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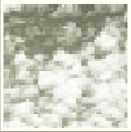

Economic Benefits Analysis of the Health Effects from Controlling Emissions from Tennessee Valley Authority Coal-Fired Power Plants

Expert Report

Prepared for:

North Carolina Department of Justice
Raleigh, NC 27602

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State of North Carolina ex rel. Roy Cooper, Attorney General v. Tennessee Valley Authority, Civil Action NO. 1:06CV20 (Western District of North Carolina)

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Expert Witness Report Prepared by:

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Expert Report

I, Leland B. Deck, have been retained by the Attorney General of the State of North Carolina as an expert in the field of economic benefits analysis of reducing emissions from power plants. This report documents my findings regarding the economic benefits from installing emission control devices at the Tennessee Valley Authority's (TVA's) coal-fired units to comply with an emissions cap equivalent to that required of power plants under North Carolina's Clean Smokestacks Act (CSA).

1. Background and Qualifications

I am a managing economist of Stratus Consulting Inc. For over 20 years I have worked in the field of economic analysis of air pollution control programs. I joined Stratus Consulting in March 2006. Prior to joining Stratus Consulting, I was employed by Abt Associates Inc. from 1992 to 2005 in a series of positions of increasing responsibilities culminating as vice president and Fellow. I was also previously employed as an economist with the Office of Air Quality Planning and Standards of the U.S. Environmental Protection Agency (EPA) in Research Triangle Park, North Carolina, from 1987 to 1992. From 1980 through 1987, I was employed as an economist by the Maryland Bureau of Business and Economic Research, the Maryland Department of Natural Resources, and the University of Maryland.

My primary professional area of activity has been in the field of benefits analysis of air pollution control programs, including economic benefits analysis, benefit-cost analysis, and risk assessment. Much of my work has directly involved analysis of potential reductions of the emissions from power plants that contribute to elevated concentrations of ambient ozone and particulate matter (PM) air pollution. I have published numerous reports, including peer-reviewed journal publications, book chapters, and EPA reports, on the health and economic benefits of improving air pollution. Since entering the economic consulting field in 1992 I have conducted air pollution benefits analysis for clients including the EPA; the Southern Appalachian Mountains Initiative; the Lake Michigan Air Directors Consortium; various state departments of environmental protection; the environmental and health ministries of Canada, Chile, Argentina, and Brazil; and not-for-profit environmental research organizations.

I received my MA (1980) and PhD (1987) in economics from the University of Maryland. I received my BS in geology from the Rensselaer Polytechnic Institute in 1975.

My resume, including a list of my publications and prior testimony, is provided in Appendix A. My statement regarding compensation for my services is included in Appendix B.

2. Summary of Testimony

Air quality improvements due to controlling emissions from the TVA's coal-fired power plants as proposed by North Carolina will result in substantial improvements in health in North Carolina and throughout the large region impacted by TVA's emissions. TVA's emissions contribute to the elevated concentrations of ozone and fine particulate matter ($PM_{2.5}$) that occur throughout the southeastern United States. Professors John Spengler and Jonathan Levy's Expert Witness Report (Spengler and Levy, 2006) provides estimates of the numbers of cases of nine health effects that will be avoided by the improvements in ozone and $PM_{2.5}$ from reducing TVA's air emissions. In this analysis I present the economic value of the avoided health effects estimated by Professors Spengler and Levy. I also compare the value of the health benefits with the cost estimates presented in the Expert Witness Report of James Staudt (Staudt, 2006).

Estimating the monetary value of avoided air pollution-related health effects has become a standard analytical component of developing air pollution legislation, regulations, and enforcement cases. The valuation methods I use in this testimony to estimate the monetary value of the health effects from reducing TVA's emissions are the same methods currently used by EPA in their recent analyses of major air pollution control programs, including the 2005 Clean Air Interstate Rule (CAIR) regulating power plant emissions (U.S. EPA, 2005) and the 2006 revision to the PM National Ambient Air Quality Standards (NAAQS; U.S. EPA, 2006). I updated the health effect valuation methods in the PM NAAQS analysis to reflect 2006 prices and incomes (EPA's analysis was presented in terms of 1999 prices).

2.1 Estimated Annual Benefits of Health Effects from Emission Reductions in 2013

I estimate the value of the health effects in North Carolina associated with the reductions in TVA's emissions in 2013 to be $672 million (measured reflecting both income and prices in 2006). These are the benefits from the emissions reductions in 2013. Each subsequent year's reductions will produce additional benefits of comparable size. As shown in Table 1, the majority of the 2013 benefit value is from avoided premature mortality.

Table 2 shows that while the 2013 economic benefits to North Carolinians are substantial ($672 million), additional economic benefits accrue to other states, reflecting the location of the air quality impacts from TVA's 2013 emissions. The total value of the quantified health benefits are $9.5 billion.

Table 1. Economic value of the quantified health effects in North Carolina avoided by controlling TVA emissions in 2013 (in 2006 prices, based on the population in 2000)

	North Carolina
Premature mortality	$651,000,000
All other quantified health effects	$21,000,000
Total	$672,000,000

Table 2. Total economic value of quantified health effects avoided by controlling TVA emissions in 2013 (in 2006 prices, based on the population in 2000)

	Total
Premature mortality	$9,213,000,000
All other quantified health effects	$282,000,000
Total	$9,495,000,000

As discussed later in this report, there are several important reasons the estimated benefits in North Carolina ($672 million), and the total benefits ($9.5 billion), are an underestimate of the total value of the avoidable health effects. One important reason is the estimated cases of avoided health effects are based on the Census population in the year 2000. As the population increases, the health benefits will increase. In order to demonstrate this effect, Spengler and Levy also used forecast population estimates for 2013 to estimate the avoided health effects in 2013. The forecasted increase in population would increase the number of cases by approximately 14% over the estimates based on the year 2000 population. The economic value of the benefits would similarly increase with the population. The estimated economic benefits in North Carolina using the forecast 2013 population are $792 million, and the total benefits are $10.9 billion (in 2006 prices and income).

The health effects included in this report are not a complete accounting of all the health effects likely to occur if emissions from TVA's power plants are reduced. Other health effects are known, or strongly believed, to be associated with changes in ozone and PM levels, but the information needed to make specific quantitative estimates of these effects is not available. Health effects omitted from the analysis lead to an underestimate of the total benefits of reducing TVA's emissions. The health effects that are included in the analysis, as well as some of the health effects not included in the quantified analysis, are shown in Table 3.

Table 3. Quantified and unquantified health effects

	Quantified health effects	Unquantified health effects
PM-related	Premature mortality (adults and infants) Chronic bronchitis Hospital admissions: Respiratory and cardiovascular Emergency room visits for asthmatics Minor restricted activity days Asthma exacerbations	Premature mortality, ages 1-30 Nonfatal heart attacks (myocardial infarctions) Low birth weight Upper and lower respiratory illness Chronic cardiopulmonary diseases other than chronic bronchitis (e.g., emphysema) Non-asthmatic emergency room visits Hospital admissions in children Work loss days
Ozone-related	Premature mortality Hospital admissions: Respiratory Emergency room visits School absence days Minor restricted activity days	Chronic respiratory damage Premature aging of lungs Lost worker productivity

In addition to the health effects that are not quantified in my analysis, there are also additional health effects from exposure to other pollutants (gaseous sulfur dioxide, gaseous nitrogen oxides, and mercury), as well as non-health benefits that are also not quantified in this analysis. Table 4 shows some of the important known health effects from other pollutants and the non-health benefits that are not quantified in this analysis.

Table 4. Additional benefits not quantified in this analysis

Effect category	Unquantified effects
Health effects from gaseous SO_2	Hospital admissions for respiratory and cardiac diseases Respiratory symptoms in asthmatics
Health effects from gaseous nitrogen (NO_x) compounds	Lung irritation Lowered resistance to respiratory infection Hospital admissions for respiratory and cardiac diseases
Health effects from mercury	Incidences of learning disabilities Incidences of developmental delays Cardiovascular effects, including: ▸ Altered blood pressure regulation ▸ Increased heart rate variability ▸ Incidences of myocardial infarction Potential reproductive effects

Table 4. Additional benefits not quantified in this analysis (cont.)

Effect category	Unquantified effects
Non-health PM effects	Visibility impacts in National Parks and other wilderness areas
	Visibility impacts in urban, residential, and rural areas
	Global climate impacts
	Increased household soiling
Non-health ozone effects	Reduced agricultural yields for commodity crops, fruits and vegetables
	Reduced commercial forest yields
	Damage to urban ornamental vegetation
	Recreational demand from damaged forest aesthetics
	Damaged ecosystem functions
Nitrogen and sulfur deposition	Commercial forests impacts due to acidic sulfate and nitrate deposition
	Commercial freshwater fishing impacts due to acidic deposition
	Recreation impacts in terrestrial ecosystems due to acidic deposition
	Commercial fishing, agriculture, and forests due to nitrogen deposition
	Recreation in estuarine ecosystems due to nitrogen deposition
	Ecosystem functions
	Passive fertilization
Non-health mercury effects	Impact on birds and mammals (e.g., reproductive effects)
	Impacts to commercial, subsistence, and recreational fishing

2.2 Benefit-Cost Analysis

A primary purpose of estimating the monetary value of the health effects of controlling emissions from TVA's power plants is to compare the benefits and the costs. In his Expert Witness Report, James Staudt provides estimates of the initial capital investment ($2.966 billion, using 2006 prices) and continuing operating and maintenance (O&M) costs ($221.8 million/year in 2006 prices) over the expected remaining life of the additional pollution control equipment (30 years). In order to compare the costs with the single year benefits, I converted the estimated stream of costs to an annual equivalent cost. Annualizing a stream of investment and operating costs that vary over time is a standard economic procedure.

The equivalent annual cost of controlling TVA's emissions is $516 million. This is an annualized cost that will occur in each of the 30 years that TVA's power plants are expected to operate with the additional pollution control equipment.

With estimated annual benefits of $9.5 billion, and annual costs of $516 million, reducing the TVA emissions to the requested levels clearly passes the benefit-cost test. The quantified annual benefits are 18.4 times the estimated annual cost. Such a large benefit/cost ratio is evidence that substantially different assumptions could be made in either the benefit or the cost analyses without changing my conclusion that the requested emission reductions do provide a substantial net benefit to society.

Even though many health benefits occur in states other than North Carolina, the annual benefits in North Carolina alone ($672 million) exceed the annual costs of the entire control program.

3. Valuing Health Benefits

A modern economic analysis of the monetary value of reducing the *risk* of an adverse health effect uses the concept of what avoiding that risk is worth to a typical person, rather than using only what it will cost to treat the health effect. Economists call this concept the “willingness to pay” (WTP) to reduce risk. In simple terms, economists measure how much people want to reduce health risks, and measure that “want” by how much they would pay to reduce risk by a small amount. This value would reflect not only the desire to avoid treatment costs, but also the value of pain and suffering, the value of the time spent while sick or in the hospital, and the adverse impacts on family caregivers.

Monetary values for reductions in pollution-related health risks should therefore reflect the full consequences to the affected individuals and to society. These include both financial and quality-of-life consequences including:

- **Medical costs.** These include personal out-of-pocket expenses for the affected individual (or family) and third-party costs paid by government or private insurance. These are referred to as the cost of illness (COI).

- **Lost productivity.** This includes lost income when an affected individual cannot work at his or her usual employment because of illness or death. This also includes the value of lost productivity that is not necessarily compensated by wages such as caregiving for children or elderly family members and normal household chores.

- **Costs for caregiving.** These include costs for special caregiving and services that may be required because of an individual’s illness, but not reflected in typical medical costs. This may include lost wages for a parent who has to miss work when a child is ill.

- **Quality-of-life impacts.** These include restrictions on or reduced enjoyment of leisure activities, discomfort or inconvenience (pain and suffering), anxiety about the future, and concern and inconvenience to family members and others.

Ideally, good estimates of the complete WTP for each separate health effect would be identified by an economic study. However, for some health effects, only COI and lost wages (productivity) are available. For this assessment, I use WTP estimates of monetary value when they are available. However, WTP estimates are not available for every type of health effect associated with air pollutants. When WTP estimates are not available, I use COI and lost wage estimates as a proxy for WTP. It is expected that in most cases COI estimates will understate the full value to society of reducing a given health effect because they do not reflect the full value of the effects of illness on quality of life. Also, potential medical costs and wage losses are only one aspect of the reasons why people value reducing their own risks of fatal illness.

Unlike monetary damages in a conventional after-the-fact damage case (where the specific health effect and who was harmed is known), the economic valuation issue I am addressing is what is the total value of the risk reductions to everyone who will be exposed to cleaner air. It is important to distinguish between a health effect and a health risk. A health effect refers to an illness or symptom, including death, which is experienced by someone. A health risk is the quantitative probability that any one individual might experience a given health effect. Changes in air quality cause changes in the number of health effects in the exposed population, but from the point of view of the individual, what changes is the risk of experiencing a given health effect. This is because it is unknown exactly which individuals might be affected. WTP estimation techniques, especially for more serious health effects such as mortality or chronic illness, tend to focus on changes in the risks of health effects that an individual might experience in a given time period. For example, WTP studies concerning mortality do not estimate what individuals would be willing to pay to avoid their certain death in a given time period, but rather estimate what they are willing to pay to reduce their risk of death by a small amount in a given time period.
For convenience, economists discuss the monetary value in terms of the “value per case” of a particular health effect. However, these “unit values” are derived from the value for each individual of a small reduction in their risk of experiencing a particular health effect.

3.1 WTP Estimation Techniques

Willingness to pay is typically measured by analyzing prices that are paid for goods and services. The maximum price that an individual is willing to pay for a good or service is a measure of how much they value that good or service. Prices cannot be directly observed for reducing health risks, because reductions in health risks are not directly purchased in the market. However, there are instances when the monetary tradeoffs that people are willing to make between income and health risks can be observed or measured. There are two general categories of economic approaches for measuring WTP for nonmarket goods such as health risk reduction. The first approach, revealed preference, involves analysis of actual situations in which WTP for health risk reductions may be revealed in specific economic choices people make. The second approach, stated preference, is a research method in which subjects respond to a hypothetical situation designed to have them reveal their WTP.

An example of a revealed preference approach is a hedonic-wage study, which estimates wage premiums for increased risks of fatal accidents on the job. This is done by analyzing factors that determine differences in actual wages between jobs, where one of these factors is on-the-job risk of death. The amount of additional wages that people are paid per unit of additional risk of fatal injury is a measure of the monetary tradeoff the individual is willing to make between additional risk and additional income. The advantage of this type of study is that it is based on actual behavior. A limitation is that it is difficult to find situations in which there is a clear tradeoff between income (or expenditures) and risks of death and it is difficult to statistically isolate WTP for a risk increment from other factors involved in the specific economic choice.

An example of a stated preference study is a survey in which respondents are presented with a hypothetical situation that involves a tradeoff between income or expenditures and a specific change in their own heath risk or health effect incidence. The respondents are then asked to estimate the most they would be willing to pay to change that risk by a specific amount. It is important that the hypothetical situation presented in a survey be realistic and easy to understand. This type of study has the advantage of being able to directly obtain estimates of WTP for any type of risk reduction that can be presented to respondents. However, a limitation with this type of study is how well respondents are able to give accurate responses to these types of hypothetical questions.

3.2 Adjusting WTP for Future Real Income Growth

Economic theory suggests that as real income (that is, income adjusted to remove the effects of inflation) rises, people will spend more for most goods and services. There is an expectation, therefore, as well as supporting empirical evidence, that the amount people are willing to pay for reducing health risks will rise as real incomes increase. If this is not taken into account, then the value of health risk reductions that occur in future years as a result of today's policy decisions will be understated.

I use the method used by the U.S. EPA (2005, 2006) to adjust for expected growth in real income in future years, which is based on available empirical evidence about the magnitude of the elasticity of WTP for health risk reductions with respect to income. This elasticity is defined as the percentage change in WTP for a health risk reduction associated with each 1% increase in income. Thus, an elasticity of 1.0 says that the WTP increases in proportion with the percentage increase in income. Empirical evidence suggests that the elasticity of WTP for health risk reduction with respect to income is positive, but less than one. This means that as incomes increase people spend more, but not proportionately more, on reducing health risks. There is also empirical evidence that the elasticities are larger for more serious health risks such as risks of death and of chronic illness. The empirical evidence for these estimates is based on limited studies and subject to some uncertainty. However, not making any adjustment for expected growth in WTP for health risk reduction would clearly undervalue health benefits in future years.

Table 5 shows the elasticity estimates I use to adjust for growth in WTP values for health risk reductions expected as real incomes rise over time. These are the same elasticity estimates used by U.S. EPA (2005, 2006). These elasticity estimates are used to adjust WTP estimates based on the growth in real per capita income [gross domestic product (GDP)] in the United States from when the original WTP study was conducted to the year 2006 (all economic benefits are presented here in terms of 2006 incomes and price levels).

Table 5. Elasticities used to adjust WTP estimates for real income growth

Health effect category	Elasticity estimate[a]	Adjustment factor for 1990 to 2006[b]
Mortality	0.40	7.9%
Chronic bronchitis	0.45	4.1%
Minor health effect	0.14	1.3%

a. Source: U.S. EPA (2005), Table 4-3.
b. Calculated based on expected real per capita income for 2006 of $29,465 (in 1999 prices) versus real per capita income in 1990 of $24,600 (in 1999 prices). All real GDP data and population data are from EPA (U.S. EPA, 2005, 2006).

3.3 Adjusting Values for Inflation

In addition to adjusting values to account for the growth in real incomes, I also adjust values from studies conducted in the past to reflect subsequent inflation. In order to adjust medical costs to reflect prices in 2006, I use the August 2006 level of the Consumer Price Index for Medical Care – Urban Consumers (CPI-Med-U). Using CPI-Med-U to adjust from EPA's 1999 prices to 2006 prices increases the EPA unit value estimates by 34.7%.

To adjust the WTP-based unit prices for inflation, I use the general CPI index for urban consumers (CPI-U). Adjusting the EPA estimates (in 1999 prices) to 2006 increases the unit values by 22.4%.

3.4 Source of Unit Value Estimates

The valuation methods I use in this report to estimate the monetary value of the health effects from reducing TVA's emissions are the same methods currently used by EPA in their analysis of air pollution control programs. Specifically, the economic values for each avoided case of a specific health effect are the values used by EPA in October 2006 in its economic benefits analysis of the new PM NAAQS, and in their analysis of the 2005 Clean Air Interstate Rule (CAIR). The only difference between the unit values I use and the unit values used by EPA in the 2006 PM NAAQS analysis (U.S. EPA, 2006) is I have updated the values to reflect 2006 prices and incomes (EPA's analysis was presented in terms of 1999 prices). I used EPA's methods and data to update the unit values for income growth and price inflation.

There is, of course, some uncertainty in each of the estimated unit values. There is a large and constantly growing amount of economic research about valuing health risks, and selecting a single value requires weighing a large number of issues. However, the range of most expert opinions will be very similar to the unit values (and their ranges) used by the EPA. The advantages in using the EPA valuation methods as the basis for my analysis include:

1. EPA's valuation methods have been extensively reviewed by EPA's Science Advisory Board (e.g., U.S. EPA, 2004) and by the National Research Council (NRC, 2002).

2. EPA's valuation methods have been used in many regulatory proceedings, in each of which EPA has solicited and received public comments about the valuation methods and overall economic benefit analysis.

3. The basis of each of the unit valuations, including the sources of the underlying information and extensive discussions of the issues and uncertainties about each estimate, are readily available online from EPA in technical support documents and Regulatory Impact Analyses and in the Docket for specific EPA air regulations.

4. Unit Values for Health Effects

The unit values I have selected for each quantifed health effect are shown in Table 5. This shows the original EPA unit values, which were expressed in terms of 1999 prices and the 1990 real income level. The results of adjusting each unit value for inflation (to 2006 prices) and income (to 2006 real income levels) are shown. As described later in this section, the adult mortality unit value (which is the most important unit value in this analysis, as it accounts for the vast majority of monetary benefits) has an additional adjustment to reflect that the premature mortality associated with air pollution improvements in a given year is assumed to occur over a 20-year period. This assumed lag structure results in an additional adjustment to the adult premature mortality value, as shown in Table 6.

I discuss the source of each estimated unit value in the remainder of this section.

Table 6. Unit values for health effects

Health effect	Pollutant	EPA unit value (1999 prices, 1990 income)	Unit value (2006 prices, 2006 income)	Unit value with mortality lag structure
Infant mortality	$PM_{2.5}$	$5,500,000	$7,249,621	$7,249,621
Adult premature mortality (ages 30+)	$PM_{2.5}$, O_3	$5,500,000	$7,249,621	$6,568,592
Chronic bronchitis	$PM_{2.5}$	$340,000	$366,895	na
Cardiovascular hospital admissions	$PM_{2.5}$	$18,387	$24,726	na
Respiratory hospital admissions	$PM_{2.5}$, O_3	$15,647	$20,190	na
Asthma emergency room visits	$PM_{2.5}$, O_3	$286	$385	na
School loss days	O_3	$75	$85	na
Minor restricted activity days	$PM_{2.5}$, O_3	$51	$55	na
Asthma exacerbation	$PM_{2.5}$	$42	$45	na

4.1 Unit Values for Premature Mortality

The estimates of WTP for reductions in mortality risk are sometimes referred to as the value of statistical life (VSL), because they are expressed on a per life basis. It is important to note, however, that they are based on the WTP of the individual for reducing his or her risk of their death by a small amount, not on the total value of a human life. The estimates provided by these studies are average dollar amounts that individuals are willing to pay for small changes in risks of death. For example, one study might find an average WTP of $50 for an annual reduction in risk of death of 1 in 100,000. These estimates are extrapolated to a per life basis by summing individuals' WTP over enough people that a value per one life saved is obtained. In this example, this value would be $5 million per life, the result of $50 multiplied by 100,000 people, each experiencing a risk reduction of 1 in 100,000. VSL is the term used to denote that it is a summation of WTP for small changes in risks of death.

Available WTP estimates for changes in mortality risks are based on revealed preference and stated preference studies. Many new economic valuation studies of VSL have been published in the past 10 years, and EPA selected two meta-analyses of this literature to provide the basis for their VSL estimates: Mrozek and Taylor (2002), and Viscusi and Aldy (2003).

U.S. EPA (2005, 2006) selected a central estimate for the VSL of $5.5 million, measured at 1999 prices and 1990 real income levels. EPA identified this value as the most likely (mean) estimate of a range with a normal distribution and a 95% confidence interval of $1 million to $11 million. The 95% confidence interval means there is only a 2.5% chance that the actual VSL will be below $1 million, and a 2.5% chance the value will be above $11 million. Values near the $5.5 million mean estimate are more likely than values further away. After adjusting these estimates to 2006 prices and real income levels, the estimate I use in this analysis is the most likely (mean) value of $7.25 million. The 95% confidence interval (in 2006 prices and real income level) is $1.3 million to $14.5 million.

I use the $7.25 million VSL estimate directly to assign a most likely value for the estimated cases of neo-natal (infant) mortality. The value for adult mortality, however, is adjusted to reflect an assumption about a cessation lag specifying when the adult mortality reductions occur after a change in pollution exposure.

Adjustment for cessation lag in PM mortality risk

Changes in mortality risk related to changes in $PM_{2.5}$ exposure are expected to occur over some extended period of time. The adult mortality risk is derived from studies based on long-term exposures; some of the deaths associated with $PM_{2.5}$ exposure are the result of chronic illnesses that take several years to develop. U.S. EPA (2006) acknowledges that empirical data to determine the specific cessation lag for $PM_{2.5}$ mortality risk are not available, but they make reasonable estimates based on recommendations from the EPA Science Advisory Board (U.S. EPA, 2004).

The assumption made by EPA is a lag spread over 20 years. The EPA assumes 30% of the risk reduction occurs in the first year, 50% is spread evenly over years two through five, and 20% is spread evenly over years six through 20. This cessation lag does not change the number of lives saved for a given reduction in $PM_{2.5}$ concentrations, but it affects the timing of when that occurs. Health effects occurring in the future are valued less than health effects that occur now because of the rate of time preference. A 3% social rate of time preference is appropriate to discount the value of premature deaths occurring in future years (U.S. EPA, 2000).

Using this discount rate, I calculate the present value of the adult VSL incorporating the assumed 20-year stream of deaths avoided due to air quality improvements occurring in 2013. The estimated adult VSL reflecting this cessation lag assumption is $6.56 million.

4.2 Unit Values for Chronic Bronchitis

EPA bases its estimate of the unit value for chronic bronchitis on two estimates of the WTP to reduce the risk of developing chronic bronchitis (Viscusi et al., 1991; Krupnick and Cropper, 1992). Both of these studies conducted a set of survey exercises to estimate WTP for reducing risks of developing chronic respiratory disease. In both studies, respondents were presented with tradeoff options for risks of developing chronic bronchitis (or chronic respiratory disease in general) versus cost of living. Respondents were presented with hypothetical residence location options where in some locations the risk of developing chronic bronchitis is lower but the cost of living is higher. An interactive computer program was used to adjust the tradeoff until the respondent reached a point of indifference between the two options. At this point a maximum WTP to reduce the risk of developing chronic bronchitis was revealed.

The health endpoint defined in these studies is a more severe case of chronic bronchitis than the typical case that is reflected in the epidemiology studies upon which the estimates of new cases of chronic bronchitis associated with $PM_{2.5}$ are based. The description of the disease included persistent symptoms of cough and phlegm, limits in physical activity, and ongoing medical care. In one survey version, Krupnick and Cropper asked respondents who had a relative with chronic bronchitis to consider the risk of developing a case "like your relative's." Respondents provided information on the severity of the relative's disease based on a scale ranging from 1 to 13. The results therefore provide estimates of how WTP to reduce the risk varies with the severity of the case prevented.

Because the Viscusi et al. sample is a better representation of the general population, the EPA uses their WTP results for reducing the risk of developing a severe case of chronic bronchitis (at 13 on the severity scale), but adjust the WTP to a value for a more average case based on the results of Krupnick and Cropper (1992).

I adopt EPA's approach of using a trimmed mean from Viscusi et al. (1991), which is $720,000 (in 1990 prices). With the adjustment to average severity, this brings the mean value per new case of chronic bronchitis to $260,000 (in 1990 prices and 1999 income). I then adjust this base central value and standard error to 2006 prices and real income levels. This produces the central estimate of $367,000 I use in my analysis.

4.3 Unit Values for Hospital Admissions and Emergency Room Visits

The EPA uses a cost of illness approach as the basis of its estimates for unit values for hospital admissions and emergency room visits. These estimates are based on national data on hospital charges for in-patient treatment of patients diagnosed with the same specific diseases used by Spengler and Levy in estimating avoided health effects. This includes hospitalization for all respiratory diseases [International Classification of Disease (ICD) codes 460 to 519] and for cardiovascular hospitalization (ICD codes 390 to 429). The data on hospital charges are for the year 2000, and were obtained from the U.S. Agency for Healthcare Research and Quality (AHRQ). The AHRQ hospital charge estimates are based on a national dataset of over 7,000,000 hospital admissions, which is also the source of data on the duration of each stay.

In addition to the hospital charges, EPA includes a value of lost time (valued at the median wage for an eight-hour work day) for patients while they are in the hospital. This considers the average duration of in-hospital care for each specific diagnosis, and the median wage. EPA's estimate of the national median daily wage is $115.20 (in the year 2000).

The EPA estimate of hospital charges and lost time for all respiratory disease hospital admissions for all age patients is $15,647 (in 2000 prices). Adjusting this estimate to 2006 prices (using the CPI-Med-U index) provides the unit cost estimate of $20,984 I use in this analysis.

EPA estimates hospital charges and lost time for cardiovascular hospital admissions among patients 65 and over is $18,387 (in 2000 prices). Adjusting this estimate to 2006 prices (using the CPI-Med-U index) provides the unit cost estimate of $24,726 I use in this analysis.

Because the AHRQ data only covers hospital admission charges, EPA derives the hospital cost information for emergency room visits for asthma from two studies: Smith et al. (1997) and Stanford et al. (1999). The average of the costs reported in these two studies is $286 (in 1999 prices). Adjusting this estimate to 2006 prices (using the CPI-Med-U index) provides the unit cost estimate of $385 I use in this analysis.

4.4 Unit Values for Other Health Effects

Table 7 presents EPA estimates of the unit values for the other morbidity health effects included in this analysis, the method used to estimate the unit value (COI or WTP), and the resulting unit values in 2006 prices that I use in this analysis.

Table 7. Unit values for other morbidity health effects

Health effect	EPA unit value (1999 prices)	Estimation method	Unit value (2006 prices)
Asthma exacerbation	$42	WTP	$45
Minor restricted activity days	$51	WTP	$55
School absence days	$76	Lost wages of employed female caregiver	$85

5. Estimated Economic Value of Reduced Health Effects

Applying the unit values for each health effect presented in Section 4 to the health effects estimates provided in Professor Spengler and Levy's report produces the estimated monetary health benefits for 2013 shown in Table 8. Table 9 shows the economic benefits in 2013 based on Professors Spengler's and Levy's estimates of the number of avoided health effects based on the forecasted population in 2013.

The total estimated monetary health benefits using the 2000 population for each of the 33 states plus the District of Columbia that are included in the air quality modeling domain are shown in Table 10. Table 11 shows the total estimated monetary health benefits using the 2013 population for each of the 33 states plus the District of Columbia.

Table 8. Estimated health benefits in 2013 using the population in 2000 (2006 prices and incomes)

Health effect	North Carolina	Other states	Total
Mortality (adult and infant)	$651,000,000	$8,563,000,000	$9,213,000,000
Chronic bronchitis	$16,000,000	$197,000,000	$213,000,000
Minor restricted activity days	$3,000,000	$32,000,000	$35,000,000
Respiratory hospital admissions and ER visits	$1,000,000	$11,000,000	$12,000,000
Asthma exacerbation	$1,000,000	$11,000,000	$12,000,000
Cardiovascular hospital admissions	$1,000,000	$7,000,000	$7,000,000
School absence days	$200,000	$3,400,000	$3,500,000
Total	$672,000,000	$8,823,000,000	$9,495,000,000

Table 9. Estimated health benefits in 2013 using the forecasted population in 2013 (2006 prices and incomes)

Health effect	North Carolina	Other states	Total
Mortality (adult and infant)	$767,000,000	$9,763,000,000	$10,530,000,000
Chronic bronchitis	$19,000,000	$228,000,000	$247,000,000
Minor restricted activity days	$3,000,000	$37,000,000	$39,000,000
Respiratory hospital admissions and ER visits	$1,000,000	$12,000,000	$14,000,000
Asthma exacerbation	$1,000,000	$12,000,000	$13,000,000
Cardiovascular hospital admissions	$1,000,000	$8,000,000	$9,000,000
School absence days	$200,000	$3,400,000	$3,600,000
Total	$792,000,000	$10,064,000,000	$10,856,000,000

Table 10. Estimated total health benefits by state using 2000 population (2006 prices and incomes)

State	Estimated benefits
Tennessee	$1,172,200,000
Ohio	$758,800,000
Georgia	$682,300,000
North Carolina	$671,700,000
Kentucky	$610,400,000
Alabama	$519,100,000
Pennsylvania	$512,000,000
Illinois	$500,300,000
Indiana	$416,000,000
Florida	$408,500,000
Virginia	$384,400,000
New York	$337,500,000
Missouri	$316,700,000
South Carolina	$280,100,000
Michigan	$252,800,000
Mississippi	$247,200,000
Arkansas	$228,700,000
New Jersey	$207,400,000
West Virginia	$199,900,000

Table 10. Estimated total health benefits by state using 2000 population (2006 prices and incomes) (cont.)

State	Estimated benefits
Maryland	$188,900,000
Louisiana	$180,200,000
Texas	$152,300,000
Wisconsin	$60,600,000
Connecticut	$47,500,000
Iowa	$40,800,000
Oklahoma	$29,000,000
Delaware	$27,500,000
District of Columbia	$25,600,000
Kansas	$19,800,000
Rhode Island	$7,500,000
Massachusetts	$5,900,000
Minnesota	$3,500,000
Nebraska	$300,000
Total	$9,495,100,000

Table 11. Estimated total health benefits by state using 2013 population (2006 prices and incomes)

State	Estimated benefits
Alabama	$586,700,000
Arkansas	$257,000,000
Connecticut	$50,400,000
Delaware	$33,000,000
District of Columbia	$25,600,000
Florida	$513,300,000
Georgia	$852,400,000
Illinois	$543,300,000
Indiana	$453,600,000
Iowa	$46,300,000
Kansas	$22,800,000

Table 11. Estimated total health benefits by state using 2013 population (2006 prices and incomes) (cont.)

State	Estimated benefits
Kentucky	$693,100,000
Louisiana	$189,500,000
Maryland	$215,700,000
Massachusetts	$27,200,000
Michigan	$267,700,000
Minnesota	$4,100,000
Mississippi	$290,400,000
Missouri	$350,900,000
Nebraska	$400,000
New Jersey	$226,500,000
New York	$394,200,000
North Carolina	$791,700,000
Ohio	$813,700,000
Oklahoma	$46,500,000
Pennsylvania	$537,000,000
Rhode Island	$9,400,000
South Carolina	$333,100,000
Tennessee	$1,368,100,000
Texas	$190,700,000
Virginia	$438,600,000
West Virginia	$210,300,000
Wisconsin	$72,600,000
Total	$10,855,800,000

6. Uncertainty

Of course, uncertainty is inherent in the analytical task of estimating the health benefits of improvements in air quality, and further estimating the economic value of those health effects. There is some uncertainty involved with each step of the chain of analyses involved. The types of uncertainty that may affect the health benefits analysis include gaps in scientific data and inquiry, errors due to misspecification of model structures, variability in estimated relationships, errors in measurement and future projections, and biases due to omissions or other research limitations. Taking into consideration all the uncertainties inherent in this benefits analysis, the total economic value I have estimated of the health effects are reasonable and appropriate estimates of the most likely value of the total quantified benefits.

7. Annual Cost Estimates and Benefit-Cost Analysis

A primary purpose of estimating the monetary value of the health effects of controlling emissions from TVA's power plants is to compare the benefits and the costs. In his Expert Witness Report, James Staudt provides estimates of the initial capital investment ($2.966 billion, using 2006 prices) and continuing operating and maintenance (O&M) costs ($221.8 million/year, also in 2006 prices) over the expected remaining life of the TVA facilities (30 years). In order to compare the costs with the single year benefits, the cost estimates must be converted into an annual equivalent cost. Annualizing a stream of investment and operating costs that vary over time is a standard economic procedure that is similar (both conceptually and mathematically) to calculating a constant monthly payment on a home mortgage, including the loan interest, debt repayment, taxes, and insurance required as part of the mortgage.

For the purpose of comparing the costs with the benefits, I assume the initial construction costs will be spent evenly over a five-year period ($593 million/year from 2008 through 2012), and the O&M costs will occur in each of the next 30 years (2013 through 2042). Following the guidance from both the Office of Management and Budget (OMB, 2000) and the U.S. EPA (2000), I use a societal opportunity cost of capital rate of 7% to estimate the annualized cost. This is the appropriate rate for use in an economic analysis of both public investment projects and for a social cost analysis of private investments.

I assume the initial capital construction investments will begin in 2008, with 1/5 of the total amount borrowed each year at a 7% interest rate. Interest will accrue through the five-year construction period. By 2013, when the control equipment is fully installed, the total debt (cost plus interest) for the control equipment will have grown to $3.65 billion. The present value of the 30-year stream of operating costs, discounted at 7%, is $2.75 billion. That brings the total net present value in 2013 of the construction and operating costs to $6.4 billion. I use this total net present value to create an annualized cost equivalent (again, using a 7% interest rate) for each of the subsequent 30 years.

The annual societal cost of the proposed reductions in TVA's emissions is $516 million. This is an annualized cost that will occur in each of the 30 years the additional control equipment is expected to operate.

With estimated annual benefits of $9.5 billion, and annual costs of $516 million, the net benefits are $9 billion from controlling TVA emissions to a level equivalent to the requirements of the North Carolina Clean Smokestacks Act. The requested emission reductions clearly pass the benefit-cost test. The quantified annual benefits are 18.4 times the estimated annual cost. Such a large benefit/cost ratio is evidence that substantially different assumptions would have to be made in either the benefit or the cost analyses to conclude that the requested emission reductions do not provide a net benefit to society.

Even though many of the health benefits occur in states other than North Carolina, the annual benefits in North Carolina alone ($672 million) exceed the annual costs of the entire control program.

8. State of North Carolina Expenditures on Health Care

The State of North Carolina expends billions of dollars annually for health care and health services for its residents. These state expenditures affect the lives of all North Carolinians, through the state support for primary health care (hospitals, clinics, etc.), medical education, public health programs, regulating health service providers, etc.

One portion of the state health-related expenditures are directly related to providing in-patient and outpatient hospital care, health clinic services, and physician care for low income and elderly residents. As discussed in this report, improving the air quality in North Carolina will reduce the amount of health care services required in the state. Reducing emissions from the TVA power plants, which will reduce the amount of health care services required in North Carolina, will reduce the state's financial health care burden.

One of the state programs that will be directly impacted by reducing the need for health care services is the Medicaid program. Medicaid is the nation's major healthcare program for low-income and disabled Americans. The federal government, the State of North Carolina, and counties within the state all share the financial cost of the Medicaid program in North Carolina. In fiscal 2005, 1.6 million people received services from the North Carolina Medicaid program, and 18% of the state's residents were eligible for Medicaid at some point during fiscal 2005 (NC DHHS, 2006). The total Medicaid costs in North Carolina for direct health care services (i.e., not program administration) were $8.2 billion. The state's share of these Medicaid expenditures was $2.6 billion, accounting for 31.5% of the total Medicaid expenditures in North Carolina for medical services. The counties contributed another $427 million (5.2% of the total).

Of the $8.2 billion cost of heath services in Medicaid, 12% ($962 million) was for inpatient hospital services, 6.5% ($534 million) was for outpatient hospital services (including emergency room services), and 17% ($1.37 billion) was for physician and clinic services. The total Medicaid expenditures on these medical services were $2.9 billion, and the state's share of this total was $888 million. Improving the air pollution levels in North Carolina will reduce the need for these types of direct health care services, and reduce the state's expenditures on health care.

9. Summary and Conclusions

In this report I summarize my testimony that requiring the TVA power plants to achieve the proposed emission levels will result in estimated benefits to North Carolina of $672 million, with total benefits of $9.495 billion per year. I reach this conclusion based on using well accepted current valuation methods for economic benefits analysis of air pollution control programs, and using the estimates of the avoided health effects provided by Professors Spengler and Levy. Furthermore, I believe this estimate of the benefit value underestimates the true value of the benefits because (1) the health effect estimates are based on the year 2000 population rather than forecasts of the year 2013 (a potential 14% underestimate), and (2) there are many health and non-health effects that are not quantified in the economic benefit analysis.

I also summarize my testimony present analysis that the proposed emissions controls will cost $516 million per year for each of the 30 years the proposed control equipment will remain in operation. This annualized cost estimate is based on the cost estimates provided by Mr. Staudt, which I annualize using standard economic methods.

With the quantified annual value of the health benefits exceeding the costs by $9 billion per year, the proposed emission reductions easily pass a basic benefit-cost test. This means that implementing the proposed emission reductions will provide a substantial net benefit to North Carolinians and other residents of the eastern United States. Furthermore, the benefit/cost ratio of 18.4, especially considering the likely underestimated benefits, makes it highly unlikely that a different set of plausible assumptions in the health or economic valuation analysis would result in estimated benefits and costs that would not pass the basic benefit-cost test.

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Viscusi, W.K. and J.E. Aldy. 2003. The value of statistical life: A critical review of market estimates throughout the world. *Journal of Risk and Uncertainty* 27(1):5-76.

Viscusi, W.K., W.A. Magat, and J. Huber. 1991. Pricing environmental health risks: Survey assessment of risk-risk and risk-dollar trade-offs for chronic bronchitis. *Journal of Environmental Economics and Management* 21(2):32-51.

A. Resume

This appendix contains the resume of Leland B. Deck. The resume includes a listing of relevant publications and reports, as well as previous expert witness testimony.

Leland B. Deck

Areas of Qualification

Environmental economics, human risk assessment, benefit-cost analysis, cost-effectiveness analysis, economic incentives, program analysis

Employment History

- Managing Economist, Stratus Consulting Inc., Boulder, CO, 2005-present
- Abt Associates Fellow, Vice President, and Manager, Environmental Economics Practice, Abt Associates Inc., Bethesda, Maryland, 1992-2005
- Senior Economist, Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, 1987-1992
- Research Assistant, Bureau of Business and Economic Research, State of Maryland College Park, Maryland, 1984-1987
- Economics Intern, Maryland Department of Natural Resources Power Plant Siting Program, 1981-1982
- Instructor and Teaching Assistant, University of Maryland Department of Economics, 1979-1984
- Exploration Geophysicist, Adobe Oil Company, Casper, Wyoming, 1977-1978
- Exploration Geophysicist, Century Geophysical Corp., Casper, Wyoming, 1976-1977

Education

- University of Maryland, PhD, Economics, 1987
- University of Maryland, MA, Economics, 1980
- Rensselaer Polytechnic Institute, BS, Geology, 1975

Professional Experience

Dr. Deck is an internationally recognized expert in benefit-cost analysis and risk assessment of air pollution policies. Much of his work involves assessing the benefits, in medical, physical, and economic terms, of improving air quality. He is also an expert in the design and implementation of effective economic incentive programs for controlling air pollution. As Principal Investigator for multiple contracts with the U.S. Environmental Protection Agency (EPA), Dr. Deck conducted the detailed economic benefits analyses for a wide variety of air regulations, as well as helping EPA develop technical guidance on air pollution economic incentive programs and conducting economic analysis at EPA. In addition to EPA, he prepared air pollution analysis for a wide range of other organizations, including the Intergovernmental Panel on Climate Change, the California Air Resources Board, the Federal Highway Administration, the Southern Appalachian Mountain Initiative, the National Renewable Energy Laboratory, the Clean Air Task Force, the Environmental Integrity Project, and the national environmental ministries of Canada, Chile, Argentina, and Brazil.

Dr. Deck is presently a managing economist with Stratus Consulting. For 12 years, Dr. Deck was with the environmental research area of Abt Associates, where he managed the environmental economics practice. He became a vice president of Abt Associates, and later was named an Abt Fellow. Previously Dr. Deck was a senior economist with EPA, where he was awarded a Gold Medal for Exceptional Service for his economic analysis in a landmark settlement to improve air quality in the Grand Canyon National Park by controlling emissions from a nearby power plant. Dr. Deck's experience includes the following:

BenMAP/CAPMS. Dr. Deck directed the development of BenMAP (the Environmental Benefits and Mapping Analysis Program, previously known as CAPMS) for EPA. Now in use throughout the world, BenMAP is Windows©-based analytical software to estimate the health and economic benefits from changes in ambient air quality, including the incidence and value of avoiding a wide range of health effects, from work loss days to hospital admissions to premature mortality. BenMAP includes detailed spatial analysis and uncertainty/variability capabilities, providing careful analysis of environmental justice issues and the range of scientifically credible results. BenMAP has been exhaustively peer reviewed by EPA's Science Advisory Board, and the National Academy of Sciences. BenMAP is publicly released and supported by EPA.

EPA Regulatory Analysis. Dr. Deck led the economic and health benefits analysis for the promulgation of a wide variety of EPA air regulations. These extensive analyses included regulations of power plants (the 1999 NO_x SIP Call and the 1997 Regional Haze Rule), mobile sources (the 2000 Tier II Automobile Exhaust Standards, the 2002 Heavy Duty Diesel Vehicle Standards, and the 2004 Non-Road Diesel Standards), and for the ozone and PM National Ambient Air Quality Standards.

Legislative Analysis of Proposals to Control Power Plant Emissions. Dr. Deck conducted the economic and health benefits analysis for proposed Clean Air Act Amendments to reduce emissions from electricity generating stations. He prepared EPA's benefit analysis of the Bush Administration's proposed Clear Skies Initiative (2001) and the proposed Clear Skies Act (2003). For other clients he also prepared analyses of the major alternative proposed alternatives introduced in Congress, including the Waxman (2001), Moynihan (2001), Carper (2003), and Jeffords (2003) Bills.

Comprehensive Benefit-Cost Analysis of the Clean Air Act. Dr. Deck prepared the economic and health benefits analysis for EPA's comprehensive "Section 812" Reports to Congress on the benefits and costs of the Clean Air Act. The first report (1997) was a retrospective estimate of the first two decades of the Clean Air Act (1970-1990). The second report (1999) examined the benefits and costs of the Clean Air Act Amendments of 1990. The Section 812 Reports to Congress are widely cited as the most comprehensive, scientifically valid, and reliable benefit cost analyses of a major federal environmental program conducted.

Ancillary Benefits of Climate Change Programs. Dr. Deck was a leader in developing the analysis of the improvements in conventional air pollution that will occur if climate change emission policies are adopted. He has conducted analysis both in the United States and worldwide of the ancillary or "co-control" near-term health effects of ambient air quality improvements resulting from policies to reduce carbon emissions.

Emissions Trading Programs. Dr. Deck was EPA's Work Group Leader for the Economic Incentive Program Rules (1994), and directed the development of EPA's technical guidance "Improving Air Quality With Economic Incentives" (2001).

Visibility. Dr. Deck was EPA's lead economist for developing and promulgating regulations to improve visibility at the Grand Canyon National Park. He conducted the benefit and cost analysis of options for improving visibility by installing emission controls at the Navajo Generation Station (Page, Arizona). He represented EPA's position on all economic issues in a successful negotiated rulemaking between the plant's owners, environmental groups, the State of Arizona, and other federal agencies. Dr. Deck received EPA's Gold Medal for Exceptional Service for his work on this project.

Risk Assessment. Dr. Deck directed the risk assessment for the 1997 and 2005 revisions to the particulate matter National Ambient Air Quality Standards.

Southern Appalachian Mountain Initiative (SAMI) Socioeconomic Assessment Project. Dr. Deck directed the assessment of regional air policy scenarios effects on recreational fishing, visibility, and resident's sense of place/stewardship. SAMI is a regional multi-stakeholder process developing integrated recommendations on air pollution policies portions of eight southeastern States, and includes representatives from eight state governments, three federal agencies, the Tennessee Valley Authority, the electricity generating and distribution industry, and environmental advocacy groups.

Expert Witness, U.S. Department of Justice. New Source Review Enforcement Case (Baldwin Power Plant).

Project Director for four EPA Contracts (Abt Associates). Dr. Deck was the project director of four "mission" five-year contracts with EPA, providing a complete array of economic and risk assessment analytical services to EPA's Air Office (two contracts), the National Center for

Environmental Economics, and the Office of Pesticide Programs. Dr. Deck directed Abt Associates' successful proposal efforts for these contracts (total value exceeding $20 million), and conducted or managed all technical projects under those contracts.

Peer Reviewer, Institute of Medicine. Peer reviewer for *Valuing Health for Regulatory Cost-Effectiveness Analysis*, Institute of Medicine of the National Academies (2006).

Lake Michigan Air Directors Consortium (LADCO) Benefit-Cost Analysis of Electricity Generating Unit Emission Reductions. Project Director for *Benefit Study of MRPO Candidate Control Options for Electricity Generation* (2006).

Selected Papers, Publications, Presentations

"Benefit Study of MRPO Candidate Control Options for Electricity Generation." Prepared for the Lake Michigan Air Directors Consortium. 2006.

"A Response to Comments Made in Sanhueza et al. (2003)" October, 2004, *Journal of the Air and Waste Management Association* (with E. Post, D. McCubbin, A. Hallberg, K. Davidson, and B. Hubbell).

"Power Plant Emissions: Particulate Matter-Related Health Damages and the Benefits of Alternative Emission Reduction Scenarios." Prepared for the Clean Air Task Force. 2004.

"Preliminary Nonroad Landbased Diesel Engine Rule: Air Quality Estimation, Selected Health And Welfare Benefits Methods, and Benefit Analysis Results." Prepared for the U.S. Environmental Protection Agency. 2003.

"Monetary Impacts of Health Effects Resulting from Baldwin Power Plant Emissions." Expert Witness Report for the U.S. Department of Justice in U.S. v. Illinois Power Company & Dynegy Midwest Generation. 2002.

"Sense of Place and Stewardship: Focus Group Report" and "The Value of Visibility Improvements in the Southern Appalachian Mountains Region." Prepared for the Southern Appalachian Mountains Initiative. 2002.

"Particulate-Related Health Impacts of Eight Electric Utility Systems." Prepared for the Rockefeller Family Fund. 2002.

"An Assessment of the Health Risk Reductions Associated with Attainment of Alternative Particulate Matter Standards in Two U.S. Cities." October 2001. *Risk Analysis*, (with E. Post, E. Smith, M. Wiener, K. Cunningham, and H. Richmond).

"An Application of an Empirical Bayes Estimation Technique to the Estimation of Mortality Related to Short-Term Exposure to Particulate Matter." October 2001. *Risk Analysis* (with E. Post and K. Larntz).

"The Particulate-Related Health Benefits of Reducing Power Plant Emissions." Prepared for the Clean Air Task Force. 2000.

Final Heavy Duty Engine/Diesel Fuel Rule: Air Quality Estimation, Selected Health and Welfare Benefits Methods, and Benefit Analysis Results." Prepared for the U.S. Environmental Protection Agency. 2000.

"The 2018 [Visibility] Milestone Benefits Assessment: Air Quality Estimation, Selected Health and Welfare Benefits Methods, and Benefit Analysis Results." Prepared for the U.S. Environmental Protection Agency. 2000.

"Climate Change and Ancillary Health and Environmental Impacts." Keynote address to the Climate Change Economic Analysis Forum, Assessment and Integration of Health and Environmental Impacts Workshop. Prepared for Environment Canada and the Canadian Energy Research Institute, Toronto, Canada. 2000.

"Co-control Benefits of Domestic Greenhouse Gas Control Policies." Presented at the Intergovernmental Panel on Climate Change's "Workshop on Assessing the Ancillary Benefits and Costs of Greenhouse Gas Mitigation Strategies," Washington, DC. 2000.

"Out of Sight: The Science and Economics of Visibility Impairment." Prepared for the Clean Air Task Force. 2000.

"Final Tier II Rule: Air Quality Estimation, Selected Health and Welfare Benefits Methods, and Benefit Analysis Results." Prepared for the U.S. Environmental Protection Agency. EPA 420-R-99-032. December 1999.

The Benefits and Costs of the Clean Air Act; 1990 to 2010. U.S. Environmental Protection Agency. EPA 410-R-99-001. 1999.

"Adverse Health Effects Associated with Ozone In the Eastern United States." Prepared for the Clean Air Task Force. 1999.

"Final Section 126 Rule: Air Quality Estimation, Selected Health and Welfare Benefits Methods, and Benefit Analysis Results" Prepared for the U.S. Environmental Protection Agency. 1999.

"Tier II Proposed Rule: Air Quality Estimation, Selected Health and Welfare Benefits Methods, and Benefit Analysis Results." Prepared for the U.S. Environmental Protection Agency. 1999.

"Air Quality Estimation for the NOx SIP Call RIA," "Selected Health and Welfare Benefits Methods for the NOx SIP Call RIA," "Benefit Analysis Results of Selected Health and Welfare Endpoints for the NOx SIP Call RIA." Prepared for the U.S. Environmental Protection Agency. 1998.

"Baselines in EPA Economic Analyses." Prepared for the U.S. Environmental Protection Agency. 1998.

"Short-term improvements in public health and global-climate policies on fossil-fuel combustion." *The Lancet*, 1997 (by the Working Group on Public Health and Fossil Fuel Combustion).

The Benefits and Costs of the Clean Air Act; 1970 to 1990. U.S. Environmental Protection Agency. EPA 410-R-97-002. 1997.

"Summary of Public Comments on Proposed Revisions to the Ozone National Ambient Air Quality Standards; EPA Docket # A-95-58, Section IV-D." Prepared for the U.S. Environmental Protection Agency. 1997.

"Summary of Public Comments on Proposed Revisions to the Particulate Matter National Ambient Air Quality Standards; EPA Docket # A-95-54, Section IV-D." Prepared for the U.S. Environmental Protection Agency. 1997.

"Visibility at the Grand Canyon and the Navajo Generating Station." In *Economic Analyses at EPA; Assessing Regulatory Impact*, edited by Richard D. Morgenstern. Resources for the Future. 1997.

"Discounting in Environmental Policy Evaluation." April, 1997. Prepared for the EPA Economic Consistency Workgroup (with F.L. Arnold and F.G. Sussman).

"An Approach to Assessing Health Risks from Particulate Matter in Two Cities." Presented at The Society for Risk Assessment Annual Meeting. December 1996.

"An Analysis of the Monetized Benefits Associated with National Attainment of Alternative Particulate Matter Standards in the Year 2007." Prepared for U.S. Environmental Protection Agency. July 1996.

"A Particulate Matter Risk Assessment for Philadelphia and Los Angeles." Prepared for U.S. Environmental Protection Agency. July 1996.

"§812 Retrospective Analysis: Quantifying Health and Welfare Benefits." Prepared for U.S. Environmental Protection Agency. May 1996.

Discussant, "Issues Concerning Tax, Fee and Subsidy-Based Programs," Air and Waste Management Association International Conference on Economic Incentives for Environmental Management. 1993.

"Benefits Transfer: How Good is Good Enough?," in *Benefits Transfer Procedures, Problems, And Research Needs*, US Environmental Protection Agency [EPA 230-R-93-018] (with L.G. Chestnut). 1993.

"The Estimation of Consumer References for Attributes: A Comparison of Hedonic and Discrete Choice Approaches," *The Review of Economics and Statistics*, 1992 (with M.L. Cropper, N. Kishor and K.E. McConnell).

"Economic Incentive Program Rules: Background and Issues," Public Information Document, Clean Air Act Section 182(g)(4). U.S. Environmental Protection Agency. 1991.

"Valuing Eastern Visibility: A Field Test of the Contingent Valuation Method," EPA Cooperative Agreement #CR-815183-01-3, 1991 (with G. McClelland, W. Schulze, D. Waldman, J. Irwin, D. Schenk, T. Stewart and M. Thayer).

"Update of the U.S. Environmental Protection Agency's (EPA's) Visibility Protection Program," Air and Waste Management Association Annual Meeting. 1991 (with D.S. Scott and A.G. Jacobs).

"Regulatory Impact Analysis of a Revision of the Federal Implementation Plan for the State of Arizona to Include SO_2 Controls for the Navajo Generating Station." 1990.

"Valuing Visibility: A Field Test of the Contingent Valuation Method [Denver Brown Cloud]," EPA Cooperative Agreement #CR-812054. 1990 (with J. Irwin, W. Schulze, G. McClelland, D. Waldman, D. Schenk, T. Stewart, P. Slovic, S. Lictenstein and M. Thayer).

"Controlling Wintertime Visibility Impacts at the Grand Canyon National Park: Preliminary Benefit Cost Analysis," *Visibility and Fine Particles: Transactions of the Air and Waste Management Association International Specialty Conference*. 1989 (with R.D. Rowe and L.G. Chestnut).

"On the Choice of Functional Form For Hedonic Price Functions," *The Review of Economics and Statistics.* 1988 (with M.L. Cropper and K.E. McConnell).

"Should the Rosen Model Be Used to Value Environmental Amenities? Further Evidence," *Proceedings, Second Annual Conference on the Economics of Chesapeake Bay Management*. 1986 (with M.L. Cropper, K.E. McConnell and T.T. Phipps).

"Should the Rosen Model Be Used to Value Environmental Amenities," Presented at The American Economic Association Annual Meetings. 1985 (with M.L. Cropper, K.E. McConnell and T.T. Phipps).

Expert Witness Testimony

"Monetary Impacts of Health Effects Resulting from Baldwin Power Plant Emissions." Expert Witness Report for the U.S. Department of Justice in U.S. v. Illinois Power Company & Dynegy Midwest Generation. 2002. Expert Witness Report and Deposition.

Honors and Awards

Abt Associates Inc.

- Abt Associates Fellow. 2002. The Abt Associates Fellows are a group of senior Abt Associates researchers charged with assess and enhance the quality of Abt Associates' work. Selected for their substantial intellectual contributions to Abt Associates projects and demonstrated commitment to quality, the Fellows are instrumental in building the skills and expertise of other Abt Associates researchers and consultants.

- First Annual Daniel Bell Social Science Research Award for the outstanding research project at Abt Associates. 1997. Cited for the Particulate Matter Risk and National Economic Benefits Analysis projects for the U.S. Environmental Protection Agency.

U.S. Environmental Protection Agency

- Gold Medal for Exceptional Service
- Special Act Award
- Superior Performance Award (4 years)
- On-The-Spot Award (Three).

Professional Affiliations

- American Economic Association
- Association of Environmental and Resource Economics
- Air and Waste Management Association
- Society for Risk Assessment.

B. Statement of Compensation

Stratus Consulting Inc. has been compensated at a rate of $165 per hour for Leland B. Deck's services to the North Carolina Department of Justice. This same rate will be used for any deposition or trial testimony to be provided by Dr. Deck.