

**Monetary Impacts of Health Effects Resulting from Baldwin Power  
Plant Emissions from 1982 to 2003**

Kathy Cunningham, Ph.D.  
Public Health Scientist  
Leland Deck, Ph.D.  
Senior Economist & Vice President  
Environmental Research Area  
Abt Associates Inc.  
55 Wheeler St. Cambridge, Massachusetts 02138  
4800 Montgomery Lane, Bethesda, Maryland 20814

March, 2002

FINAL REPORT

## Executive Summary

The Baldwin power plant's emissions that resulted from the plant's non-compliance with the Clean Air Act<sup>1</sup> caused a number of illnesses, including chronic obstructive pulmonary disease (COPD), pneumonia, asthma episodes, and various cardiovascular diseases (Lippman, 2002). The medical costs associated with those illnesses are evaluated in this report. The report assigns monetary values to the aspect of the illnesses that can be most objectively measured: the direct medical costs associated with the illnesses. The report provides estimates of the medical costs for the 627 hospitalizations for pneumonia, 519 hospitalizations for COPD, 450 hospitalizations for asthma, 1,527 hospitalizations for cardiovascular disease, and 1,235 emergency room visits for asthma that have occurred from 1982 to 2003 due to the Baldwin power plant's excess emissions (Lippmann, 2002). The average costs of care were applied to the number of illness "events"<sup>2</sup> to obtain the total medical cost. The calculations indicate that the medical cost burden imposed by the Baldwin power plant exceeds 47 million dollars. This value addresses only a portion of the actual impact of the illness. It does not include lost wages of the patient or their caregiver, pain and suffering associated with the illness, nor some aspect of medical care, such as physician charges, and prescriptions. Hence, the full financial burden of harm related to illnesses caused by the Baldwin power plant's excess emissions is likely to be much greater than the 47 million dollars in direct medical costs calculated in this report.

*Information on report authors is provided in Appendix A, including resumes reflecting qualifications and publications (including those within the last ten years). The authors have not testified within the preceding four years.*

---

<sup>1</sup> Referred to as "excess" emissions in this report.

<sup>2</sup>The medical services evaluated in this report occur as a result of hospitalization or emergency room use. The Lippmann (2002) report was used as the basis for the services that are used in this report represent how often people have been hospitalized or required emergency room services over the 22 year period. However, the Lippmann (2002) report does not allow estimation of the number of people affected because the same person may be hospitalized more than once. Consequently, the hospitalizations and emergency room use occurrences are referred to as "serious medical events" rather than patients because the actual number of patients affected is not known.

**Table of Contents**

**I. Introduction.....1**

**II. Methodology.....2**

**Hospitalization Costs.....2**

**Emergency Room Costs for Asthma.....4**

**III. Results.....5**

**Direct Medical Costs.....6**

**Sources of Cost Underestimation.....8**

**Qualifiers.....10**

**Conclusions.....11**

**Appendices**

- A. Resumes and Signature Page for Kathy Cunningham and Leland Deck.**
- B. References Cited & Considered**
- C. Descriptions of Illnesses Resulting from the Baldwin Power Plant’s Excess Emissions**
- D. Comprehensive Valuation of Impacts**
- E. Illnesses Not Considered in This Valuation**
- F. Acronyms**

**Tables**

**Table 1. Illnesses Resulting From Excess Baldwin Power Plant Emissions: Illnesses With and Without Direct Medical Costs .....5**

**Table 2. Direct Medical Costs of Hospitalizations and Emergency Room Use for Select Illnesses Caused by Baldwin Power Plant 1982 -2003.....7**

**Table 3. Confidence Bounds on Direct Medical Costs of Illnesses Caused by the Baldwin Power Plant 1982 - 2003.....11**

## I. Introduction

The purpose of this report is to summarize the monetary value of certain illnesses<sup>3</sup> caused by pollutant releases from the Baldwin power plant in excess of those allowed by the Clean Air Act for the period from 1982 to 2003. The air emissions from the Baldwin power plant cause a number of illnesses that vary widely in their severity. They range from relatively mild respiratory symptoms, through serious illnesses such as chronic bronchitis and pneumonia, up to the death of the individual (Lippmann, 2002). This cost analysis focuses on the "direct medical costs" of a subset of specific medical services (hospitalization and emergency room use) for some of the more serious illnesses including pneumonia, asthma, COPD, and cardiovascular diseases. (Figure 1 in Appendix D shows those elements of cost that are not included in this report, as well as where the direct medical cost category fits in the overall valuation process.) Dr. Mort Lippman evaluated the number of serious medical events that resulted from the Baldwin power plant's non-compliance with the Clean Air Act between 1982 and 2003, and concluded that 627 hospitalizations for pneumonia, 519 hospitalizations for COPD, 450 hospitalizations for asthma, 18,000 hospitalizations for cardiovascular disease, and 1,235 emergency room visits for asthma occurred from 1982 to 2003 (Lippmann, 2002). ( In addition, Lippmann (2002) estimated mortality which is not considered in this report.) The area evaluated covers populations within 500 to 800 kilometers of the Baldwin power plant (Gray, 2002) containing approximately 85 million people (Lippmann, 2002). The direct medical costs associated with treatment of the illnesses listed above are evaluated in this report. Direct medical costs of hospitalization and emergency room treatment were chosen for evaluation because they are the aspects of cost that can be most objectively and reliably calculated.

Section II of this report describes the methods used to quantify the values. Section III summarizes and discusses the results and conclusions. Citations and considered materials are presented in Appendix B. Appendix C contains descriptions of the illnesses resulting from the Baldwin power plant excess emissions as reported in Lippmann (2002), Appendix D provides a discussion of the valuation of all aspects of the impact of illnesses and Appendix E discusses illnesses not included in this cost analysis and why they could not be assigned a direct medical cost at this time. Abbreviations used throughout the report are listed in Appendix F: Acronyms.

This analysis is directed at the medical treatment costs of the illness and not at the person who is experiencing the illness. For a better understanding of the personal impacts of an illness, which can be devastating, see Appendix C, which contains descriptions of many of the illnesses and the effects that they have on individuals.

---

<sup>3</sup>For simplicity, the term "illness" will be used to represent the diseases, symptoms, mortality, and other effects attributed to the Baldwin power plant in Dr. Lippmann's report.

## II. Methodology

One of the more straightforward and objective aspects of an illness is the medical cost directly related to the treatment of that illness. Although there is some variation in the cost of medical services within and across geographic areas, there are excellent data on "average" medical costs for many services, as discussed below. The medical costs associated with hospitalization and emergency room use were considered in this report.<sup>4</sup>

### Hospitalization Costs

Dr. Lippmann calculated the number of hospitalizations that resulted from excess emissions from the Baldwin power plant for the following illnesses:

- pneumonia,
- COPD,
- asthma, and
- cardiovascular disease.

The cost of hospitalization for these illnesses was determined using the average medical cost values reported in the Healthcare Cost and Utilization Project (HCUP) database maintained by the Agency for Health Care Policy and Research (AHRQ). The HCUP database project is a federal-state-industry partnership to build a standardized, multi-state health data system, containing patient-level information compiled in a uniform format with privacy protections in place. This is the best national source of data on cost of medical services in hospitals in the United States and includes inpatient data from a national sample of over 1,000 hospitals. The mean hospital charges provided in HCUP are based on a very large, nationally representative sample of about seven million hospital discharges. Because the database is so large it provides the best estimate of mean hospital charges and mean lengths of a stay available, with negligible standard errors (AHRQ, 2000). The most recent HCUP cost data are for 1997 and have been adjusted in this report to costs for the year 2000 using the Consumer Price Index (CPI) Medical Services adjustment (URL: <http://146.142.3.24/cgi-bin/surveymost?cu>).<sup>5</sup>

---

<sup>4</sup>See Appendix E for a discussion of why some illnesses reported in Lippmann, 2002 were not included in this report.

<sup>5</sup>Health effects occur over a 22 year period and the appropriate approach is to calculate a present value in year 2000 dollars of this stream of medical costs. Present value calculations reflect the "time value of money" (an expenditure at some time in the past could have been put to an alternative use (e.g., invested), and be worth more in 2000). Present value calculations do not involve inflation or the change in the quality of medical services (these important issues are reflected by using the CPI for Medical Services to reflect costs as year 2000 "constant dollar" costs). A compounded value would reflect the value of the earlier costs in the year 2000 and a discounted value would represent costs for the years 2001-2003 in the year 2000. The "Total Medical Cost" estimates provided in this report effectively use a zero percent compounding/discounting rate. The USEPA typically uses a range of interest rates from three to seven percent to calculate present values. The present value of the medical costs, when calculated using an interest rate greater than zero, would result in higher values than those estimated here.

The reported hospitalization charges do not include physician charges, which can be substantial. Most hospital patients are seen at least once a day by a physician. Physician charge information was not included because it is typically billed separately from hospital charges and is not provided to the hospital. The charges will depend on the physician's degree of specialization, the nature of the physician services provided, time required, and other factors. There is no reliable source of information on average physician charges for the illnesses considered in this analysis.<sup>6</sup> Excluding these costs leads to an underestimate in one aspect of the total medical cost. Other costs that are not included are: prescription drugs required by the patient after leaving the hospital, follow-up office visits, in home care (professional and non-professional), nursing home care, and medical equipment rental (e.g., oxygen tanks).

The hospitalizations calculated by Dr. Lippmann were based on epidemiological studies that focused on specific age groups (Lippmann, 2002).<sup>7</sup> The HCUP hospital charge data, which is available by patient age, was matched to the age groups considered by Dr. Lippmann. The HCUP data were extracted for the four illnesses resulting in hospitalization that are listed above and were matched to the International Classification of Disease, 9th Edition (ICD-9) codes that Dr. Lippmann used in his calculations.<sup>8</sup> The epidemiological studies used in his work report on illnesses that are described by sets of ICD-9 codes. These sets include the different variations of an illness that may occur. For example, pneumonia is described by ICD-9 codes 480-487, and includes viral, bacterial, and other types of pneumonia.

A set of ICD-9 codes is a compilation of variations of the disease that may incur varied costs and occur at different rates in the population. It was therefore necessary to consider the occurrence of these variations and their associated costs, to calculate an average hospitalization cost for a disease. The relative frequency (probability) of the occurrence of each variation of an illness was multiplied by the cost for that variation to obtain a weighted average cost. The following equation was used:

$$\text{Average cost} = \frac{(\text{cost of variation A}) \times (\text{frequency of A}) + (\text{cost of variation B}) \times (\text{frequency of B}) \text{ and so on}}{\text{number of variations for a disease}}$$

---

<sup>6</sup>For reference, it is useful to note that Medicare paid approximately \$50.00 for an average physician's office visit and \$100.00 for a complex visit in 1999.

<sup>7</sup>These subgroups are often a small subset of the total population (e.g. people over the age of 64 years). Using the subgroups, rather than extrapolating to the entire population, leads to an underestimate of the serious medical events (and the associated costs) that result from plant emissions.

<sup>8</sup>These codes and their associated illnesses can be viewed on the Internet at many sites. One of the more user-friendly sites can be found at the following URL: <http://www.mcis.duke.edu/standards/termcode/icd9/>. Diagnoses are categorized worldwide using this code, which provides a standardized way to describe an illness or condition that requires medical attention.

The costs for each ICD-9 code were obtained from the HCUP database, and the relative frequency of each code was obtained from a database that describes hospital discharges across the United States by ICD-9 codes: the National Hospital Discharge Survey, Table 1 (NCHS, 1999).<sup>9</sup> The relative frequency of occurrences is just the probability of hospitalizations for a specific variation (e.g., a distribution might be 0.3 of variation A, 0.5 of variation B, and 0.2 of variation C). Using pneumonia as the example again, the costs for each of the ICD-9 codes 480 through 487 and the relative frequencies of each of these codes were used in the above calculation to estimate the average cost of hospitalization for pneumonia.

The average hospitalization costs for an illness, calculated as described above, were multiplied by the number of hospitalizations for each illness calculated by Dr. Lippmann to obtain the total direct medical costs for hospitalizations for those illnesses:

$$\text{total costs for an illness} = \text{costs per hospitalization} \times \text{the number of hospitalizations}$$

#### Emergency Room Costs for Asthma

Data of comparable quality to the HCUP database for hospitalizations is not available for other medical services. Consequently, it is necessary to estimate costs using other sources. A study completed last year on asthma costs and savings associated with asthma management plans provided a summary of the literature through the year 2000 on asthma-related emergency room costs (EPA, 2001a). Eight studies that reported costs were identified, and these provided a range of values from \$131 to \$551 per visit with six of the eight studies reporting costs between \$219 and \$330 (in year 2000 dollars, adjusted using the CPI for medical care). The average of these costs is \$297; this value was used to estimate the direct medical cost associated with asthma emergency room visits for the Baldwin power plant.

The illnesses resulting from the Baldwin power plant's excess emissions require different types of medical treatment, depending on the nature of the illness and its severity. Because only hospitalization and emergency room use are considered in this analysis, the analysis is restricted to the more severe manifestations of the illnesses. Table 1 lists all the illnesses and related medical services, as well as other health impacts resulting from the Baldwin power plant's excess emissions calculated by Dr. Lippmann (2002) and indicates those that are included in and excluded from in this report. A discussion of many of these illnesses is contained in Appendix C and a discussion of why the direct medical costs were not included in this report is contained in Appendix E.

---

<sup>9</sup> This source provides a statistically reliable sample of a large number of discharges and is the most extensive compilation of information on the number of hospitalizations for each illness that is available in the United States.

<b>Table 1. Illnesses Resulting from Excess Baldwin Power Plant Emissions: Those With and Without Direct Medical Cost Data</b>	
<b>Illness (from Lippmann, 2002)</b>	<b>Costs Provided</b>
hospitalization for pneumonia	YES
hospitalization for COPD	YES
hospitalization for asthma	YES
hospitalization for cardiovascular disease	YES
emergency room use for asthma	YES
acute bronchitis	NO
lower respiratory symptoms	NO
upper respiratory symptoms	NO
asthma attacks	NO
chronic bronchitis	NO
premature mortality	NO
minor restricted activity days	NO
work loss days	NO

The valuation of direct medical costs in this report addresses a portion of the total value of the impacts of an the illness. It does not include lost wages of the patients or their caregivers, costs associated with secondary effects of medication and treatment, and some aspects of medical care such as physician charges, prescriptions, and pain and suffering associated with the illness. Appendix D provides a discussion of the various impacts of an illness that are not considered in this analysis.

### **III. Results**

This section includes a presentation of the costs calculated in this report, a discussion of why these costs are likely to be a substantial underestimate of the total value of illnesses caused by the excess emissions from the Baldwin power plant, and a discussion of qualifiers related to the cost and scientific data used in the analysis.



### Direct Medical Costs

The calculated direct medical costs for hospitalization and emergency room use associated with the Baldwin power plant's excess emissions are shown in Table 2. The specific ICD-9 codes that are relevant for the illnesses considered in this analysis are listed with the costs of each illness. The illnesses and services considered in this report impose a medical cost burden of over 47 million dollars. As discussed throughout the report, these are only a subset of the illnesses caused and services required as a result of the Baldwin power plant's excess emissions that result from non-compliance with the Clean Air Act. The actual burden is likely to be much higher.

To put the medical costs in a human context, the illnesses generated by the Baldwin power plant's excess emissions are serious in nature and impose substantial hardship on patients and their families. The descriptions of these illnesses provided in Appendix C give some insight into the human toll that the diseases take. This toll should be considered in addition to the information provided here on medical cost impacts. Although air pollution can affect healthy members of the population, and cause some members to become less healthy, it disproportionately affects individuals with immature or already-compromised respiratory and cardiovascular systems. These individuals are often infants, young children and the elderly, as well as people with medical conditions such as asthma, emphysema, sickle cell disease, heart conditions, and other chronic illnesses.

<b>Table 2. Direct Medical Costs of Hospitalizations and Emergency Room Use for Select Illnesses Caused by Baldwin Power Plant 1982 - 2003 ( in Year 2000 Dollars)</b>					
<b>Medical Service</b>	<b>Disease (ICD-9 codes)*</b>	<b>Ages Considered</b>	<b>Number of Events**</b>	<b>Cost per Case ***</b>	<b>Total Medical Costs****</b>
Hospitalization	Pneumonia (480-487)	≥ 65 yrs	627	\$14,693	\$9,213,000
	COPD (490-492, 494-496)	≥ 65 yrs	519	\$12,378	\$6,424,000
	Asthma (493)	< 65 yrs	450	\$6,633	\$2,985,000
	Cardiovascular diseases (390-429)	≥ 65 yrs	1527	\$18,387	\$28,077,000
Emergency room use	Asthma (493)	< 65 yrs	1235	\$297	\$367,000
<b>TOTAL Direct Medical Costs*****</b>					<b>\$47,065,000</b>
* Descriptions of the diseases can be found in Appendix C. ICD-9 codes are discussed in the text.					
** From Lippmann, 2002. Confidence bounds on the number of serious medical events and resulting medical costs listed in this table are presented in the section on qualifiers that follows.					
*** Values to the nearest dollar.					
**** Calculated as (# of total events) x (cost per event), without considering the effects of compounding or discounting on the present value of the 22 year distribution of serious medical events.					
***** This does not include all direct medical costs associated with illnesses that result in hospitalization and emergency room use. Physician visits in the hospital and follow-up visits, prescriptions, in-home care and nursing home care, and medical equipment are not included. The total costs are rounded to the nearest thousand dollars.					

### Sources of Cost Underestimation

There are a number of factors in this analysis and the Dr. Lippman's calculation of illnesses that preceded it (Lippmann, 2002) that result in an underestimation of the value of harm caused by the Baldwin power plant's excess emissions. The factors include:

- evaluating only select age groups for all impacts except asthma attacks (e.g., over 64 years of age for pneumonia, COPD, and cardiovascular disease)
- evaluating effects for only particulate matter (excluding lead, cadmium, etc)
- modeling effects for a limited geographic region
- evaluating costs for only those illnesses with direct medical cost data
- evaluating costs for only some medical services
- evaluating cost for only the primary illness, not secondary illnesses
- the using year 2000 costs, rather than calculation of a present value for 1982 - 1999 costs
- the using direct medical costs to represent the value of an illness, and
- excluding costs for mortality, which has a very high value

Many of these factors are discussed in the preceding text. When detail has not been provided in the text, they are provided below.<sup>10</sup>

- Only specific age groups were considered in calculating the number of serious medical events (e.g., 65 years of age and over for all hospitalizations considered). These age cohorts were selected because they reflect the ages of the groups evaluated in epidemiological studies. However, people of all ages are affected by particulate matter.

The cost estimates therefore underestimate the total direct medical costs and may do so substantially. The fact that serious respiratory illnesses (e.g., pneumonia) occurs in young children as a result of the types of emissions that are released from the Baldwin power plant supports this contention (Woodruff et al., 1997; Burnett et al., 1994).

- Only the effects of particulate matter were considered. Numerous other highly toxic materials are released from the plant (e.g., mercury, cadmium, lead). These materials cause developmental toxicity, infertility, cancer, and other effects (Lippmann, 2002).
- Baldwin power plant emissions and their byproducts travel beyond the modeled region. The modeling range was defined by the limitations of the air model used (CALPUF) (Gray, 2002). Impacts outside of the modeling range would affect large population centers on the East coast.
- Reliable nationally representative direct medical cost data were not available for many of

---

<sup>10</sup> Many of these factors are also discussed in Lippmann, 2002.

the adverse effects that resulted from the Baldwin power plant's excess emissions. These effects include, but are not restricted to chronic bronchitis, upper and lower respiratory symptoms, acute bronchitis, and asthma attacks (as reported in Lippmann, 2002). No costs were attributed to these effects, some of which are quite serious. These illnesses incur substantial medical costs (EPA, 2001b). (Table 1 indicates those illnesses reported in Lippmann, 2002 that were not included in this valuation analysis.) In addition, HCUP excludes physician charges and the numerous costs associated with an illness once the patient leaves the hospital (e.g., physician follow-up visits, nursing home care, in-home care, pharmaceuticals, and medical equipment).

- Only illnesses that result in hospitalization or emergency room use were considered in this analysis. Less serious episodes of these illnesses are also caused by pollutants (some addressed in the symptoms reported by Dr. Lippmann), and the illnesses generate the need for less aggressive medical treatment that may occur in clinics, doctors offices, or at home (See Appendix E). These serious medical events of the illnesses caused by the Baldwin power plant are not considered in this analysis. (This does not refer to the medical costs associated with hospitalization that are not included in HCUP. These costs are discussed below under "Qualifiers".)
- Direct medical cost data used in this analysis do not take into account secondary effects of medication and treatment, which can be costly. Most treatments are not without adverse side effects and many are associated with specific additional illnesses. For example, heart attacks, angina, and other cardiovascular diseases and events are treated with medications that can cause morbidity. It was beyond the scope of this analysis to evaluate those impacts.
- As discussed above, health effects occur over a 22 year period. The present value of the medical costs, when calculated using an interest rate greater than zero, would result in higher values than those shown in Table 2.
- One of the most important sources of underestimation in valuing the harm done by the Baldwin power plant's excess emissions is that direct medical costs represent only a small portion of the value of an illness to the affected parties. The direct medical costs provide information on one component of the value of an illness to affected parties, and exclude such important issues as lost work and leisure time, and the pain and suffering that an illness imposes on a patient and those who care for the patient.
- Mortality is the most serious effect attributable to the Baldwin power plant. Although there is no widely accepted way to value the loss of life, the 5,707 deaths attributable to the plant merit careful consideration when evaluating the impacts of the plant. (See Appendix E.)

## Qualifiers

This section discusses factors that may either increase or decrease the costs reported in Table 2.<sup>11</sup>

Medical costs vary among patients, physicians, hospitals and geographic areas. Because national data are available for per capita hospitalization costs reported in this analysis and numerous recent study results were used for emergency room cost determination, the costs used in this report are considered reliable and representative over a large area and population (as in this case). However, the average cost to patients affected by the Baldwin power plant may vary slightly from the values reported here.

Assigning costs to an illness with a specific cause raises questions regarding whether the severity of the illness (or mix of severities) is the same as the "average" case of that illness for all causes. If there are differences, this may affect medical treatment and cost. For example, illnesses that occur simultaneously in multiple systems, such as the respiratory and cardiovascular systems (both affected by particulate matter), may incur greater than additive costs due to treatment difficulties. Quantitative data are not available that would allow us to evaluate this reliably.

The costs reported in this analysis assume a consistent expenditure from 1982 through 2003. In reality the cost of medical services has increased, along with societies' ability to pay for those increases (both wages and costs were lower in 1982). In addition to the impacts of inflation, some medical treatments now available are more sophisticated and expensive. This increased cost is balanced in some cases by the ability of these treatments to expedite patient recovery, thus avoiding lengthy and costly hospitalizations. In addition, hospital stays are also now often controlled by the medical payer, with restrictions on length of stay commonly encountered to control costs. Because no time trend cost analysis was performed, it is not known if the medical cost of hospitalization for the illnesses of concern has increased or decreased (when adjusted for inflation) between 1982 and 2003. (Adjustments for inflation were made only to costs reported for years prior to 2000. This was done using the CPI for Medical Services. This allowed standardization of costs to the year 2000.)

A large number of people were used in the epidemiological studies on which the case calculations were based. This yields very reliable estimates of serious medical events. The central estimate was used in this analysis. However, a statistical approach can be taken to determine the possible range of serious medical events between the 5th and 95th percentile confidence bounds, based on the epidemiological studies. These are not numbers that are expected to occur, but provide a statistical bound to the case estimates. The range of serious medical events and the resulting medical costs that could be incurred if the number of serious medical events were at the upper and lower bound limits are shown in Table 3. The central estimates are listed in the last column of the table for reference. Based solely on uncertainty associated with the epidemiological studies, the calculated range pneumonia, asthma, COPD, and cardiovascular disease occurrences requiring hospitalization

---

<sup>11</sup>The variability associated with the calculation of airborne concentrations (i.e., in Gray, 2002) are not discussed here.

and asthma requiring emergency room treatment would lead to a range in direct medical treatment costs for these services from approximately 28 million to 66 million dollars. This range does not capture the increased costs that would occur if the limitations outlined under "Sources of Cost Underestimation" above were addressed.

Service	Disease	Medical Cost per Case*	Confidence Bounds Number of Events**		Confidence Bounds Total Medical Cost***		Central Estimate From Table 2 (for reference)
			Low	High	Lower Bound	Upper Bound	
Hospitalization	Pneumonia	14,693	292	976	\$4,290,000	\$14,340,000	\$9,213,000
	COPD	12,378	32	1,001	\$396,000	\$12,390,000	\$6,424,000
	Asthma	6,633	89	818	\$590,000	\$5,426,000	\$2,985,000
	Cardiovascular	18,387	1,248	1,799	\$22,947,000	\$33,978,000	\$28,077,000
Emergency room use	Asthma	285	405	2,078	\$120,000	\$617,000	\$367,000
<b>Total Direct Medical Costs</b>					<b>\$28,344,000</b>	<b>\$65,852,000</b>	<b>\$47,065,000</b>
* Values to the nearest dollar.							
** Based on upper and lower confidence limits on the serious medical events from Lippmann, 2002.							
*** Calculated as (# of total events) * (cost per event) for the upper and lower confidence bounds, without considering the effects of compounding or discounting on the present value of the 22 year distribution of the events. The bounded costs do not include all direct medical costs associated with an illness. Physician visits in the hospital and follow-up visits, prescriptions, in-home care and nursing home care, and medical equipment are not included. The total costs are rounded to the nearest thousand dollars.							

## Conclusions

Valuation is one way of considering the harm that is done by air pollution. In this report, we have evaluated one aspect of valuation: the direct medical costs associated with illnesses. The analysis focuses on a select group of illnesses for which there are very reliable data on medical treatment costs (hospitalizations and emergency room use). For these specific services, the analysis estimates a direct medical cost of over 47 million dollars for four illnesses (asthma, pneumonia, cardiovascular disease and COPD). These costs are generated by illnesses that result from the Baldwin power plant's excess emissions between 1982 and 2003.

The value provided here is very conservative and is likely to substantially underestimate the total medical costs of all the illnesses generated by the plant, especially the total value of these illnesses to patients, their families, and society. This underestimate is the result of the methods used to model and calculate serious medical events, as well as the conservative approach taken in this report to medical costs (see Sources of Underestimation above). While there is some potential for variation in the costs provided in this report, they represent a reliable valuation of the serious

medical events enumerated by Dr. Lippmann, and are based on sound, publically-available data sources. The actual value of harm done to the people exposed to excess Baldwin power plant emissions is likely to be considerably greater than the 47 million dollars calculated here, but this value provides an indication of the very substantial impact that these emissions have on one aspect harm: the medical expenditures required to treat some of the illnesses. Considering the large number of people who become ill and even die as a result of the excess emissions from the Baldwin power plant, this estimate is a very conservative representation of harm to human health.

## Appendix A. Resumes for Kathy Cunningham and Leland Deck

Disclosure material relevant to Rule 26 and signatures are provided at the end of this Appendix.

**Name:** KATHLEEN CUNNINGHAM  
**Profession:** Senior Health Scientist  
**Years Associated with Firm:** 10  
**Citizenship:** U.S.A.

### Key Qualifications

---

Dr. Kathleen Cunningham is a senior scientist who specializes in human health risk assessment, environmental policy, public health issues and economic valuation of diseases and disabilities. She has had extensive experience in managing and conducting health evaluations of water, air, and food pollutants and developing guidance documents and resource materials for federal and state agencies. For Abt she has carried out toxicological evaluations of carcinogens, teratogens, and systemic toxins, developing benefits evaluations and new methods of evaluating risks, and in characterizing sensitive subpopulations. She previously managed environmental health groups that developed drinking water guidelines, evaluated health risks, and coordinated outreach to communities, health professionals, and stake-holders on environmental issues. Dr. Cunningham has written books on the toxicology of pesticides, risk assessment methods, valuation of medical costs, and methods of establishing fish advisory programs.

### Education

---

Ph.D., University of Illinois School of Public Health, Environmental and Occupational Health.  
 M.A., University of Chicago, Public Administration.  
 B.A., University of Chicago, Biological Sciences.

### Relevant Professional Experience

---

#### Experience with Abt Associates Inc.

- 2001-present **Project Manager. Mercury Benefits Methodology.** In order to provide estimates of the economic benefits of reducing mercury air emissions from coal-fired power plants, methods are being developed to map changes in mercury emissions to changes in human health outcomes and to changes in ecological service flows such as uncontaminated fish populations. The main purposes of the project are to develop a framework and methods for estimating human health and welfare benefits from reductions in mercury concentrations in fish tissues and to estimate the current costs (human health and welfare) of existing mercury-related fish consumption advisories. The work involves the following: Preparation of a database of mercury fish contamination using sources within EPA mapped using a GIS system. Development of dose-response functions for health outcomes applicable to reductions in mercury levels taking into account non-linearities and thresholds to provide a spectrum of probabilities of effects over various doses. Overlaying demographic data on mercury fish contamination data and using exposure assumptions evaluate risk. Valuing health risks. Incorporating the resulting model into the Criteria Air Pollutant Modeling System (CAPMS). The work also includes: assessing the costs and economic impacts of current mercury-related fish consumption advisories for subsistence and recreational fishers and their communities and evaluating the welfare losses over the different populations comparing total costs and cost per affected individual of fish contamination to the total costs and costs per affected individual expected from applying mercury controls at power plants. (Client USEPA, OAQPS)
- 2001-present **Project Manager. Communication on Risk Assessment and Risk Economics.** This project involves identifying strategies to increase the communication between risk assessors and risk

---

Abt Associates Inc., 55 Wheeler Street, Cambridge, Massachusetts 02138



- economists with the goal of producing more accurate and comprehensive economic evaluations of the impacts of rules and policies. The work includes preparation of a report suitable for publication and preparation of a presentation to be used in training staff. (Client: Health Canada)
- 2001-present **Project Manager. Cost of Illness Methods.** This project requires the development of a guidance document explaining various approaches to calculating the lifetime stream of direct incremental medical costs of illnesses. It includes emphasis on the use of data available regarding Canadian costs and populations. It is designed to provide staff with both a method and data sources that can be used to estimate average medical costs for illnesses related to air pollution and other illnesses currently of interest to Health Canada. (Client: Health Canada)
- 2001-present **Project Manager/Principal Investigator. Epidemiological Study of Breast Cancer Incidence in Massachusetts and Environmental Indicators of Pollution.** This project is designed to determine the utility of the RSEI (TRI Indicators) data as a tool to identify areas of high risk for breast cancer. Using Massachusetts as a test case, pollutant release data, demographic data, pollutant transport models, and pollutant toxicity data are overlaid using a GIS system on the cancer incidence data for the state. RSEI data are supplemented with drinking water, transportation, and other pollutant data to characterize to the extent possible the relative levels of carcinogenic pollutants in each town. The correlation between the carcinogenic potency of local pollutants and the occurrence of breast cancer is evaluated. The goal of this research is to determine what refinements are necessary to carry out this type of work and to develop an approach that can be applied to other cancers, birth defects, and other environmentally-induced illnesses. (Funding source: Department of Defense, Breast Cancer Research Program)
- 2000-present **Project Manager. Environmental Tobacco Smoke Economics.** Individuals in the vicinity of tobacco smokers are exposed to the numerous pollutants released into the environment as tobacco is burned. Populations exposed to environmental tobacco smoke (ETS) suffer from a number of adverse health effects, including upper and lower respiratory infections, exacerbations of asthma, tonsillitis, ear infections and other symptoms and illnesses. This is especially problematic in indoor environments and is believed to have a substantial impact on the health of children in the United States. The purpose of this research was to estimate the national annual direct medical costs of the effects of ETS on children, with a focus on cost to health insurance companies and managed care organizations (MCOs). This research estimated the direct medical costs of the numerous above-listed health effects associated with ETS exposure of children. Using a risk-based approach, a set of low, medium, and high relative risk values were identified for each illness/symptom based on this literature. The ETS-attributable risk fraction of each illness/symptom was used with national prevalence data and cost of illness data to determine national costs. NHIS, NHDS, NAMCS, and NHAMCS data were used to estimate medical service utilization and associated costs. This work was in support of the Indoor Environments Division's efforts to reduce morbidity associated with ETS. A final goal of this project is to develop a journal article reporting the results. (Client: USEPA, OAR)
- 1999-present **Project Manager. Asthma Economics.** Asthma is a widespread and growing disease in the United States. It disproportionately affects children and low income groups and imposes a substantial economic burden on our health care system, particularly in instances where hospitalization and emergency room visits are common. This research provided estimates of (1) the costs of asthma to Managed Care Organizations (MCOs) and other health insurers that do not offer asthma management programs (baseline costs), (2) estimate the potential cost savings to MCOs that could be realized if they offered effective asthma management

programs, and (3) to estimate the potential cost savings that could be attained through asthma trigger avoidance. This research was provided in support of efforts by the Indoor Environments Division to work with MCOs and other insurers in reducing morbidity associated with asthma. A final goal of this project is to generate a journal article reporting the results (Client: USEPA, OAR)

- 1996-present **Project Manager. Cost of Illness Handbook.** This research involved the development of direct incremental lifetime medical cost estimates for a number of illnesses linked to environmental pollutants. Abt Associates has developed this information for numerous cancers, birth defects, respiratory and cardiac diseases, and symptoms, and continues to expand the research. Work includes detailed medical disease causality, occurrence, and prognosis data, medical cost estimates based on practice methods, and provides an estimate of the average lifetime medical costs of treating a disease. This handbook, now available on an OPPT website developed under this project, is designed for use throughout EPA's offices for policy analysis, planning, and cost benefit analysis applications. (Client: USEPA, OPPT)
- 1997-present **Senior Health Scientist. Title X 402 (C3) Economic Analysis.** The U.S. Environmental Protection Agency requires an evaluation of the cost and benefits associated with a renovation and remodeling rule currently under development that is designed to reduce the release of lead paint into the home environment. Work includes estimating health benefits of the rule and associated economic benefits of morbidity avoidance. The analysis is carried out through evaluation of at risk population characterization, exposure assessment, dose response evaluation, risk projections, and estimation of direct medical costs associated with projected risks for various regulatory options. Potential impacts on workers as well as residents has been evaluated. (Client: USEPA, OPPT.)
- 1998-present **Senior Health Scientist. PB402/3 Public and Commercial Buildings Economics.** The U.S. Environmental Protection Agency requires an evaluation of the cost and benefits associated with reductions in lead exposure during the lead paint removal process from steel structures, including buildings. Work includes estimating health benefits of the rule through at risk population characterization, exposure assessment, dose response evaluation, risk projections, and estimation of direct medical costs associated with projected risks. (Client: USEPA, OPPT)
- 1998-present **Senior Health Scientist. Arsenic Drinking Water Regulatory Impact Analysis.** Supported EPA in the development of an RIA for arsenic in drinking water. Work focused on evaluation of health effects associated with arsenic and provision of the direct medical costs of specific cancers. (Client, USEPA, OW)
- 1996-2000 **Senior Health Scientist. Russia-World Bank Environmental Project.** With a goal of developing the capabilities to evaluate health risks and carry out epidemiological studies to serve as the basis for government action in environmental protection, training in risk assessment and site-specific risk evaluations of select cities in Russia were provided to the Russian government with World Bank funding. In cooperation with Harvard University, medical and scientific personnel from Russia were trained in methods and problem solving related to health impacts of environmental pollution and risk assessment. Risk assessments were carried out cooperatively with the staff and outcomes were used as the basis for decisions on pollution prevention and remediation. (Client: World Bank and Russian Republic)
- 1996-1997 **Senior Scientist. Pilot Project to Evaluate New Methods of Estimating Benefits for Noncarcinogens.** Abt Associates provided support to EPA's Superfund Office in the

development of new methods to evaluate noncarcinogens, including numerous heavy metals; to improve methods for estimating benefits associated with pollution reduction. A benchmark dose approach, with numerous extrapolation strategies was tested in comparison to more traditional methods to assess the relative value of different approaches for benefits estimation. (Client: USEPA , Superfund Office)

- 1996-1997 **Senior Scientist. Sector Facility Indexing Project.** Abt Associates supported EPA in the development of a data base and information access system that brings together existing data from a wide range of databases on environmental releases from industrial facilities. This is a community-right-to-know pilot project within EPA's Reinvention Initiative. Facility environmental performance data for over 650 facilities within five industrial sectors were evaluated in detail. The results provide tracking information that can be used to assess compliance patterns of sectors and individual facilities. In addition, a national analysis of releases and highest polluters organized by SIC codes, chemicals released, and by risk levels linked to sectors was carried out in pilot form. This was conducted for each state, EPA region, and at the national level. (Client: USEPA, OECA)
- 1994-1996 **Project Manager. Risk and Benefit Analysis for Revising the PM NAAQS** EPA evaluated various options for revising the Clean Air Act NAAQS. The particulate matter (PM) NAAQS was last revised in 1987 and a large volume of recently completed scientific research indicated that there were significant health effects associated with exposure to airborne PM that were not well understood at the time of the 1987 revision. The research primarily evaluated the relationship between PM and health effects in epidemiological studies. Effects ranged from coughing and chest congestion to premature mortality. Abt Associates supported EPA in evaluating health effect, including development of concentration response functions; evaluated impacts of PM10 versus PM 2.5; and evaluated the benefits of various reduction strategies. The national distribution of PM was considered to obtain a nation-wide evaluation of potential benefits.(Client: USEPA, OAR)
- 1995-1996 **Senior Health Scientist. Risk and Benefit Analysis for the Clean Air Act.** Abt Associates supported EPA in the evaluation of the benefits analysis of the clean air act in a retrospective evaluation of changes in air pollutant levels over the 20 years from 1970 to 1990, as a result of the Clean Air Act. This evaluation focused on the benefits of damages avoided as a result of the Act in the areas of human health, agriculture, visibility, and welfare. Abt Associates developed the Criteria Air Pollution Modeling System (CAPMS), a Windows-based national exposure, risk, and economic valuation model for this project. The product included the analysis used in the report to Congress: "The Benefits and Costs of the Clean Air Act, 1970-1990". (Client: USEPA, OAR)
- 1994-1995 **Project Manager. Training for Risk Assessment of Chemically Contaminated Fish.** Abt Associates developed training materials and provided training in risk assessment methods for the evaluation of population risks arising from consumption of chemically contaminated fish. The training was based on a document developed by Abt on risk assessment methods appropriate for fish contaminants (see project listed below). Training was provided to an audience of federal, state, tribal, and local health and environment professionals at multiple sites and utilized specialized training materials developed for the course. (Client: USEPA, Office of Water, OST).
- 1993-1996 **Project Manager. Guidance Documents on Developing Risk-based Intake Limits for Chemically Contaminated Fish and Risk Management for Development of Fish Advisories for Chemically Contaminated Fish.** Provided support to EPA in the development of two documents that describe methods for development of fish advisories for

non-commercial fish. These guidance documents were written for use by state, local, and tribal governments and cover risk assessment methods (Volume II) and risk management (Volume III). The risk assessment document includes both methodology and toxicological data for 23 high priority fish contaminants, along with recommended exposure limits for children, adults, and pregnant women. The risk management document includes identification of options for mitigating risks associated with chemically contaminated fish, evaluating the benefits and costs associated with each option, including social, economic, cultural, and health impacts, and selection of the optimal set of options based upon site-specific conditions. Environmental justice issues were evaluated through extensive research into cultural patterns of Native American, Asian American and urban fishers and the unique needs and problems of these populations. (Client: USEPA, OW)

- 1994-1997 **Senior Scientist. Technical Support for the Revision of National Methodology for Deriving Ambient Water Quality Criteria for the Protection of Human Health.** Abt supported EPA in the toxicological and risk evaluations of numerous chemicals to assess various options for new AWQC derivation methods. The work involved projecting and comparing water quality criteria using various new methodologies. Support was provided in the development of a Federal Register Notice to present the revised methodology, and in the preparation of a Technical Support Document to provide detailed guidance to state and local officials responsible for implementation of the new methodology. (Client: USEPA, OW)
- 1994-1996 **Senior Scientist. Relative Source Contribution Policy Support.** Abt Associates provided support to the Relative Source Contribution Policy Workgroup in the development of a general approach for assessing human exposure to multi-media contaminants. Assistance was provided in determining the relative source contributions for all relevant exposure sources to several chemicals, including selenium, ethylbenzene, and chlorpyrifos. (Client: USEPA, OW)
- 1992-present **Senior Scientist. Toxic Chemical Release/TRI Indicators.** The Environmental Protection Agency is evaluating the allocation of resources to maximize environmental risk reduction. The EPA seeks to accomplish this through emissions control, exposure reduction, and risk abatement. To monitor the effectiveness of these programs and to gauge quantitative achievements in environmental progress, the Toxic Substances Program Strategy discusses the formation of a set of indicators to provide a summary estimate of changes in risk across all media. Under this project Abt Associates developed a set of indicators, using the Toxic Release Inventory database, that consider several different elements, including toxicity, exposure potential, and population size. In particular, the methodology uses release data, toxicity data, geographic information, and modeling techniques to weight the potential impacts from TRI releases to air, water, and soil. (Client: USEPA, Office of Pollution Prevention and Toxics.)
- 1992-1993 **Senior Scientist. Identification and Ranking of Chemical Use Clusters.** The Office of Pollution Prevention and Toxics developed a new strategy for evaluating chemicals under the Existing Chemicals Program (ECP). The new strategy is to identify clusters of chemicals and processes that perform a specific function. By simultaneously evaluating the risk posed by each cluster member and ranking total cluster risk against other clusters, OPPT will be able to prioritize its efforts. Abt Associates developed the information and ranking for evaluating the universe of TSCA chemicals in a system that can be perpetually updated as new information becomes available. Evaluated all currently available toxicology and epidemiology data bases to identify the most accurate and appropriate data sources for carcinogenic and non-carcinogenic health risk values. (Client: USEPA, Office of Pollution Prevention and Toxics.)

- 1991-present     **Senior Scientist. Comparative Risk/Benefit Analysis of Corn Pesticides.** This study used a "cluster analysis" methodology developed by Abt Associates to predict how regulating the use of individual herbicides and insecticides on field corn would affect total risks and economic benefits. Human health risks were estimated for pesticide residues in field corn and animal products; for worker exposure; and for contamination of groundwater, surface water, and fish. Product substitution and the associated cost of yield changes were estimated. (Client: USEPA, Office of Policy Analysis.)
- 1991-1993     **Senior Scientist. U.S. EPA/AMOCO Pollution Prevention Project: Risk Assessment.** Amoco Corporation and the U.S. EPA jointly conducted a project to address multi-media pollution prevention opportunities at Amoco's Yorktown, Virginia Refinery. Abt's work involved estimation of the relative risks and benefits of different environmental management strategies and the application of methods that incorporate the multi-media nature of environmental releases into facility management. The goal was to identify how the framework established at this site could be generally applied. (Client: USEPA, Office of Policy Analysis)
- 1991     **Senior Scientist. Snow and Ice Control Program.** This work updated the 1978 Environmental Impact Report on the use of road salt on Massachusetts highways. Abt assessed the economic and environmental impact of salt use, including health risks associated with dietary salt intake for the general population and population subgroups (infants, elderly, hypertensives). (Client: Commonwealth of Massachusetts, Executive Office of Environmental Affairs.)

#### Other Professional Experience

- 1989-1991     **Consultant. Rhode Island Department of Health, Providence, Rhode Island.** Developed risk assessment protocols for air and water contaminants. Evaluated and summarized hazardous and solid waste facility siting criteria nationally; recommended criteria for state. Evaluated interagency agreement on health assessment methods for waste treatment facilities. Conducted risk assessment on radon in drinking water. Developed public information materials on chemical contaminants in drinking water.
- 1986-1988     **Manager, Environmental Risk Assessment Section. New Jersey Department of Health, Trenton, New Jersey.** Carried out health risk assessments for the state's first drinking water standards for chemical contaminants. Provided agency's technical support to regional air pollution toxics risk assessment forum (NESCAUM). Evaluated proposals for hazardous and solid waste treatment facilities. Managed epidemiological studies of: hazardous waste and reproductive outcomes, waterborne solvent exposure and leukemia incidence. Developed notification guidelines for regulation and public information materials for pesticide exposure in air, water and food to prevent toxic releases from industrial sites. Developed health-based occupational exposure guidelines for 50 chemicals, presented in testimony at OSHA hearings, Washington, 1988. Set up occupational and environmental toxicology course for division. Evaluated health risks associated with chemical exposures scenarios: offshore ocean release of chemical plant effluents; water, air, and soil contamination from hazardous waste sites; indoor chemical releases from building materials and water contaminants, public exposure to structural and consumer-use pesticides. Designed and managed groundwater sampling study of pesticide contamination in agricultural areas. Linked study to community migrant health monitoring. Developed protocol to provide coordinated response to environmental issues with state environmental agency and Rutgers University.

- 1981-1985      **Research Associate. Environmental and Occupational Health Division, University of Illinois School of Public Health, Chicago, IL.** Conducted risk assessment of airborne radon and multiple cancer endpoints. Developed guidelines and questionnaire for state health department staff to use in evaluation of chemical exposures. Managed research project on solvent and pesticide chronic and reproductive toxicity. Investigated suspected link between birth defects cluster and environmental pollutants in East St. Louis, IL.
- 1974-1981      **Research Assistant. University of Chicago, Chicago, IL.** Sociology: Analyzed municipal fiscal policies regarding budgeting, management methods, and service delivery for U.S. Conference of Mayors. Genetics: Conducted mutation assays, genetic manipulation and mapping of *Ustilago violacea*. Pathology: Conducted research on atherosclerosis following coronary bypass surgery.

#### Other Related Experience

Developed Health-Based Exposure Limits (HBELs) for approximately 400 chemicals in conjunction with the Occupational Health Section of the American Public Health Association (Pro bono - ongoing)

Developed risk assessment protocol for proposed nuclear waste repository at Hanford, Washington

Conducted enzyme extraction, HPLC and electrophoresis assays of antineoplastic pharmaceutical (Adriamycin) to identify cardiotoxic moiety.

Policy Analyst for Illinois Law Enforcement Commission: health topics.

Taught Ecology, Algebra, Biology, Anatomy, and Physiology in high schools and colleges.

#### Papers, Publications, Presentations

---

- Strategies for Improving Communication Between Risk Assessors and Risk Economists. 2001. Presentation prepared for Health Canada, Ottawa, Ontario, Canada
- Cost of Illness Handbook. Prepared for EPA, Office of Pollution Prevention and Toxics, 2001 (currently being prepared for online access at EPA-OPPT website).
- Risk Assessment of Verkhnyaya Pyshma in Russian Republic. Accepted for publication in Environmental Health Perspectives, 2001. Prepared for Russian Republic.
- Potential Savings to MCOs Associated with Asthma Management Plans and Asthma Trigger Avoidance. Prepared for EPA - Indoor Environments Division, August, 2001.
- An Assessment of the Health Risk Reductions Associated with Attainment of Alternative Particulate Matter Standards in Two U.S. Cities. Accepted by *Risk Analysis*, 2000.
- Potential Cost Savings to MCOs Associated with Asthma Management Plans and Asthma Trigger Avoidance. Prepared for EPA - Indoor Environments Division. October, 2000
- Direct Medical Costs of Health Symptoms Associated with Indoor Air Pollution. Prepared for EPA - Indoor Environments Division, November 1999.
- Application of Multimedia Risk Assessment in a Russian Setting. Presented at the ISSE meeting in Athens, Greece, September, 1999.
- Quantifying the Human Health Benefits for Reducing exposure to Noncarcinogens at Superfund Sites: Pilot Study of Cadmium, Methylmercury, and Chromium. Prepared for EPA, January, 1997.

Retrospective Analysis for the Clean Air Act (812): Quantifying Health and welfare Benefits. Prepared for EPA, May, 1996. Cited in Report to Congress: The Benefits and Costs of the Clean Air Act, 1970-1990. EPA, 1997.

TRI Environmental Indicators Project: Toxicity Weighting Summary Document. Prepared for EPA Office of Pollution Prevention and Toxics, May, 1997.

Quantifying the Human health Benefits from Reducing Exposure to Noncarcinogens in Water: Pilot Study on Cadmium-Induced Morbidity and Mortality. Prepared for EPA, May, 1996.

An Analysis of Monetized Benefits Associated with National Attainment of Alternative Particulate Matter Standards in the Year 2007. November 22, 1996. Cited in : Regulatory Impact Analysis for Proposed Particulate Matter National Ambient Air Quality Standard. EPA, 1996 and: Review of the National Ambient Air Quality Standards for Particulate Matter: Policy Assessment of Scientific and Technical Information. July 1996. EPA-452/R-96-013

A Particulate Matter Risk Assessment for Philadelphia and Los Angeles. Prepared for EPA, OAQPS, July, 1996.

Risk Assessment Guidance Document for the Development of Fish Advisories for Chemically Contaminated Fish, Prepared for EPA Office of Water, 1994.

Risk Management Guidance Document for the Development of Fish Advisories for Chemically Contaminated Fish, Prepared for EPA Office of Water, 1994

Comparative Risk Benefit Analysis of Corn Pesticides, Prepared for EPA Office of Policy Planning and Analysis, 1994.

Amoco/EPA Pollution Prevention Project Yorktown Refinery Risk Reduction, Prepared for EPA Office of Policy Planning and Analysis, 1993.

Siting Criteria for Hazardous and Solid Waste Facilities, A National Survey and Recommendations, Prepared for the Rhode Island Department of Health, Providence, Rhode Island, 1990

Cunningham, K.M., Fagliano, J.A., "Toxics in Drinking Water - A Multifaceted Approach", Presented at APHA Conference, 1987.

Cunningham, K.M., Hallenbeck, W.H., Quantitative Risk Assessment for Environmental and Occupational Health, CRC Press (Lewis), 1986.

Cunningham, K.M., A Risk Assessment of Lung Cancer Due to Indoor Airborne Radon and Radon Daughters, Ph.D. Dissertation, University of Illinois at Chicago Health Sciences Center, 1985.

Cunningham, K.M., Hallenbeck, W.W., Pesticides and Human Health, Springer-Verlag Press, 1985.

### **Professional Memberships**

---

American Public Health Association  
 Society for Epidemiological Research  
 Sigma Xi  
 American Association for the Advancement of Science

---

**Abt Associates Inc., 55 Wheeler Street, Cambridge, Massachusetts 02138**

**Name:** LELAND B. DECK, Ph.D.  
**Profession:** Vice President & Economics and Environmental Effects Practice Manager  
**Years Associated with Firm:** 9  
**Citizenship:** U.S.A.

### Key Qualifications

---

Leland Deck has over 20 years experience specializing in economic benefit cost analysis of environmental regulations and the design and implementation of economic incentive programs. His analytical skills include contingent valuation, travel cost, hedonic and resource cost approaches for benefit estimation, econometrics, and operations research, risk assessment, computer model development, and integrated environmental modeling. His research projects include estimating the risks and economic value of health and welfare benefits from reducing air pollution, the costs of alternative pollution prevention technologies, and designing effective and enforceable economic incentive programs as a part of an overall strategy for controlling pollution from stationary and mobile sources. In addition to his own research projects, Dr. Deck manages Abt Associates' Economics and Environmental Effects Practice, and is a Vice President of Abt Associates Inc.

### Education

---

Ph.D., University of Maryland, Economics.  
M.A., University of Maryland, Economics.  
B.S., Rensselaer Polytechnic Institute, Geology.

### Relevant Professional Experience

---

#### Experience with Abt Associates Inc.

November, 1997-

Present

**Project Director. Economic Analyses and Control and Innovative Regulatory Strategy Development for Air Pollution Control Regulations, Implementation and Integration** This 5 year Contract provides mission support for a complete range of economics analysis of air pollution policy issues. Projects under this contract include analysis of National Ambient Air Quality Standards, New Source Performance Standards, Maximum Achievable Control Technology, New Source Review, Small Business Regulatory Flexibility Analysis, Federal Operating Permits, and other regulations under the Clean Air Act. (Client: U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Innovative Strategy and Economics Group)

October, 1996-

Present

**Project Director. Technical Support for Office of Pesticide Programs Regulatory Development** These two successive 5-year Contracts (1996-2001, and 2001-06) provide mission support for a complete range of economics analysis of pesticide regulation. Projects under this contract include economic, science and programmatic support for the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA). Projects under this contract include regulatory impact analyses of proposed FIFRA regulations, conducting economic and biological analyses of the impacts of pesticide regulatory actions, and analyses in support of regulatory and non-regulatory options for reducing use of higher risk pesticides. (Client: U.S. Environmental Protection Agency, Office of Pesticide Programs, Economic Analysis Branch)



- 2001-present **Senior Economist. Development of Trade Environmental Assessment Model.** In an effort for the EPA National Center for Environmental Economics, Dr. Deck is leading development of a model to assess the environmental impacts of trade agreements and other trade-related policy events. This model builds from prior work by Abt Associates in developing an environmental input-output model for EPA. The current effort is to build a comprehensive framework for the analyzing environmental effects of trade events in a range of pollutant and resource categories: criteria air pollutants, toxic chemicals, water discharges of conventional and heavy metal pollutants, hazardous waste disposal, pesticides and fertilizer use, and land and water use. Using emission and resource use factors by economic sector and region, the model will estimate the change in discharge or use of pollutants and resources by state and sub-state regions for sectors affected by trade agreements. Aggregate discharge or resource use effects by region will be analyzed in relation to existing baselines of ambient concentrations or other measures of baseline environmental condition to identify potentially significant impacts of a trade policy event. (Client: U.S. Environmental Protection Agency, National Center for Environmental Economics)
- February, 2001-Present **Senior Economist and Project Manager. Southern Appalachian Mountain Initiative Socioeconomic Assessment Project.** The Southern Appalachian Mountain Initiative (SAMI) is a regional multi-stakeholder process developing integrated recommendations on air pollution policies in the mountainous portions of eight southeastern States. SAMI includes representatives from all eight state governments, three federal agencies, the Tennessee Valley Authority, the electricity generating and distribution industry, and environmental advocacy groups. In this project, Abt Associates is assessing the three areas of physical and economic effects of the selected future policy scenarios being developed by SAMI. The three categories are: recreational fishing; visibility; and resident's sense of place and stewardship. (Client: Southern Appalachian Mountain Initiative, Asheville, NC)
- April, 2000 - present **Senior Economist. Particulate Matter Risk Analysis.** This project is providing support to EPA's Office of Air Quality Planning and Standards (OAQPS) in carrying out a risk analysis of the health and welfare effects that could be avoided by meeting alternative particulate matter (PM) standards. This risk analysis will follow the same general approach taken in a risk analysis carried out by Abt Associates for OAQPS in 1995-1996 (see below), in support of EPA's previous review of its PM standards. The risk analysis will estimate the risk reductions associated with reductions in ambient levels of respirable particles ( $PM_{10}$ , or  $PM \leq 10$  microns in diameter), and the fine fraction of the PM ( $PM_{2.5}$ ). The project will use information from a wide variety of epidemiological research projects to estimate the avoided health and welfare effects associated with reductions in PM. The analysis will use a case study approach, assessing risk reductions in Philadelphia and Los Angeles, two locations where good  $PM_{10}$  and  $PM_{2.5}$  data exist. (Client: U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards)
- 2000 - 2001 **Senior Economist. Heavy Duty Diesel Benefits Analysis** Abt Associates conducted benefits analyses estimating the benefits resulting from changes in particulate matter (PM) and ozone as a result of the Heavy Duty Vehicle Standards rulemaking from projected year 2030 baseline levels to projected year 2030 control scenario levels. The benefit analysis for ozone used air quality data from the UAM-V model. Two separate benefit analyses for PM were conducted, using each of two different air quality models: the CRDM S-R Matrix model and the Regulatory Modeling System for Aerosols and Deposition (REMSAD). Because each model produced a different set of projected baseline and control scenario PM concentrations for the year 2030, Abt Associates conducted two (parallel) benefits analyses (using two different sets of projected PM concentrations) for PM.

- 1999 - 2000 **Project Manager/Senior Economist. Benefit Analysis for Tier II Automobile Exhaust Standards** EPA promulgated more stringent (Tier 2) motor vehicle tailpipe standards as well as new standards for the sulfur content of gasoline. Abt Associates provided an extensive benefit analysis of the human health, agricultural and other welfare improvements associated with adopting alternative revised standards. The analysis included regulatory alternatives both the proposed rule (February, 1999), and the final rule (December, 1999). The analysis included estimating alternative future ambient levels of ozone and particulate matter throughout the United States. The benefits analysis estimated the changes in air quality and human exposure, as well as the physical and economic benefits of improvements in ozone and PM, and included estimates of human health, welfare, visibility and commodity crop agricultural effects. Abt Associates used the CAPMS model developed by Abt Associates to estimate the health and visibility benefits, and the AGSIM model to estimate the agricultural effects. (Client: U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Innovative Strategy and Economics Group)
- 1998 - 1999 **Project Manager/Senior Economist. Regulatory Impact Analysis (RIA) for the OTAG Regional NO<sub>x</sub> Budget SIP Call** This project supported EPA by conducting and coordinating all phases of economic analysis of a proposed regulation limiting nitrogen oxide (NO<sub>x</sub>) emissions in the eastern United States. The proposed regulation, limiting emissions in 22 states through an economic incentive (cap-and-trade) program, will help the eastern states make significant progress towards meet the ambient ozone standard. (Client: U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Innovative Strategy and Economics Group)
- 1996 - 1999 **Project Manager/Senior Economist. Risk and Benefit Analysis for the Clean Air Act Prospective Assessment** This project supported EPA preparing an integrated risk and economic benefit-cost analysis of the damages from air pollution that were avoided by implementation of the Clean Air Act Amendments of 1990. This project built on the work performed by Abt Associates in the "812 Retrospective Analysis" project, but expands the methods, coverage and analytical scope of that analysis. The scope of the project included the health and welfare effects (all effects other than human health, including agricultural effects, materials damage, visibility, etc.) of five Criteria Air Pollutants: carbon monoxide (CO), nitrogen oxides (NO<sub>x</sub>), sulfur oxides (SO<sub>x</sub>), particulate matter (PM), and ozone (O<sub>3</sub>). The project also estimated the economic value of these avoided damages. Abt Associates' analysis prepared for this project underwent extensive external scientific peer review conducted by EPA's Science Advisory Board. (Client: U.S. Environmental Protection Agency, Office of Air and Radiation)
- 1998 **Senior Economist. Development of a Strategic Assessment and Plan for the US Country Studies Program** This project provided research design support to the Ministry of the Environment of the State of Sao Paulo, Brazil. Sao Paulo is designing a study of the immediate health and economic benefits from controlling air pollution emissions necessary to meet long-run climate change policy obligations. Abt Associates assisted the EPA's support to the Sao Paulo Ministry in designing a workable research approach, and identifying analytical and data requirements to implement the agenda. (Client: U.S. Environmental Protection Agency, Office of Economy and the Environment)
- 1997 **Project Manager/Senior Economist. Estimation of International Health Impacts Associated with Changes in Fossil Fuel Combustion** This project was a cooperative research project with the US EPA, AID and DOE, and the United Nations Environment Program, and the World Health Organization. In addition to long-run world wide environmental benefits, climate change policies aimed at reducing fossil fuel use will result in reductions in the release of conventional air pollutants. Abt Associates estimated the potential excess mortality worldwide if an aggressive climate change policy was implemented in both the developed and developing worlds. Results of this study were published in *The Lancet*, and were presented during the Kyoto round of climate

change treaty negotiations. (Client: U.S. Environmental Protection Agency, Office of Economy and the Environment)

- 1996 - 1997 **Project Manager/Senior Economist. Economic Benefit Analysis for Revising the Particulate Matter (PM) and Ozone National Ambient Air Quality Standards (NAAQS)** This work assignment assisted the EPA by estimating the economic benefits of meeting alternative PM and ozone NAAQS. Using the Criteria Air Pollution Modeling System (CAPMS) developed by Abt Associates, this project estimated the changes in both incidence and economic value for adverse effects associated with PM and ozone. These effects include mortality, hospital admissions, respiratory illnesses, agriculture, soiling and visibility. An aggregation approach using a Monte Carlo technique combined valuation uncertainty information with information on health effects uncertainty to produce a quantitative uncertainty analysis exploring the credible interval of economic benefits estimates. This project produced the benefits estimates EPA used in both the PM and the ozone Regulatory Impact Analysis. (Client: U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards)
- 1995 - 1996 **Project Manager/Senior Economist. Economic Benefit Analysis for Proposed PM NAAQS Review** This work assignment assisted the EPA by preparing an economic benefits of the health effects that would be avoided by meeting alternative particulate matter standards. The first phase of the project was an economic benefits analysis of achieving alternative PM standards in selected sample cities. The second phase of the project was a national analysis of the risk reductions and economic benefits of achieving the alternative standards considered in the November, 1996 proposed revisions to the PM NAAQS. Abt Associates estimated the economic value of changes in health effects associated with PM, including mortality, hospital admissions, respiratory illnesses, soiling and visibility. Valuation uncertainty information was combined with information on health effects uncertainty to conduct a quantitative uncertainty analysis using Monte Carlo techniques to explore the credible interval of economic benefits estimates. (Client: U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards)
- 1994 - 1997 **Project Manager/Senior Economist. Risk and Benefit Analysis for the Clean Air Act Retrospective Assessment** This work assignment assisted the EPA by preparing a risk and economic benefit analysis of the damages from criteria air pollutants that were avoided by implementation of the Clean Air Act. This project provided the risk and benefits analysis for EPA's Clean Air Act §812 Draft Report to Congress "The Benefits and Costs of the Clean Air Act, 1970 - 1990". Abt Associates used health science information on the physical effects relationships identified in other work assignments to quantify the reductions in physical effects associated with reduced air pollution levels from 1970 to 1990, including human health, agriculture, visibility, and welfare damages. Abt Associates developed the Criteria Air Pollution Modeling System (CAPMS), a major MS Windows-based national exposure, risk and economic valuation model, for this project. The project also estimated the economic value of the avoided damages. The project estimated the credible range of measured uncertainty by developing a quantitative Monte Carlo uncertainty model, capturing both between study differences and within study measured variance. (Client: U.S. Environmental Protection Agency, Office of Air and Radiation, Office of Policy Analysis and Review; and Office of Policy, Planning and Evaluation).
- 1995 - 1997 **Project Manager/Senior Economist. Risk Assessment for Revising the PM NAAQS** This work assignment assisted the EPA in revising the PM NAAQS by preparing a risk analysis of the health effects that could be avoided by meeting alternative PM standards. The risk analysis estimated the risk reductions associated with future reductions in ambient levels of respirable particles ( $PM_{10}$ , or  $PM \leq 10$  microns in diameter), and the fine fraction of the PM ( $PM_{2.5}$ ). The project used information from a wide variety of cohort and ecologic epidemiological research projects worldwide to estimate the avoidable health effects. The analysis used a case study approach, preparing city-specific analyses in locations where good  $PM_{2.5}$  data exists. The risk

assessments separately estimated the risk changes from exposure to both short term PM levels (i.e., episodes of elevated PM lasting several days) and chronic exposure (long term exposure to elevated PM levels). The Abt Associates reports for this project were reviewed by EPA's Clean Air Science Advisory Committee, and were extensively used in EPA's PM NAAQS Staff Paper. (Client: U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards)

- 1997 **Senior Economist. Modeling Transport of USA & Canada Transboundary PM Precursors**  
Abt Associates is assisting Environment Canada in assessing the existing PM<sub>2.5</sub> ambient levels throughout southern Canada, and estimating the proportion of the ambient levels that originates in the United States. Abt Associates, working with Latimer & Associates, is using detailed Canadian emissions inventory and air quality data to revise the PM source/receptor coefficient model used by the EPA in the PM NAAQS revision project. The resulting model will extend the transport matrix to include Canadian Census Districts as separate source/receptor nodes. (Client: Environment Canada).
- 1996 - 1997 **Project Manager/Senior Economist. Summary of Comments Concerning the Review of the NAAQS for PM and Ozone Proposal Notices**  
Abt Associates assisted the EPA by summarizing written over 40,000 public comments concerning the controversial 1996 proposal to revise the ozone and particulate matter (PM) standards. EPA received over 40,000 written comments on these proposed rules. Abt developed a sophisticated Windows-based computer application known as CART (the Comments and Response Tracking system) to identify and organize each issue raised in the unprecedented volume of comments. CART assists EPA management and staff manage the preparation of comment responses by providing a flexible indexing system to quickly locate all references to specific issues raised in the comments. CART allows multiple users to simultaneously use and update data, and is designed to be flexible and usable on other rulemakings. In the second phase of the project, Abt staff reviewed all the written comments, and summarized each issue discussed. This included identifying and classifying issues on every aspect of the two rules. By using a database approach to organize the public comments, Abt was able to produce separate final reports organized by topic, author, and specific rule. Abt also produced interim special reports (such as summarizing comments from local officials, health care professionals, etc.) and analysis of the overall "for or against" positions of the commentors. (Client: U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards)
- 1997 - 1998 **Project Manager/Senior Economist. Economic Analysis Consistency Project: Discounting & Baselines**  
Abt Associates is assisting EPA's Office of Economy and the Environment develop a series of guidance documents for the Regulatory Policy Council's Economic Consistency Project. These guidance documents will be a comprehensive assessment of current economic theory, consideration of practical limits and challenges with implementing the theory in applied EPA analysis, and a description of the approaches adopted by different EPA offices in specific circumstances. Abt Associates was involved with developing white papers and extensive briefing documents on the issues of social discounting, intergenerational equity, and identifying an analytical and regulatory baseline (Client: Office of Economy and the Environment of the Office of Policy, Planning and Evaluation)
- 1995 **Senior Economist. Dry Cleaning Technology Evaluation for the Office of Technology Assessment.**  
As part of the Office of Technology Assessment's evaluation of barriers and incentives for environmental technology innovation, Abt Associates prepared a report on the dry cleaning industry that examined the market structure, financial health, alternative technologies, and regulatory structure. The report analyzed barriers to new technology in the United States and compared this to the dry cleaning technology development in Europe and Japan. (Client: U.S. Congress, Office of Technology Assessment)

Summer to

- Fall, 1994 **Project Manager/Senior Economist. Ecological Benefits of Reducing NO<sub>x</sub> Emissions from Power Plants** Abt Associates evaluated the economic benefits of avoiding ecological damage due to nitrogen oxide (NO<sub>x</sub>) emissions. Title IV of the Clean Air Act requires certain power plants to reduce acid rain by reducing emissions of both sulfur and NO<sub>x</sub>. NO<sub>x</sub> damages waterborne organisms and terrestrial plants both through its role as a precursor to tropospheric ozone formation and through deposition as an acid aerosol or as a particle. Abt Associates developed an approach to quantifying the monetary value from improved recreational fishing and commercial forestry through a benefits transfer procedure linked with ecological modeling. (Client: U.S. Environmental Protection Agency, Office of Policy, Planning and Evaluation).
- 1993 - 1994 **Project Manager/Senior Economist. Assessment of Science for Use in Clean Air Act Retrospective Assessment.** Abt Associates assisted the EPA in documenting scientific support for assessing the health effects associated with air pollution. The EPA will use this information in preparing retrospective and prospective benefit cost studies of federal air pollution programs. Abt Associates reviewed and revised existing summaries of health effects information for all six Criteria Air Pollutants (ozone, sulfur oxides, nitrogen oxides, particulate matter, carbon monoxide and lead), and recommended concentration/dose-response functions, with special emphasis on health effects amenable to economic valuation. Using information from newly published health research, Abt Associates developed dose-response functions for mortality, morbidity and hospitalization, and lung function using a robust meta-analysis technique. (Client: U.S. Environmental Protection Agency, Office of Policy, Planning and Evaluation).
- 1993 - 1994 **Project Manager/Senior Economist. Lead and Heavy Metals Benefits.** For the "retrospective" assessment of the costs and benefits associated with compliance with the Clean Air Act, Abt Associates used the up-to-date modeling techniques and the latest information on health effects from lead to: estimate human health effects attributable to reductions in gasoline lead; model changes in lead exposures and health effects from industrial processes and boilers; model changes in exposures to lead and other heavy metals and health effects for electric utilities; estimate monetary benefits associated with avoiding these effects, and perform uncertainty analysis of the benefits. (Client: U.S. Environmental Protection Agency, Office of Policy, Planning and Evaluation).
- 1993 - 1994 **Project Manager/Senior Economist. Evaluating Economic Models of Ozone's Impact on Agriculture** In support of developing ozone National Ambient Air Quality Standards (NAAQS), EPA previously developed an agricultural benefit assessment model known as the Regional Model Farm (RMF) model. In preparation of EPA's Office of Air Quality Planning and Standards review of the ozone NAAQS, OAQPS needed to evaluate whether RMF should provide the basis for estimating ozone's agricultural benefits. This project compared the RMF and other agricultural benefits assessment models that could be used in support of NAAQS review. The evaluation reviewed models to determine how readily updated ozone dose-response data can be incorporated, how the models evaluate producer decisions resulting from ozone-related changes in crop yields, and what benefit measures are estimated by each model. (Client: U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards).
- 1993 - 1996 **Senior Economist. RIA for §402, Residential Lead-Based Paint Hazard Reduction Act of 1992** As part of a national strategy to eliminate lead-based paint hazards in housing as expeditiously as possible, EPA is promulgating regulations to ensure that individuals are properly trained; that training programs are accredited; and that contractors are certified, as well as developing a model program for states to adopt. In addition, EPA is setting operating standards for lead paint inspections and abatements. The RIA developed under this project estimated the costs of these requirements and the benefits of these regulations to workers, occupants of the buildings, and the general population in the vicinity of the buildings. (Client: U.S. EPA, Office of Pollution Prevention and Toxics).

- 1993 **Project Manager. Complex Model Analysis of the Regulatory Effectiveness of the Reformulated Gasoline Rule.** Abt Associates conducted a study analyzing various aspects of EPA's proposed reformulated gasoline program. Abt Associates assessed the difference in emission reductions and the cost implications for the refining sector of EPA's use of alternative versions of its complex model to set standards for reformulated gasoline. In addition, Abt Associates assessed the relative economics of using MTBE, ETBE, and ethanol as oxygenates in reformulated gasoline, and explored "incentive-type" approaches for promoting the use of ETBE in reformulated gasoline. (Client: U.S. Environmental Protection Agency, Office of Policy, Planning and Evaluation).
- 1993 **Project Manager. Effectiveness of California Phase II Reformulated Gasoline Program in Reducing Air Toxics.** Abt Associates conducted a study using the Advanced Refinery Modeling System to assess the costs and impacts of adopting California's Phase 2 reformulated gasoline standards in the Northeast. These standards are significantly more stringent than proposal federal standards, and would require East Coast refiners to make investments in new process technologies beyond those needed to meet either federal Phase 1 or Phase 2 standards for reformulated gasoline. (Client: U.S. Environmental Protection Agency, Office of Policy, Planning and Evaluation).
- 1993 **Project Manager/Senior Economist. Valuing Ozone Damage to Urban Forestry and Materials Damage.** This work assignment identified which urban plant species (e.g., ornamentals, grasses, trees, shrubs) are at risk from elevated levels of ozone in non-attainment areas, and developed an economic model of an ecosystem damage functions for the at-risk species. Abt Associates compiled a data base from horticultural and botanical literature on ozone's known and suspected effects on plants. Using a Geographical Information System, the geographic distribution of susceptible species was mapped against the current ozone non-attainment areas. This allowed cross referencing the location of the sensitive species with the ozone non-attainment areas where the species could grow. (Client: U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards).
- 1992 -1994 **Project Manager/Senior Economist. Clean Technology Substitutes Assessment for Dry Cleaning.** Dry Cleaning establishments comprise one of the largest groups of chemical users with direct contact with the general public. The majority of dry cleaners use perchlorethylene as their primary cleaning solvent. Perchlorethylene is a toxic chemical with risks to human health and ecosystems. Abt Associates, in cooperation with the dry cleaning industry and environmental groups, directed a large scale demonstration project cleaning clothes using both perchlorethylene-based dry cleaning and the Multiprocess Wet Cleaning method. The results of the demonstration project were used to construct a financial model of commercial cleaning establishments using either process, as well as "mixed-mode" establishments offering both types of cleaning. (Client: U.S. Environmental Protection Agency, Office of Pesticides and Toxic Substances).
- 1993 -1995 **Project Manager/Senior Economist. Risk Communication and Consumer Behavior.** This project designed a method to aid the analysis of EPA's risk reduction efforts through risk communication. The project developed a formal mathematical model of consumer choice that potentially can be used to analyze consumer preferences for less risky (environmentally benign) consumer products. This model can be used both to assess the potential for influencing consumer choices via risk communication strategies aimed at influencing voluntary risk-reducing behavior, and to estimate the changes in consumer behavior likely to occur because of a future risk communication program. The estimates of behavioral changes can be used to prepare both risk analysis and economic analysis of potential risk communication programs. (Client: Office of Pesticides and Toxic Substances, U.S. Environmental Protection Agency.)
- 1993 -1994 **Project Manager/Senior Economist. Changes in Consumer Surplus from Regulatory Action Restricting Usage of Turf Pesticides.** This project involved developing a methodology for

estimating the changes in economic welfare (in terms of producer and consumer surplus) associated with regulating pesticides used for maintenance of turf. A derived demand analysis, using data on current markets for turf pesticides, serves as the basis for a model of the benefits currently associated with use of turf pesticides, and for evaluation of changes in these benefits under various regulatory scenarios. (Client: U.S. Environmental Protection Agency, Office of Policy Analysis.)

1992-1993 **Project Manager/Senior Economist. Lead Solder Economics Study.** This analysis estimated the costs and benefits from banning or otherwise controlling the use of lead solder in drinking water distribution systems. Abt Associates collected information on markets, uses and substitutes for lead solder. This information was used to calculate the costs of potential regulations. Human health benefits were estimated with a model developed by Abt Associates to relate reduced concentrations of lead in drinking water to health effects. Additional benefits and costs (e.g., impacts on service life of installations, ease of use/repair, availability of substitutes, etc.) were also calculated. Estimates of the benefits and costs were incorporated into a draft Regulatory Impact Analysis. (Client: U.S. Environmental Protection Agency, Office of Pollution Prevention and Toxics).

#### Other Professional Experience

1987-1992 **Economist. Project Manager.** Office of Air Quality Planning and Standards, United States Environmental Protection Agency. Dr. Deck directed and conducted benefit-cost and economic incentive analyses for a wide range of regulatory actions involving setting Ambient Air Quality Standards, New Source Performance Standards, State and Federal Implementation Plans, and National Emission Standards for Hazardous Air Pollutants. Project manager for developing Clean Air Act rules on using economic incentives programs in State and Federal Implementation Plans. Senior Economist for developing and promulgating regulations to improve visibility at the Grand Canyon by reducing sulfur emissions from the Navajo Generating Station. Dr. Deck directed the benefit and cost analysis of options for improving visibility by installing emission controls at one of the largest sources of sulfur emissions west of the Mississippi. Dr. Deck 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.

1983-1987 **Research Assistant. Bureau of Business and Economic Research, University of Maryland.** Research on integrating environmental impacts into a regional economic model of the Chesapeake Bay Basin.

1982-1984 **Teaching Assistant. Department of Economics, University of Maryland.** Environmental Economics and Natural Resource Economics.

1981-1982 **Economics Intern. Power Plant Siting Program, Maryland Department of Natural Resources.**

1977-1978 **Geologist & Field Manager. Adobe Oil Corporation, Casper, Wyoming.**

1976-1977 **Geologist. Century Geophysical Corporation, Casper, Wyoming.**

## Computer Experience

---

Over twenty years of extensive experience with many applications running in Windows, UNIX, DOS, DEC-VAX, and IBM mainframe (TSO, ISPF and CMS) environments. Significant programming and application experience in SAS, Systat/Sygraph, LIMDEP, Gauss, Shazam, FORTRAN, Paradox, MS Access, Lotus 123, Excel, and Quattro Pro. Managed and directed the development of major software applications (written in Borland Delphi Rapid Application Development) for risk and economic benefit analysis and regulatory process support.

## Papers, Publications, Presentations

---

“Sense of Place and Stewardship: Focus Group Report” Abt Associates Inc. Prepared for the Southern Appalachian Mountains Initiative. 2002

“The Value of Visibility Improvements in the Southern Appalachian Mountains Region” Abt Associates Inc. Prepared for the Southern Appalachian Mountains Initiative. 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. Lamtz.)

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

“The Particulate-Related Health Benefits of Reducing Power Plant Emissions.” Abt Associates Inc. Prepared for the Clean Air Task Force. 2000.

*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.” Abt Associates Inc. Prepared for the Clean Air Task Force. 1999.

“Tier II Proposed Rule: Air Quality Estimation, Selected Health and Welfare Benefits Methods, and Benefit Analysis Results.” Abt Associates Inc. 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”. Abt Associates Inc. Prepared for the U.S. Environmental Protection Agency, 1998.

“Baselines in EPA Economic Analyses”. Prepared for the EPA Economic Consistency Workgroup, 1998. (With E. Post)

“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". Abt Associates Inc. 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". Abt Associates Inc. 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". Abt Associates Inc. Prepared for U.S. Environmental Protection Agency. July, 1996

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

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

"MultiProcess Wet Cleaning: Cost and Performance Comparison of Conventional Dry Cleaning and An Alternative Process". U.S. Environmental Protection Agency. EPA 744-R-93-004. 1993.

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

"Benefits Transfer: How Good is Good Enough?." Association of Environmental and Resource Economists Workshop on Benefits Transfer, presented June 1992 (with L. G. Chestnut).

"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<sub>2</sub> 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. Lichtenstein 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).

## Honors and Awards

---

Abt Associates Inc.

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)

## Memberships

---

American Economic Association

Association of Environmental and Resource Economics

Air and Waste Management Association

Society for Risk Assessment

## Background of Authors


Dr. Cunningham has worked on environmental health issues since 1981 for various state health departments, USEPA, the Republic of Russia, and other governments. She has training in toxicology, epidemiology, medicine, public policy, and accounting. Her work focuses on risk assessment and the valuation of human health impacts. In her work at Abt Associates, she has evaluated the direct medical costs of numerous illnesses associated with environmental pollution and compiled the results of much of this research into the Cost of Illness Handbook for USEPA. She has also co-authored Quantitative Risk Assessment for Environmental & Occupational Health, and other books and papers. Her research has included a retrospective analysis of the benefits of the Clean Air Act (§812 Retrospective), which dealt with particulate matter, as well as a number of other pollutants.

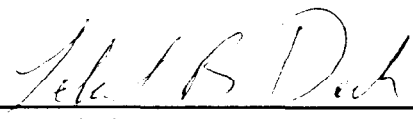
Dr. Deck has conducted environmental effects analysis, risk assessments, and economic benefit analysis of air pollution since 1981 while employed by two Maryland state agencies, the USEPA, and Abt Associates. Since joining Abt Associates in 1992 he has directed and conducted risk and economic analyses of changes in air pollution for the USEPA, the US Department of Energy, state and foreign governments, regional air pollution organizations, and other clients. His research includes the air pollution health risk and economic valuation analysis for two USEPA Reports to Congress (the §812 Retrospective and Prospective benefit-cost studies), the 1997 revisions to the PM and ozone NAAQS, and numerous EPA regulations on mobile, stationary and area air pollution sources.

Dr. Cunningham and Deck's resumes are attached in Appendix A and include a list of their publications during the last 10 years. Their opinions and conclusions are contained in this report. The exhibits to be used in summary of, or support for, their opinions are the Figures and Tables in this report. Appendix B lists the data and other information considered in developing this report.

Drs. Cunningham and Deck are carrying out this work as staff of Abt Associates, Inc., which is being paid approximately \$61,900 for 550 hours of work on this report and any testimony that may be provided. Through March, 2002 Abt Associates has billed approximately \$48,000.

Neither Dr. Cunningham nor Dr. Deck have testified or been deposed within the preceding four years.

  
Kathleen Cunningham, Ph.D.  
Ph.D.

  
Leland B. Deck, Ph.D.

## Appendix B. References Cited and Considered

- AHRQ (Agency for Health Care Policy and Research). 2001. Healthcare Cost and Utilization Project (HCUP, 1988-1997). URL: <http://www.ahrq.gov/data/hcup/hcup-pkt.htm>.
- Burnett, R.T.; R.E. Dales; M.E. Raizenne; D. Krewski; P.W. Summers; G.R. Roberts; M. Raadyoung; T. Dann; and J. Brook. 1994. "Effects of Low Ambient Levels of Ozone and Sulfates On the Frequency of Respiratory Admissions to Ontario Hospitals." *Environ Res.*, Vol. 65(2): 172-194. URL: <http://www-us.ebsco.com/online/article.asp?PPV=True&ArticleId=HKJR7M7XXFRPG2VXUPG2>
- Dockery, D.W.; C.A. Pope; W.P. Xu; J.D. Spengler; J.H. Ware; M.E. Fay; B.G. Ferris; and F.E. Speizer. 1993. "An Association Between Air Pollution and Mortality in Six U.S. Cities." *N Engl J Med.*, Vol.329(24): 1753 - 1759
- EPA (United States Environmental Protection Agency). 2000. *Final Heavy Duty Engine/Diesel Fuel Rule: Air Quality Estimation, Selected Health and Welfare Benefits Methods, and Benefit Analysis Results*. OAQPS, Research Triangle Park, North Carolina. URL: [http://www.epa.gov/ttn/ecas/reg\\_doc.html](http://www.epa.gov/ttn/ecas/reg_doc.html)
- EPA (United States Environmental Protection Agency). 2001a. *Asthma-related Cost Savings Obtained Through Asthma Management Plans and Environmental Trigger Avoidance* (Draft). Prepared for the Indoor Environments Division by Abt Associates Inc.
- EPA (United States Environmental Protection Agency). 2001b. *Cost of Illness Handbook*. Prepared for the Office of Pollution Prevention and Toxics by Abt Associates Inc. URL: <http://www.epa.gov/oppt/coi/>
- Gray, H. A. 2002. *Air Quality Modeling and Visibility Impacts Associated with Baldwin Power Plant Emissions*. Expert report to USDOJ, March, 2002.
- Krewski, D.; R. Burnett; M. Goldberg; K. Hoover; J. Siemiatycki; M. Jerrett; M. Abrahamowicz; and M. White. 2000. *Reanalysis of the Harvard Six Cities Study and the American Cancer Society Study of Particulate Air Pollution and Mortality*. Health Effects Institute. Cambridge, Massachusetts. URL: [www.healtheffects.org](http://www.healtheffects.org)
- Lippmann, M. 2002. *Health Effects of Power Plant Emissions on Downwind Populations*. Expert report to USDOJ, March, 2002.
- NCHS (National Center for Health Statistics). 1999. *Detailed Diagnoses and Procedures, National Hospital Discharge Survey, 1997*. Hyattsville, Md. Vital Health Statistics, Series 13, No. 145, December. URL: <http://www.cdc.gov/nchs/>
- Pope, C.A.; M.J. Thun; M.M. Namboodiri; D.W. Dockery; J.S. Evans; F.E. Speizer; and C.W. Heath. 1995. "Particulate Air Pollution as a Predictor of Mortality in a Prospective Study of U.S. Adults." *Am J Respir Crit Care Med*, Vol.151(3): 669-674.
- Pope, C.A.; R. Burnett, M. Thun, E. Calle, d. Krewski, K. Ito, and G. Thurston. 2002. "Lung Cancer, Cardiopulmonary Mortality and Long-Term Exposure to Fine Particulate Air Pollution." *J Am Med Assoc*, Vol. 287:1132-1141. URL: [www.jama.com](http://www.jama.com)
- Smith, D.H., D.C. Malone; K.A. Lawson; L.J. Okamoto; C. Battista; and W.B. Saunders. 1997. "A National Estimate of the Economic Costs of Asthma." *Am J Respir Crit Care Med*, Vol. 156:787-793. URL: <http://ajrccm.atsjournals.org/>
- Woodruff, T.J.; J. Grillo; and K.C. Schoendorf. 1997. "The Relationship Between Selected Causes of Postneonatal Infant Mortality and Particulate Air Pollution in the United States." *Environmental Health Perspectives*, Vol. 105(6): 608-612. URL: <http://ehpnet1.niehs.nih.gov/docs/allpubs.html>

## **Appendix C. Descriptions of Illnesses Resulting from the Baldwin Power Plant's Excess Emissions**

This appendix contains a brief description of some of the illnesses caused by the Baldwin power plant. They are grouped according to the general categories that are used in this and the Lippmann, 2002 report.

**Chronic Obstructive Pulmonary Disease:** includes Emphysema and Bronchitis

### **Bronchitis**

Bronchitis is an inflammation of the bronchi, the main air passages of the lungs. Chronic bronchitis, emphysema, and asthma as a group are the fifth-leading cause of death in the United States. Patients with either acute and chronic bronchitis experience a cough that produces mucus and may include blood. They have shortness of breath aggravated by exertion or mild activity. They suffer from frequent respiratory infections, such as colds; and from wheezing and fatigue. Their ankles, feet, and leg swell; and their face, palms, cheeks, or mucous membranes become reddish. They also have headaches and vision abnormalities.

Doctors also use chest X-rays, arterial blood gas and/or pulmonary function tests, and lungs sounds to diagnose this condition. Treatments may include nebulizers and postural drainage, which help remove thick mucus from the airways. Doctors may prescribe oral antibiotics, home oxygen therapy, physical exercise programs, and breathing exercises. Patients may need to restrict their activities and movement may be difficult when ankle, feet and leg swelling occurs. Bronchitis may require hospitalization and in the most serious cases results in death.

### **Emphysema**

Emphysema is a lung disease involving damage to the air sacs (alveoli). As noted above, emphysema, chronic bronchitis, and asthma as a group are the fifth-leading cause of death in the United States. People with emphysema have lungs that become less able to expand and contract. Their air sacs, which cannot completely deflate, cannot fill completely with fresh air. Emphysema patients experience wheezing, a chronic cough, and chronic shortness of breath with and without mild exertion. Their skin may become bluish from lack of oxygen. Emphysema may also cause flaring nostrils; bulging eyes; vision abnormalities; dizziness; temporary absence of breathing; breathing difficulty while lying down; swelling in the ankles, feet, and legs; unintentional weight loss; headache; impotence; fatigue; impaired ability to concentrate; excessive daytime sleepiness; insomnia; memory loss; and clubbing of the fingers or toes.

Doctors diagnose this condition by detecting decreased or abnormal breath sounds, prolonged exhalation, and enlargements of the chest. Alpha-1 antitrypsin deficiency, chest X-rays, arterial blood gas levels, and pulmonary function tests are used to diagnose this condition. Treatments may include bronchodilators (hand-held inhaler or nebulizer), diuretics, and corticosteroids. Antibiotics are used to fight respiratory infections, as well as chest physical therapy (postural drainage and chest clapping). Many emphysema patients use low-flow oxygen at home. An experimental surgery, called lung reduction, is currently being used to treat some patients with severe emphysema. Lung reduction surgery removes the damaged portions of the lung, thus allowing the normal portions of the lung to expand more fully. Emphysema can severely restrict

a person's ability to carry out normal activities and may require hospitalization. In the most serious cases it results in death.

### **Pneumonia**

Pneumonia is a very common, serious illness that can range in seriousness from very treatable up to life-threatening. There are several types of pneumonia. Various studies suggest that one type, mycoplasma pneumonia, most commonly affects people under 40, and causes 15 to 50 percent of all pneumonia in adults and an even higher percentage of the pneumonia in school-aged children. Symptoms generally appear as an upper respiratory infection that progresses to pneumonia. People may also have a sore throat and/or an earache. They may experience headaches, coughs, fatigue, fever, excessive sweating, clammy skin, chills and shaking, loss of appetite, nausea and vomiting, abdominal pain, coughing up blood, and chest pains. Less frequent symptoms include rashes, eye pain, muscle aches and joint stiffness, neck lumps, and rapid breathing.

Doctors listen for specific chest sounds, perform chest X-rays, sputum gram stain, CBC, lung needle biopsy, and other tests to diagnose pneumonia. Doctors prescribe antibiotics when bacterial infection is diagnosed. Treatment may include oxygen and respiratory treatments to remove secretions. Most patients respond to treatment, but elderly or debilitated patients may die from respiratory failure.

### **Asthma**

Bronchial asthma is an inflammatory disorder of the airways. Asthma, chronic bronchitis, and emphysema as a group are the fifth-leading cause of death in the United States. Patients with asthma experience wheezing that is episodic and may resolve spontaneously or require medicine or aggressive medical treatment to control. Patients can experience extreme difficulty breathing and other acute and severe symptoms including bluish lips and faces, severe anxiety, rapid pulse, sweating, confusion, severe drowsiness, a decreased level of consciousness, coughing up blood, breathing may temporarily stop, and they may experience chest tightness and angina.

Asthma is diagnosed based on wheezing, chest X-ray characteristics, arterial blood gas evaluation, pulmonary function tests, white blood cell counts, and allergy testing. Treatments may include anti-inflammatory medications, corticosteroids, leukotriene inhibitors, nedocromil sodium, and/or bronchodilators. Acute severe asthma attacks may require hospitalization, oxygen, and intravenous medications. A peak flow meter, which measures lung volume, can be used at home daily to examine lung functions and indicate when medication is needed. The illness often causes restrictions on activities among those with moderate to severe asthma and requires the use of drugs that have serious side effects. Asthma is potentially life-threatening disease and deaths occur across all ages and socioeconomic strata.

**Cardiovascular Diseases include:** hypertension, myocardial infarction, angina, congestive heart failure, and other related diseases.

**Hypertension**

Hypertension is characterized by high blood pressure. Often no symptoms are present, but patients may experience headaches or other central nervous system effects. In cases of severe hypertension, they experience tiredness, confusion, nausea and vomiting, vision changes, and anxiety. They perspire excessively and can have pale skin or redness of the face or other areas. They can also experience muscle tremors and crushing chest pain. Other symptoms can include nosebleeds, buzzing or noise in the ear, and palpitations. Hypertension may lead to more serious cardiovascular disease.

Doctors diagnose hypertension based on blood pressure readings over time. Treatments may include diuretics, potassium replacements, beta-blockers, calcium channel blockers, and ACE inhibitors, hydralazine, diazoxide, nitroprusside, and other medications. Most hypertension medications have adverse side effects.

**Myocardial Infarction**

Myocardial infarction (MI) is also known as a heart attack. Heart disease is the number one cause of death and disability in the United States. MI involves damage to an area of heart muscle due to inadequate oxygen. People suffering a heart attack can experience prolonged chest, back, and abdominal pain that can radiate to the chest, arms, shoulder, neck, teeth, and jaw. They may feel what seems like bad indigestion, squeezing or heavy pressure and a tight band on the chest, and shortness of breath. They may cough or have a dry mouth, feel dizzy or faint, experience nausea and vomiting, and sweat profusely. They might also experience seizures, difficulty breathing or a temporary lack of breathing, low blood pressure, or fatigue. In addition, a person suffering from MI may have no symptoms at all (a "silent attack") and may deny that he or she is having a heart attack.

Doctors can diagnose this condition by hearing crackles in the lungs, a heart murmur, or other abnormal sounds. They may find a rapid pulse, though blood pressure can be high, normal, or low. An electrocardiogram (ECG) will also indicate MI. Other tests, such as echocardiography, coronary angiography, and others, may also indicate MI. Finally, MI can alter other test results. MI is a medical emergency, requiring hospitalization for anywhere from one to 14 days. Treatment may include intensive care and/or emergency surgery (e.g., angioplasty or coronary artery bypass surgery). ECG monitoring begins immediately, because life-threatening dysrhythmias (abnormal heart rhythms) are the leading cause of death in the first few hours after a heart attack. An intravenous catheter is inserted to administer emergency medications and fluids. Additional invasive monitoring devices may also be used; a urinary catheter may be inserted to closely monitor fluid status. The patient usually receives oxygen even if blood oxygen levels are normal. Medications can include morphine for pain, nitrates (e.g., nitroglycerin), digitalis, calcium channel blockers, anti-arrhythmics, and diuretics. In addition, thrombolytic (clot-dissolving) therapy and medications are usually initiated within six hours of chest pain onset, unless contraindicated (e.g., stroke, pregnancy). This therapy may lead to complications such as bleeding and hemorrhage. Recovery from MI may be slow and among those that survive, some patients do not fully recover. They may have severe activity restrictions due to heart damage incurred during the MI.

**Angina**

Angina is a specific type of chest pain, caused by inadequate blood flow through the blood vessels of the heart. Patients experience pain, pressure, heaviness, or discomfort in the chest. This pain can radiate to the back, jaw, or shoulder (usually the left), and may be accompanied by nausea, sweating, dizziness, palpitations, or shortness of breath. Angina can lead to a heart attack, also known as myocardial infarction (see above). The pain associated with angina causes many angina sufferers to limit their physical activities.

Doctors diagnose this condition by performing various blood tests, electrocardiograms, chest X-rays, and lung scans. They also monitor vital signs and gather medical history documenting chest pains in general.

**Congestive Heart Failure (CHF)**

CHF is a disorder in which the heart loses its ability to pump blood efficiently. Its loss of pumping action may cause blood to back up into other areas of the body, including the liver, gastrointestinal tract, and extremities (right-sided heart failure) or the lungs (left-sided heart failure). People with CHF may experience shortness of breath, nausea and vomiting, fatigue and weakness, and coughing. Their abdomen, feet, and ankles may swell, and their neck veins may become pronounced. They may lose their appetite or experience unintentional weight gain. They may have difficulty sleeping, and may experience palpitations. They may produce less urine or have to urinate at night.

Doctors diagnose CHF by performing various tests, including an echocardiogram, chest X-ray, chest CT scan, and ECG, and blood tests. They may find a rapid heartbeat when examining the patient. They may also find fluid around the lungs, an enlarged liver, lung crackles or abnormal heart sounds. CHF can also alter other test results. The patient may require hospitalization if symptoms are severe or unstable, and may require medications, surgery, or other treatments. Doctors may prescribe vasodilators and diuretics, and may administer medications intravenously. They may also perform mechanical fluid removal and insert circulatory-assist devices, such as an intra-aortic balloon pump. The patient may need dialysis to remove excess fluid, and, in severe cases, a heart transplant. In the most severe cases, CHF results in death.



## Appendix D. Comprehensive Valuation of Illnesses

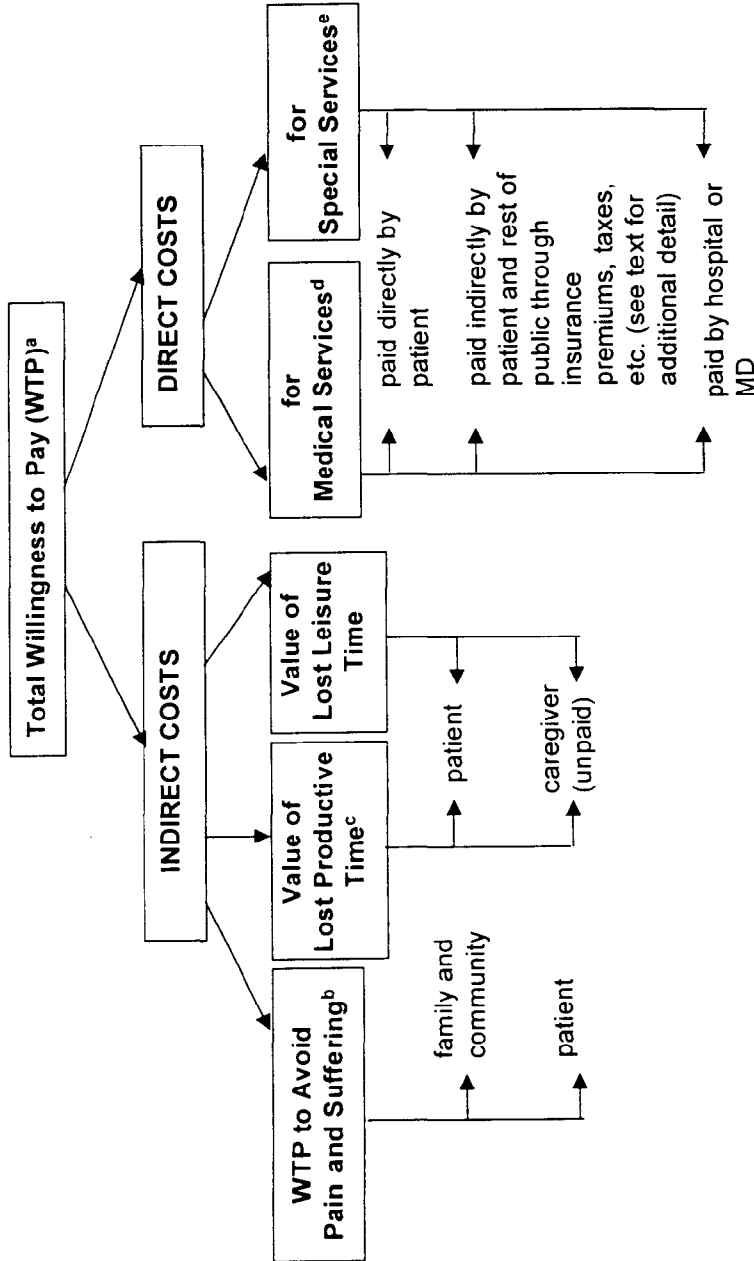
The adverse health effects associated with air pollution from the Baldwin power plant quantified by Dr. Morton Lippmann in his recent report (2002) have a variety of direct impacts on the individuals suffering the health effects, as well as their friends, families, communities, and society at large. The health effects associated with the plant emissions range very widely, from relatively mild respiratory symptoms, through serious illnesses such as chronic bronchitis and pneumonia, up to the death of the individual. Likewise, the impacts incurred by these effects also range very widely. While this report discusses those that can be most objectively measured, the direct medical costs, it is important to note that the effects of an illness that direct medical costs represent are only a small portion of the total impacts of the illness.

Illness imposes burdens on patients, their friends, families, communities, and society at large. (For simplicity, these will be referred to as affected parties in this report.) The nature and degree of impact varies from case to case. In most cases the patients may be thought to be most seriously affected, followed by their immediate family and friends. However, employers, schools (in the case of children), and the patient's local communities may suffer direct effects through the loss of an individual's ability to perform work; to learn in step with classmates; or to participate in work, play, and the community. Often there are direct burdens through loss of wages, reliance on government-provided financial support systems, and use of specialized resources for those who are temporarily or permanently disabled (e.g., in the case of chronic bronchitis). Finally, there is the pain and suffering associated with an illness, which most affected parties would place a value on avoiding. (For a description of some of the physical effects experienced by patients with the illnesses caused by the Baldwin power plant, see Appendix C above.)

When calculating the value of a health effect, the ideal approach would be to estimate the total value to all affected parties. Economists measure such values in terms of how much affected parties would have been willing to pay to avoid the illness and resulting medical treatments and, in some cases, death. Obtaining the detailed information necessary to comprehensively estimate willingness to pay (WTP), however, is a difficult and complex task, and the results often incorporate considerable uncertainty. Total WTP, which includes the value of avoiding pain and suffering, is difficult to estimate with accuracy in the absence of complex economic studies. As an alternative to estimating WTP, the direct medical costs of treating diseases provides a lower-bound estimate of the value of the illness. Direct medical costs have been used to provide a cost conservative estimate in many analyses carried out for environmental rules and policies as a way of obtaining an objective measure of the minimum economic benefits that a rule or policy will generate in terms of avoiding illnesses.

While this report focuses on the direct medical costs resulting from the Baldwin power plant emissions, it is important to recognize that these costs do not include any valuation of the numerous health impacts that are not quantified in this report. These impacts comprise the elements of WTP that are shown in Figure 1 (adapted from EPA, 2001b). These elements are organized into categories, the simplest being direct and indirect costs. Direct costs result from the increased resource utilization caused by the illness, may be medical or non-medical, and may be paid by various parties. For example, the cost of an ambulance used to transport a person to the hospital is a direct medical cost, while child care and housekeeping expenses required due to illness are non-medical direct costs. These cost may be covered by insurance,

**Figure 1. Elements of Willingness to Pay**



a. See text for a discussion of cost elements. The cost components above are associated with contracting a disease. People who avoid disease by employing averting behavior may incur other costs (e.g., the cost of buying bottled water). Both the cost components listed above, and those associated with risk avoidance would be reduced or eliminated if the risks were reduced or eliminated.

b. Heightened morbidity or other adverse effects associated with a lack of treatment (e.g., due to insufficient resources) may increase pain and suffering. This indirect cost category is very difficult to measure.

c. Lost time includes a partial or complete loss of the ability to carry out activities (paid or unpaid).

d. This is the only component of WTP that is calculated in this report.

e. Includes special education (children); worker retraining (adults); and/or specialized equipment, transportation, and other services required due to the illness.

Medicare (taxpayers), the patient, or some other source. In addition to the direct costs, there is a value to the productive and leisure time lost that is referred to as the opportunity cost. These costs can be imposed on the patient and others.<sup>12</sup>

Finally, illness causes anxiety, pain, and suffering, the cost of which, although difficult to measure, is very real and may be very high. As noted above, most people would be willing to pay something to avoid the pain and suffering that comes with illness, as well as to see loved ones avoid pain and suffering. There is also a perceived value to most individuals for maintaining public health (e.g., most people would place some value on reducing the number of children with asthma, the number of people with cancer, the incidence of birth defects, and the occurrence of most illnesses). Finally, in some cases people may take precautionary actions to avoid contracting environmentally-related illnesses. People may stay indoors during high pollution days; asthmatics may restrict their physical activities even on moderately high pollution days to avoid asthma attacks. In these cases, there are not only costs associated with the occurrence of the illness, but costs incurred in efforts to prevent the illness. These costs would be avoided or reduced if the risk of the illness were reduced.

Individuals may be willing to bear almost any medical costs necessary for the treatment of serious illnesses (e.g., to avoid death) and society is often willing to spend very large sums to avoid illness or death among otherwise healthy individuals. Extensive and expensive health programs for indigent populations illustrate the interest in the overall health of the population. This may be both the provision of a public good and a self-protective strategy. Likewise, societies are often willing to pay very large medical costs under special circumstances. For example, communities have raised millions of dollars to provide cancer treatments for a relatively small number of children. What a society or individual would be willing to pay for medical services may be strongly affected by a society's response to potentially drastic consequences. The willingness to pay very large medical costs to avoid dire consequences is expressed both by the individual with the illness and by those who are aware of the individual's plight.<sup>13</sup>

As Figure 1 illustrates, there are many components of the impacts of an illness, each having some value to the affected parties. Due in part to the varied impacts, variations in individual's resources, aversion to their or other's illnesses, and other factors that affect how they place a value on an illness, it is very difficult to fully ascertain the total "value" of an illness.

---

<sup>12</sup> Opportunity cost is the cost associated with forgone opportunities. Time spent in the hospital, for example, is time that would otherwise have been spent in productive and/or leisure activities. The opportunity cost of a hospital stay is the value of the productive and or leisure time lost during the hospital stay.

<sup>13</sup> Alternatively, there is often opposition to high medical costs associated with prolonging life for the very elderly, terminally ill, or those with certain types of health problems.

In summary, the direct medical costs calculated in this report represent only a portion of the impacts of an illness (as evidenced by Figure 1.) There are many other impacts that cannot readily be evaluated, but that have substantial value. These impacts include:

- physician costs
- pharmaceutical costs
- in home nursing care
- nursing home care
- transportation and rental of treatment equipment
- loss of work and leisure time and attendant wages for the patient and their caregivers
- pain and suffering of the patient
- pain and suffering of the patient's family, friends, and the larger community

Although this report does not address WTP estimates, interested readers can review WTP values for many of the illnesses relevant to the Baldwin power plant in Exhibit 4-3 of the EPA document *Final Heavy Duty Engine/Diesel Fuel Rule: Air Quality Estimation, Selected Health and Welfare Benefits Methods, and Benefit Analysis Results* (EPA, 2000), prepared for USEPA by Abt Associates. The "Heavy Duty Diesel" document includes WTP estimates for all the illnesses calculated in Lippmann, 2002. Some of these values are referred to in Appendix E.

## **Appendix E. Illnesses Not Considered in This Valuation Analysis**

The following illnesses and effects were evaluated by Dr. Lippmann (Lippmann, 2002) and occur in substantial numbers as a result of the non-compliance of the Baldwin power plant. Due to data limitations, the direct medical costs of treating them cannot be reliably calculated at this time. The reasons they are not provided are discussed for each illness below. By omitting the direct medical costs of these illnesses, a considerable underestimation of the total medical costs may occur. Valuation information for these illnesses is contained in EPA, 2000 in 1999 dollars. These values are for reference and informational purposes only. They were not critically evaluated for this report.

### **Chronic Bronchitis**

Number of occurrences calculated: 3,629 (Lippmann, 2002)

The evaluation of direct medical costs for a chronic disease is very complex. There are two options for ascertaining the average direct medical costs for chronic illnesses. The empirical method requires extensive and comprehensive information on medical costs that have been paid by patients. This typically is confidential information and is usually not available at the national level; national values are optimal to obtain representative average cost estimates. It is not available at this time for chronic bronchitis. For some diseases, large scale studies of federal payments have been conducted (e.g., EPA, 2001b), but this is a substantial undertaking and it has been done for few diseases. The second approach, which is theoretical, requires constructing an average treatment protocol from diagnosis through death and assigning average costs to each aspect of treatment. To do this it is necessary to obtain detailed clinical information on disease course possibilities, ascertain the probability that a specific service will be provided (these may vary by physician, geographic area, HMO policy, etc), and determine the average national cost of each service. Since many potential disease courses may occur, each with different probabilities and each with differing sequelae, this exercise becomes very complex and has substantial uncertainty associated with it. There are a number of uncertainties associated with the results that are obtained for any chronic disease, and medical advancements may cause the data to become outdated quickly. There was not a recent and comprehensive medical cost estimate available for chronic bronchitis. As a point of reference, economists have estimated a WTP value of over \$300,000 per individual for this disease (EPA, 2000). Considered in light of the 3,629 people who have been diagnosed with chronic bronchitis as a result of excess emissions from the Baldwin power plant (Lippmann, 2002), the overall WTP to avoid this serious chronic disease could exceed one billion dollars.

## **Lower Respiratory Symptoms and Upper Respiratory Symptoms**

Number of occurrences calculated: 252,242 (Lippmann, 2002)

Symptoms cannot readily have medical costs assigned because they typically are considered, with a cluster of additional diagnostic information, when the physician determines if and how they will be treated. For example, a cough alone in a healthy person may not be treated. The person may or may not even seek medical attention, or may take some over-the-counter medication. When coupled with other symptoms, or when chronic, more aggressive action is likely to be taken by the patient and physician. In some cases the symptoms may be indicative of a very serious disease. As a result of the wide variation in the causes and treatment of symptoms, the medical costs resulting from the symptoms (or their underlying medical cause) can vary widely. Even if a minimum expenditure is considered, the large number of these cases (over 150,000) that are attributable to the Baldwin power plant is likely to incur considerable medical cost. As a point of reference, economists have estimated a WTP value of approximately \$20 per individual for this disease (EPA, 2000). When this is applied to the 252,242 cases generated by the Baldwin power plant's excess emissions (Lippmann, 2002), the overall WTP to avoid this is approximately 5 million dollars.

### **Asthma Attacks**

Number of attacks calculated: 105,812 (Lippmann, 2002)

Asthma attacks share many characteristics with symptoms described above. They range from a very mild awareness by the asthmatic that their breathing is somewhat more difficult, to a life-threatening episode requiring immediate and aggressive medical attention. Although there have been descriptions of direct medical costs for various medical strategies employed during asthma attacks (e.g., use of an inhaler, medical office visit, emergency room visit), no average cost has been calculated that could be considered widely representative. (A detailed description of various medical costs of treating asthma can be obtained in the *Cost of Illness Handbook* developed by Abt Associates for EPA (EPA, 2001b). As with symptoms, the very large number of asthma attacks attributable to the Baldwin power plant (over 65,000) are likely to incur substantial total costs, even if a minimal medical expenditure per attack is assumed. As a point of reference, economists have estimated a WTP value of approximately \$41 per individual for this disease (EPA, 2000). When this is applied to the 105,000 asthma attacks generated by the Baldwin power plant's excess emissions (Lippmann, 2002), the overall WTP to avoid this could exceed 4.3 million dollars.

### **Minor Restricted Activity Days and Work Loss Days**

Number of days calculated: 6,673,832 (Lippmann, 2002)

These are not medical conditions, although they are limitations that result from them. The more than 6.7 million restricted activity days and work loss days attributable to excess emissions from the Baldwin power plant can be considered using WTP and wage rates, respectively reported in EPA, 2000. When these values are applied to the losses, they incur a cost of over 382 million dollars.

### **Mortality**

Number of deaths calculated: 5,707 (Lippmann, 2002)

Death is the most serious of impacts and attempts to value it do not always reflect the magnitude of its impact on the deceased, their families, and communities. Medical costs cannot be assigned because there are many causes of death. It is reasonable, however, to consider the hospitalizations resulting from the Baldwin power plant as a good indicator of the causes of mortality attributable to the plant. This link is borne out by studies that demonstrate increased mortality due to respiratory and cardiovascular diseases that are attributable to particulate matter (Pope, et al., 1995, Dockery, et al., 1993, Krewski, et al., 2000, and Pope, et al., 2002). Particulate matter has also been associated with excess premature mortality due to lung cancer (Pope et al., 2002). As discussed above, these hospitalization costs range from 6 to 18 thousand dollars, depending on the cause of hospitalization. It is likely that in many cases patients are in intensive care units prior to death, which may substantially increase their costs above the averages reported above. Presenting medical costs as even a lower bound of the value of a human life is not appropriate and is not suggested here. One point of reference that has been used extensively in government rulemaking assigns a WTP value of 6 million dollars per individual (EPA, 2000). Many court cases have made awards much higher than this for the loss of a single life. When the WTP value of 6 million dollars is applied to the 5,707 deaths caused by the Baldwin power plant's excess emissions (Lippmann, 2002), the WTP to avoid these deaths approaches 35 billion dollars.

**Appendix F. Acronyms**

AHRQ	Agency for Health Care Policy and Research
COPD	chronic obstructive pulmonary disease
EPA	United States Environmental Protection Agency
HCUP	Healthcare Cost and Utilization Project
HMO	Health Maintenance Organization
ICD-9	International Classification of Disease, 9 <sup>th</sup> Edition
NCHS	National Center for Health Statistics