APPENDIX 2.1
SUMMARY OF BENEFITS DATA

1. INTRODUCTION AND SOURCE MATERIAL

The focus of this report is to catalogue the benefits available from elimination of air pollutants resulting from the combustion of fuels and to calculate the optimal taxes to account for energy-related pollution. Throughout this research effort, the benefits associated with fuel sources were drawn from existing government (or government sponsored) benefit assessments typically written for a specific pollutant, for example, sulfur dioxide or lead in gasoline. Several of these studies were conducted by the U.S. EPA's Office of Air and Radiation in the review of National Ambient Air Quality Standards (NAAQS). The benefits study cited for lead in gasoline was performed by the EPA's Office of Policy Analysis. Other studies were performed by the Office of Mobile Sources, also of the EPA, and by the National Acid Precipitation Assessment Program (NAPAP). One cited study was performed by a nonprofit research and consulting firm, Resources for the Future, under contract to the Office of Technology Assessment (OTA).

Because of the diverse set of benefits studies that we have drawn from, benefits values were often reported for different time frames using different accounting conventions. The numbers drawn from each study have been normalized to the annual dollar value of benefits in 1986 constant dollars for calendar year 1986. The year 1986 was chosen strictly for computational convenience. The specific steps taken to normalize the benefits from each study are reported in detail below.

Table A2.1.1 lists the normalized benefits drawn from each government assessment. Source documents typically reported total benefits for all sources of a particular pollutant. This research report, however, focusses only on pollutants resulting from fuel-related sources. Many pollutant sources in the source documents are nonfuel-related. For example, particulate pollution may be the result of dust from dirt roads, forest fries and volcanos. Ozone pollution may result from evaporation of solvents in paints. Therefore, benefits data were adjusted to account for fuel-related sources of pollution, only.

The most desirable method of adjusting the benefits data for pollution sources would be to first determine the background concentration of each pollutant and then to determine the marginal contribution to ambient concentration resulting from fuel sources. Unfortunately, this approach is precluded by the lack of detailed air quality data. As a second best measure, emissions to the environment will be used as a proxy for environmental quality data.

The EPA annually publishes air pollutant emissions estimates in the National Air Pollutant Emission Estimates series. Emissions estimates from this source were used to relate the 1986 normalized health and environmental benefits to fuel-related pollution sources. The EPA reports emissions for each of the following pollutants, lead, particulate, sulfur oxides (SO_x), nitrogen oxides (NO,), volatile organic compounds (VOC's), and carbon monoxide (CO) for each of the following source categories, transportation, stationary source fuel combustion, industrial processes, solid waste disposal, and miscellaneous.

No comprehensive benefits data were identified for the pollutants NO_x and carbon monoxide; therefore, any health and environmental benefits resulting from reduction of these two pollutants are not captured in this study. To the extent that such benefits exist, the documented externalities may be underestimated because NO_x and CO effects are not incorporated.

Another source of potential underestimation may occur because benefits estimates drawn from the source documents were scaled downward to account for benefits which could not be linked with a specific fuel-related emissions source. The EPA emissions data delineate emissions into two fuel-related categories, namely, transportation and stationary source fuel combustion. For the transportation category, the EPA emissions estimates are further detailed into the following subcategories, highway, diesel, aircraft, railroads, vessels, farm machinery, construction machinery, industrial machinery, and other. As will be explained in more detail below, only the first three categories relate to a specific fuel source (e.g. gasoline, diesel fuel, or aircraft fuel). Because of the difficulty of assigning the other emission categories to specific fuel sources, benefits estimates were scaled downward to exclude these source subcategories. Table A2.1. 1 lists the proportion of benefits identified in the government assessments which have been allocated to transportation and fuel combustion based upon this EPA data. The net benefits used in the remainder of this research report are found in the final two columns of Table A2. 1.1.

Throughout this report, ambient air quality is proxied by emissions of each pollutant of concern. Table A2. 1.2 lists the emissions of each pollutant in 1986, and calculates the net benefits (from Table A2.1.1) of existing regulations measured per unit of emissions. Clearly, the lead in gasoline regulation yields several orders of magnitude higher benefits per gram emissions than other regulations. Relative comparisons among the other pollutants should be made with caution, however. These specific figures are subject to the inadequacies/assumptions of the source materials such as choices of categories of benefits to include in each benefits assessment.

Another way to evaluate the data is by comparing benefits across fuel sources. Much of the remainder of this discussion focusses on fuel source comparisons. Table A2. 1.3 lists the net benefits from Table A2.1.1, but the benefits are allocated over fuel sources. Clearly, the lead in gasoline regulations have generated significant benefits from gasoline. But looking at the upper bound estimates, it appears that the greatest source of potential benefits if from coal consumption. When looking at the benefits measured in BTU-equivalents across fuel sources, the greatest benefits are again from coal consumption, while most petroleum-derived products have similar benefits when measured in BTUS [BTU conversion factors drawn from the "Monthly Energy Review," January, 1987]. Throughout the projections made later in this report, this pattern will remain. The greatest potential to capture future benefits appears to be from the consumption of coal.

In the remainder of this research report, the net benefits identified in Table A2.1.1 are used to calculate benefits per unit of each fuel used in 1986 (i.e. dollar value of benefits per gallon of gasoline consumed in 1986). For example, the total benefits allocated to gasoline (based upon the proportion of emissions in 1986 from gasoline sources) are divided by the consumption of gasoline in 1986 to yield benefits per gallon. These unit benefits can be thought of as the unit benefits of strict compliance with current standards/regulations.

For computational convenience, unit benefits are assumed to be constant over time and constant for the level of emissions. This second assumption is equivalent to assuming that the health and environmental effects of each pollutant are linear with respect to air quality (proxied by emissions).

Assuming that unit benefits are constant, the unit benefits are used to extrapolate to the potential benefits from reducing emissions from identifiable fuel-related sources to zero. The unit benefit estimates and the projections to zero are found in Table A2.1.4 and Tables A2.1.6 through Table A2.1.1O. The calculation of unit benefits and the method for projecting to zero are discussed in more detail below.

2. SOURCES OF UNCERTAINTY

Two types of uncertainty enter into the analysis. The first type is evident in Table A2.1. 1 by ranges over which benefits are stated. The ranges reflect uncertainty in the source documents' calculation of benefits, and in some cases, 'the uncertainty may be extremely large--as in the range of benefits for $S0_4$ mortality. The second type of uncertainty arises from the assumptions and limitations of this analysis and the data upon which the analysis is based.

For each pollutant listed in Table A2.1.1, benefits are displayed in ranges resulting from uncertainties in the benefits assessments. For lead in gasoline, the actual benefits of the regulation depend upon automobile owners' compliance with regulations requiring use of unleaded fuel. If cars are misfueled, by adding leaded fuel, the emissions systems may be impaired. The benefits range, therefore, reflects two different assumptions, no misfueling (upper bound) and partial misfueling (lower bound).

EPA's estimate of the benefits of controlling particulate incorporates uncertainty as to the extent of the health and environmental effects of particulate pollution and uncertainty regarding the economic valuations of health and environmental effects. The benefits analysis calculated benefits for a number of different scenarios reflecting underlying uncertainty in the health and environmental effects of particulate exposure. For this analysis, two scenarios were chosen as upper bound and lower bound benefits estimates based upon EPA's assertion that the two scenarios were most inclusive of the range of health and environmental effects without double-counting. In addition to the uncertainty over the precise health and environmental effects of particulate exposure, EPA's benefit range is due in part to the valuation assigned to mortality risk. Each case was assigned a value from $430,000 to $7,460,000.

In EPA's benefits analysis for sulfur dioxide, uncertainty is introduced by the air quality modelling procedures and by the economic valuations assigned health and environmental effects.

For mortality related to SO_4, the benefits range in Table A2.1.1 is significantly wider than the ranges for other pollutants. This range reflects the divergence of opinion in the scientific community regarding the mortality risk from exposure to SO_4 as well as a broad valuation for reduction in incremental mortality risks. EPA's benefits estimates included all available risk estimates with no attempt made to select the most appropriate values. The broad range adopted by EPA was incorporated in this study; however, in addition to EPAs range, this study identifies an alternate upper bound estimate (referred to as the "modified upper bound") which may more accurately reflect the risks associated with SO_4 exposure. The question of the risks associated with SO_4 exposure is discussed in more detail below (section III.D).

The analysis of the benefits related to ozone includes uncertainty regarding both rate of incidence and valuation of symptoms.

The range of benefits related to visibility is the result of uncertainty in the economic valuation of visibility improvements.

The range of benefits associated with air toxics in motor vehicles results from uncertainty in the rate of incidence of several different air toxic pollutants.

The second type of uncertainty in this report results from limitations in source data and analysis method. While the intent of this exercise is to identify the optimal level of taxes on fuel sources to account for associated externalities, the optimal taxes can only be as comprehensive as the accounting of externalities. For example, no direct benefits from control of carbon monoxide or NO_x are included in this report. In the ozone analysis, impaired lung function is not valued. If these pollutants/effects are significant risks/endpoints in the population, they are not accounted for in the calculation of optimal energy taxes.

A second source of uncertainty is regional variation reflected--or not reflected--in the results. Some adverse health or environmental endpoints may be of concern only in some regions of the country. However, due to data and methodological limitations, such variations are not captured in this analysis. The EPA regulatory analyses that provided the foundation of our study are national in scope. Emissions data are a critical element in the unit benefit calculations described in detail below, but fuel consumption and pollutant emissions data are not available on a regional basis. Therefore, this analysis assumes that emissions are distributed evenly throughout the country. This assumption may lead to some oversimplified results.

Another source of uncertainty is the true risk of exposure to different pollutants as ambient loadings of those pollutants change. Is the risk of an incremental exposure at high levels of ambient concentration equal to the risk of an incremental exposure at low levels of ambient concentration? In this analysis, unit benefits of emission reductions calculated at a given ambient concentration are used to estimate the benefits of further emissions reductions beyond the initial ambient concentrations. If the adverse health and environmental effects of pollutant exposures are actually nonlinear or exhibit a threshold effect, then using unit benefit estimates may introduce inaccuracies.

In some sense, despite its wide application in the literature, the linear, no threshold model incorporated in this report is an arbitrary approach. Adopting some other model is precluded by the lack of scientific consensus of the underlying relationships between air quality and health/environmental effects, and between emissions and air quality. In a recent report [New York 1991], the New York State Energy Office proposes an alternative linear threshold model; however, this approach is similarly arbitrary without a scientific basis for the threshold chosen and the resulting relationship between emissions and health effects. The New York State study is briefly reviewed elsewhere in this appendix.

An additional uncertainty relates to the base year and the fuel mix observed in that year. The volume of coal consumed in 1986, 768 million short tons, is composed of some mix of different types of coal, for example “high sulfur” and “low sulfur.” If the mix of coal types changes over time, perhaps as a result of compliance with Clean Air Act requirements, then the unit benefits calculated for the base year would not necessarily be representative of the true unit benefits in future years. This caveat could apply to any nonhomogeneous fuel source, especially coal and heating oils.

Many of these underlying uncertainties are discussed in more detail in other sections of this report, and other uncertainties are addressed where appropriate.

3. UNIT BENEFIT CALCULATIONS

This section presents a more detailed description of the benefit data for each pollutant and of the unit benefit estimation method. As mentioned above, unit benefits incorporate government estimates of benefits, and can be interpreted as the unit benefits of strict compliance with existing regulations/standards. Table A2.1.4 which details unit benefits by pollutant and fuel source can be considered the benefits of compliance with existing regulations.

In Table A2.1.4, unit benefits are presented for the following pollutants, lead in gasoline, particulate (more specifically, PM_{10}), sulfur oxides (excluding SO_4 mortality), SO_4 mortality, and ozone. The benefits are allocated over the following fuel sources, gasoline, diesel fuel, aircraft fuel, coal, heating fuel oil, natural gas, and wood. The allocation of benefits occurs as follows. Recall that emission data are available for several transportation fuel categories and several stationary fuel source categories. For each pollutant, the proportion of total emissions resulting from each fuel category was calculated. This figure is multiplied by the total benefits for that pollutant to yield the benefits allocated to each fuel. For example, from the EPA emissions data in the report, National Air Pollutant Emission Estimates 1940-1988, gasoline accounts for 11.22% of the emission of particulate in 1986. The net benefits due to particulate are $31,193 million (upper bound estimate as adjusted in Table A2. 1. 1). The benefits allocated to gasoline are $31,193 million multiplied by 0.1122. Unit benefits are then estimated by dividing this result by the volume of gasoline consumed in 1986. Table A2.1.4 contains estimated unit benefits for each fuel-pollutant combination as well as a comparison of the magnitude of unit benefits and the price of each fuel type.

The benefits data for each pollutant are outlined in more detail below. See particularly the section on particulate to find the specific citations for fuel consumption and price data.

Lead in Gasoline

Benefits data were drawn from EPA's Costs and Benefits of Reducing Lead in Gasoline, final Regulatory Impact Analysis which was produced in 1985 to accompany regulations reducing lead in gasoline. The specific benefits estimates used in this report were drawn from Table VIII-7c (low bound with partial misfueling) and from Table VIII-7a (high bound with no misfueling).

Categories of Benefits Incorporated:

Children: Benefits to children from reduced lead exposure included savings in expenditures for medical treatment (for lead testing and blood chelation therapy) and savings in compensatory education for IQ loss. Other adverse effects of lead exposure, including, chronic health effects, prematurity, birth malformation, and neurological disorders were not quantified.

Adults: Benefits to adults included morbidity and mortality effects of lead exposure. Morbidity benefits were restricted to avoided medical costs and foregone earnings for hypertension, stroke, and myocardial infarction. Mortality benefits valued at one million per individual based on occupational risk premium studies. Note: benefits were estimated for white males ages 40-59, only, with the exception of hypertension with also included nonwhite males in this age group.

Fuel economy benefits: The change in gas formulation was estimated to reduce fuel consumption. The dollar value of fuel savings were included.

Auto maintenance benefits: The changes would also lead to savings in vehicle maintenance. Dollar value of savings for spark plugs, exhaust systems, and oil changes included.

Conventional Pollutants: The fuel economy benefits will also reduce the release of other pollutants (primarily ozone) associated with gasoline combustion. Related benefits to health, agricultural crops, ornamental plants, materials, and visibility are included.

Benefit Scenarios Used:

Three scenarios are incorporated in the RIA, assuming no misfueling, partial misfueling, and full misfueling (misfueling occurs when conventional lead gasoline is used instead of unleaded gasoline). The benefit range used in the draft report reflects the latter two scenarios.

Unit Benefit Calculations:

Benefits estimated for 1986 were used in all calculations. These numbers were inflated from 1983 (as reported in the RIA) to 1986 using the implicit price deflator. All benefits are assumed to result from consumption of gasoline. The upper and lower bounds on the benefits range were each divided by the number of gallons of gasoline consumed domestically in 1986 (source: Basic Petroleum Data Book, section VII Table 21, 9/89) to yield a unit benefit value in terms of dollars per gallon consumed. The percent of 1986 price calculation incorporated the weighted [for lead and unleaded and for gasoline grades] average retail price per gallon based upon data from "Monthly Energy Review," 7/90, Table 9.4, from the Energy Information Administration.

Particulates

Benefits data were drawn from EPA's Regulatory Impact Analysis of the National Ambient Air Quality Standards for Particulate Matter 2nd addendum, December, 1986, Table III.C.1. [low bound] and Table III.C.2 [upper bound]. This analysis was completed to accompany the most recent revision the National Ambient Air Quality Standard (NAAQS) for particulate.

Categories of Benefits Incorporated:

Mortality Incorporated a range of benefit from $0.43 to $7.46 per reduction of 1 X 10^{-6} in mortality risk.

Morbidity: Valued lost workdays, reduced activity days, and direct medical expenditures from chronic respiratory disease. Lost work days were valued at the average daily wage, and reduced activity days were valued at one-half the daily wage.

Soiling: Estimated benefits from cleaning and well-being of reduced household soiling. Excluded soiling and materials damage in commercial, institutional, and government sectors.

Benefit Scenarios Used:

EPA's estimates are based upon an extensive literature review of the adverse effects of particulate. The many studies reviewed each utilized different assumptions about the types of particles of concern, the exposed population, etc. EPA organized these results into six alternative standards (some more and some less strict than the current standard) and six aggregation methods. This report incorporates the estimates for strict adherence to the current standard (PM_{10} at 50, annual and 150 24-hour) and for aggregation scenarios C and D which where judged by the EPA as most inclusive without double-counting.

Unit Benefit Calculations:

EPA reported benefits as 1983 discounted present value in 1984 dollars at a 10 percent discount rate. The benefit flow was for the seven years from 1989 through 1995. For the draft report, total benefits were converted to typical year values for 1989 through 1995 in 1986 dollars.

Typical year benefits were allocated over fuel sources (including gasoline, diesel, aircraft fuel, heating fuel oil, natural gas, coal, and wood) based upon the proportion of emissions from each source. EPA has published emissions data for the NAAQS pollutants for 1940 through 1988 in the publication National Air Pollutant Emission Estimates 1940-1988. Emissions are reported for the following categories, transportation, stationary source fuel combustion, industrial processes, solid waste disposal and miscellaneous. Emissions from transportation are further detailed for gasoline powered highway vehicles, diesel powered highway vehicles, aircraft railroads vessels, farm, industrial, and commercial machinery, and other. Emissions from stationary fuel combustion are broken down into coal, fuel oil, natural gas, wood, and other. Total emissions combining the transportation and fuel combustion categories were allocated to fuel-related categories based upon the reported emissions for 1988. Note that in some cases, for example VOCS, a large portion of the emissions result from activities other than fuel combustion. The benefits values drawn from existing reports were adjusted to reflect nonfuel emission sources. In addition, some benefits related to fuel combustion were excluded due to the difficulty in identifying the appropriate fuel source. The transportation categories: vessels, farm machinery, industrial machinery, commercial machinery, and other were excluded from our analysis because the actual fuel source for the emissions is not identified. The proportion of benefits uncounted due to these omissions is listed in Table A2.1.1.

After allocating the benefits over each fuel source based upon the emissions from that source, unit values (e.g. benefits per gallon) were calculated using consumption data from 1986. Consumption values for gasoline, diesel, aircraft fuel, and natural gas were drawn from the Basic Petroleum Data Book (BPDB) [gasoline, Table 21 section VII; diesel, Table lOa, section VII; aircraft fuel, Table 21 section VII; natural gas, Table 5a section XIII]. Consumption of heating fuel oils was estimated by summing residual and distillate fuels designated for the following uses, heating oils, industrial use, oil company fuel, and electric utilities [Basic Petroleum Data Book, Tables 10a and 12a, section VII]. Coal (net of coal used for coke plants) and wood consumption figures were drawn from the Annual Energy Review, 1987, from the Energy Information Administration, Tables 76 and 95, respectively. Wood consumption is for 1984.

The sources of price data are as follows: gasoline from the Energy Information Administration's (EIA) "Monthly Energy Review," Table 9.4, 7/90. Diesel fuel was drawn from the International Energy Annual, 1986, from the EIA, Table 17. The price of aircraft fuel is a weighted average based upon prices (excluding taxes) reported in the "Monthly Energy Review," Table 9.7 for aviation gas and kerosene-based jet fuel. The prices were weighted by the consumption volume for each found in the EIA's State Energy Data Report: Consumption estimates 1960-1986, Table 12. As this yielded a tax-free price, the unit tax on aircraft fuel identified in this report was added to the weighted price. The price of heating fuel oil is an average--weighted by the volumes of residual fuel oil (assumed to be equivalent to heavy oil) and distillate fuel oil (assumed equivalent to light oil)--of the reported price of No. 2 home heating oil from the Annual Energy Review, 1987, Table 65, and the price discount between residual fuel oil and No. 2 fuel oil found in the Monthly Energy Review, Tables 9.7 and 9.5. The BPDB provided the price of natural gas in Table 13, section VI. The price of coal, delivered at electric utility power plants, CIF (i.e. cost, insurance and freight) was drawn from the Annual Energy Review, 1987, Table 81. The price per ton of wood was estimated from information in the Regulatory Impact Analysis: Residential Wood Heater New Source Performance Standard conducted by the EPA in 1986. The report lists regional prices of wood sold by the cord at the retail level. These regional prices were weighted by 1986 regional population to yield a national average. This national average was discounted by 25 percent, as suggested by the EPA analysis, to account for consumers who pay less than retail prices. Finally, the adjusted price per cord wasconverted to price per short ton based on the conversion factor found in "Monthly Energy Review," Table Al, January 1990. The values used for consumption and price are listed in Table **A2.1.5.**

Sulfur Oxides (excluding SO_4 mortality)

Benefits data were drawn from EPA's 1988 Regulatory Impact Analysis on the National Ambient Air Quality Standards for Sulfur Oxides, Table 7 [for strict interpretation of current standards]. Benefits are estimated for 31 Eastern states, only. $S0_4$ mortality benefits were drawn from Tables B.2 and B.3. Agricultural benefits are calculated for only three crops, soybeans, wheat, and oats. Some ancillary benefits reported under sulfur oxides are the result of reduced particulate emissions from compliance with the sulfur oxides standards.

Categories of Benefits Included:

Mortality: Benefits are attributed to the reduced short-term non-episodic exposure to sulfur dioxide. Each statistical case is valued at from $420,000 to $7.3 million.

Morbidity: Sulfur dioxide morbidity is estimated only for short-term exposure. Long-term exposure is not included due to uncertainties. The symptoms valued include wheezing, shortness of breath, nose and throat irritation, and coughing. Symptoms are valued at from zero to $50 per hour reduced. Particulate benefits are valued as in the particulate section.

Agricultural: Benefits calculated for increased crop yield for soybeans, wheat, and oats resulting from lower sulfur dioxide exposure.

Visibility: Benefits from improved visibility from reduced $S0_4$ emissions are included based on contingent valuation studies in nine cities. Materials Damage/Soiling: Soiling benefits from particulate are included similarly to those discussed in the particulate section. Materials damage from sulfur dioxide is valued at from $0.77 to $6.89 per year per household within the applicable distance from power plants.

Unit Benefit Calculations:

As in the particulate section discussed above, EPA reported in 1983 the present value of benefits in 1984 dollars for reductions from 1990 through 2000 discounted at 10 percent. These benefits were converted to typical year values in 1986 dollars and allocated as detailed in the particulate section.

SO_4 Mortality

As in the case of sulfur oxides, benefits data were drawn from EPA's 1988 Regulatory Impact Analysis on the National Ambient Air Quality Standards for Sulfur Oxides, from Tables B.2 and B.3. Mortality associated with exposure to SO, is quite controversial. EPA did not explicitly include these benefits in the RIA; however, in an appendix, estimates of SO_4 mortalities are presented. Due to the controversial nature of the benefits, EPA estimated the lower bound of the benefits range at zero cases. Reflecting this uncertainty, the tables include $S0_4$ mortality as a separate category from sulfur oxides.

In estimating the range of benefits associated with $S0_4$ mortality, EPA cited all the available studies as well as the opinion of two unnamed experts. The study upon which the upper bound is based, Chappie and Lave, 'The Health Effects of Air Pollution: a Reanalysis/' has been criticized on many fronts. In Evans et al., "Cross-Sectional Mortality Studies and Air Pollution Risk Assessment," the authors perform a comprehensive review of the literature on $S0_4$ risk including reexamining the data analyzed by Chappie and Lave. In particular they correct for the seemingly arbitrary inclusion of three measures of SO_4 by Chappie and Lave, and they run regressions with separate measures of particulate and SO_4. By using measures of these two pollutants as regressors, Evans estimates should decouple the effects of particulate from the $S0_4$ risk estimates. The paper by Evans admits to potential multicollinearity and lack of significance of some important variables; nevertheless, this risk estimate may be more appropriate than that of Chappie and Lave.

Taking the above discussion into account, Table A2.1.6, presents the unit benefits estimates as in the previous Table A2.1.4, except that the upper bound reflects the Evans estimate rather than Chappie and Lave. The total benefits for this assumption were calculated by the EPA in the analysis referenced above. Throughout the rest of this research summary, this scenario will be referred to as the "modified upper bound."

One other aspect of the SO_4 mortality estimates is of note. EPA's emission estimates are listed as for all sulfur oxides. In the most part, the emissions are sulfur dioxide. Once in the atmosphere, sulfur dioxide maybe transformed to $S0_4$. It is assumed throughout this research report that there is a one-to-one relationship between the EPA's reported level of sulfur oxides and $S0_4$. Therefore, unit benefit calculations for the pollution categories sulfur oxides and $S0_4$ mortality utilize the same emissions figures.

Ozone

Benefits data were drawn from The Health and Agricultural Benefits of Reductions in Ambient Ozone in the United States by Alan Krupnick and Raymond Kopp in 1988 [page 3-21 for health benefits and Tables 5-3, 5-5, 5-9, 5-11 for agricultural benefits] prepared under contract to the Office of Technology Assessment. The Office of Technology

Assessment (OTA) published a 1989 report Catching Our Breath which estimated the health and environmental effects of ambient ozone; however, most of the OTA estimates were based on Krupnick and Kopp. By adjusting the assumptions made by Krupnick and Kopp, OTA estimated a broader range of benefits, particularly for health effects.

Categories of Benefits Incorporated:

Morbidity: Benefits estimated for reduced incidence in Metropolitan Statistical Areas (MSAs) of acute respiratory effects, acute non-respiratory (eye irritation), restricted activity days, and asthma attacks. Each effect was valued using willingness-to-pay criteria based on review of the available contingent valuation studies. Benefits not included in the valuations included chronic respiratory disease, premature aging of the lung, links to cancer, and other non-asthma respiratory diseases.

Agricultural: Benefits estimated as the net change in consumer and producer surplus for nine crops based on increased crop yield from lower ozone. Crops included peanuts, barley, sorghum, oats, alfalfa, soybeans, corn, wheat, and cotton. Agricultural benefits excluded were other crops, forests, and ornamental plants.

Visibility, materials damage: Not included.

Benefit Scenario Used:

Krupnick and Kopp included a number of scenarios based upon the available data and data uncertainty. Benefits were estimated for a number of different levels of ambient ozone exposure. The level, rollback to 0.12 ppm, was incorporated in this report as that most closely associated with compliance with the current standard. Agricultural benefits were estimated using a broader range of ozone exposure levels. Because of the differences in ozone levels in the health and agricultural benefits estimates, some inaccuracy is introduced by summing the benefits.

Allocation Over Sources:

The cause of tropospheric ozone pollution is a controversial issue. Ozone is caused by the interactions of different chemicals in the atmosphere, and the chemical pathways generating ozone may differ under varying conditions and in different regions of the country (for example, in urban vs. rural areas). VOCS are clearly one cause of ozone pollution, and nitrous oxides (NO_x) is considered another cause under certain conditions. Therefore, the estimates in this report assume that VOCS account for 75 percent of ozone while NO_x accounts for the remaining 25 percent of ozone pollution. Benefits were allocated over fuel sources (as explained in the particulate section) for the emissions of both VOCS and NO_x and then weighted by 75% to 25% respectively.

4. UNIT BENEFITS OF EMISSIONS REDUCTIONS TO ZERO

Using the unit benefit ratios discussed in Section III, projections of potential benefits for reducing emissions to zero from identifiable fuel-related sources are detailed in Tables A2.1.7 through A2.1.1O.

Two new categories of benefits are introduced in these tables, benefits from visibility related to acid deposition and benefits from air toxics associated with motor vehicles. In both cases, the source documents estimate the total adverse health/environmental result of existing air quality/emissions. In effect, these estimates calculate the potential benefits of eliminating emissions altogether. Therefore, the benefits are classified in this report as potential benefits from reducing emissions to zero, and are included only in the tables summarizing projected benefits (as opposed to the tables summarizing the benefits of compliance with existing regulations). This section first discusses the benefits from these two sources, and then presents the method for projecting future benefits for the categories presented in section II.

Visibility (related to acid deposition)

Benefits data on visibility were drawn from the National Acid Precipitation Program (NAPAP) study. The Integrated Assessment of the NAPAP study, (Question 1: Economics, p.26) cites work by Chestnut and Rowe who developed a “consensus function” to examine visibility values across a number of studies. Using their approach, Chestnut and Rowe estimated that the benefits of visibility improvement from an average visual range of 30 kilometers (km) to 150 km fall in the range from $3.2 to 12.8 billion annually. Thirty km is the approximate average visual range in the eastern United States, and 150 km is the approximate average visual range in the absence of air pollution. Therefore, the estimate by Chestnut and Rowe can serve as a proxy for the benefits associated with reduction of emissions of sulfur oxides (and associated visibility inhibiting pollutants like NO_x).

Unit Benefit Calculations:

Visibility benefits were allocated to fuel sources based on sulfur oxides emissions. Although other pollutants such as NO_x and PM contribute to visibility reduction, sulfur oxides are the primary pollutant of concern. Benefits have been allocated across emissions categories based on 1986 output levels. Allocating benefits across emission sources may understate the benefits associated with coal fired electric utilities, the largest single source of visibility degradation.

Air Toxics from Motor Vehicles

Benefits for this section were drawn from a report from the EPA's Office of Mobile Sources, Air Toxics Emissions From Motor Vehicles, September, 1987, Table S-1.

Categories of benefits included:

The report identifies carcinogens associated with motor vehicles. As several of the source categories are not products of fuel consumption, such categories were excluded from our analysis. The remaining categories include diesel particulate, formaldehyde, benzene gasoline vapors, butadiene, ethylene, gasoline PIC/POM and VOCS from motor vehicles. Benefits are reported as a range of cancer deaths from each source. For two sources, butadiene and ethylene, uncertainties in the actual health effects resulted in a lower bound of zero deaths. No morbidity benefits are included.

Allocation over sources:

The pollutants cited result from combustion of gasoline and/or diesel fuel. Benzene, gasoline vapors, and PIC/POM were allocated entirely to gasoline. Diesel particulate are allocated entirely to diesel fuel. The remaining categories were allocated over gasoline and diesel based upon the volume of each consumed in 1986, gasoline 85.57 percent and diesel 14.43 percent. Source: Basic Petroleum Data Book, Table 21 section VII and Table 10a section VII, respectively.

Mortality Valuation:

No dollar valuations were included in the EPA study. For this report, each case was valued at four million dollars.

Lead in Gasoline

Two data elements are necessary to extrapolate to the benefits of reducing emissions to zero. The first element was estimated in Section III (above), namely, the available benefits, in this case, denominated in dollars per unit of fuel consumed. The second element is the level of ambient concentration of the pollutant from which the reduction to zero will be estimated. As in Section III, emissions will be used as a proxy for ambient pollutant concentration.

In the ease of lead in gasoline, EPA issued regulations in 1985. Roughly two years were required for complete implementation of the lead phasedown. Over those two years, as the EPA documented in National Air Pollutant Emission Estimates 1940-1988, lead emissions from transportation fell 31.2 million metric tons, from 34.7 million metric tons in 1984 to only 3.5 million metric tons in 1986.

Two important assumptions are incorporated into the projections of the benefits of reducing lead emissions from gasoline to zero. First, it is assumed that unit benefits are constant over any level of emissions. In other words, the benefit of reducing emissions by one unit when emissions are high is the same as the benefit of reducing emissions by one unit when overall emissions are low. While this assumption may well be an oversimplification, no generally accepted data are available to create a better relationship. In addition, the assumption is consistent with the linear dose-response models used by the EPA in the source documents.

While the preceding assumption is generic to the method used to calculate projected benefits, a second assumption is specific to lead in gasoline. As emissions fell 31.2 million metric tons from 1984 to 1986, it is assumed in these calculations that one-half of the emission reduction occurred in 1985 and one-half in 1986, i.e. emissions fell 15.6 million metric tons each year.

The annual emission reduction resulting from the regulation and the total emission level remaining were used to create an emission ratio. When multiplied by the unit benefit of compliance with the regulations, the result is the unit benefit of reducing emissions to zero [($ benefit / fuel consumption) * (remaining emission / emission reduction)]. Perhaps more intuitively, the equation could be rearranged [(($ benefit / emission reduction) * remaining emission) / fuel consumption]. In either case, the equation extrapolates from the annual unit benefit of complying with existing regulations to the quantity of emissions remaining, thereby yielding the annual benefit per unit of fuel consumption of reducing emissions from fuel-related sources to zero in one year. The results of this calculation for gasoline are found in the first row of Tables A2.1.7 through A2.1.1O. Projections of the unit benefits for the pollutants particulate, sulfur oxides, and ozone require additional assumptions--leading to the four different cases captured in Tables A2.1.7 through A2. 1.1 O--and are explained below.

Particulate, Sulfur Oxides, and Ozone

Recall from above, that two information elements are necessary to extrapolate to the benefits of reducing emissions from fuel-related sources to zero, benefits data and ambient air quality (here represented by remaining emissions). For the case of lead in gasoline, the benefits data were available from the EPA regulatory impact analysis, and the emissions data were available from retrospective estimates of emissions.

For **particulates--and** for sulfur oxides and ozone as well--retrospective emissions data are not available. In the case of particulate and sulfur oxides, the EPA source documents estimate benefits of future emissions reductions. In the case of ozone, the source document predicts benefits if compliance with existing standards could be achieved. Because of the limitations of these analyses, we cannot peer into the records of pollutant emissions, rather some estimate of the emissions reductions which will/would result from compliance with the regulations must be made. A review of the background documents used by the EPA for the regulatory impact analyses yields little guidance on the air quality improvements or emissions reductions which would be associated with the regulations. Based primarily on an a priori judgement of what maybe reasonable, two initial cases have been used in these calculations. First, it is assumed that the existing regulations for particulate, sulfur oxides, and ozone will result in a 25% reduction in emissions in the year that the regulations are implemented (or in the case of ozone, in the year that compliance is achieved). It is secondly assumed, that there will be a **10%** reduction in emissions.

Unlike the case for lead in gasoline where gasoline was the only fuel of concern, the calculation of projected benefits for these pollutants must occur on a fuel-by-fuel basis. Incorporating the unit benefit estimate for a particular pollutant and fuel combination, the calculation may be as follows [($ benefits / fuel consumption) * (75% emission remaining / 25% emission reduction)]. This calculation is repeated for each pollutant and each fuel combination using baseline emissions estimates from the most recent year available, 1988. The results are summarized in Table **A2.1.7** for the case assuming a 25% emissions reduction in the first year following implementation of the regulation. Table A2. 1.8 summarizes the results assuming a 10?4 emissions reduction. Tables **A2.** 1.9 and **A2.**1.10 repeat the same estimates incorporating the modified upper bound estimate for SO_4 mortality.

As discussed in section 11 (above), projections of benefits beyond the base year introduces uncertainty due to the possibility of changing fuel qualities. If the mix of different types of coal or heating oils change over time, then the unit benefit values based on the fuel mix in 1986 may not represent the true benefits of the fuel source in some other year.

5. PROJECTED BENEFITS OF SELECTED CLEAN AIR ACT' AMENDMENTS EMISSIONS REDUCTIONS TARGETS

We have not attempted to conduct a comprehensive assessment of the benefits associated with the recent Clean Air Act Amendments. However, as a number of emissions reductions targets have been discussed widely, the unit benefits estimates from Section 11 have been applied to these targets. The resulting rough estimates of the benefits of the emissions targets are summarized in Table **A2.1.11.**

The estimates in Table A2.1.11 assume that sulfur dioxide emissions will be reduced by 10 million tons annually. Projected benefits of the 10 million ton target were calculated by applying unit benefit values--discussed in Section III. For sulfur dioxide, benefits were calculated for the following categories, SO_x morbidity, SO_4 mortality, and visibility. The emissions reductions are anticipated at electric utilities, only; therefore, benefits were calculated for coal and heating fuel oil in proportion to their consumption by electricity utilities.

Anticipated reductions in VOCS were used to estimate the potential benefits associated with ozone reduction. An annual target of 10 million tons of VOC emission reduction was assumed. It was further assumed for this estimate that VOCS account for 100 percent of ozone formation. Benefits were allocated over all fuel sources.

6. SUMMARY OF ENERGY-RELATED TAX DATA AND TAX ALLOCATIONS

This section summarizes information collected to determine the average unit tax on each fuel source. Taxes include federal and state excises, state severance taxes, and city and county excises and utility taxes. Table A2.1.12 summarizes the average per unit tax in 1986 for each fuel type. Similarly, Table A2.1.13 summarizes average taxes, but taxes designated for a specific use, e.g. gasoline taxes dedicated to the federal highway trust fund, have been excluded. For some taxes, revenues were allocated over fuel sources because the fuel source could not be readily identified. For example, severance taxes on petroleum were allocated over gasoline, diesel, aircraft fuel, and heating oils. Allocation methods are discussed in detail below. Tables A2.1. 12 and A2.1.13 also present taxes for each fuel relative to the total BTU content of each fuel consumed in 1986.

Federal Excises

Taxes on gasoline and diesel fuel were drawn from "Statistics of Income Bulletin" from the IRS, Spring 1987, Table A2.1.12. Excises for gasoline and lubricating oils were $8,857,380,000 and for diesel and special motor fuels, $2,613,980,000. The full value of each excise was allocated to gasoline and diesel fuel, respectively. These funds are earmarked for the Federal Highways Trust Fund. These figures differ slightly from Department of Transportation figures for the trust fund in 1986, but the difference is small.

The black lung tax levied on coal was $561,158,000 in 1986 according to the same source. The entire tax was allocated to coal.

Other Federal Trees

The windfall profits tax totalled $8,866,967,000 in 1986, while the superfund tax was $68,538,000 [IRS, "Statistics of Income Bulletin," Spring 1987, Table 12]. At that time, the windfall profits tax was falling rapidly. The superfund tax has grown significantly since this time. These taxes were allocated over all refined oil products based on the proportion of each product to the total volume of refined products in 1986. Approximately 20 percent of these taxes is not included in the tables because only gasoline, aviation fuel, diesel fuel, and fuel oil are included.

State Excises

State excises for motor fuel were $14,836,960,000 according to the U.S. Dept. of Commerce "Quarterly Summary of Federal, State, and Local Tax Revenue," Ott/Dec 1986, Tables 3,5. This figure differs slightly from the Department's "Government Finances: State Government Tax Collections in 1987," Table 9. The difference is probably due to revisions in the data. For some states, the latter source specified the amount collected from gasoline, diesel, and aircraft fuel, and other fuels not included in this study. Accordingly, taxes collected on other fuels were deleted from total state excises. The remaining taxes (approximately $14 billion) were allocated over gasoline, diesel, and aircraft fuel according to 1986 consumption levels. Reviewing the tax policies of individual states indicates that many different policies exist for inclusion/exclusion of aircraft fuel, special fuels, etc. These differences could not be captured in the tax allocations.

State excises for timber were $83 million; however, the proportion relevant for wood fuel could not be determined. Timber taxes were accordingly excluded from the report.

Local Excises

Local taxes for gasoline and other fuels were $260,040,000 according to the "Quarterly Summary of Federal, State, and Local Tax Revenue," Ott/Dee, 1986, Tables 3, 5. These taxes were allocated to gasoline, diesel fuel, and aviation fuel according to 1986 consumption levels.

Severance Taxes

State severance taxes on coal were $463 million, and on oil and gas, $5,325 million according to the Energy Information Agency's "Monthly Energy Review" of July 1988, Tables FE2, FE4. The coal taxes were allocated to coal. The petroleum and gas taxes were allocated between petroleum and natural gas based on the total BTUS of each consumed in 1986, according to consumption figures published in the U.S. Statistical Abstracts, 1989, Table 929. The petroleum taxes were further allocated to gasoline, diesel fuel, aircraft fuel, and heating oil in the same manner as the windfall profits tax.

Utility Taxes

State utility tax collections were $6,022,529,000 according to the Department of Commerce's "Government Finances: State Government Tax Collections in 1987," Table L No information was available to help allocate these tax collections between fuel-related and nonfuel-related (e.g. telephone) utilities. State utility taxes were therefore not included in the draft report.

City and county taxes for natural gas were $2,294 million, and city and county taxes for electric utilities were $15,028 million. These figures were drawn from "Government Finances: City Government Finances in 1986-87," Table 1, and "Government Finances: County Government Finances in 1986-87," Table 1, both published by the Bureau of the Census. According to the Statistical Abstracts of the United States, Table 952, in 1986, 46 percent of electric utility generation was due to coal and 12 percent from fuel oil. The remaining amount was for nuclear, hydro, and natural gas. These percentages were adjusted upward to eliminate natural gas from the total leaving coal with 60.85 percent and fuel oil, 15.87 percent of the nongas electricity generation. Accordingly, $9,145 million was allocated to coal and $2,385 to fuel oil.

7. CALCULATION OF RELATIVE CARBON TAXES

The carbon taxes calculated below apportion externality costs to different fuel sources based on the carbon content of each fuel type. The results of this approach may differ from other estimates found in the literature. Tax values in dollars are not calculated; rather, the estimates address the appropriate tax magnitude for each fuel source by comparing the tax for each fuel to a common reference, the tax for natural gas.

Estimated carbon taxes for each fuel type are based upon the carbon dioxide content of each fuel. Fuel carbon contents were drawn from Marland (1983). In Table **A2.1.14,** a relative carbon tax is estimated for each fuel, based upon these carbon loadings. First, the carbon content is converted from emissions of carbon per 10^9 joules to emissions per unit fuel (e.g. emissions per gallon of gasoline). Joules were converted to BTUS [10^{15} joules = 0.948 quadrillion **BTUs],** and BTUS converted to fuel equivalents using the BTU conversion factors found in the "Monthly Energy Review," January, 1987. This carbon dioxide emissions estimate is divided by the estimated externality cost (in this case for the midpoint of the benefits range assuming 25% emission reduction due to current regulations) to yield a measure of carbon dioxide emissions relative to externality costs per unit **fuel--labelled** the carbon tax. The relative taxes in the last column of the table are scaled with natural gas equal to one by dividing the carbon tax for each fuel by the value for natural gas.

8. SUMMARY OF COLLECTED INFORMATION

Much of the information discussed throughout this research **summary** is collected in a few simple tables. Tables **A2.1.15** and **A2.1.16** report the total benefits for each fuel. These tables aggregate over all pollutants the total benefit--by fuel type--of compliance with existing regulations and the total benefit--by fuel type--of reducing emissions to zero. Table **A2.1.15** reports these figures assuming a **25%** emissions reduction for compliance with existing regulations, while Table A2. L 16 incorporates a 10'% emission reduction.

Tables **A2.1.17** and **A2.1.18** present an overall summary of the unit benefit and unit tax information compiled to date. For each fuel type, the tables present the lower and upper bound of the unit benefits aggregated over **all** pollutants, summing the benefits of compliance with existing regulations and the benefits of reducing emissions to zero. The midpoint of the unit benefits range is presented as is the modified upper bound based on the $S0_4$ mortality estimate from Evans. Net unit taxes from Table **A2.1.** 13 are presented, and both the modified upper bound and the net unit tax are presented as a percent of the 1986 price of each fuel. Table **A2.1.17** reports these figures assuming a 25% emissions reduction for compliance with existing regulations, while Table A2. 1.18 incorporates a 10% emission reduction.

TABLE A2. 1. I : TOTAL BENEFITS DRAWN FROM SOURCE DOCUMENTS AND NET BENEFITS USED IN UNIT BENEFIT CALCULATIONS

POLLUTANT	TOTAL BENEFITS * FOR 1986 AS DRAWN FROM SOURCE DOCUMENT ($ MILLIONS)		°/0 OF TOTAL RESULTING FROM TRANSPORTATION & FUEL COMBUSTION -	°/0 OF TOTAL ALLOCATED TO AN IDENTIFIED FUEL SOURCE~~	NET BENEFIT AS USED IN STUDY ($ MILLIONS)	
	LOW	HIGH			LOW	HIGH
LEAD IN GASOLINE	8,566	8,686	1.00	1.00	8,566	8,686
PARTICULATE	1,461	72,206	0.46	0.43	631	31,193
SULFUR OXIDES (EXCLUDING S04 MORTALITY)	1,220	1,820	0.85	0.83	1,011	1,509
S04 MORTALITY	0	109,230	0.85	0.83	0	90,552
OZONE +	279	6,007	0.55	0.48	133	2,865

* SOURCE: EPA 1985, EPA 1986a, EPA 1988, RFF 1 ALL BENEFITS NORMALIZED TO 1986.

\- PERCENT OF TOTAL EMISSIONS ATTRIBUTABLE TO TRANSPORTATION AND STATIONARY SOURCE FUEL COMBUSTION IN EPA 1990.

--SAME AS PRIOR COLUMN ELIMINATING THE FOLLOWING CATEGORIES: RAILROADS, VESSELS, FARM MACHINERY, INDUSTRIAL MAC] OTHER OFF-HIGHWAY VEHICLES, AND OTHER STATIONARY SOURCES.

\+ ASSUMES VOC's ACCOUNT FOR 750/0 OF OZONE FORMATION AND NOX ACCOUNTS FOR 25°/0.

TABLE A2.1.2: ANNUAL BENEFIT OF COMPLIANCE WITH EXISTING REGULATIONS

POLLUTANT	NET BENEFIT ($ MILLIONS)+ LOW	HIGH	EMISSIONS IN BASELINE YEAR* (METRIC TONS)	BENEFIT PER TON EMISSION ($ MILLION/TON) LOW	HIGH
LEAD	8,566	8,686	32,600	262,775	266,429
PARTICULATE	631	31,193	9,100,000	69	3,428
SULFUR OXIDES	1,011	1,509	23,400,000	43	64
S04 MORTALITY	0	90,552	23,400,000	0	3,870
OZONE**	133	2,865	20,175,000	7	142

+ FROM TABLE 1, FINAL TWO COLUMNS.

•BASELINES DRAWN FROM BENEFITS SOURCE DOCUMENTS: LEAD, 1984; PARTICULATES, 1978; SULFUR OXIDES, 1980; OZONE, 1984.

•* SUM OF 75% OF VOC EMISSIONS AND 25% OF NOX EMISSIONS.

TABLE A2.1 .3: BENEFITS OF COMPLIANCE WITH CURRENT REGULATIONS SUMMARIZED IN BTU-EQUIVALENTS

FUEL SOURCE	GROSS BENEFIT OF COMPLIANCE WITH CURRENT REGULATIONS * TOTAL BENEFIT ($ MILLIONS)		GROSS BENEFIT PER BTU FUEL CONSUMED 1986 + ($/MILLION BTUs)	
	LOW	HIGH	LOW	HIGH
GASOLINE	8,818.49	19,699.64	0.61	1.35
DIESEL	96.98	5,157.93	0.04	1.89
AIRCRAFT FUEL	23.21	1,121.26	0.01	0.50
COAL	1,017.51	86,390.24	0.06	5.23
FUEL OIL	122.79	9,965.96	0.02	1.98
NATURAL GAS	16.16	507.16	0.00	0.03
WOOD	246.88	11,977.02	NA	NA

* BENEFITS FROM TABLE 1 ALLOCATED TO FUEL SOURCES BASED ON PERCENT OF TOTAL EMISSIONS FROM EACH FUEL TYPE. EMISSIONS DATA FROM EPA 1990.

+ TOTAL BENEFIT DIVIDED BY VOLUME OF FUEL CONSUMED (FROM TABLE 5) MULTIPLIED BY BTU CONVERSION FACTORS. CONVERSION FACTORS FROM "MONTHLY ENERGY REVIEW," JANUARY, 1987.

TABLE A2. 1.4: UNIT VALUE OF BENEFITS OF COMPLIANCE WITH EXISTING STANDARDS-BASE CASE "

BENEFITS SOURCE	GASOLINE	DIESEL	AIRCRAFT FUEL	COAL	HEATING OILS	NATURAL GAS	WOOD	TOTALS
LEAD IN GASOLINE	0.07362 - 0.0746S (S PER GAL)							0.07362
	7.91 - 8.02% (% OF PRICE)							
PARTICULATE	0.03141 - 0.06963 (S PER GAL)	0.00366 - 0.18070 (S PER GAL)	0.00115 - 0.05689 (S PER GAL)	0.14264 - 7.04944 (S PER TON)	0.00073 - 0.03614 (S PER GAL)	0.00031 - 0.01510 (s PER 1000 CU FT)	1.54488 - 76.35152 (S PER TON)	1.69477
	0.15 - 7.48?? (% OF PRICE)	0.39 - 19.22% (% OF PRICE)	0.18 - 8.85% (% OF PRICE)	0.43 - 21.17% (% OF PRICE)	0.11 - 5.25% (% OF PRICE)	0.01 - 0.38% (% OF PRICE)	2.50 - 123.59% (% OF PRICE)	
SULFUR OXIDES EXCLUDING S04 MORTALITY	O.(IY313 - 0.00019 (S PER GAL)	0.00078 - 0.00116 (S PER GAL)	0.00007 - 0.00010 (S PER GAL)	1.15046 - 1.71626 (S PER TON)	0.00272 - 0.00406 (S PER GAL)	0.00002 - 0.00003 (s PER 1000 CU FT)	0.00645 - 0.00962 (S PER TON)	1.16062
	0.01 - 0.02% (% OF PRICE)	0.08 - 0.1 2% (% OF PRICE)	0.01 - 0.02'% (% OF PRICE)	3.45 - 5.15% (% OF PRICE)	0.40 - 0.59?? (% OF PRICE)	0.00 - 0.00% (% OF PRICE)	0.01 - 0.02% (% OF PRICE)	
SULFUR OXIDES SO4 MORTALITY	0.00000 - 0.01122 (S PER GAL)	0.00000 - 0.06975 (S PER GAL)	0.00000 - 0.00622 (S PER GAL)	0.00000 - ####### (S PER TON)	0.00000 - 0.24341 (S PER GAL)	0.00000 - 0.00163 (S PER1OCGCUFT)	0.00000 - 0.57728 (S PER TON)	0.00000
	0.00 - 1.21% (% OF PRICE)	0.00 - 7.42% (% OF PRICE)	0.00 - 0.97% (% OF PRICE)	0.00 - 309.32% (% OF PRICE)	0.00 - 35.38% (% OF PRICE)	0.00 - 0.04% (% OF PRICE)	0.00 - 0.93% (% OF PRICE)	
OZONE	0.00063 - 0.01362 (S PER GAL)	0.00051 - 0.01121 ($ PER GAL)	0.00016 - 0.04)351 (S PER GAL)	0.03128 - 0.67397 (S PER TON)	0.00006 . 0,03131 (S PER GAL)	0.00067 - 0.01451 ($ PER 1000 CU FT)	0.06229 - 1.34275 (S PER TON)	0.09560
	0.07 - 1.46% (% OF PRICE)	0.05 - 1.19% (% OF PRICE)	0.02 - 0.55% (% OF PRICE)	0.09 - 2.02?4 (% OF PRICE)	0.01 - 0.1 9% (% OF PRICE)	0.02 - 0.37% (% OF PRICE)	0.10 - 2.1 7% (% OF PRICE)	
VISIBILITY • **								0
AIR TOXICS FROM ••• MOTOR VEHICLES								

• ALL VALUES NORMALIZED TO S 1986.

•• VISIBILITY BENEFITS OF CURRENT REGULATIONS INCLUDED IN SULFUR OXIDES CATEGORY.

• ** NO BENEFITS RESULTING FROM CURRENT REGULATIONS.

Footnotes for Table A2.1.4.

* ALL VALUES NORMALIZED TO $1986.

** VISIBILITY BENEFITS OF CURRENT REGULATIONS INCLUDED IN SULFUR OXIDES CATEGORY.

*** NO BENEFITS RESULTING FROM CURRENT REGULATIONS.

Sample Calculation for Particulates:

Total benefits from Table 1: $631 million (lower bound) to $31,193 million (upper bound). Percent of identifiable fuel related emissions from each fuel source: gasoline 25.96%, diesel 11.36%, aircraft fuel 3.06%, coal 17.35$?0, heating oils 4.0570, natural gas 0.78%, wood 37.43%. Source: EPA 1990.

Multiply total benefit by percent of emissions from each fuel source divided by volume of each fuel consumed in 1986 (from Table 5) to find unit benefit (e.g. benefit per gallon).

For gasoline: $631 million X 0.2596 / 116,354,196,000 gallons equals $0.0014 per gallon.

To find unit benefit as a percent of price, divide unit benefit by unit price (from Table 5) and multiply by 100.

For gasoline: $0.0014 / $0.931 X 100 equals 0.15 percent of the unit price of gasoline.

TABLE A2.1.5: FUEL CONSUMPTION AND PRICE DATA USED IN UNIT BENEFIT CALCULATIONS

FUEL TYPE	CONSUMPTION (1986)		PRICE (1986)	
GASOLINE	116,354,196,000	GALS	$0.931	PER GAL
DIESEL	19,625,760,000	GALS	$0.940	PER GAL
AIRCRAFT	16,805,124,000	GALS	$0.643	PER GAL
COAL	768,300,000	SHT TONS	$33.300	PER SHT TON
HEATING OILS	34,979,448,000	GALS	$0.688	PER GAL
NATURAL GAS	16,221,296,000	1000 FT**3	$3.960	PER 1000 FT ● *3
WOOD	153,000,000	SHT TONS	$61.780	PER SHT TON

SOURCE: CONSUMPTION DATA FOR GASOLINE, DIESEL, AIRCRAFT FUEL, NATURAL GAS, AND HEATING OIL FROM BASIC PETROLEUM DATA BOOK. HEATING OIL ADJUSTED TO INCLUDE ONLY NONTRANSPORTATION FUEL USES. COAL AND WOOD FROM AER 1987.

PRICES FOR GAS FROM MONTHLY ENERGY REVIEW, AUGUST, 1990. DIESEL FUEL FROM INTERNATIONAL ENERGY ANNUAL, 1986. COAL FROM AER 1987. AIRCRAFT FUEL AND FUEL OILS PRICES ARE WEIGHTED AVERAGES CALCULATED AS DESCRIBED IN SECTION III.B. WOOD PRICE FROM EPA 1986b, WEIGHTED BY 1986 REGIONAL POPULATION WEIGHTS.

TABLE A2.1.6: UNIT VALUE OF BENEFITS OF COMPLIANCE WITH EXISTING STANDARDS-MODIFIED UPPER BOUND "

BENEFITS SOURCE	GASOLINE	DIESEL	AIRCRAFT FUEL	COAL	HEATING OIL	NATURAL GAS	WOOD
LEAD IN GASOLINE	0.0736 - 0.0746 (S PER GAL)						
	7.91 - 8.02% (% OF PRICE)						
PARTICULATE	0.0014 - 0.0696 ($ PER GAL)	0.0037 - 0.1807 ($ PER GAL)	0.0012 - 0.0569 ($ PER GAL)	0.1426 - 7.0494 ($ PER TON)	0.0007 - 0.0361 (S PER GAL)	0.0003 - 0.0151 ($ PER 1000 CU FT)	1.5449 - 76.3515 ($ PER TON)
	0.15 - 7.48% (% OF PRICE)	0.39 - 19.22% (% OF PRICE)	0.18 - 8.85% (% OF PRICE)	0.43 - 21.17% (% OF PRICE)	0.11 - 5.25% (% OF PRICE)	0.01 - 0.38% (?? OF PRICE)	2.50 . 123.59?4 (% OF PRICE)
SULFUR OXIDES EXCLUDING S04 MORTALITY	0.0001 - 0.0002 (S PER GAL)	0.0008 - 0.0012 (S PER GAL)	0.0001 - 0.0001 (S PER GAL)	1.1505 - 1.7163 (S PER TON)	0.0027 - 0.0041 ($ PER GAL)	0.0000 - 0.0000 ($ PER 1000 CU FT)	0.0064 - 0.0096 (s PER TON)
	0.01 - 0.02% (% OF PRICE)	0.08 - 0.1 2% (% OF PRICE)	0.01 - 0.02% (% OF PRICE)	3.45 - 5.15% (% OF PRICE)	0.40 - 0.59% (% OF PRICE)	0.06 - 0.00% (% OF PRICE)	0.01 - 0.0% (% OF PRICE)
SULFUR OXIDES S04 MORTALITY	0.0000 - 0.0030 (S PER GAL)	0.0000 - 0.0184 (s PER GAL)	0.0000 - 0.0016 ($ PER GAL)	0.0000 - 27.1772 (S PER TON)	0.0000 - 0.0642 ($ PER GAL)	0.0000 - 0.0004 ($ PER 1000 CU FT)	0.0000 - 0.1523 (s PER TON)
	0.00 - 0.32% (% OF PRICE)	0.00 - 1.96% (% OF PRICE)	0.00 - 0.26% (% OF PRICE)	0.00 - 81.61% (% OF PRICE)	0.00 - 9.33% (% OF PRICE)	0.00 - 0.01 % (% OF PRICE)	0.00 - 0.25% (% OF PRICE)
OZONE	0.0306 - 0.0136 ($ PER GAL)	0.0005 - 0.0112 (S PER GAL)	0.0002 - 0.0035 (S PER GAL)	0.0313 - 0.6740 ($ PER TON)	0.0301 - 0.0013 (S PER GAL)	0.0007 - 0.0145 ($ PER 1000 CU FT)	0.0623 - 1.3427 (S PER TON)
	0.07 - 1.46% (% OF PRICE)	0.05 - 1.19% (% OF PRICE)	0.02 - 0.55% (% OF PRICE)	0.09 - 2.0294 (% OF PRICE)	0.01 - 0.19% (% OF PRICE)	0.02 - 0.37% (% OF PRICE)	0.10 - 2.17% (% OF PRICE)
VISIBILITY ***							
AIR TOXICS FROM *** MOTOR VEHICLES							

● ALL VALUES NORMALIZED TO $1986.

● C VISIBILITY BENEFITS OF CURRENT REGULATIONS INCLUDED IN SULFUR OXIDES CATEGORY.

● *o NO BENEFITS RESULTING FROM CURRENT REGULATIONS.

Footnotes for Table A2.1.6.

* MODIFIED UPPER BOUND INCORPORATES S04 MORTALITY RISK ESTIMATE FROM EVANS, ET AL. 1984 AS UPPER BOUND RISK LEVEL FOR MORTALITY FROM EXPOSURE TO S04.

ALL VALUES NORMALIZED TO 1986.

** VISIBILITY BENEFITS OF CURRENT REGULATIONS INCLUDED IN SULFUR OXIDES CATEGORY.

*** NO BENEFITS RESULTING FROM CURRENT REGULATIONS.

For Sample Calculations, see Table 4.

TABLE A2. 1.7: UNIT VALUE OF BENEFITS OF EMISSION REDUCTION TO ZERO FOLLOWING COMPLIANCE WITH CURRENT STANDARDS
BASE CASE, ASSUMING 25?4 EMISSION REDUCTION •

BENEFITS SOURCE	GASOLINE	DIESEL	AIRCRAFT FUEL	COAL	HEATDIG OILS	NATURAL GAS	WOOD
LEAD IN GASOLINE	0.0104 - 0.0112 ($ PER GAL) 1.12 - 1 .20% (% OF PRICE)						
PARTICULATE	0.0042 - 0.1619 ($ PER GAL) 0.45 - 17.39% (% OF PRICE)	0.0110 - 0.4202 ($ PER GAL) 1.17 - 44.70% (% OF PRICE)	0.0035 - 0.1322 ($ PER GAL) 0.54 - 20.56% (% OF PRICE)	0.4278 - 16.3860 ($ PER SHT TON) 1.28 - 49.21% (% OF PRICE)	0.0022 - 0.0841 ($ PER GAL) 0.32 - 12.23% (% OF PRICE)	0.0009 - 0.0353 (S PER1OOOCUFII 0.02 - 0.s9% (% OF PRICE)	4.6346 - 177.5229 (S PER SHT TON) 7.50 - 287.35% (% OF PRICE)
SULFUR OXIDES EXCLUDING S04 MORTALITY	0.0004 - 0.0006 ($ PER GAL) 0.04 - 0.06% (% OF PRICE)	0.0023 - 0.0035 ($ PER GAL) 0.25 - 0.37% (% OF PRICE)	0.0002 - 0.0003 (S PER GAL) 0.03 - 0.05% (% OF PRICE)	3.4518 - 5.1493 ($ PER SHT TON) 10.37 - 15.46% (% OF PRICE)	0.0082 - 0.0122 ($ PER GAL) 1.19 - 1 .77% (% OF PRICE)	0.0001 - 0.0001 (S PER 1000 CU FT) 0.00 - 0.00% (% OF PRICE)	0.0203 - 0.0301 (S PER SHT TON) 0.03 - 0.05% (% OF PRICE)
SULFUR OXIDES S04 MORTALITY	0.0000 - 0.0338 ($ PER GAL) 0.00 - 3.63% (% OF PRICE)	O.0000 - 0.2087 ($ PER GAL) 0.00 - 22.20% (% OF PRICE)	O.0000 - 0.0182 (S PER GAL) 0.00 - 2.84% (% OF PRICE)	0.000o - 309.0251 ($ PER SHT TON) 0.00 - 928.00% (% OF PRICE)	O.0000 - 0.7305 (s PER GAL) 0.00 - 106. 18% (% OF PRICE)	0.0000 - 0.0052 ($ PER 1000 CU FT) 0.00 - 0.1 3% (% OF PRICE)	O.0000 - 1.8216 (S PER SHT TON) 0.00 - 2.95% (% OF PRICE)
OZONE	0.0019 - 0.0409 ($ PER GAL) 0.20 - 4.39% (% OF PRICE)	0.0015 - 0.0336 ($ PER GAL) 0.16 - 3.58% (% OF PRICE)	0.0005 - 0.0105 (S PER GAL) 0.07 - I .64% (% OF PRICE)	0.0938 - 2.0219 (S PER SHT TON) 0.28 - 6.07% (% OF PRICE)	0.0002 - 0.0039 (s PER GAL) 0.03 - 0.57% (% OF PRICE)	0.0020 - 0.0435 ($ PER 1000 CU FT) 0.05 - 1.10% (% OF PRICE)	0.1869 - 4.0282 ($ PER SHT TON) 0.30 - 6.52% (% OF PRICE)
VISIBILITY	0.0003 - 0.0013 ($ PER GAL) 0.04 - 0.14% (% OF PRICE)	0.0020 - 0.0082 ($ PER GAL) 0.22 - 0.87% (% OF PRICE)	0.0002 - 0.0007 ($ PER GAL) 0.03 - 0.11% (% OF PRICE)	3.0176 - 12.0704 (S PER SHT TON) 9.06 - 36.25% (% OF PRICE)	0.0071 - 0.0285 ($ PER GAL) 1.04 - 4.15% ('?? OF PRICE)	0.000o - 0.0002 ($ PER 1000 CU FT) 0.00 - 0.00% (% OF PRICE)	0.0170 - 0.0680 (S PER SHT TON) 0.03 - 0.11% (% OF PRICE)
AIR TOXICS FROM MOTOR VEHICLES	0.0060 - 0.0386 ($ PER GAL) 0.65 - 4.14% (% OF PRICE)	0.0423 - 0.2138 ($ PER GAL) 4.50 - 22.75% (% OF PRICE)					

• ALL VALUES NORMALIZED TO $1986.

Footnotes for Table A2.1.7.

* ASSUMES STRICT COMPLIANCE WITH EXISTING STANDARDS FOR PARTICULATE, SULFUR OXIDES, AND OZONE ACHIEVE A 25% REDUCTION IN TOTAL EMISSIONS OF EACH POLLUTANT.

ALL VALUES NORMALIZED TO $1986.

Sample Calculation for Particulate from Gasoline:

Using unit benefits from Table 4, multiply unit benefit times ratio of emissions remaining to emissions reduced due to strict compliance with existing regulations.

For particulate from gasoline: $0.0014 (lower bound of unit benefit from Table 4) X (0.75 of emissions remaining /0.25 of emissions reductions achieved) equals $0.0042 per gallon of gasoline.

To find unit benefits as a percent of unit price, divide unit benefit by unit price (from Table 5) and multiply by 100.

For gasoline: $0.0042 /$0.931 X 100 equals 0.45% of the unit price of gasoline.

TABLE A2.1 .8: UNIT VALUE OF BENEFITS OF EMISSION REDUCTION TO ZERO FOLLOWING COMPLIANCE WITH CURRENT STANDARDS
BASE CASE, ASSUMING 10% EMISSION REDUCTION •

BENEFITS SOURCE	GASOLINE	DIESEL	AIRCRAFT FUEL	COAL	HEATING OILS	NATURAL GAS	WOOD
LEAD IN GASOLINE	0.0104 - 0.0112 (S PER GAL)						
	1.12 - 1 .20% (% OF PRICE)						
PARTICULATES	0.0127 - 0.6267 ($ PER GAL)	0.0329 - 1.6263 ($ PER GAL)	0.0104 - 0.5120 ($ PER GAL)	1.2837 - 63.4449 ($ PER SHT TON)	0.0066 - 0.3252 (s PER GAL)	0.0027 - 0.1359 ($ PER 1000 CU FT)	13.9039 - 687.1636 ($ PER SHT TON)
	1.36 - 67.31% (% OF PRICE)	3.50 - 173.01'% (% OF PRICE)	1.61 - 79.62% (% OF PRICE)	3.86 - 190.53% (% OF PRICE)	o.% - 47.27% (% OF PRICE)	0.07 - 3.43% (% OF PRICE)	22.51 - 1112.28% (% OF PRICE)
SULFUR OXIDES EXCLUDING S04 MORTALITY	0.0011 - 0.0017 ($ PER GAL)	0.0070 - 0.0105 ($ PER GAL)	0.0006 - 0.0009 ($ PER GAL)	10.3541 - 15.4463 ($ PER SHT TON)	0.0245 - 0.0365 ($ PER GAL)	0.0002 - 0.0002 ($ PER 1000 CU FT)	0.0580 - 0.0865 ($ PER SHT TON)
	0.12 - 0. 18% (% OF PRICE)	0.75 - 1.11% (% OF PRICE)	0.10 - 0.1 5% (% OF PRICE)	31.09 - 46.3% (% OF PRICE)	3.56 - 5.31% (% OF PRICE)	0.00 - 0.01% (% OF PRICE)	0.09 - 0.14% (% OF PRICE)
sULFUR OXIDES S04 MORTALITY	O.0000 - 0.1010 (S PER GAL)	O.0000 - 0.6277 ($ PER GAL)	0.0000 - 0.0560 ($ PER GAL)	0.0000 - 927.0333 ($ PER SHT TON)	0.0000 - 2.1907 ($ PER GAL)	0.0000 - 0.0147 ($ PER 1000 CU FT)	0.0000 - 5.1955 ($ PER SHT TON)
	0.00 - 10.85% (% OF PRICE)	0.00 - 66.78% (% OF PRICE)	0.00 - 8.71% (% OF PRICE)	0.00 - 2783.88% (% OF PRICE)	0.00 - 3 18.42% (% OF PRICE)	0.00 - 0.37% (% OF PRICE)	0.00 - 8.41% (% OF PRICE)
OZONE	0.0057 - 0.1226 ($ PER GAL)	0.0046 - 0.1009 (S PER GAL)	0.0014 - 0.0316 ($ PER GAL)	0.2815 - 6.0657 ($ PER SHT TON)	0.0005 - 0.0117 ($ PER GAL)	0.0061 - 0.1306 ($ PER 1000 CU FT)	0.5606 - 12.0847 ($ PER SHT TON)
	0.61 - 13.16*A (% OF PRICE)	0.4s - 10.73Y. (% OF PRICE)	0.22 - 4.91% (% OF PRICE)	0.85 - 18.22% (% OF PRICE)	0.08 - 1.71% (% OF PRICE)	0.15 - 3.30% (% OF PRICE)	0.91 - 19.56% (% OF PRICE)
VISIBILITY	0.0003 - 0.0013 ($ PER GAL)	0.0020 - 0.0082 (S PER GAL)	0.0002 - 0.0007 (S PER GAL)	3.0176 - 12.0704 ($ PER SHT TON)	0.0071 - 0.0285 ($ PER GAL)	0.0000 - 0.0002 ($ PER 1000 CU FT)	0,0170 - 0.0680 (S PER SHT TON)
	0.04 - 0.14% (% OF PRICE)	0.22 - 0.87% (% OF PRICE)	0.03 - 0.11% (% OF PRICE)	9.06 - 36.25% (% OF PRICE)	1.04 - 4.15% (% OF PRICE)	0.00 - 0.00% (% OF PRICE)	0.03 - 0.11% (% OF PRICE)
AIR TOXICS FROM MOTOR VEHICLES	0.0060 - 0.0386 (S PER GAL)	0.0423 - 0.2138 ($ PER GAL)					
	0.65 - 4.14% (% OF PRICE)	4.50 - 22.75% (% OF PRICE)					

* ALL VALUES NORMALIZED TO S 1986.

TABLE A2. 1.9: UNIT VALUE OF BENEFITS OF EMISSION REDUCTION TO ZERO FOLLOWING COMPLIANCE WITH CURRENT STANDARDS
MODIFIED UPPER BOUND, ASSUMING 25% EMISSION REDUCTION •

BENEFITS SOURCE	GASOLINE	DIESEL	AIRCRAFT FUEL	COAL	HEATING OILS	NATURAL GAS	WOOD
LEAD IN GASOLINE	0.0104 - 0.0112 ($ PER GAL)						
	1.12 - 1 .20% (% OF PRICE)						
PARTICULATE	0.0042 - 0.1619 ($ PER GAL)	0.0110 - 0.4202 (s PER GAL)	0.0035 - 0.1322 ($ PER GAL)	0.4278 - 16.3860 (S PER SHT TON)	0.0022 - 0.0841 (s PER GAL)	0.0009 - 0.0353 (S PER 1000 CU FT)	4.6346 - 177.5229 ($ PER SHT TON)
	0.45 - 17.39% (% OF PRICE)	1.17 - 44.70% (% OF PRICE)	0.54 - 20.56% (% OF PRICE)	1.28 - 49.21% (% OF PRICE)	0.32 - 12.23% (% OF PRICE)	0.02 - 0.89% (% OF PRICE)	7.50 - 287.35% (% OF PRICE)
SULFUR OXIDES EXCLUDING S04 MORTALITY	0.0004 - 0.0006 (S PER GAL)	0.0023 - 0.0035 (S PER GAL)	0.0002 - 0.0003 (S PER GAL)	3.4518 - 5.1493 (S PER SHT TON)	0.0082 - 0.0122 (s PER GAL)	0.0001 - 0.0001 (s PER 1000 CU FT)	0.0203 - 0.0301 (S PER SHT TON)
	0.04 - 0.06% (% OF PRICE)	0.25 - 0.37% (% OF PRICE)	0.03 - 0.05% (% OF PRICE)	10.37 - 1 5.46% (% OF PRICE)	1.19 - I .77% (% OF PRICE)	0.00 - 0.00'% (% OF PRICE)	0.03 - 0.05'% (% OF PRICE)
SULFUR OXIDES S04 MORTALITY	0.0000 - 0.0089 (s PER GAL)	0.0000 - 0.0552 (S PER GAL)	0.0000 - 0.0049 (S PER GAL)	0.0000 - 81.5317 ($ PER SHT TON)	0.0000 - 0.1927 (S PER GAL)	0.0000 - 0.0013 (S PER1OOOCUFT)	0.0000 - 0.4569 (S PER SHT TON)
	0.00 - 0.95% (% OF PRICE)	0.00 - 5.87% (% OF PRICE)	0.00 - 0.77% (% OF PRICE)	0.00 - 244.84% (% OF PRICE)	0.00 - 28.00% (% OF PRICE)	0.00 - 0.03% (% OF PRICE)	0.00 - 0.74% (% OF PRICE)
OZONE	0.0019 - 0.0409 (S PER GAL)	0.0015 - 0.0336 (S PER GAL)	0.0005 - 0.0105 (s PER GAL)	0.0938 - 2.0219 (S PER SHT TON)	0.0002 - 0.0039 ($ PER GAL)	0.0020 - 0.0435 (S PER1OOOCUFI)	0.1869 - 4.0282 (S PER SHT TON)
	0.20 - 4.39?? (% OF PRICE)	0.16 - 3.58% (% OF PRICE)	0.07 - 1.64% (% OF PRICE)	0.28 - 6.07% (% OF PRICE)	0.03 - 0.57% (% OF PRICE)	0.05 - I.1O% (% OF PRICE)	0.30 - 6.52% (% OF PRICE)
VISIBILITY	0.0003 - 0.0013 (S PER GAL)	0.0020 - 0.0082 ($ PER GAL)	0.0002 - 0.0007 (S PER GAL)	3.0176 - 12.0704 (S PER SHT TON)	0.0071 - 0.0285 (s PER GAL)	0.0000 - 0.0002 ($ PER 1000 CU FT)	0.0170 - 0.0680 ($ PER SHT TON)
	0.04 - 0.14% (% OF PRICE)	0.22 - 0.87% (% OF PRICE)	0.03 - 0.11% (% OF PRICE)	9.06 - 36.25% (% OF PRICE)	1.04 - 4.1 5% (% OF PRICE)	0.00 - 0.00% (% OF PRICE)	0.03 - 0.11% (% OF PRICE)
AIR TOXICS FROM MOTOR VEHICLES	0.0060 - 0.0386 (S PER GAL)	0.0423 - 0.2138 ($ PER GAL)					
	0.65 - 4.14% (% OF PRICE)	4.50 - 22.75% (% OF PRICE)					

• ALL VALUES NORMALIZED TO S 1986.

TABLE A2.1 .10: UNIT VALUE OF BENEFITS OF EMISSION REDUCTION TO ZERO FOLLOWING COMPLIANCE WITH CURRENT STANDARDS
MODIFIED UPPER BOUND, ASSUMING 10% EMLSS1ON REDUCTION •

BENEFITS SOURCE	GASOLINE	DIESEL	AIRCRAFT FUEL	COAL	HEATING OILS	NATURAL GAS	WOOD
LEAD IN GASOLINE	$0.0104 - $0.0112 ($ PER GAL)						
	1.12 - 1.20'% (% OF PRICE)						
PARTICULATES	$0.0127 - $0.6267 (s PER GAL)	$0.0329 - $1.6263 (s PER GAL)	SO.O1O4 - $0.5120 ($ PER GAL)	S1.2837 - $63.4449 (S PER SHT TON)	S0.0066 - $0.3252 (S PER GAL)	S0.0027 - S0.1359 **($ PER 1000 CU FT)**	$13.9039 - S687.1636 ($ PER SHT TON)
	1.36 - **67.31%** (% OF PRICE)	3.50 - 173.01% (% OF PRICE)	1.61 - 79.62% (% OF PRICE)	3.86 - 190.53% (% OF PRICE)	0.96 - 47.27% (% OF PRICE)	0.07 - 3.43% (% OF PRICE)	22.51 - 1 I 12.28% (% OF PRICE)
SULFUR OXIDES EXCLUDING SO4 MORTALITY	$0.0011 - $0.0017 (S PER GAL)	$0.0070 - $0.0105 (S PER GAL)	$0.0006 - $0.0009 (S PER GAL)	$10.3541 - $15.4463 (S PER SHT TON)	$0.0245 - $0.0365 (s PER GAL)	$0.0002 - $0.0002 (S PER1OOOCUFT)	S0.0580 - $0.0865 ($ PER SHT TON)
	0.12 - 0.1 8% (% OF PRICE)	0.75 - 1.119'. (% OF PRICE)	0.10 - 0.15% (% OF PRICE)	31.09 - 46.39% (% OF PRICE)	3.56 - 5.31% (% OF PRICE)	0.00 - 0.01% (% OF PRICE)	0.09 - 0.14% (% OF PRICE)
SULFUR OXIDES S04 MORTALITY	$0.0000 - S0.0266 (S PER GAL)	$0.0000 - S0.1656 (S PER GAL)	S0.0000 - $0.0148 (s PER GAL)	S0.0000 - S244.5949 (S PER SHT TON)	S0.0000 - S0.5780 (s PER GAL)	$0.0000 - $0.0039 **($ PER 1000 CU FT)**	$0.0000 - $1.3708 (S PER SHT TON)
	0.00 - 2.86% (% OF PRICE)	0.00 - 17.62% (% OF PRICE)	0.00 - 2.30% (% OF PRICE)	0.00 - 734.52% (% OF PRICE)	0.00 - 84.01% (% OF PRICE)	0.00 - 0.10% (% OF PRICE)	0.00 - 2.22% (% OF PRICE)
OZONE	S0.0057 - S0.1226 (s PER GAL)	$0.0046 - $0.1009 ($ PER GAL)	S0.0014 - S0.0316 (s PER GAL)	S0.2815 - S6.0657 ($ PER SHT TON)	$0.0005 - $0.0117 (S PER GAL)	$0.0061 - $0.1306 (S PER1OOOCUFT)	S0.5606 - $12.0847 (S PER SHT TON)
	0.61 - 13.16% (% OF PRICE)	0.48 - 10.73% (% OF PRICE)	0.22 - 4.91% (% OF PRICE)	0.85 - 18.22% (% OF PRICE)	0.08 - 1.71% (% OF PRICE)	0.15 - 3.30% (% OF PRICE)	0.91 - 19.56% (% OF PRICE)
VISIBILITY	$0.0003 - $0.0013 (s PER GAL)	$0.0020 - S0.0082 (S PER GAL)	$0.0002 - $0.0007 (s PER GAL)	$3.0176 - S12.0704 (S PER SHT TON)	$0.0071 - $0.0285 ($ PER GAL)	$0.0000 - $0.0002 (s PER 1000 CU FT)	$0.0170 - $0.0680 (S PER SHT TON)
	0.04 - 0.14% (% OF PRICE)	0.22 - 0.87% (% OF PRICE)	0.03 - 0.11% (% OF PRICE)	9.06 - 36.25% (% OF PRICE)	1.04 - 4.15% (% OF PRICE)	0.00 - 0.00% (% OF PRICE)	0.03 - 0.11% (% OF PRICE)
AIR TOXICS FROM MOTOR VEHICLES	S0.0060 - $0.0386 (s PER GAL)	S0.0423 - $0.2138 (s PER GAL)					
	0.65 - 4.14% (% OF PRICE)	4.50 - 22.75% (% OF PRICE)					

• ALL VALUES NORMALIZED TO S 1986.

TABLE A2. 1.11: UNIT BENEFIT VALUE OF SELECTED CLEAN AIR ACT AMENDMENTS EMISSIONS TARGETS

BENEFITS SOURCE	GASOLINE	DIESEL	AIRCRAFT FUEL	COAL	HEATING OILS	NATURAL GAS	WOOD
LEAD IN GASOLINE							
PARTICULATES							
SULFUR OXIDES EXCLUDING S04 MORTALITY				$2.1164 - $3.1576 ($ PER SHT TON) 6.36 - 9.48% (% OF PRICE)	S0.0019 - $0.0276 ($ PER GAL) 0.27 - 4.01% (% OF PRICE)		
SULFUR OXIDES S04 MORTALITY				S0.0000 - $189.4833 ($ PER SHT TON) 0.00 - 569.02% (% OF PRICE)	S0.0000 - $0.1658 ($ PER GAL) 0.00 - 24.09% (% OF PRICE)		
OZONE	$0.0012 - S0.0258 ($ PER GAL) 0.13 - 2.7S% (% OF PRICE)	S0.0003 - $0.0058 ($ PER GAL) 0.03 - 0.62% (% OF PRICE)	$0.0003 - $0.0073 ($ PER GAL) 0.05 - 1.13% (% OF PRICE)	$0.0021 - $0.0451 ($ PER SHT TON) 0.01 - 0.14% (% OF PRICE)	$0.0001 - $0.0020 ($ PER GAL) 0.01 - 0.29% (% OF PRICE)	S0.0001 - S0.0027 ($ PER 1000 CU FT) 0.00 - 0.07% (% OF PRIcE)	so. 1484 - $3.1955 ($ PER SHT TON) 0.24 - 5. 17% (% OF PRICE)
VISIBILITY				$1.3875 - $5.5512 ($ PER SHT TON) 4.17 - 16.67% (% OF PRICE)	$0.0012 - $0.0049 ($ PER GAL) 0.17 - 0.71% (% OF PRICE)		
AIR TOXICS FROM MOTOR VEHICLES							

• ALL VALUES NORMALIZED TO S 1986.

Footnotes for Table A2.1.11.

* ALL VALUES NORMALIZED TO $1986.

+ ASSUMES SULFUR DIOXIDE EMISSIONS FROM ELECTRIC UTILITIES WILL BE REDUCED BY 10 MILLION TONS ANNUALLY. EMISSION REDUCTIONS ALLOCATED BETWEEN COAL AND HEATING OILS BASED UPON PROPORTION OF ELECTRIC UTILITY OUTPUT FROM EACH SOURCE. UNIT BENEFITS CALCULATED AS IN TABLE 4 fn.

^ ASSUMES OZONE POLLUTION REDUCED BY 10 MILLION TONS ANNUALLY. ASSUMES THAT VOCS ACCOUNT FOR 100 PERCENT OF OZONE FORMATION. UNIT BENEFITS CALCULATED AS IN TABLE 4 fn.

Footnotes for Table A2.1.11.

* ALL VALUES NORMALIZED TO $1986.

+ ASSUMES SULFUR DIOXIDE EMISSIONS FROM ELECTRIC UTILITIES WILL BE REDUCED BY 10 MILLION TONS ANNUALLY. EMISSION REDUCTIONS ALLOCATED BETWEEN COAL AND HEATING OILS BASED UPON PROPORTION OF ELECTRIC UTILITY OUTPUT FROM EACH SOURCE. UNIT BENEFITS CALCULATED AS IN TABLE 4 fn.

" ASSUMES OZONE POLLUTION REDUCED BY 10 MILLION TONS ANNUALLY. ASSUMES THAT VOCS ACCOUNT FOR 100 PERCENT OF OZONE FORMATION. UNIT BENEFITS CALCULATED AS IN TABLE 4 fn.

Table A2.1.12

Taxes Per Unit of Fuel Consumption

Fuel Tvoe	Total taxes per Fuel Type (in $ billions)	Taxes per Unit of Fuel	Taxes as a Percent of of Price
Gasoline	**26.87**[1]	.2309 /gallon	24.91
Diesel fuel	**5.00**[2]	.2548/gallon	***27.14***
Aircraft fuel	**1.71**[3]	.1019 /gallon	15.53
Natural gas	**4.11**[4]	***.2536/1000* cu** ft	6.40
coal	10.17[5]	12.6445/short ton	***37.97***
Fuel oil	**4.72**[6]	.1009/gallon	12.07

Note: **All** figures are in 1986 dollars.

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[1]**Includes** Federal, state, and local excises, state **severence** taxes (allocated), windfall profits tax (allocated), and Superfund tax (allocated).

[2]**Includes** Federal, state, and local excises, state severance taxes (allocated), windfall profits tax (allocated), and Superfund tax (allocated).

[3]**Includes** state and local excises, state severance taxes (allocated), windfall profits tax (allocated), and Superfund tax (allocated).

[4]**Includes** state severance taxes, and city and county utility taxes. Excludes state utility taxes. Total for all state utilities over $6 billion.

[5]**Includes** state severance taxes, black lung **tax,** and city and county utility taxes (allocated). Excludes state utility taxes. Total for all utilities over $6 billion.

[6]**Includes** city and county utility taxes (allocated), state severance taxes (allocated), windfall profits tax (allocated), and Superfund tax (allocated). Excludes state utility taxes. Total for all utilities over $6 billion.

Table A2.1.13

Taxes Per Unit of Fuel Consumption Net of Taxes
Earmarked for Specific Programs+

Fuel Type	Net Taxes* per Fuel Type (in $ billions)	Net Taxes per Unit of Fuel	Taxes as a Percent of Price	Net Tax Per Million BTU
Gasoline	*17.98*	.1545/gal	16.60	$1.24
Diesel Fuel	2.38	.1213/gal	12.90	0.87
Aircraft Fuel	1.71	.1016/gal	15.49	0.76
Heating Oil	4.70	.1005/gal	14.61	0.93
Natural gas	4.11	.2536/cu.ft.	*6.40*	0.58
coal	9.61	11.9458/ton	*35.87*	0.25

● Excludes taxes designated for Federal Highways Trust Fund, Superfund Tax, and Black Lung Tax. Some state and local tax revenues may be designated for specific uses but are not excluded from this table.

+ All figures are for tax year 1986 in 1986 dollars.

TABLE A2.1 .14: RELATIVE CARBON TAXES, ASSUMING 25% EMISSION REDUCTION

FUEL TYPE	POUNDS C02 EMISSION PER UNIT FUEL+	EXTERNALITY COST PER UNIT ++ LOW	MIDPOINT	HIGH	RELATIVE CARBON TAX**
GASOLINE (GALS)	5.48	$0.10	$0.28	$0.46	27.89
DIESEL (GALS)	6.31	$0.06	$0.61	$1.15	52.88
AIRCRAFT FUEL (GALS)	NA	$0.01	$0.12	$0.23	NA
COAL (SHT TONS)	1,219.02	$8.32	$232.71	S457.1O	104.87
HEATING OILS (GALS)	6.67	$0.02	$0.58	$1.14	47.99
NATURAL GAS (1000 FT**3)	32.85	$0.00	$0.06	$0.12	1.00
WOOD (SHT TONS)	NA	$6.47	$134.11	$261.75	NA

+ SOURCE: C02 EMISSIONS FOR EACH FUEL FROM MARLAND 1983.
CONVERTED TO POUNDS C02 EMISSION PER UNIT FUEL BASED UPON CONVERSION FACTORS IN "MONTHLY ENERGY REVIEW," JANUARY 1987.

i-t FROM SUMMING DOWN THE COLUMNS OF TABLES 4 AND 7.

** MODIFIED UPPER BOUND DIVIDED BY CARBON CONTENT, SCALED WITH NATURAL GAS EQUAL TO ONE BY DIVIDING THE CARBON TAX FOR EACH FUEL TYPE BY THE CARBON TAX FOR NATURAL GAS.

TABLE A2.1. 15: GROSS VALUE OF BENEFITS BY FUEL-ASSUMING 25% EMISSION REDUCTION

FUEL SOURCE	GROSS BENEFIT OF COMPLIANCE WITH CURRENT REGULATIONS * TOTAL BENEFIT ($ MILLIONS) LOW	HIGH	GROSS BENEFIT OF REDUCTION TO ZERO+ TOTAL BENEFIT ($ MILLIONS) LOW	HIGH
GASOLINE	8,818.5	19,699.6	2,708.9	33,528.8
DIESEL	97.0	5,157.9	1,161.0	17,427.6
AIRCRAFT FUEL	23.2	1,121.3	72.6	2,722.9
COAL	1,017.5	86,390.2	5,371.2	264,796.7
HEATING OILS	122.8	9,966.0	618.0	30,056.5
NATURAL GAS	16.2	507.2	49.4	1,367.1
WOOD	246.9	11,977.0	743.4	28,071.0

* THE SUNI FOR EACH FUEL TYPE OF THE UNIT BENEFIT VALUES FROM TABLE 4 MULTIPLIED BY FUEL CONSUMPTION FROM TABLE 5.

+ THE SUM FOR EACH FUEL TYPE OF THE UNIT BENEFIT VALUES FROM TABLE 7 MULTIPLIED BY FUEL CONSUMPTION FROM TABLE 5.

TABLE A2.1 .16: GROSS VALUE OF BENEFITS BY FUEL-ASSUMING **10%** EMISSION REDUCTION

	GROSS BENEFIT OF COMPLIANCE WITH CURRENT REGULATIONS * TOTAL BENEFIT ($ MILLIONS)		GROSS BENEFIT OF REDUCTION TO ZERO+ TOTAL BENEFIT ($ MILLIONS)	
FUEL SOURCE	Low	HIGH	LOW	HIGH
GASOLINE	8,818.5	19,699.6	**4,220.9**	105,069.6
DIESEL	97.0	5,157.9	1,742.9	50,778.5
AIRCRAFT FUEL	23.2	1,121.3	212.0	10,103.7
COAL	1,017.5	86,390.2	11,476.0	786,785,8
HEATING OILS	122.8	9,966.0	1,354.5	90,691.3
NATURAL GAS	16.2	507.2	146.2	4,567.5
WOOD	246.9	11,977.0	**2,224.5**	107,803.5

* THE SUM FOR EACH FUEL TYPE OF THE UNIT BENEFIT VALUES FROM TABLE 4 MULTIPLIED BY FUEL CONSUMPTION FROM TABLE 5. (SAME AS IN TABLE 15).

+ THE SUM FOR EACH FUEL TYPE OF THE UNIT BENEFIT VALUES FROM TABLE 8 MULTIPLIED BY FUEL CONSUMPTION FROM TABLE 8.

TABLE A2. 1.17: SUMMARY OF ENERGY EXTERNALITIES AND TAXES-ASSUMING 25'% EMISSION REDUCTION

FUEL TYPE	EXTERNALITY COSTS PER UNIT * LOW	HIGH	EXTERNALITY COSTS PER UNIT MIDPOINT **	EXTERNALITY COSTS PER UNIT + MODIFIED UPPER BOUND	MODIFIED UPPER BOUND AS A ++ PERCENT OF PRICE (1986)	NET TAX PER UNIT FUEL - (1986)	NET TAX AS PERCENT OF PRICE ~ (1986)
GASOLINE (GAL)	$0.10	$0.46	$0.28	$0.42	45.58%	$0.15	16.60%
DIESEL FUEL (GAL)	**$0.06**	$1.15	$0.61	$0.95	100.63%	$0.12	12.90%
AIRCRAFT FUEL (GAL)	$0.01	$0.23	$0.12	$0.21	32.79%	$0.10	15.80%
COAL (SHORT TONS)	$8.32	$457.10	$232.71	$153.78	**461.79%**	$11.95	**35.87%**
HEATING OILS (GAL)	$0.02	$1.14	$0.58	$0.43	62.08%	$0.10	14.61%
NATURAL GAS (1000 CUBIC FT)	$0.00	$0.12	$0.06	$0.11	2.79%	$0.25	6.40%
WOOD (SHORT TONS)	$6.47	$261.75	$134.11	**$259.96**	420.79??	NA	NA

• FROM SUMMING DOWN THE COLUMNS OF TABLES 4 AND 7.

** MIDPOINT OF TWO PREVIOUS COLUMNS.

+ FROM SUMMING DOWN THE COLUMNS OF TABLES 6 AND 9.

i-t PRICE FROM TABLE 5 DIVIDED BY MODIFIED UPPER BOUND MULTIPLIED BY 100.

- FROM TABLE 13.

TABLE A2. 1.18: SUMMARY OF ENERGY EXTERNALITIES AND TAXES-ASSUMING 10% EMISSION REDUCTION

FUEL TYPE	EXTERNALITY COSTS PER UNIT • LOW	EXTERNALITY COSTS PER UNIT • HIGH	EXTERNALITY COSTS PER UNIT MIDPOINT **	EXTERNALITY COSTS PER UNIT + MODIFIED UPPER BOUND	MODIFIED UPPER BOUND AS A ++ PERCENT OF PRICE (1986)	NET TAX PER UNIT FUEL ~ (1986)	NET TAX AS PERCENT OF PRICE ~ (1986)
GASOLINE (GAL)	$0.11	$1.07	$0.59	$0.99	106.31%	$0.15	16.60%
DIESEL FUEL (GAL)	$0.09	$2.85	$1.47	$2.34	248.59%	$0.12	1 2.90%
AIRCRAFT FUEL (GAL)	$0.01	$0.67	$0.34	S0.62	96.76%	$0.10	15.80%
COAL (SHORT TONS)	S16.26	$1,136.50	$576.38	S378.24	1135.85%	$11.95	35.87%
HEATING OILS (GAL)	$0.04	S2.88	$1.46	$1.09	157.81%	$0.10	14.61%
NATURAL GAS (1000 CUBIC FT)	$0.01	$0.31	$0.16	$0.30	7.60'%	S0.25	6.40%
WOOD (SHORT TONS)	S16.15	$782.88	$399.52	$778.63	1260.3370	NA	NA

• FROM SUMMING DOWN THE COLUMNS OF TABLES 4 AND 8.

** MIDPOINT OF TWO PREVIOUS COLUMNS.

+ FROM SUMMING DOWN THE COLUMNS OF TABLES 6 AND 10.

++ PRICE FROM TABLE 5 DIVIDED BY MODIFIED UPPER BOUND MULTIPLIED BY 100.

APPENDIX 2.2

SUMMARY OF DRAFT NEW YORK STATE ENERGY PLAN: 1991 BIENNIAL UPDATE ISSUE 9: ENERGY/ENVIRONMENTAL TAXES

Two types of externality taxes are considered in the report. One is the traditional Pigouvian tax approach which is referred to as a general revenue tax. The second approach, called the trust fund tax, is a variation on environmental taxes where the taxes are paid into a trust fund. The trust fund is in turn used to finance abatement measures. While the trust fund approach will not be as economically efficient as the general revenue tax because the pricing mechanism of the Pigouvian approach is diluted, the trust fund tax significantly reduces the tax bill for emitters.

The pollutants for which externality cost estimates are made include sulfur dioxide (SO_2), nitrous oxides (NO_x), and carbon dioxide (CO,). For SO_2 and NO_x, estimates are made for electricity generation only. Estimated externality costs are listed in the table.

ESTIMATED EXTERNALITY COSTS(MILLIONS)

POLLUTANT	TRUST FUND	GEN REVENUE
SO_2	S 2s0	S1,274
NO_x	$1,405	$6,081
CO_2	$7.9	S107

These figures are based on marginal damages and marginal abatement costs following compliance with the Clean Air Act Amendments of 1990.

For sulfur dioxide, a damage function was specified by first estimating the health risks of SO, emissions at the state's tonnage cap of 280,000 tons. The risk estimates were based on New York State population characteristics and a review of available research studies, several of which were included in EPA's assessment of the risks of SO_2 emissions. Resulting risk estimates at the emissions cap were: mortality risk, 60 x 10^{-7} for exposure at one u/m^3 of SO_2, estimated number of deaths, 12.44, valuation, $4 million. For a generic coal plant, emissions of 22,350 tons are valued at $50 million for an average damage cost of $2,244 per ton. It was then assumed that at emissions levels below 100,000 tons, damages are diminimus. The risk function was completed by assuming a linear damage relationship between the estimated risk at the tonnage cap and the assumed diminimus level of emissions.

The marginal abatement cost function is a step function derived from the incremental " SO_2 reductions which can be achieved with various retrofit technologies. Comparing the intersection of the damage and abatement functions leads to the conclusion that an additional 75,000 tons of emissions should be reduced over and above the emissions reductions in the Clean Air Act Amendments. The optimal tax rate consistent with this emissions reduction is $1,274 per ton of SO_2, measured in 1990 dollars. Following the trust fund approach, the estimated tax would be $280 per ton.

Due to a paucity of information on the direct risks of NO_x exposure, a damage function was not estimated; rather, an implied valuation was generated based upon the highest marginal costs previously committed to compliance with NO_x emissions reductions requirements. It is further assumed that this implied marginal damage value, $6,100 per ton of emissions reduction at coal-fired utilities, is the optimal environmental tax rate.

Environmental taxes for control of carbon dioxide are also estimated with an implied valuation. The values are based on a 10 percent reduction in carbon emissions from a 1988 baseline. Details of the estimate are not included in this report, but are found in Analysis of Carbon Reduction in New York State (June 1991). The general revenue tax for CO_2 is projected at $107 per ton emitted, and the trust fund tax at $7.9 per ton.

Contrast with Estimates from Viscusi-Magat

The pollutants under consideration, the health and environmental endpoints of concern, and the sources of pollution differ markedly between the New York State study and Part II of the report. The New York study considers only sulfur dioxide, nitrous oxide, and carbon dioxide. Several additional pollutants are considered in Part II, including, residual lead in gasoline, air toxics from motor vehicles, particulate, SO_4 and related by-products, and ozone producing VOC's. The class of sulfur-containing compounds and the endpoints valued are considerably broader. In addition to the direct damages of sulfur dioxide, other health and environmental endpoints considered are morbidity, environmental and materials damage, and visibility diminution. Part II of our study may include a narrower set of endpoints for NO_x, however, because only ozone related effects are considered, not direct health and environmental effects.

The New York State study includes environmental tax estimates aimed at reducing carbon dioxide emissions by 10%; no such estimates are considered in Part II. We do, however, consider the size of a carbon tax which would be required if a carbon tax was used as a mechanism to implement environmental taxes for the externalities created by other pollutants.

Only electricity generation is considered as a source of SO, and NO_x, while we consider all combustion sources, including both transportation and stationary source fuel combustion, composed of fuel use by public utilities, commercial/industrial sources, and private sources such as homeowners. By focusing on utility combustion only, several important fuels will be under represented, especially home heating oils, natural gas, and wood fuel.

Estimated environmental taxes may differ between the two studies because of significantly different baselines used in the two studies. The New York State study assumes compliance with the Clean Air Act Amendments of 1990 in the baseline from which health effects are measured. We incorporate a 1986 baseline which falls before the expected implementation of the most recent standards for ambient air concentrations of criteria pollutants.

The approaches used to determine the optimal tax rates are similar, but both studies are subject to uncertainty about the methods used. Our study assumes that the adverse effects of pollutants on health and environment are proportional to fuel consumption. The New York State study includes a linear relationship between emissions and adverse effects based upon an assumed no effects threshold for SO,. Because our study includes health effects as a constant proportion to fuel consumption, the optimal tax rate is constant over any level of emissions. The New York study, on the other hand, must also estimate a marginal abatement cost function to help determine the optimal degree of pollution reduction. Estimating this relationship introduces another level of uncertainty.

The environmental taxes for NO_x and CO_2 in the New York State study are based on the assumption that maximum marginal abatement costs reflect the optimal marginal benefit of abatement. The existing environmental regulations which led to these observed expenditures were not based on measures of optimal levels of abatement. Therefore, there is no reason to believe that the observed abatement costs reflect social cost marginal prices.

There is an environmental externality costing research project under preparation by the New York Dept of Public Service, the New York State Energy Research Development Authority, the Empire State Electric Energy Research company, and the Electric Power Research Institute with the objective of developing a methodology for estimating environmental externality costs for electricity generation. The project is expected to be completed in 1994.