Appendix J: Future Directions

Research Implications

In virtually any benefit analysis of environmental issues, the state of scientific information limits the degree of coverage possible and the confidence in benefit estimation. For most benefit categories, further scientific research would allow for a better quantification of benefits. One of the major outcomes of the retrospective analysis is a clear delineation of the major limitations in the scientific and economics literature in carrying out an analysis of this scope. Often, a list of research needs is generated in studies such as this, but there is no clear internal mechanism to address these needs. With this study (and the ongoing section 812 program), a process has been initiated where identified research needs are to be integrated into EPA's overall extramural research grants program, administered by the Office of Research and Development. It is hoped that the research projects that flow from this process will enable future analyses to be less uncertain and more comprehensive.

Certain of the limitations in the retrospective analysis are directly related to the historical nature of the analysis, such as sparse information about air quality in the early 1970's in many areas in the country. Other important limitations are related to the effects of elevated airborne lead concentrations, which has been virtually eliminated by the removal of lead from gasoline. A better understanding of these relationships would improve our understanding of the historical impact of the Clean Air Act, but would only indirectly contribute to developing future air pollution policy. However, most of the research that will reduce the major gaps and uncertainties needed to improve the section 812 analyses will be directly relevant to EPA's primary ongoing mission of developing and implementing sound environmental policies to meet the national goals established in the Clean Air Act and other legislation.

There are a number of biological, physical and economic research areas which the EPA Project Team identified as particularly important for improving future section 812 analyses. These research topics can be divided into two principal categories: (1) those which might reduce uncertainties in cost and benefit estimates with significant potential for influencing estimated net benefits of the Clean Air Act, and (2) those which might improve the comprehensiveness of section 812 assessments by facilitating quantification and/or monetization of currently excluded cost or benefit endpoints. The following subsections provide examples of research topics which, if pursued, might improve the certainty and/or comprehensiveness of future section 812 studies.

Research Topics to Reduce Uncertainty

Scientific information about the effects of long-term exposure to air pollutants is just beginning to emerge, but continues to be the subject of intense scientific inquiry. The relationship between chronic PM exposure and excess premature mortality included in the quantified results of the present analysis is one example of such research. However, many other potential chronic effects that are both biologically plausible and suggested by existing research are not included. Research to identify the relationship linking certain known or hypothesized physical effects (e.g., ozone's effects on lung function or fibrosis) with the development of serious health effects (e.g., cardiopulmonary diseases or premature mortality), and the appropriate economic valuation of the willingness to pay to avoid the risks of such diseases, would reduce the uncertainty caused by a major category of excluded health effects which could have a significant impact on the aggregate benefits estimates.

As described in Chapter 7 and Appendix I, premature mortality is both the largest source of benefits and the major source of quantified uncertainty in the retrospective analysis. In addition to the quantified uncertainty, there is considerable additional unquantified uncertainty about premature mortality associated with air pollution. Much of the information base about these relationships is relatively new, more is coming out virtually daily, and there is substantial disagreement in the scientific community about many of the key issues. EPA's Research Strategy and Research Needs document for particulate matter, currently under development, will address many of these scientific issues as they relate to PM. The following selection of highly uncertain issues could have a significant impact on both the aggregate mortality benefits estimates and the measured uncertainty range:

- the relationship of specific pollutants in the overall premature mortality effect, including the individual or interactive relationships between specific chemicals (e.g., ozone, sulfates, nitrates, and acid aerosols), and particle sizes (i.e., coarse, fine and ultra-fine particles);

- the degree of overlap (if any) between the measured relationships between effects associated with short term exposures and effects from long term exposure;

- the confounding effect of changes in historic air pollution, including changes over time in both pollution levels and the composition of the pollutant mix;

- the extent to which life spans are shortened by exposure to the pollutants, and the distribution of ages at the time of death;

- the willingness to pay to avoid the risks of shortened life spans; and

- the extent to which total $PM_{2.5}$ exposure incrementally augments the variability of outdoor $PM_{2.5}$ and increases the dose that would cause excess morbidity or mortality.

After premature mortality, chronic bronchitis is the next largest health effect benefit category included in the retrospective analysis. There is considerable measured uncertainty about both the incidence estimation and the economic valuation. Additional research could reduce uncertainties about the level of the pollutants associated with the observed effects, the baseline incidence used to model the changes in the number of new cases, and the correspondence between the definition of chronic bronchitis used in the health effects studies and the economic valuation studies.

Another area of potentially useful research would be further examination of the effects of criteria pollutants on cardiovascular disease incidence and mortality. Considering available epidemiological evidence and the potential economic cost of cardiovascular disease, the value of avoiding these outcomes may significantly influence the overall benefit estimates generated in future assessments.

Further research on the willingness to pay to avoid the risk of hospital admissions for specific conditions would reduce a potentially significant source of non-measured uncertainty. The Project Team used "avoided costs" for the value of an avoided hospital admission, based on the avoided direct medical cost of hospitalization (including lost wages for the employed portion of the hospitalized population). Avoided costs are likely to be a substantial underestimate of the appropriate willingness to pay, especially for such serious health effects as hospitalization for strokes and congestive heart failure, particularly because they omit the value of avoided pain, suffering, and inconvenience. Furthermore, in addition to hospitalization, there is evidence that some people seek medical assistance as outpatients. It is also likely that there are additional people adversely affected by short-term air pollution levels who seek physician services (but stop short of hospital admissions). Revised estimates of the appropriate economic value of avoided hospitalization and other primary care medical services could increase the total economic benefits of this cluster of health effects sufficiently that it could be a much larger portion of the aggregate benefit total.

Finally, one of the challenges in preparing the retrospective analysis was modeling the integrated relationships between emissions of many different chemicals, the subsequent mixture of pollutants in the ambient air, and the resulting health and welfare effects of simultaneous exposure to multiple pollutants. One element of the uncertainty in the analysis derives from the limited current understanding of any interactive (synergistic or antagonistic) effects of multiple pollutants. The need to better understand these complex issues is not a limited scientific question to improve section 812 analyses, but is the primary focus of EPA's current activities, organized under the Federal Advisory Council Act (FACA) process, to develop an integrated set of attainment policies dealing with ozone, particulate matter, sulfur and nitrogen oxides, and visibility. Further research on multi-pollutant issues may both (a) reduce a source of unmeasured uncertainty in the section 812 analyses and (b) allow for effective apportionment of endpoint reduction benefits to specific pollutants or pollutant mixes.

Research Topics to Improve Comprehensiveness

Even though research efforts falling in this category may not result in significant changes in net monetary benefit estimates, one of the goals of the section 812 studies is to provide comprehensive information about Clean Air Act programs. For example, programs to control hazardous air pollutants (HAPs) tend to impose costs and yield benefits which are relatively small compared to programs of pervasive national applicability such as those aimed at meeting National Ambient Air Quality Standards. Nevertheless, there are significant social, political, financial, individual human health, and specific ecosystem effects associated with emissions of HAPs and the programs implemented to control them. Under these circumstances, continued efforts to understand these consequences and evaluate their significance in relation to other programmatic and research investment opportunities might be considered reasonable, particularly in the context of comprehensive program assessments such as the present study.

Some cost and benefit effects could not be fully assessed and incorporated in the net monetary benefit estimate developed for the present study for a variety of reasons. Various effects were excluded due to (a) inadequate historical data (e.g., lack of data on historical ambient concentrations of HAPs), (b) inadequate scientific knowledge (e.g., lack of concentration-response information for ecological effects of criteria and hazardous air pollutants), or (c) resource-intensity or limited availability of analytical tools needed to assess specific endpoints (e.g., indirect effects resulting from deposition and subsequent exposure to HAPs). Other specific examples of presently omitted or underrepresented effect categories include health effects of hazardous air pollutants, ecosystem effects, any long-term impact of displaced capital on productivity slowdown, and redirected technological innovation.

Although the primary focus of 1970 to 1990 CAA programs was reduction of criteria pollutants to achieve attainment of national ambient air quality standards, emissions of air toxics were also substantially reduced. Some air toxics were deliberately controlled because of their known or suspected carcinogenicity, while other toxic emissions were reduced indirectly due to control procedures aimed at other pollutants, particularly ozone and particulate matter. The current analysis was able to present only limited information on the effects of changes in air toxic emissions. These knowledge gaps may be more serious for future section 812 analyses, however, since the upcoming prospective study will include evaluation of the effects of an expanded air toxic program under the CAA Title III. Existing knowledge gaps that prevented a more complete consideration of toxics in the present study include (a) methods to estimate changes in acute and chronic ambient exposure conditions nationwide, (b) concentration-response relationships linking exposure and health or ecological outcomes, (c) economic valuation methods for a broad array of potential serious health effects such as renal damage, reproductive effects and non-fatal cancers, and (d) potential ecological effects of air toxics.

In addition to research to improve the understanding of the consequences of changes in air pollution on human health and well-being, further research on non-health effects could further improve the comprehensiveness of future assessments. Improvements in air quality have likely resulted in improvements in the health of aquatic and terrestrial ecosystems and the myriad of ecological services they provide, but knowledge gaps prevented them from being included in the current analysis. Additional research in both scientific understanding and appropriate modeling procedures could facilitate inclusion of additional benefits such as improvements in water quality stemming from a reduction in acid deposition-related air pollutants. Water quality improvements would benefit human welfare through enhancements in certain consumptive services such as commercial and recreational fishing, in addition to non-consumptive services such as wildlife viewing, maintenance of biodiversity, and nutrient cycling. Similarly, increased growth, productivity and overall health of U.S. forests could occur from reducing ozone, resulting in benefits from increased timber production, greater opportunities for recreational services such as hunting, camping, wildlife observation, and nonuse benefits such as nutrient cycling, temporary CO_2 sequestration, and existence value. Finally, additional research using a watershed approach to examine the potential for ecological service benefits which emerge only at the watershed scale might be useful and appropriate given the broad geographic scale of the section 812 assessments.

While there are insufficient data and/or analytical resources to adequately model the short-run ecological and ecosystem effects of air pollution reduction, even less is known about the long-run effects of prolonged exposure. Permanent species displacement or altered forest composition are examples of potential ecosystem effects that are not reflected in the current monetized benefit analysis, and could be a source of additional benefits. In addition to these ecological research needs, an equally large, or larger, gap in the benefit-cost analysis is the lack of adequate tools to monetize the benefits of such ecosystem services.

Future Section 812 Analyses

This retrospective study of the benefits and costs of the Clean Air Act was developed pursuant to section 812 of the 1990 Clean Air Act Amendments. Section 812 also requires EPA to generate an ongoing series of prospective studies of the benefits and costs of the Act, to be delivered as Reports to Congress every two years.

Design of the first section 812 prospective study commenced in 1993. The EPA Project Team developed a list of key analytical design issues and a "strawman" analytical design reflecting notional decisions with respect to each of these design issues.[1] The analytical issues list and strawman design were presented to the Science Advisory Board Advisory Council on Clean Air Compliance Analysis (Council), the same SAB review group which has provided review of the retrospective study. Subsequently, the EPA Project Team developed a preliminary design for the first prospective study. Due to resource limitations, however, full-scale efforts to implement the first prospective study did not begin until 1995 when expenditures for retrospective study work began to decline as major components of that study were completed.

As for the retrospective, the first prospective study is designed to contrast two alternative scenarios; however, in the prospective study the comparison will be between a scenario which reflects full implementation of the CAAA90 and a scenario which reflects continued implementation only of those air pollution control programs and standards which were in place as of passage of the CAAA90. This means that the first prospective study will provide an estimate of the incremental benefits and costs of the CAAA90.

The first prospective study is being implemented in two phases. The first phase involves development of a screening study, and the second phase will involve a more detailed and refined analysis which will culminate in the first prospective study Report to Congress. The screening study compiles currently available information on the costs and benefits of the implementation of CAAA90 programs, and is intended to assist the Project Team in the design of the more detailed analysis by providing insights regarding the quality of available data sources and analytical models, and the relative importance of specific program areas; emitting sectors; pollutants; health, welfare, and ecological endpoints; and other important factors and variables.

In developing and implementing the retrospective study, the Project Team developed a number of important modeling systems, analytical resources, and techniques which will be directly applicable and useful for the ongoing series of section 812 Prospective Studies. Principal among these are the Criteria Air Pollutant Modeling System (CAPMS) model developed to translate air quality profile data into quantitative measures of physical outcomes; and the economic valuation models, coefficients, and approaches developed to translate those physical outcomes to economic terms.

The Project Team also learned valuable lessons regarding analytical approaches or methods which were not as productive or useful. In particular, the Project Team plans not to perform macroeconomic modeling as an integral part of the first prospective analysis. In fact, there are currently no plans to conduct a macroeconomic analysis at all. Essentially, the Project Team concluded, with confirmation by the SAB Council, that the substantial investment of time and resources necessary to perform macroeconomic modeling would be better invested in developing high quality data on the likely effects of the CAA on key emitting sectors, such as utilities, on-highway vehicles, refineries, etc. While the intended products of a mac-

[1] Copies of the prospective study planning briefing materials are available from EPA.

roeconomic modeling exercise – such as overall effects on productivity, aggregate employment effects, indirect economic effects– are of theoretical interest, the practical results of such exercises in the context of evaluating environmental programs may be disappointing for several reasons.

First, the CAA has certainly had a significant effect on several industrial sectors. However, the coarse structure of a model geared toward simulating effects across the entire economy requires crude and potentially inaccurate matching of these polluting sectors to macroeconomic model sectors. For example, the J/W model used for the retrospective study has only 35 sectors, with electric utilities comprising a single sector. In reality, a well-structured analysis of the broader economic effects of the CAA would provide for separate and distinct treatment of coal-fired utility plants, oil-fired plants, and so on. Furthermore, the outputs of the macroeconomic model are too aggregated to provide useful and accurate input information for the sector-specific emission models used to project the emissions consequences of CAA programs. Again, the critical flaw is the inability to project important details about differential effects on utilities burning alternative fuels.

The second critical problem with organizing a comprehensive analysis of the CAA around a macroeconomic modeling approach is that the effect information produced by the macroeconomic model is relatively unimportant with respect to answering the fundamental, target variable: "*How do the overall health, welfare, ecological, and economic benefits of Clean Air Act programs compare to the costs of these programs?"* The Project Team believes that any adverse effect, no matter how small in a global context, should not be deemed "insignificant" if even one individual is seriously harmed. However, the retrospective study results themselves have shown that, when analytical resources are limited, the resources invested in the macroeconomic modeling would have been better spent to provide a more complete and less uncertain assessment of the benefit side of the equation. Even on the cost side of the equation, it is far more important to invest in developing accurate and reliable estimates of sector-specific compliance strategies and the direct cost implications of those strategies. This will be even more true in the prospective study context when the Project Team will be faced with forecasting compliance strategies and costs rather than simply compiling survey data on actual, historical compliance expenditures.

The third and most important limitation of macroeconomic modeling analysis of environmental programs is that, unlike the economic costs of protection programs, the economic benefits are not allowed to propagate through the economy. For example, while productivity losses associated with reduced capital investment due to environmental regulation are counted, the productivity gains resulting from reduced pollution-related illness and absenteeism of workers are not counted. The resulting imbalance in the treatment of regulatory consequences raises serious concerns about the value of the macroeconomic modeling evaluation of environmental programs. In the future, macroeconomic models which address this and other concerns may be developed; however, until such time EPA is likely to have limited confidence in the value of macroeconomic analysis of even broad-scale environmental protection programs.

Based on these findings and other factors, the design of the first prospective study differs in important ways from the retrospective study design. First, rather than relying on broad-scale, hypothetical, macroeconomic model-based scenario development and analysis, the first prospective study will make greater use of existing information from EPA and other analyses which assess compliance strategies and costs, and the emission and air quality effects of those strategies. After developing as comprehensive a data set as possible of regulatory requirements, compliance strategies, compliance costs, and emissions consequences, the data set will be reviewed, refined, and extended as feasible and appropriate. In particular, a number of in-depth sector studies will be conducted to develop up-to-date, detailed projections of the effects of new CAA requirements on key emitting sectors. Candidate sectors for in-depth review include, among others, utilities, refineries, and on-highway vehicles.

The first prospective study will also differ from the retrospective study in that analytical resources will be directed toward development of a more complete assessment of benefits. Efforts will be made to address the deficiencies which prevailed in the retrospective study relating to assessment of the benefits of air toxics control. In addition, the Project Team will endeavor to provide a more complete and effective assessment of the ecological effects of air pollution control.