades to sustain more production while emitting less and stashing away more greenhouse gases?[32]

The first phrase begins with the warming that precipitated our thinking about adaptation. If the question had more detail, it would add "for a warmer planet with an uncertain change in the distribution of the extra precipitation caused by the warming." To begin, the first phrase of the question emphasizes the simultaneous changes in other factors, more people and more trade. The world population of some 5 billion seems sure to double to 10 billion during the same decades envisioned for climate change. Although trade in grain and oilseeds stagnated during the 1980s, the U.S. proposals at the current trade negotiations are designed to accelerate trade again. Finally, the phrase "more CO_2 in the air" reminds us that, while CO_2 is a greenhouse gas, it is also the stuff of photosynthesis and crop yields.

The middle phrase, "can U.S. farming and forestry prepare within a few decades to sustain more production" concentrates on preparation. It verily exudes adaptation. Setting a period of a few decades, the phrase matches the period envisioned for climate change.

Concluding with "sustain more production" the question departs from impact studies that worry whether production in the year 1990 would be affected by a climate scenario. The phrase reminds that, by the time climate changes in several decades, 1991 production will be irrelevant. Even if present crop production were entirely eaten by people, the present crop could provide only about 2000 calories per day and could feed no animals for the 10 billion people anticipated in the year 2050. If present diets are to be maintained and improved in the year 2050, the farmers of 2050 must produce more than twice the present crop. They must also continue to increase yield, keeping production in step with population and rising expectations.

The final phrase is "while emitting less and stashing away more greenhouse gases." That phrase reminds that mitigators might require farmers and foresters to do more than single-mindedly grow food. Farming does emit the greenhouse gases methane and nitrous oxide. Although the contribution of greenhouse forcing added by U.S. agriculture is dwarfed by the burning of fossil fuels, farming might be ordered to emit less methane and nitrous oxide. Also, forestry might be commanded to stash away in wood carbon assimilated by photosynthesis from the CO_2 in the air.

The question about farming and forestry set by a panel of the Council on Agricultural Science and Technology illustrates that the search for adapta-

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32. The preparation of farming and forestry for global warming is being studied by a panel commissioned by the Council on Agricultural Science and Technology, Ames Iowa. At the time of this writing, the study was still underway.

tions to climate change will be difficult because it will come amidst other great changes and hobbles and because it will never end. These hardships are the precise reasons to begin the search rather than be dismayed.

XI. WHAT ADAPTATIONS MAY LOOK LIKE

History helps surmount the dismay. Successful adaptations encompass hardware like dams to store water and domes to shelter games. They also encompass software like weather forecasts and flood insurance.[33]

Because adjustment of an entire nation (let alone planet) to a new climate surely will hold surprises not anticipated by even sophisticated models, scientists at *Resources for the Future* studied the outcome of an analogue of climate change—the Dust Bowl years in four Farm Belt states.[34] Starting from an understanding of the region as it is today, they projected the agriculture, forests, water resources, and energy economy to the year 2030. Without climate change, they projected crops would yield about 75% more than now. Imposing the Dust Bowl climate cut yields about 25%, but the accompanying CO_2 enrichment offset about half that decrease. Adaptations, both autonomous—in the sense of being easily accessible and relatively inexpensive to adopt—and policy-driven—prompted by the perception or knowledge of certain climate change—brought yields back almost to the level of no climate change. Or so the analysts estimated.

What inexpensive, off-the-shelf adjustments to the climate of the Dust Bowl were identified by local farm advisors and considered by the analysts of this project? (1) conserving water by fallowing and diking furrows, (2) selecting varieties for longer or shorter seasons or tolerance of more stress, (3) switching from cropping to grazing, (4) shifting planting dates, (5) planting deeper or fewer plants to the acre, and (6) using less fertilizer.[35] These examples remove some dismay about adaptation.

Another class of adaptations concern institutions. Water resources are highly sensitive to climate and are ensnared in complex and long-lived institutions. Generating hydroelectricity is a major use of runoff. In fact, the volume of water that passes through turbines to generate electricity dwarfs all withdrawals from streams, and the volume through turbines is more than twice the average runoff in the United States.[36] Considering the growing competition between hydropower and irrigation in the Snake River Basin as

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33. Jesse H. Ausubel, *Does climate still matter?*, 350 Nature 649 (1991).

34. The studies are frequently referred to by the acronym MINK taken from the names of the states studied: Missouri-Iowa-Nebraska-Kansas. For a report of the study see W.E. Easterling, M. McKenney, N.J. Rosenberg, and K. Lemon, U.S. Dep't of Energy Study, A Farm-Level Simulation of the Effects of Climate Change on Crop Productivity in the MINK Region (1991).

35. *Id.*

36. Wayne B. Solley et al., U.S. Geological Survey, Estimated Use of Water in the United States, U.S. Geological Survey Circular 1004, 44, tbl. 28, at 65 (1985).

an analogue of climate change competition, K.A. Miller found an institutional adaptation.[37]

During summers the Idaho Power Company suffered the double stretch of simultaneous low stream flow and high power demand. Its water rights were ambiguous, and its expansion was foreclosed. It was permitted, however, to buy water. The Snake River Water Bank ("Bank") was set up for the annual rental of water stored in federal reservoirs. At the time of K.A. Miller's study, Bank rules limited water transfers outside of farming uses by a ceiling on the price and an early in the season preference for farmers. Nevertheless, the farmers sold much water to the power company. Changes in Bank policy and operation show that competition for water can evoke adaptations that procure the advantages of markets while simultaneously protecting vested rights.

A water supply is perhaps the preeminent asset for coping with climate change, and markets are commonly recommended for the flexibility necessary to employ or adapt that asset. In the United States, prices generally give the signals and incentives to conserve, increase supply and reallocate scarce resources to the most valued uses. The fundamentals for economically efficient markets are (1) free market exchange of well-defined property rights in open, competitive markets where the buyers and sellers bear all the costs, and (2) marginal-cost pricing by public agencies. However, truly efficient water markets face many obstacles. Water is an integral part of healthy lives and beautiful scenes. In a stream or aquifer it may be considered public—not private—property. Third parties are affected by sales. Nevertheless, the Snake River Water Bank example illustrates a step toward a true market and demonstrates that even water supply is adaptable. Added to many others, the examples of the adaptability of farming and hydroelectricity allay dismay at adapting to climate change.

XII. A WAY TO FACTOR IN CLIMATE CHANGE

After easing dismay about adaptation, I could easily recommend "factor in climate change." The need to factor in is embodied in the conventional wisdom that "waiting to make policy [about climate change] and to take action will drive up the costs of response."[38]

Unfortunately, factoring in climate change is more easily recommended than done. From coast to coast and shore to mountain, managers of water supplies have acknowledged that climate change could harm their systems, but they are not rushing to act. The only adaptation yet taken has been the

37. K.A. Miller, *Water, Electricity, and Institutional Innovation, in* Climate Change and U.S. Water Resources (Paul E. Waggoner ed., 1990).

38. Ausubel, *supra* note 22.

inexpensive raising of a drainage outlet.[39] If *factor in* means *act*, practical people are not factoring climate change in.

Just how a manager would actually *factor in* is murky. Fortunately, Jon Liebman showed how to weigh acting now versus waiting until costs are driven up.[40] His method sets a ceiling on the money that can be justifiably spent now to adapt to climate change rather than waiting until the adaptation is actually needed, even though waiting drives up costs.

Imagine an engineer factoring the rise of sea level into the building of a long-lived bridge over an estuary. He must choose between building the bridge higher now versus waiting until sea level rises and then raising it, probably for more dollars. Essentially, building a higher bridge now is justified if it is cheaper than the present value of the money for later adaptation that may be needed. The ceiling on justified expenditure now is set by the probability that the bridge will have to be raised later, on how long the wait until it must be raised, and on the discount or interest rate. If there is a low ceiling, then little current expenditure can be justified. If there is a high ceiling, much can be justified now.

The probability that a later generation will need to raise the bridge depends both on whether the forecast of rising sea level is correct and whether people still want to cross the estuary. The probability of need incorporates both the accuracy of the meteorologist's forecast of future climate and sea level and the planner's forecast that people will still want to cross at that place.

The length of the wait and the discount rate control the present value of the money spent raising the bridge later if it is needed. Lesser probability of need, longer wait and dearer discount rate all drop the current ceiling justified spending to avoid spending later.

For example, at 6% discount the present value of $1 million for raising the bridge fifty years from now is $54,000. The present value must be multiplied by the probability that people want to cross and the sea rises. If that probability is fully $^1/_2$, then the ceiling on present expenditure to forestall raising the bridge later falls to $27,000. That is, if a smart engineer cannot raise the bridge for less than $27,000 now, he will wait until it must be raised, even though time drives up the cost to fully $1 million.

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39. H.E. Schwarz and L. A. Dillard, *Urban Water, in* Climate Change and U.S. Water Resources (Paul E. Waggoner ed., 1990).

40. Jon C. Liebman's suggestion for justifying adapting in advance rather than waiting to retrofit a structure was incorporated into Adaptation Panel Report, *supra* note 3, at 30.

Mathematically, the ratio ϕ'of justified prior to retrofit cost is $\phi' = P/(1 + i)^n$ where P is the probability of need, i is the discount rate and n is the wait in years until retrofit is needed. The equation explicitly expresses Ingram, Cortner and Landy's thesis that only issues that are serious, certain, and soon evoke action.

XIII. DEDUCTIONS FROM FACTORING IN CLIMATE CHANGE

Deductions flow from this orderly, explicit way of factoring in climate change. First, the chance that the bridge will not need to be raised for a long time—if at all—lowers the ceiling on what can be justified now versus waiting. This low ceiling handicaps premeditated adaptation versus adaptation as needed.

Down-right premeditated mitigation versus adaptation as needed can be evaluated in the same way. Simply replace the cost of raising the bridge now with the cost of mitigation now. This handicaps premeditated mitigation versus adaptation by adjustment. The handicap of a low ceiling on what can be spent now on mitigation makes people wary of costly, premeditated mitigation and spurs their search for cheap mitigation. It spurs their hope that other influences like economy, technology and sparing stratospheric ozone will slow the flow of greenhouse gases and not require that climate change stand alone to justify down-right mitigation.

My second deduction from factoring in climate change is a surprise. It opens jobs for lawyers and policy-makers. The relative effectiveness of more accurate forecasts versus shorter waits can be deduced.[41] Improving forecasts 10% raises the ceiling on justified expenditure 10%. Surprisingly, shortening the wait 10% from 50 to 45 years raises the ceiling three times as much. In general terms, so long as the wait is longer than the reciprocal of the discount rate, shortening the wait raises the ceiling on premeditated mitigation or adaptation more than improving the forecast.

XIV. WORK FOR LAWYERS AND POLICY-MAKERS

When I first factored climate change into decisions, I concentrated on the accuracy of climate forecasts. I put the wait from now until climate changes aside as something set by emissions and the atmosphere. Tantalized by the power of shortening the wait, however, I realized the wait is not from now until climate changes. It is from decision until need. People can shorten the

41. For commonplace discount rates, log (ϕ') is approximately log(P) - (in). So, the elasticity or relative change in the justified ratio per relative change in P is 1 and per relative change in i or n is (in). If i is 6% per annum and n is 50 years, the elasticity of waiting or lower discount rate is fully 3. Hence, the surprise remarked in the text: Improving the probability of the forecast P by 10% only raises the ratio of justified cost 10%, but shortening the wait n by 10% raises the ratio by about a third. In general terms, the elasticity for changing the wait n or discount rate i exceeds the elasticity for changing P when (in) exceeds 1 or n is longer than 1/i. Clearly, the elasticity of changes in i and n are the same. In the text, I concentrate on changes in n because I assume discount rates are given rather than manipulated to encourage or discourage measures for climate change.

wait, lifting the ceiling on premeditated action. Flexibility is a short wait and inflexibility a long wait.

Several recommendations of a recent study[42] of policies for adaptation to climate change, in fact, shorten the wait and impart flexibility. Although "*Monitor the Climate*" might only seem to mean collecting data to test models, it also means wait secure in the knowledge that climate change has not sneaked in. "*Promote Markets*" and "*Advance Regional Mobility*" speed action on news of change, shortening waits between decision and need. Finally, "*Cope with Present Vulnerability*" means fulfill immediate needs, which shortens the wait to zero.

But what work is there for lawyers and policy-makers? Plenty so long as laws, regulations and lawsuits prolong the wait from decision to need. Laws are the preeminent protectors of rights, yet like the mills of God, they grind slowly.[43] The method for factoring in climate change shows that the agent who shortens the hold-up between decision and action lifts the ceiling for a premeditated adaptation even more than the meteorologist or planner who more accurately forecasts the climate for people of the next century.

XV. IN THE END

One can hope that other influences will stanch people's emission of greenhouse gases or that the climate will change to a better one. However, the ceiling on down-right premeditated mitigation of climate change is low. So, the time has come to think of adaptation.

Although discovering adaptations may seem hard, examples show they can be found and will be used. A logical factoring of climate change into decisions discloses the leverage of flexibility—a shorter wait from decision until action. Since institutions as well as physical facts set inflexibility, many sorts of people, especially policy-makers, can call forth the flexibility essential for adapting to a new climate. In the end, the people who discover adaptations and impart the flexibility to adopt them will deserve better of mankind and do essential service to their country.[44]

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42. Adaptation Panel Report, *supra* note 3, at 9-14.

43. "Though the mills of God grind slowly, yet they grind exceedingly small." Friedrich von Logau, 1604-1655: *Retribution*, translated by Henry Wadsworth Longfellow, *reprinted in* John Bartlett, *Familiar Quotations*, Fifteenth and 125th Anniversary Edition (1980) at 273:14.

44. Jonathan Swift, Gulliver's Travels pt. II, ch. VII, Voyage to Brobdingnag (1727). "And he gave it for his Opinion, that whoever could make two Ears of Corn, or two Blades of Grass, to grow upon a Spot of Ground where only one grew before, would deserve better of Mankind, and do more essential Service to his Country, than the whole Race of Politicians put

FIGURE 1

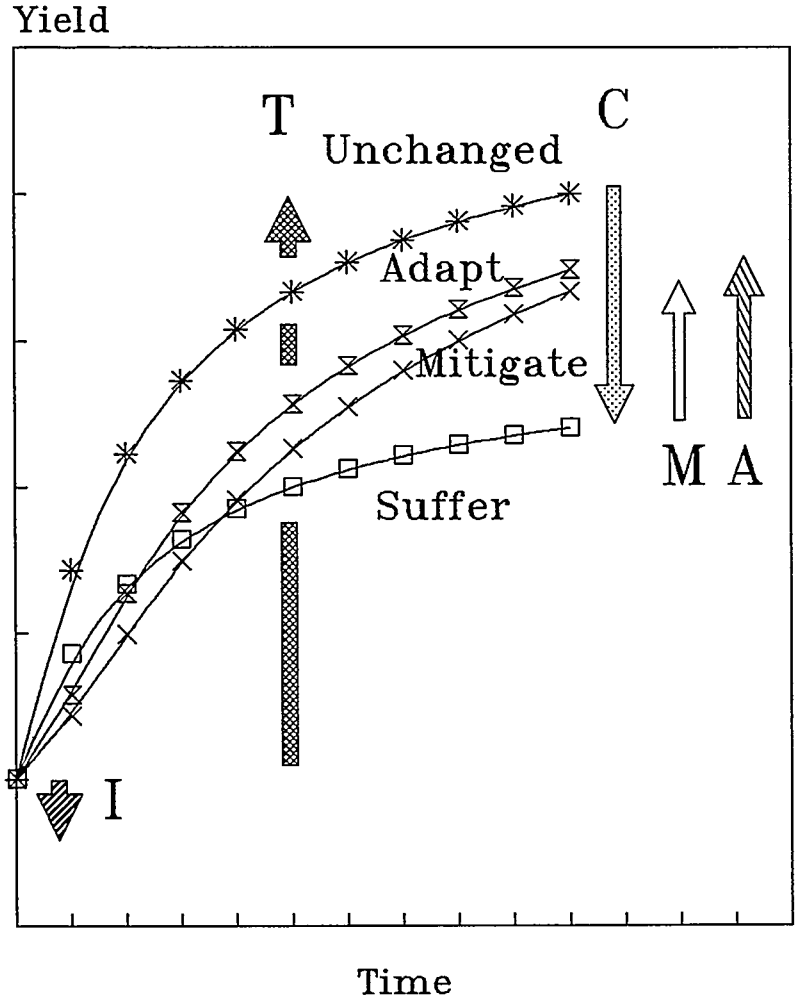

Figure 1. The course of the yield of a crop conceived during the half century or so envisioned for climate change. The top curve marked *UNCHANGED* is the course in a favorable, unchanged climate, and the arrow T measures the impact of all the things, such as technology, that raise yields. The curve *SUFFER* at the bottom is the course of yields if an unfavorable climate is suffered dumbly, causing an impact C. The curve *MITIGATE* represents yield if climate change is stopped by a means that reduces yield. Finally, curve *ADAPT* represents yield if the sensitivity of the crop to the change is reduced.