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# ECONOMIC METHODS AND APPLICATIONS FOR NAPAP'S ASSESSMENT REPORTS

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## INTRODUCTION

The conversion of acid precursors into acid deposition, as well as the relationship between acid deposition and its resulting effects on the environment, are complex and not completely understood. The scientific uncertainties would be of little concern to policy makers except for two additional issues. On the one hand, the costs of reducing acid precursors appear to be substantial and of major concern to important segments in our society. On the other hand, the benefits of reducing emissions may also be large and are also of interest to our society. To many analysts evaluating acid deposition controls is an evaluation of the gains and losses of any proposed action. While economists usually think about these trade-offs in monetary terms, other policy analysts often do not.

In light of these scientific and political uncertainties, the National Acid Precipitation Assessment Program (NAPAP) was implemented in 1980 with two primary objectives. First, through a comprehensive research and monitoring program, it seeks to fill many of the gaps in scientific understanding of the acid deposition phenomenon. Second, NAPAP seeks to assess the consequences of various methods of reducing acid deposition. These consequences are to be measured both in physical changes to the environment and in economic terms. These objectives are consistent with NAPAP's founding legislation, Public Law 96-294, which states that NAPAP is to provide the nation with comprehensive scientific, technological and economic information regarding acidic deposition.

In this paper, we review the role of economics in NAPAP. The paper explains the criteria NAPAP uses to assess whether quantification of the benefits of reduced acidic deposition will be attempted and the criteria for selecting a particular technique or model. Next, the paper reports NAPAP's plans for including economic information in its State-of-Science/Technology Reports and Integrated Assessment. The paper concludes with an overview of what we have already learned regarding integrating economics with a physical science research program.

The desire to include economics in NAPAP Reports is due in large part to the kinds of information Congress mandated should be included in NAPAP's assessments. In general, these assessments provide information that decision makers in the executive and legislative branches of the federal government, the state government, and others, can use to make informed policy decisions regarding acid deposition. To determine the importance of the acid deposition problem, these decision makers require information about current and expected future impacts of acid deposition. To determine the appropriateness of a particular control policy, many decision makers desire information about both the total positive and negative impacts that such a policy will have on their constituents and the nation as a whole[1].

Although these general information requirements include economic impacts, NAPAP does not plan to report all benefit information in monetary (economic) terms. Instead, three categories of benefits will be reported: (1) health; (2) economic, and (3) conservation. These categories reflect NAPAP's view of how best to describe the consequences of reduced acid deposition to decision makers.

Health benefits are treated separately because of their general importance and their prominent role in air pollution regulatory practice. For example, the Clean Air Act distinguishes between primary standards based on health effects and secondary standards based on other "welfare" effects.

The second category of benefits are those for which economic values based on market behavior can be provided. In general, improvements in physical effects commonly bought and sold in markets, for example, crops, construction materials, and commercial timberland, could be evaluated as economic benefits. These economic values can be measured using actual market behavior.

The third category of effects includes those for which the public's concern is principally the preservation of resources. Examples include protection of cultural structures and improvements in lake and stream water quality. It may be possible to estimate economic values associated with these changes, and available estimates will be reported when practical. NAPAP intends to describe all conservation benefits in physical terms, but, will adopt economic measures as far as reasonable and appropriate.

By presenting information from the three categories, NAPAP hopes to help public officials evaluate the trade-offs among control strategies. It is <u>not</u> NAPAP's objective to convert all effects into a common yardstick, economic or otherwise, to recommend any particular strategy. Specifically, the NAPAP Integrated Assessment is not a formal benefit-cost analysis; therefore, comprehensive converting all physical effects to monetary terms is not an objective[2].

## CRITERIA FOR EFFECT VALUATION AND MODEL SELECTION

This section discusses NAPAP's criteria for two important decisions: which physical effects to value, and which economic models or valuation techniques to apply.

Economic analysis has not always been part of NAPAP's research and assessment program and valuing some effects might require more research investments or time than is possible within NAPAP's schedule. Therefore, some criteria are needed to determine which effects should be included in the economic benefits estimation process. The criteria used for deciding the scope of the economics program are outlined below:

- o Certainty of Ecological Effects. In spite of NAPAP's efforts, there are still major uncertainties regarding the ecological effects of emission reduction scenarios. For example, although reductions in forest growth have been reported in several areas of the United States, the linkage of the reductions to acidic deposition remains somewhat uncertain. NAPAP's economic analyses are unlikely in areas where the effects are extremely uncertain and lack scientific credibility.

- o Magnitude of Possible Benefit. Economists argue that, when expressed in monetary terms, the size of the benefit indicates information regarding the importance of the resource to society. Thus, NAPAP would like to emphasize those effects that, through the results of prior studies, are believed to be relatively large. Unfortunately, NAPAP has concluded that the effects with potentially large benefits (e.g. visibility) are also particularly difficult to value.

- o Status of Methodology. The only methodology appropriate for valuing some effects (visibility) would require major investments by NAPAP in developing the appropriate methods or techniques for credible economic analyses. In these cases, the feasibility of performing a credible economic analysis within NAPAP's budgets and schedules becomes an important criteria in choosing which effects to value.

NAPAP's criteria for choosing among several alternative models or valuation techniques focus on the information required in NAPAP's Assessment along with consideration of certain model features.

- o Accurate and Defensible. Decision makers must have confidence that benefit and cost estimates are accurate and defensible; otherwise, they will not use the estimates. Models should be consistent with economic theory and based on analytical techniques and data accepted both by the profession and by decision makers. This is the most important criteria used by NAPAP to judge economic models and techniques.

- o Broad Geographic Basis. Since comprehensive benefit and cost estimates are preferred, models that generate estimates for broad regions are preferred to purely local models. In some cases, this criteria is amended to emphasize coverage of geographic regions most impacted by acidic deposition.

- o Linkages. It is important for NAPAP economics models to accurately incorporate the magnitude and characterization of physical and biological effects. Benefit models should, therefore, to the extent possible, use input estimates provided by NAPAP physical and biological scientists. These linkages result in an integrated analysis and allow decision makers to extract consistent information at either the effect stage or following the economic valuation.

- o Uncertainty. Decision makers want to know the level of certainty that can be attached to specific benefit and cost estimates. Benefit models should thus, to the extent possible, provide probabilistic estimates or ranges of values. Models should consider both the uncertainty in the economic process under study as well as uncertainty in the inputs from other NAPAP effect information.

## OVERVIEW OF PLANS FOR ECONOMICS STATE-OF-SCIENCE/TECHNOLOGY REPORTS

State of Science/Technology (SOS/T) Report 27, Methods for Valuing Acidic Deposition/Air Pollution Effects, deals with methods economists generally use to estimate the values associated with environmental effects. The report consists of two parts. The first part is a broad review of the theoretical and applied foundations for NAPAP's economic analysis. The section contains a critical assessment of the major methods that could potentially be used by NAPAP. The review helps assess whether the methods are defensible, our major criterion for choice of models. Gardner Brown, of the University of Washington, is author of the first part of SOS/T 27. Principal headings and methods covered in the first part are shown below.

Market Measures of User Benefits

- o Simple Models (e.g. Price Times Quantity)
- o Market Simulation Models-Econometric
- o Market Simulation Models-Linear Programming

Non-Market Measures of User Benefits

- o Simple Travel Cost (single site)
- o Advanced Travel Cost (multiple sites and multiple characteristics)
- o Random Utility Model
- o Contingent Valuation
- o Hedonic Property Value Studies
- o Hedonic Wage Studies
- o Hedonic Travel Cost

Non-Market Measures of Non-User Benefits

The second section of SOS/T 27 covers the models and techniques appropriate for valuing acidic deposition effects. In most cases, it is premature to assess which specific effects will be valued. However, it is extremely unlikely that all effects covered in the SOS/T will be valued for the Integrated Assessment. The SOS/T Report will be used to help determine, based on criteria presented earlier in this paper, which effects to value and which methods or techniques to use. It will also offer an evaluation of which methods/techniques to use if the available physical science inputs are available. The principal sections and authors of the second section of SOS/T 27 are shown below:

| | | |
|---|---|---|
| Aquatics | - | Jeff Englin (Pacific Northwest Lab)<br>Mary Jo Kealy (US Environmental Protection Agency) |
| Forests | - | Fred Kaiser, Richard Haynes (US Forest Service)<br>Don Rosenthal (US Department of Interior) |
| Crops | - | Richard Adams (Oregon State University) |
| Materials | - | Joel Scheraga (US Environmental Protection Agency) |
| Visibility | - | Robert Rowe (RCG/Haigler Bailly)<br>Gardner Brown (Univ. of Washington) |
| Non Use | - | John Calloway (Pacific Northwest Lab)<br>Rick Freeman (Bowdoin Univ.) |

## OVERVIEW OF PLANS FOR ECONOMICS IN INTEGRATED ASSESSMENT

Preliminary plans for the economics component of the Integrated Assessment for each of the NAPAP effect areas are presented below along with a discussion of the application of the criteria for attempting to estimate benefits.

### Aquatics

Numerous studies have indicated acid deposition is likely to lower the pH of streams and lakes and reduce the number of fish and other aquatic life in sensitive lakes. If this hypothesis is valid, we would expect that a reduction in fishing opportunities is one of the impacts of acid deposition.

First, we apply the criteria for deciding whether to attempt to value aquatic effects. Because of the importance that aquatic damages have played in the policy debates over acid rain controls, NAPAP has focused much of its effects research effort in this area. As a result, regional quantitative estimates are available as inputs for an economic analysis. In addition, several non-market approaches (travel cost, contingent valuation) have been successfully applied to valuing recreational fishing. For these reasons, NAPAP has instituted a major research effort to develop models capable of estimating the benefits associated with reductions in acidic deposition. Although previous estimates of damages were fairly small, NAPAP felt additional research involving better valuation techniques, broader geographic regions and better forecasts of <u>future</u> damages was warranted.

The next step is to select the model type or valuation techniques to estimate the value of changes in recreational fishing. Using two model variations and different estimates of physical effects, NAPAP's Interim Assessment reported

the current level of economic damages caused by acid deposition to Adirondack lakes was in the range of $1 to $12 million per year[3]. These damages are based on the welfare losses recreational fishermen experience as a result of reduced fishing opportunities. This estimate was derived using two economic methodologies, a damage function model and a travel cost model, in conjunction with very limited information about the reduction in the number of fishable acres in the Adirondacks attributed to acidic deposition.

Both approaches were reviewed for applicability for the Integrated Assessment. The damage function approach involves first determining the effect of changes in fishing opportunities (reduction in fishable acres) on participation rates (fishing days) and then multiplying the reduction in the participation rate by a fixed unit value, such as dollars per fishing day.

A number of travel cost methods were reviewed to find ones better suited for the 1990 Assessment:

- o multiple site travel cost
- o hedonic travel cost
- o random utility travel cost
- o varying consumer surplus travel cost
- o share travel cost

Three criteria should be applied to differentiate among the methodologies. The most important criterion is that the methodology must be able to distinguish the benefits associated with changes in a site's attributes. Recreational fishing is one site attribute. The benefits associated with improved recreational fishing, or forestalled damages, must be dealt with directly. Secondly, the methodology must be able to generate unique benefit measures under a variety of fishing scenarios. Some techniques are sufficiently ambiguous to leave room for interpretation of the proper way to measure benefits. These techniques are especially poor at measuring the benefits associated with a policy that changes two or more kinds of fishing at once, a case we are likely to encounter. Finally, since fishermen substitute among fish species or fishing sites, the methodology must be able to account for this substitution phenomenon. Some techniques make restrictive assumptions about what kinds of fishing opportunities are available to fishermen.

Three of the methodologies for economic valuation appear to meet these criteria: the random utility model, the share approach, and the hedonic travel cost method. Each of these is capable of producing a measure of economic benefits that is markedly superior to estimates currently available.

Following review and decisions of which models to develop, four principal research efforts are needed to provide economic information in aquatics for NAPAP's Integrated Assessment:

- o obtain necessary primary data
- o develop participation/economic models
- o link to NAPAP's Aquatics Effects Research Program
- o estimate changes in participation in recreational fishing and in economic values for the Integrated Assessment

Obtain Necessary Data. Many of the limitations of existing studies of the benefits of reduced acidic deposition are the result of inadequate data. A review of existing data potentially available for NAPAP's research indicated few sources. Thus a major task of this research is to collect primary data to be used in developing NAPAP's economic models. The task has paid particular attention both to the data needs, including demographic and socioeconomic, necessary to estimate the three economic models (random utility, hedonic, and share models) and to the design and pretesting of the survey instrument.

The survey will begin in late spring 1989. There are some regional considerations yet to address; however, the survey will include at least the Adirondack region and, likely other areas of the northeast. Although the survey will not be completed until fall 1989, preliminary data will be available for analysis by this summer.

Develop Participation/Economic Models. The approach NAPAP is adopting is to model recreation in two stages. The first stage focuses on the decisions to make a recreational trip--to "participate"; the second stage focuses on the economic value of the recreational trip. Decomposing the model into two stages introduces a misspecification, since the decision to participate is presumably affected by the value of the recreation. Experience, both theoretical and empirical, with implementing models that integrate participation and economic value is limited. As a result, we will concentrate on the traditional two-stage modeling approach.

There are two strong reasons for modeling participation. First, from a policy perspective it is important to understand how many people will change their behavior as a result of the policy. In this case, it means how many more or how many fewer people will go fishing as an acid deposition policy affects the available fishing opportunities. Estimates of changes in fishing participation may, to some decision makers, be more relevant or useful information than changes in economic values. Second, the estimated change in

social economic value results from aggregating the individual's economic value over the change in the number of participants. Generating the social benefits and understanding their importance over time depends on the quality of the modeling of participation choices. Thus, participation modeling provides an important element in our attempts to understand the effect of acid deposition policy.

The second stage in modeling recreation involves developing the economic model. NAPAP has focused on using variants of the travel cost methods rather than rely on contingent valuation surveys or other survey techniques. This is because the travel cost models use data on actual consumer behavior, distance travelled to reach a site, rather than rely on surveys of hypothetical markets. As mentioned earlier, NAPAP plans to rely on several recent improvements and developments in the travel cost technique, in particular the random utility model, the hedonic travel cost model and the share travel cost model.

Link to NAPAP's Aquatics Research. An important step in our research and one often not available in economic research is linking the economic analysis to NAPAP's effects research. Obviously, the ability of the economic model to portray accurately the value of changes in recreational fishing depends critically on the availability of good data on how acidic deposition changes fishing opportunities. NAPAP has devoted considerable effort to assessing the effects of acidic deposition on lake chemistry and biology.

Our review found that much of the NAPAP work to date has been on the chemistry of the lakes with a smaller effort to link the lake chemistry directly to biological effects. This ongoing effort is the Direct Delayed Response Program (DDRP). Under the DDRP, a representative sample of lakes and streams in several regions were studied for current characteristics, and specific predictions of changes in lake chemistry will be made for each individually. Predictions will be extrapolated to individual regions. The DDRP regions are northeastern lakes (including Adirondacks, Catskills, and Poconos), Southern Blue Ridge streams, and mid-Appalachian streams.

The review indicates that the DDRP data, by linking the biological effects to the chemical data, will be the best source of information on how different scenarios of acidic deposition will affect fish. This information will be crucial in the simulations of the economic value models. Other studies, including the Adirondack Lake Survey Corporation's survey of over 1400 Adirondack lakes are expected to help supplement and evaluate the DDRP results.

Estimate Changes in Participation and Economic Values. Finally, NAPAP will develop and implement an efficient method/computer code for linking the participation model and travel cost models to simulate the effects of changes in acidic deposition on recreational benefits in the pre-selected regions. This

method will be used to estimate the changes in participation and economic values associated with changes in physical effects reported for the Integrated Assessment. These changes will include those associated with the sensitivity analysis (NAPAP Assessment Question III) and the estimates of future conditions and evaluations of illustrative control strategies (Questions IV and V).

## Terrestrial

NAPAP's terrestrial effects research includes investigations into possible effects on both crops and forests. It has been particularly difficult to assess possible acidic deposition or ozone damages to eastern forests. This is because any effects are confounded by other influences on forest growth. For example, the Southern Commercial Forest Research Cooperative is attempting to determine if a recently observed decline in forest productivity is due to acidic deposition, ozone, a possible combination of pollutants or non-pollution factors. However, research into possible declines has proceeded slowly because these effects are relatively small compared to the natural variability in growth.

Research on acidic deposition or ozone damage to crops has been more straightforward. While acidic deposition effects have been consistently demonstrated to be small or non-existent at ambient levels, ozone damages to economically important crops are significant.

Fortunately economists have reasonably well developed models for both crops and forests that can be applied with a minimum of additional development. For crops, NAPAP plans to use a model previously employed to assess economic damages resulting from ozone[4] and from acidic deposition[5]. This model is a multi-regional, non-linear programming model of the U.S. agricultural sector. It can be used to estimate the regional changes in consumer and producer surplus for a number of different markets. Changes in crop yields, at the regional level, are required as inputs to the model[6].

Similarly, NAPAP plans to use an existing U.S. Forest Service Model, the Timber Assessment Market Model (TAMM), to conduct any quantitative assessments of commercial forest effects. TAMM is a multi-regional model linked to an inventory model (TRIM) capable of simulating market conditions out to the year 2030. The scope of NAPAP's forest economics assessment will be determined primarily by the degree of certainty with which the forest scientists can attribute any effects to acidic deposition or other pollutants.

## Materials

NAPAP has had considerable difficulty in performing a regional or national economic assessment of materials damages. Again, part of the problem is in the length of time required before researchers can develop a credible dose-response

function. However, the materials program has also been hindered by technical difficulties in linking laboratory dose-response functions to real structures and buildings. Initial research indicates building orientation is crucial and that important damages can often occur through subtle mechanisms. In addition, consumer maintenance practices can mitigate or eliminate economic damages when the maintenance occurs for reasons unrelated to the acidic deposition effects. For example, an acid deposition effect that might require some additional maintenance every 10 years to avoid damages may be irrelevant if the same maintenance occurs annually for aesthetic reasons.

Finally, initial NAPAP efforts required applying damage functions to inventories of materials. These inventories proved both more difficult and more costly to compile and validate than originally estimated. With these problems in mind, NAPAP has redirected its materials assessment efforts toward attempting to answer a series of questions:

- what materials are most sensitive to acidic deposition?
- which materials susceptible to damage are most economically important?
- what is the feasibility (statistical likelihood) of identifying regional differences in damages even if they exist?
- how does pollution change the useful service life and performance of materials under use?
- how do consumers respond to loss of material life or component performance?
- what are the marginal changes in repair frequency due to acidic deposition?

A set of research tasks has recently been implemented to answer as many of these questions as feasible. Economic estimates of damage (or benefits) are unlikely to be available for the Assessment. However, NAPAP is considering collecting primary data on consumer maintenance and repair behavior to fill an important void in materials research and assessment.

## Health, Visibility and Non-Use

NAPAP is not likely to fund new efforts to value health, visibility or non-use effects. This decision was made after the criteria discussed earlier in the paper had been applied and the status of methods used to estimate the values and the scientific certainty of the effects were reviewed. The SoS/T papers will critically review methods appropriate for valuation as well as the results of existing studies. However, it is still uncertain whether specific health effects

will be identified for valuation. NAPAP's three-part benefit categorization does not suggest calculating economic benefits for health effects is necessary for its assessment.

A number of existing studies have attempted to estimate the value of visibility, but these studies tend to suffer from a number of methodological shortcomings. The studies usually use contingent valuation as a valuation technique and, in many cases, these studies could not separate health and visibility effects. They were also usually for a particular location or area, which means we lave limited ability to extrapolate these studies to broad geographic areas with improvements in visibility. However, two studies, one funded by EPA, the other by the Electric Power Research Institute (EPRI), show promise of overcoming many of the problems of past studies. NAPAP will be reviewing the results of these projects to determine their utility for NAPAP's Integrated Assessment.

Following a review of estimating non-use values (for example, existence or bequest values), NAPAP decided to limit its discussion on this topic to SOS/T reports. It was felt that the theory was not sufficiently developed and methods to estimate non-use values (contingent valuation) were especially difficult to apply in this area.

Omitting economic values for health, visibility or non-use in the Integrated Assessment will be troublesome for economists and policy makers attempting to explicitly compare benefits and costs. However, as indicated by Barse, such an attempt to comprehensively assess net benefits is probably unrealistic principally because of the unresolved scientific questions[7]. Unfortunately, existing studies indicate the values for health visibility and non-use could be large enough to be relevant for policy makers evaluating acidic deposition policies.

## WHAT HAVE WE LEARNED?

In addition to being an "experiment" in interagency cooperation on research and assessment, NAPAP also represents an unusual opportunity for economists and other scientists to work together. Although NAPAP's Assessments are not due until 1990, NAPAP has gained considerable experience with integrating economics and physical science. The section below discusses what we have learned to date both in terms of our economic research results and in terms of integrating a physical science research program and an economics assessment effort.

- o Economic Methods Need to Be Further Developed. Economic methods are not well developed for regional estimates of acidic deposition benefits. This is particularly true for recreational and aesthetic benefits where the usual techniques (travel cost and contingent valuation) are usually applied for specific sites. Much less effort has been devoted to

regional estimates of economic effects. For this reason, NAPAP is devoting a great deal of effort to valuing regional changes in recreational fishing. In addition, estimates of values from existing studies seem most uncertain in effects that would seem to yield the largest benefits. These include health, visibility, materials, and non-use effects.

- o Physical Uncertainties Limit Progress in Valuing Effects. In areas involving marketed commodities, particularly forests and crops, the major problem in developing economic benefits is obtaining useful inputs from the physical science. In other areas, such as visibility, both the physical uncertainties and problems with the valuation techniques impede the estimation of benefits.

- o Integrating Economics and Physical Science Research Programs Increases Relevance of Scientific Presentations. In order to be useful for policy questions, science needs to pull together the results of numerous scientific studies and experiments, each with a different protocol and method, into statements or estimates of damage. Economists are often maligned for performing this linkage without adequate support from the physical and biological scientists. When scientists provide this as input to economic models, the obvious result is that the scientific integrity of the research is preserved, but the task also forces the scientist to regionalize or aggregate his or her results. For example, presenting the results of numerous studies of the effects of ozone on vegetation is much less useful to a decision maker than stating, for example, at ambient levels ozone reduces corn yields by some amount.

- o Uncertainty of Effects and Weak Estimates of Benefits Limit Benefit-Cost Analyses. Both because of the large uncertainties in effects and the weak estimates of benefits in crucial areas (visibility, non-use, materials), explicit comparisons of the benefits and costs of control policies seem unwarranted. Both advocates of controls and the status-quo can point to studies or estimates of the economic benefits to indicate that benefits are either greater than or less than costs. The inability to more comprehensively cover the important effect areas limits the role of economic benefit analysis in the debate over controls.

- o Economic Planning and Analysis Needs to Proceed with Physical Science. Economics can be useful and helpful even in the early stages of a research effort such as NAPAP. Through sensitivity analyses with various levels of physical effects, economic analyses can point out areas where additional research can help reduce large and important uncertainties. In addition, if decision makers require economic information, the necessary economic methods and techniques must be developed to enable the economist to incorporate the information on changes in physical effects estimated by scientists.

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