ACID PRECIPITATION: CONTROVERSY OVER POLICY OPTIONS

F. Perry Sioshansi, Ph.D

Research and Development
Southern California Edison Company
P.O. Box 800
Rosemead, CA 91770

ABSTRACT

Acid precipitation is a complex and controversial issue. Its potential long-term adverse effects on the environment are not fully understood nor scientifically documented. This has resulted in disagreement on the choice of appropriate policy options. This paper develops a systematic and structured framework to analyze the consequences of following alternative strategies. It focuses attention on the major points of contention in the debate and specifically considers the uncertainties involved in the policymaking process. The methodology developed can serve as a tool in evaluating alternative policies and to test the roboustness of alternative assumptions.

1. INTRODUCTION

Acid precipitation (AP) has become one of the most controversial, yet least understood, environmental issues of the 80s. [3] [18] Many ecologists, environmentalists and conservationists contend that AP is "one of the most serious global pollution problems associated with fossil fuel combustion," rivaled only by the buildup of carbon dioxide in the atmosphere. [14, p. 140] AP refers to all forms of precipitation that has a pH[1] of less than 5.6. The 5.6 pH is used as a reference point to represent "natural" or "background" precipitation in an atmosphere removed from anthropogenic emissions.[2]

AP became the subject of extensive scientific research since the 1960s when Scandinavian scientists detected a pattern of increasing acidity in their soils and lakes. They hypothesized a link between an increase in the acidity of precipitation over time and sources of sulfur and nitrogen oxide in industrial Europe. Allegations of the adverse impacts of AP include acidification of sensitive lakes and streams, reduction in the yield of susceptible crops and forests, damage to man-made material and potential human health threat [11] [12] [17] [18].

While it is clear that fossil fuel combustion in the heavily industrialized and urbanized areas has contributed to increased acidity of precipitation, the casual relationship between emissions and alleged adverse impacts of AP are subject to interpretation. [1] [3] [5] [10] Allegations that rain has become more acidic in recent times cannot be substantiated based on the available scientific evidence [8] [9].

The crux of the AP problem is disagreement over three fundamental issues: (i) Whether acid precipitation constitutes a "serious" environmental problem requiring immediate action; (ii) what are the causes of the alleged problem; and (iii) what, if anything, should be done about it given the lack of consensus on (i) and (ii). The policy implications of the AP debate on environmental quality and national -- some would say global -- energy policy are profound, particularly in view of the emphasis placed on increased coal use as a substitute for imported oil. The debate on the choice of appropriate policy options is confused by inaccurate, sometimes misleading, statements made by both opponents and proponents of more stringent regulations. A more detailed version of this paper may be found in [16].

2. POSITIONS AND POLICY OPTIONS

Depending on one's predisposition

Proceedings of the 1982
Winter Simulation Conference
Highland * Chao * Madrigal, Editors

82CH1844-0/82/0000-0043 $00.75 © 1982 IEEE

and particular point of view, AP may appear as a critical environmental hazard with potentially significant --possibly irreversible -- adverse consequences or as a non-issue -- blown out of proportion and greatly exaggerated by doomsday environmentalists -- and everything in between these two extremes.

Since it is not possible to consider many different points of view, in the remainder of this paper we have chosen to focus on two extreme and a moderate, middle-of-the-road position. These positions and the corresponding policies, outlined below, are selected to approximate or simulate three representative points of view. Other positions fall between these extremes and can be analyzed in a similar fashion. A more detailed discussion of these positions may be found in [16].

The "Rush to Judgment" Position This position is based on three premises: (i) AP constitutes a "serious" environmental hazard requiring immediate action; (ii) we know enough about the problem to make sound decisions and; (iii) the opportunity cost of inaction could be so large as to make any control costs justified. Advocates of this approach are in favor of more stringent regulations that would reduce emissions significantly over a short period of time. [15] [18] [19]

The "Acid Precipitation is a Non-Issue" Position This position is based on the belief that there is no scientific basis for alarm and no justification for immediate drastic action. Altogether, those who subscribe to this position contend that there is no reason to conclude that acidity of precipitation has been increasing over the past two decades, and no reason to believe that a reduction in emissions from power plants would have a measureable impact, hence, no need to impose additional regulations at this time based on the information currently available. [1] [3] [5] [10]

The "Wait and See" Position This position is based on the presumption that (i) we simply don't know enough about the problem at the present time to confirm or deny that AP constitutes a serious environmental hazard; (ii) we cannot be sure that any controls/regulations would be effective in reducing or reversing the impact of the alleged problem; and (iii) in the absence of such evidence, there is no justification for imposing stricter emission control regulations. Proponents of this approach are in favor of an accelerated research effort designed to determine if acid precipitation is indeed a serious problems, and if so what is causing it and what is the most effective way to deal with it. [4] [7] [17]

3. STRUCTURING THE DECISION PROBLEM

A primary factor contributing to the confusion surrounding the acid precipitation controversy is that much of the debate is based on emotional arguments and pure rhetoric. To analyze the problem in an objective way, and to help focus attention on the key points of disagreement, it is helpful to structure the problem and follow a systematic approach.

While there is no single best way to structure the problem, we have organized the fundamental issues facing the policy-makers in terms of two questions (Figure 1): (i) Whether acid precipitation is a serious problem; and what, if anything,

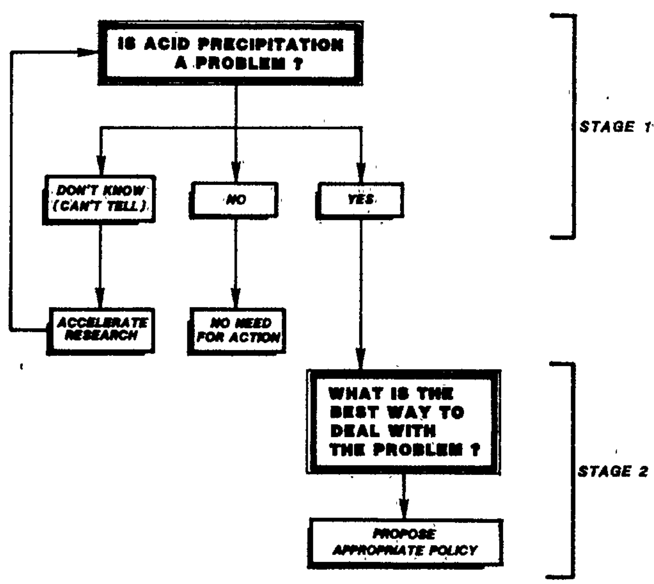

FIGURE 1 STRUCTURE OF THE PROBLEM

should be done about it. To help arrive at a rational and defensible answer, we have redefined the first question in terms of three hierachical sub-questions (Figure 2).

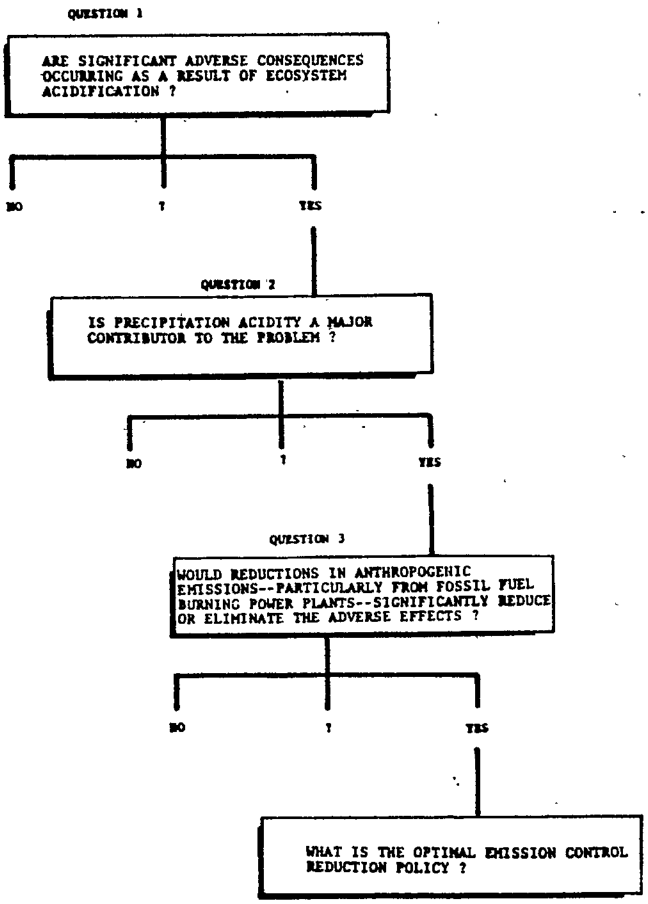

FIGURE 2.

SYSTEMATIC FRAMEWORK FOR DECISION MAKING

Since the answers to questions 1, 2 and 3 (hereafter Q1, Q2 and Q3) are not unequivocally known (e.g., because the available data is insufficient, of poor quality, or is subject to interpretation), Figure 2 allows for a "qualified no" answer in addition to definite yes and no. A "qualified no" answer is interpreted as "inconclusive," implying that additional research is needed prior to proceeding to the next question [16]. It follows from the above discussion that a proposal to impose emission controls cannot be logically defended unless one can present reasonable evidence that the answers to Q1, Q2 and Q3 are all positive.

4. ANALYSIS

Following Figure 1, we shall proceed to analyze the problem in two stages.

4.1 Stage One - "Does AP Constitute a Serious Environmental Problem?"

This question may be paraphrased as "how likely is it that one could proceed from Q1 to Q4?" Since the available information is (assumed to be) inconclusive or subject to interpretation, we have to supplement it with intuitive judgment to confirm or reject the "Q Link" -- evidence supporting the Q1, Q2 and Q3 sequence [16].

Following our discussion of Section 2, we shall continue with the two extreme and one moderate positions. Naturally, an overwhelming number of those who favor the "Rush-to-Judgment" position would take the path that leads to Q4. Opponents of stricter emission control policies, on the other hand, would paint an entirely different picture. According to this school of thought, acid precipitation, for all practical purposes, is a nonissue. The "moderates" are a bit more cautious in their assessment in the sense that they maintain a certain degree of neutrality. This is represented by the high probabilities assigned to the "qualified no" paths in Figure 2. Space limitations do not permit an illustration of this approach, simulating the diversity of opinions in the AP debate. The interested reader is referred to [16].

4.2 Stage Two - "What, if Anything, Should be Done About it?"

Given the lack of a clear-cut consensus in Stage One and the complicating factors mentioned above, it would be wise to evaluate the consequences of all three positions. Since it is not clear what strategy should be followed, it is necessary to compare the expected costs, potential benefits and the opportunity costs of each strategy. This is the approach followed in Stage Two and schematically shown in Figure 3.

Initially, one must decide whether to act immediately or to postpone a decision until some future time. This is shown as the two branches emanating from the box in the extreme left hand side of the figure. If the top branch is followed, one must immediately decide (or proceed with the presumption) that either AP <u>is</u> or <u>is not</u> a problem. These two de-

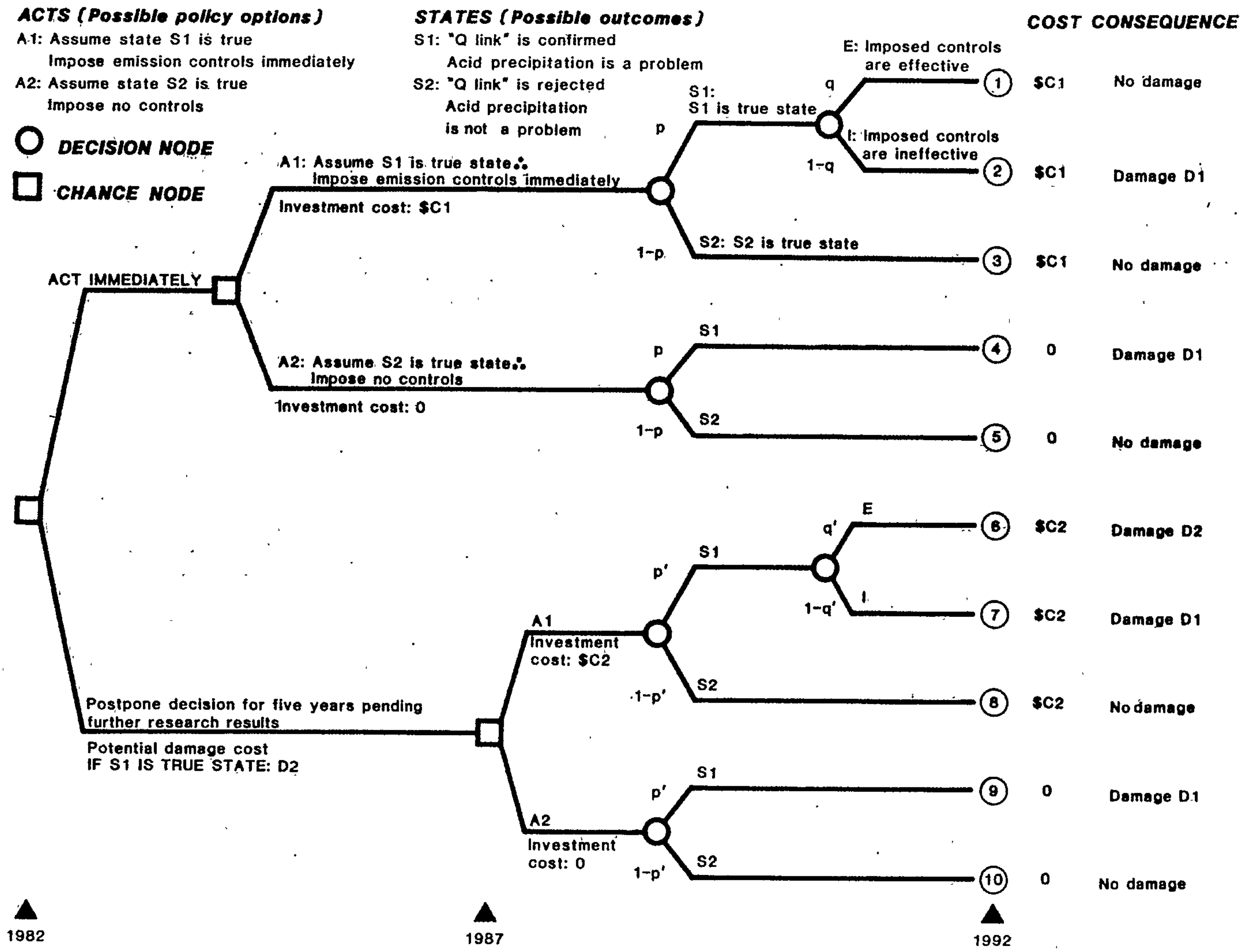

FIGURE 3 Decision Analysis Formalization of the Policy Options & Their Consequences

cision options are referred to as A1 and A2, respectively. If option A1 is accepted, then it follows that appropriate emission controls should be imposed immediately. Choosing option A2 suggests that no controls should be imposed. It is assumed that the true state of nature will become known over time, i.e., AP is either confirmed or rejected as a serious environmental problem. S1 denotes the state "Q Link" is confirmed and S2 refers to the state "Q Link" is rejected. [16]

The bottom part of Figure 3 represents the case where judgment is witheld until further -- presumably more conclusive -- evidence becomes available. We cannot, however, postpone decision making forever because some issues may remain unresolved and some disagreements may persist no matter how long the decision is postponed. In deciding how long to procrastinate, one must balance the expected costs and the expected benefits of waiting. In Figure 3, we have assumed that a period of five years is a reasonable time to wait prior to making a commitment. [4] The entire time frame of the problem is assumed to be ten years.

Following action A1 and outcome S1 (that is, assuming that AP is a problem, and being confirmed) brings us to another chance node, namely whether the imposed emission controls/regulations turn out to be effective or ineffective. [16]

Data Assumptions - To analyze the problem, we have to make assumptions about the probabilities of particular states occurring, the expected costs of pursuing particular policies and the estimated costs of potential damage to the environment should we decide to postpone a decision and state S1 occurs. We also have to estimate the potential cost of damage should we opt for a no-control policy and prove to be wrong (i.e., if we choose A2 and S1 occurs). Finally, we have to consider the possibility that any imposed regulations/controls may turn out to be either totally or partially ineffective. [2] [6] [14] Analysis assumptions are presented and qualified with appropriate caveats in Table 1. In all cases, the numbers shown are based on what is believed to be the best information currently available, as discussed in [16, Appendices B, C and D].

Table 1. Input Assumptions
(See [16] for explanation and details)

Symbol (Figure 3)	Description	Assumed Value
\$C1	Cost of Compliance with imposed emis-mandated now.	\$3 billion/yr
\$D2	Potential cost of damage due to five year delay in decision-making should state S1 occur.	\$5 billion/yr
\$D1	Potential cost of damage over a 10 year period if no action is taken	\$75 billion (D_2 + \$10/yr for 2nd five yrs)
\$C2	Cost of compliance with imposed emission controls/regulations following a five year delay.	\$3 billion/yr
p,p'+	Probability that state S1 will occur, based on the information available at the time.	0.81 high* 0.21 low 0.448 middle
q	Probability that controls/regulations presently imposed would be effective	0.7 high* 0.2 low 0.4 middle
q'	Probability that controls/regulations imposed five years from now would be effective.	0.9 high* 0.7 low 0.8 middle

5. RESULTS AND DISCUSSION

Since Table 1 assumptions are only representative, and not based on a thorough survey of acid rain experts, it would be premature to draw firm conclusions from the analysis on the optimal policy regarding AP. Nevertheless, some useful insights can be gained from the results obtained and these are discussed below.

Let us, for the time being, assume that the expected monetary value (EMV) of the consequences forms the basis for decision making.[13] This assumption, which can be relaxed [16], implies risk neutrality on the part of the decision makers.

If we were to act immediately, i.e., ruling out the option to postpone decision making pending further research results, what strategy should be followed? This subset of the decision problem is shown in Figure 4. An examination of the EMVs indicate that the optimum strategy depends on the particular position (or scenario) assumed. According to the "rush-to-judgment" scenario, emission controls should be mandated immediately because the expected cost of Act A1 (\$48.225b) is less than the corresponding figure for Act A2 (\$60.75b). If, on the other hand, one subscribes to the view that acid precipitation is a "non-issue," then it follows that no controls should be imposed (compare EMV = \$15.75b vs. \$42.60b). Following the moderate position would also favor the no control option. These results correspond to the policies advocated by these groups and come as no surprise.

Now, let us include the option to postpone decision making for five years (Figure 4). Comparing the expected consequence of the four available strategies produces some interesting results. Under the "rush-to-judgment" scenario, the optimal policy changes from [Act Now, A1] to [Postpone Decision, A1] because the EMV of the former (\$48.225b) exceeds the latter (\$39.30b). The implications of this result are significant. It suggests that even those who subscribe to this position and favor the imposition of immediate emission controls could benefit from improved information that becomes available over time -- despite the cost of the environmental damage that could potentially take place while the decision is postponed.

This conclusion, a key point in the AP controversy, follows from the assumption that as time goes on and emission control technologies improve, more effective standards could be mandated. The difference between the expected cost of the two strategies (\$48.225 - \$39.30 = \$8.925b) may be thought of as the value of improved information. Needless to say, this result is sensitively dependent on assumptions regarding the cost of potential environmental damage and the ex-

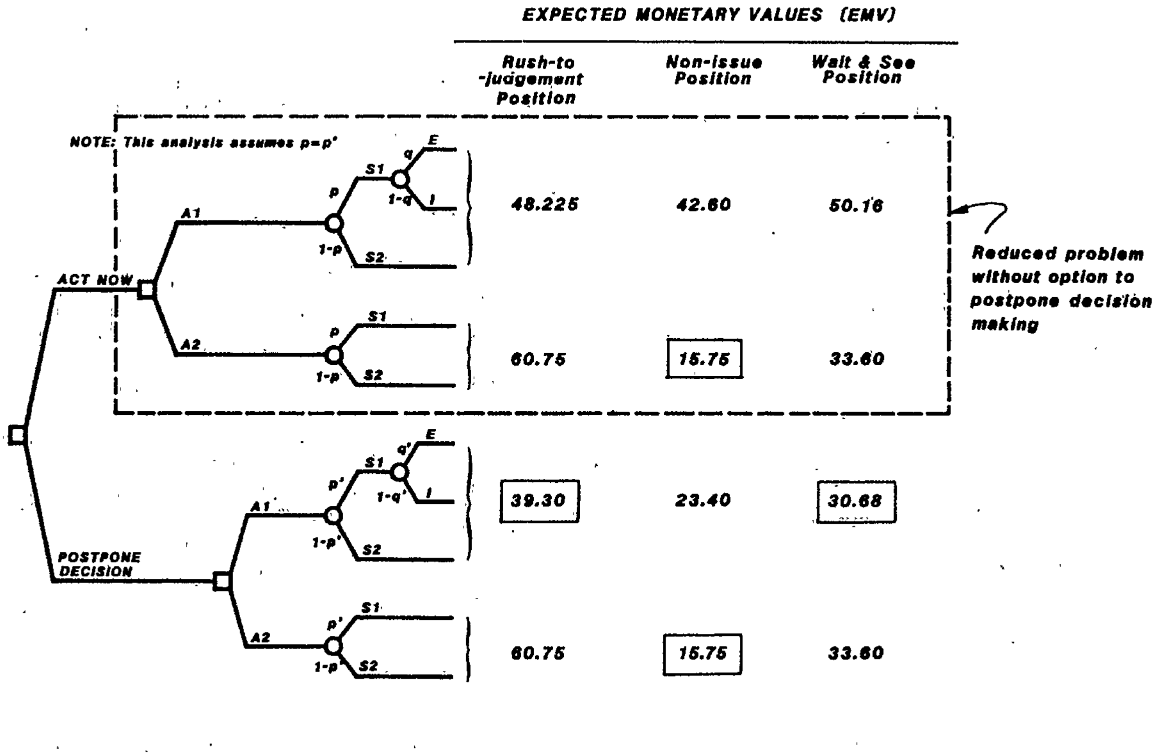

Figure 4. Results summary corresponding to the three positions considered.

pected improvements in the effectiveness of a delayed control policy.

The optimal strategy does not change under the "non-issue" scenario in the sense that the EMV of [Act Now, A1] and [Postpone Decision, A1] are identical. Those who subscribe to this position do not gain by postponing the decision. Under the assumptions of the present analysis, it may be said that there is no value to the additional information in this case because it does not change the optimal strategy (A1) nor does it lower the EMV of the policy.

Interestingly, the optimum strategy changes under the "wait and see" scenario. While those subscribing to this scenario would be against the imposition of any controls if they were to act immediately, five years from now they would switch alliance in favor of imposing emission controls. Once again, this conclusion, a significant point, is based on the assumption that more effective regulations and more efficient emission control technologies would become available if one is willing to postpone decision making for a finite length of time. In this case, additional information is valuable not only because it reduces the EMV of the optimal strategy ($33.60 - $30.68 = $2.92b), but also because it results in a policy switchover.

Altogether, postponing decision making results in less costly (or more cost effective) policy under the "rush-to-judgment" scenario, and leads to a switchover under the "wait and see" scenario (which is also more cost effective). In no case does it result in a more costly policy given the particular assumptions of the present analysis. Alternative assumptions can be substituted to test the robustness of these results.

It may be argued that the subjective basis of some of the key assumptions and using the EMVs as the basis for decision making limits the useful implications of the above results. Both criticisms are valid and pose serious problems for anyone trying to use Figure 4 results too literally.

For a discussion of these and an examination of decision rules other than the expected value hypothesis, the interested reader is referred to [16]. It suffices to say, however, that in using other decision rules and not relying on the state/outcome probabilities does not change the overall results of the analysis. Similarly, performing sensitivity analysis on the input assumptions does not change the overall thrust of the above results. These results and a discussion of their policy implications may be found in [16].

6. CONCLUSIONS

AP is a complex and controversial issue. Its long-term adverse effects on the environment are not fully understood nor scientifically documented. Some scientists and policymakers believe that the potential risks could be so great that immediate action is warranted. Policies advocated include mandating strict regulations on SO_2 and NO_x emissions from coal burning power plants and more stringent air quality standards.

Other scientists and policymakers believe that such drastic measures are premature given our lack of understanding of the casual relationships between emissions and alleged adverse impacts of AP. They argue that there is no convincing evidence to suggest that the proposed measures would be effective, while it is reasonably clear that they would be costly. Postponing decision making, they believe, would result in more effective, less costly policies.

The methodology illustrated in this paper provides a systematic and structured framework to analyze the consequences of following alternative policies. The main strength of the methodology is that it focuses attention on the main points of contention in the AP debate. The methodology does not "resolve" the controversies but is useful in two ways: (i) it illustrates a logical approach to decision making if agreement is reached on some of the key issues; and (ii) it indicates that the policy to impose controls immediately is dominated by other options under a wide range of assumptions. The latter conclusion supports the position advocated by those politicians and scientists who favor an accelerated program of research specifically intended to resolve some of the key uncertainties prior to mandating any emission control regulations.

Although the numerical analysis presented in this paper is illustrative and cannot be taken literally, we believe that the general results obtained are insightful and can serve as a tool in arriving at rational policy decisions. The approach can be used to evaluate the consequences of following different policies and to test the robustness of the results under alternative assumptions.

NOTES

1. Acidity of a solution is determined by the concentration of hydrogen ions present and is measured in pH units. The pH scale ranges from 0 to 14 with pH of 7 representing pure (distilled) water. Anything with a pH less than 7 is considered acidic; the more acidic, the lower the pH number. Since the scale is logarithmic, pH 4 is 10 times more acidic than pH 5.

2. This natural or background acidity is attributed to the presence of carbon dioxide in the air, combining with the water to form a weak solution of carbonic acid. The problem with this definition is that many natural and manmade phenomena can affect the pH level, causing it to deviate from this arbitrary point.

REFERENCES

1. Commonwealth Edison Company, Statement of A. Courtney before the Health and Environment Subcommittee of the U.S. House of Representatives, October 20, 1981.

2. Council on Environmental Quality (CEQ), "The Benefits of Air and Water Pollution Control: A Review and Synthesis of Recent Estimates," December 1979.

3. Edison Electric Institute, "An Updated Perspective on Acid Rain," November 1981.

4. Environmental Protection Agency (EPA) Statement of K. M. Bennett, before the Subcommittee on Health and the Environment of the Committee on energy and Commerce, U.S. House of Representatives, October 20, 1981.

5. EPRI, Statement of R. W. Brocksen, before the Subcommittee on Health and Environment, U.S. House of Representatives, October 2, 1981.

6. Freeman, A. M., The Benefits of Environmental Improvement, Baltimore, MD: Johns Hopkins University, Press, 1979.

7. Gregg, J., Member of Congress, Proposed Acid Precipitation Bill, August 1981.

8. Hansen, D. A. and G. M. Hidy, "Review of Questions Regarding Rain Acidity Data," Atmos. Environ., Vol. 16, No. 5, 1982.

9. Hidy, G. M., "Acid Precipitation: Two Environmental Paradoxes," Draft paper to be published, July 1981.

10. Illinois Power Company, Statement of W. C. Gerstner, before the Senate Committee on Environment and Public Works, U.S. Senate, October 29, 1981.

11. La Bastille, A., "Acid Rain-How Great a Menance?" National Geographic, November 1981, pp. 652-680.

12. Likens, G. E. et al., "Acid Rain," Scientific American, October 1979, pp. 43-51.

13. Luce, R. D. and H. Raiffa, Games and Decisions, Wiley, 1957.

14. National Research Council (NRC), "Atmosphere - Biosphere Interactions: Toward a Better Understanding of the Ecological Consequences of Fossil Fuel Combustion," July 1981.

15. National Wildlife Federation, Statement of J. D. Hair, at hearings on acid rain before the House Committee on Energy and Commerce subcommittee on Health and Environment, U.S. House of Representatives, October 20, 1981.

16. Sioshansi, F. P., "Acid Precipitation: Controversy Over Policy Options" Research & Development Report No. 82-RD-70, Southern California Edison Company, Rosemead, CA, May 1982.

17. Sports Illustrated, "An American Tragedy," September 21, 1981, pp. 69-82.

18. U.S. General Accounting Office, "The Debate Over Acid Precipitation: Opposing Views; Status of Research," Report by the Comptroller General, September 1981.

19. U.S. Senate, Statement of Senator G. J. Mitchell, on S.1706, The Acid Deposition Control Act, before the subcommittee on Health and Environment, U.S. House of Representatives, October 20, 1981.