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PACIFIC NORTHWEST LABORATORY
operated by
BATTELLE MEMORIAL INSTITUTE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC06-76RLO 1830

Printed in the United States of America

Available to DOE and DOE contractors from the
Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN 37831;
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INFORMATION AND ISSUES RELATED TO THE QUANTIFICATION OF ENVIRONMENTAL EXTERNALITIES FOR NEW POWERPLANTS

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October 1990

Prepared for
the Bonneville Power Administration
under a Related Services Agreement
with the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

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SUMMARY

This report provides background information for the Bonneville Power Administration (Bonneville) in its efforts to quantify the environmental externalities associated with new electricity resources. A more detailed companion document has been provided to Bonneville for internal use.

This report defines what is meant by externalities, particularly in the context of electricity resources. It outlines the economics issues associated with assigning an economic value, such as cents per kilowatt hour, to the residual environmental impacts of electricity powerplants. It examines two generic theoretical approaches for estimating such values and discusses their advantages and disadvantages. The report also addresses the need to include relevant stages in the fuel cycle in estimating the costs of externalities. The fuel-cycle concept is defined and its importance is discussed.

The approaches used by several states to quantify externalities are described. A review of the valuation efforts of various states and utilities indicates that three states have actually developed methodologies for assigning economic values to externalites. Information that Bonneville may need to request from resource developers to quantify externalities is discussed, and an appendix presents suggested forms for obtaining the required information. Summary information also is presented on models for analyzing the dispersion of powerplant plumes for the purpose of estimating environmental externality costs.

The only way to fully assess externalities for a particular plant is to document and analyze a range of information about the potential environmental impacts. Required information includes the steps in the fuel cycle, the types and extent of all environmental disturbances throughout the fuel cycle, the location of the plant and sites where disturbances occur throughout the fuel cycle, and the characteristics of the geographic regions affected by all environmental disturbances. These regional characteristics include the number of people affected, the types and quantities of plant and animal life affected, and the types and quantities of materials affected. Much of this information is already required in the siting, permitting, and environmental evaluation processes. Our approach in this document is to identify the types

of information required to assess the externalities and to recognize that much of that information will have to be provided by developers in the course of siting a new plant.

Until more information and better methodologies can be developed, Bonneville may have to rely a mixture of control costs and damage cost estimates to value externalities. An incremental approach is suggested for developing the required information base and methodologies.

CONTENTS

SUMMARY iii

1.0 INTRODUCTION AND OVERVIEW OF APPROACHES FOR QUANTIFYING EXTERNALITIES 1.1

2.0 VALUING EXTERNALITIES 2.1

2.1 BACKGROUND 2.1

2.2 EXTERNALITIES OF POWERPLANTS 2.2

2.3 THE ENVIRONMENTAL IMPACT PROCESS AND ECONOMIC VALUATION . . 2.3

2.4 TWO APPROACHES TO ECONOMIC VALUATION 2.8

3.0 DATA REQUIREMENTS AND DISCUSSION OF PLUME DISPERSION MODELS . . . 3.1

3.1 DETERMINATION OF SIGNIFICANCE 3.1

3.2 FUEL-CYCLE ANALYSIS 3.3

3.3 QUESTIONNAIRES 3.5

3.4 PLUME DISPERSION MODELS 3.8

4.0 TWO APPROACHES TO THE ECONOMIC VALUATION OF EXTERNALITIES 4.1

4.1 THE COST-BASED APPROACH 4.1

4.1.1 Theoretical Rationale 4.1

4.1.2 Mitigation and Control Costs 4.3

4.2 THE DAMAGES-BASED APPROACH 4.5

4.2.1 Theoretical Background 4.6

4.2.2 Market Values 4.9

4.2.3 Non-Market Use Values 4.9

4.2.4 Non-Market Non-Use Values 4.11

4.2.5 Estimating Damages: Practice 4.12

4.3 CONCLUSIONS 4.13

5.0 STATUS OF EXTERNALITY VALUATIONS AND CONCLUSIONS 5.1

5.1 STATE ENVIRONMENTAL EXTERNALITY REQUIREMENTS 5.1

5.2 SUMMARY AND CONCLUSIONS 5.3

6.0 REFERENCES 6.1

APPENDIX A - DETERMINING OPTIMAL CONTROL LEVELS A.1

APPENDIX B - GENERAL ENVIRONMENTAL QUESTIONNAIRE B.1

1.0 INTRODUCTION AND OVERVIEW OF APPROACHES FOR QUANTIFYING EXTERNALITIES

This report was prepared by Pacific Northwest Laboratory (PNL)[a] for the Bonneville Power Administration (Bonneville). It provides background information on issues affecting the quantification of environmental externalities associated with powerplants. Externalities are residual environmental impacts that are not priced in the marketplace or included in internal resource costs. In the context of this report, externalities are uncompensated environmental damages.

By definition, the persons or firms bearing the costs associated with an externality absorb them without compensation. The costs are the result of impacts that can include fairly tangible damages, such as increased health care or depressed property values, and less tangible effects, such as reduced attractiveness of a scenic vista. Many of the latter types of impacts fall into the category of non-market values because they include effects on resources and goods that are typically not bought and sold in markets.

Electricity generation involves a wide range of potential and actual environmental impacts. Legislative, permitting, and regulatory requirements directly or indirectly control certain environmental impacts, implicitly causing them to become internalized in the cost of electricity generation. Electricity generation, however, often produces residual environmental impacts that constitute externalities.

State regulators and utility officials are paying increasing attention to the issue of externalities associated with new electricity resources. A growing number of states are requiring utilities to factor externalities, particularly residual environmental damages, into their decision-making processes for new resources. However, only three states--New York, Wisconsin, and Vermont--and the Northwest Power Planning Council (NWPPC) have actually specified values to be used in such evaluations.

The 1986 Northwest Conservation and Electric Power Plan, Volume Two, Appendix II-A (NWPPC 1986) outlines a 10-step process that the Bonneville

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Administrator is to use to quantify all residual environmental costs and benefits directly attributable to a conservation measure or energy resource. The process distinguishes among impacts for which 1) an economic cost can be determined (priceable impacts), 2) no economic cost can be determined (unpriceable impacts) but the impacts can be measured in some other terms, and 3) no quantification at all is possible. This report primarily focuses on quantifying impacts of powerplant externalities. While the focus here is on economically quantifiable impacts, the information presented may be useful for assessing the significance of other impacts as well.

Two generic economic approaches to valuing externalities are considered. The first and simpler approach, called here the cost-based approach, is usually the default approach because of a lack of suitable alternatives. This approach uses the costs of controlling or mitigating externalities as proxies for the actual damages or costs associated with the externalities. This approach assumes that the marginal costs society has elected to impose through emission (and other environmental disruption) regulations equal the marginal benefits that society receives from avoiding environmental damages. However, this approach is unlikely to give an accurate estimate for the value of residual damages for many obvious and not so obvious reasons. Nevertheless, for practical reasons this approach has been used in almost all cases where attempts have been made to value externalities so far.

The second approach, called here the damages-based approach, entails listing and quantifying all economic costs associated with each type of damage caused by the residual environmental effects. This can be a complex and expensive undertaking. Furthermore, although this is the theoretically preferred approach, a comprehensive application to externality valuation has not yet been done. This document briefly outlines how this approach ideally would be implemented and suggests how Bonneville might conduct some of the steps required in a comprehensive damages-based methodology.

This report is intended as a source document for Bonneville in support of its resource acquisition process. A more comprehensive document has been

provided to Bonneville for its internal use only.[a] Following this introductory chapter, Chapter 2 examines the concept of economic externalities and how they arise from powerplant operation and electricity generation. It also examines the process by which environmental effects are translated into economic impacts and identifies the kinds of economic values that must be quantified to derive a total cost associated with residual environmental damages.

Chapter 3 identifies some of the information needs associated with the process of valuing externalities and reviews existing "plume dispersion" models for analyzing atmospheric emissions from powerplants. Chapter 4 examines the two approaches to economic valuation of externalities in greater detail. Chapter 5 summarizes current valuation efforts by selected states and presents some conclusions and preliminary recommendations to guide Bonneville in developing a methodology for quantifying externalities.

Appendix A presents more information on economics of optimal regulation of externalities. Appendix B is a sample data collection form for obtaining some of the necessary information associated with the process by which environmental effects are translated into economic impacts.

(a) Lee, A. D., M. C. Baechler, J. M. Callaway, L. O. Foley, and C. S. Glantz. 1990 (Draft). Technical Information in Support of Bonneville's Quantification of Environmental Externalities. Pacific Northwest Laboratory, Richland, Washington. This draft report provides an extensive reference list for additional sources of information on the issues discussed here.

2.0 VALUING EXTERNALITIES

This chapter first defines externalities and then discusses general issues associated with eliminating externalities. It next discusses how the concept of externalities applies to environmental impacts caused by powerplant operation and electricity generation. Finally, it illustrates the different kinds of values that must be included for quantifying the economic damages associated with these externalities.

2.1 BACKGROUND

According to Baumol and Oates (1975), an external effect, or externality, is said to exist when both of the following conditions are satisfied:

1. The utility or production relationships of one economic agent, A, include nonmonetary variables whose values are chosen by another economic agent, B, without regard to the effects on A.

2. B does not pay A compensation equal to the incremental costs inflicted on A.

Neither condition alone is sufficient for an externality to exist. Although externalities can include non-environmental effects, in this report we only consider residual environmental damages.[a]

In the context of electricity-generating resources, if a new plant discharges air pollutants that harm A, this discharge satisfies the first condition for an externality. The second condition rules out effects that are effectively "priced" either by efficient[b] legal remedies or by efficient market-like mechanisms such as marketable air-pollution permits. Regulations that require firms to reduce their levels of environmental damages to specified levels by adopting pollution-control technologies or best-

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(a) Externalities can involve both positive and negative effects. While negative externalities are more common, there are situations in which A can also be benefitted by the actions of B, or be both harmed and benefitted by B, depending on the level of B's activity.

(b) The term "efficient" is used here to refer to a compensation scheme in which the compensating payment is equal to the value of the marginal damage or benefit associated with the externality.

management practices are a third means of internalizing costs associated with externalities.

Externalities usually arise because of the inappropriate assignment of property rights. Air pollution provides a classical example of this. An unregulated firm has no economic incentive to consider the potentially harmful effect of the residuals it releases into the atmosphere in large part because 1) the ownership of the air we breath is not well-defined and 2) given the difficulty of determining the source of the potentially harmful elements and compounds we inhale as air pollution, legal liability is very difficult to establish. Therefore, when an unregulated firm discharges pollution into the environment, it effectively pays no price to discharge the waste, while society faces the social cost of the pollution damage.

Although regulations theoretically could be designed to set economically optimal levels of reductions in environmental damage (marginal control costs equal marginal benefits), the levels at which environmental damages are regulated is typically governed by the extent of the biophysical damages caused. These issues are examined later when alternative methods of valuing externalities are discussed.

2.2 EXTERNALITIES OF POWERPLANTS

In the case of powerplants, externalities can arise during any stage of the process of generating electricity and at any time during the life cycle of the plant. Most commonly, environmental externalities arise when the electricity is produced through emissions of potentially harmful gases and particles, discharge of various substances into water, and other mechanisms that affect the welfare of other economic agents without any compensation paid for damages caused.

To comprehensively assess externalities associated with powerplants it is necessary to examine the complete "fuel cycle" relevant to specific plants (Callaway and Currie 1989). By "fuel cycle" we mean all the steps from extraction of the fuel and other materials used in a powerplant to the ultimate end-use of the electricity and decommissioning of the plant, including transportation of the fuel and materials to the plant, use of the

fuel onsite, and transmission of the electricity generated by the plant. The fuel-cycle perspective addresses the need to include all environmental costs directly attributable to a powerplant or other resource.

Environmental externalities result from some disturbance to one or more components of the environment at the various stages in the fuel cycle. Typically the initial environmental disturbances directly affect the air, water, or land. Many types of powerplants emit air pollutants that get into the atmosphere and can be deposited near the plant or carried many miles away. Materials produced at the powerplant or during fuel extraction can enter bodies of water and cause water pollution. Construction of a powerplant can disrupt the land by eliminating animal habitats and destroying natural vegetation.

Where the externalities occur in the fuel cycle can vary considerably from one type of plant to another. Typically, the largest impacts will be at the plant during electricity generation. Some plants, however, will have significant impacts at other stages in the fuel cycle. A photovoltaic plant, for example, may have relatively large externalities associated with the production of the solar cells, whereas the impacts during electricity generation may be relatively small. The effects likely to be associated with the various stages of the fuel cycle for specific types of generating facilities are discussed in the next chapter.

When quantifying a specific powerplant's externalities at different points in the fuel cycle <u>it is important to count only those marginal impacts attributable to the plant</u>. For example, a plant that uses a fuel readily available in the market in large quantities is unlikely to cause significant marginal impacts associated with fuel extraction. In addition, those impacts are likely to be distributed over many sites where fuel is extracted, and it is virtually impossible to attribute those impacts correctly to a specific powerplant.

2.3 THE ENVIRONMENTAL IMPACT PROCESS AND ECONOMIC VALUATION

In efforts to attach economic costs to environmental disruptions at different points in the fuel cycle, the initial environmental disturbances

must be traced through the chain of events and conversions that lead to ultimate impacts that can be valued monetarily. This point is very important because air pollutants, for example, have no economic consequences by themselves; it is only through their ultimate interaction with some economic agent that they take on an economic value.

Figure 2.1 illustrates the chain of events by which environmental effects are translated into economic impacts (changes in economic welfare). The generic economic activity, shown at the very left of Figure 2.1, represents any relevant economic activity at any stage in the fuel cycle of a powerplant. For example, this "activity" can be the operation of a large coal-fired plant at the power-generation stage of the coal fuel cycle. The input from the previous stage of the fuel cycle is coal. The output from this activity to the next phase of the fuel cycle is the electricity generated by the plant.

The process of placing an economic value on environmental externalities entails tracking and quantifying effects throughout the entire chain. This process ideally consists of four stages (indicated in Figure 2.1).[a] The data collection and analysis efforts required for each stage of the valuation are described below.

Stage 1 is the point where the primary disruption to the environment occurs. The change is usually measured at the source and may affect the air, water, or land. At this level the externality can be quantified in physical units, e.g., tons/kWh, using standard engineering sources for a given technology.

(a) The only way to fully assess externalities for a particular plant is to document and analyze a range of information about the potential environmental impacts. Required information includes the steps in the fuel cycle, the types and extent of all environmental disturbances throughout the fuel cycle, the location of the plant and sites where disturbances occur throughout the fuel cycle, and the characteristics of the geographic regions affected by all environmental disturbances. Much of this information is already required in the siting, permitting, and environmental evaluation processes. Chapter 3 addresses these information needs in more detail.

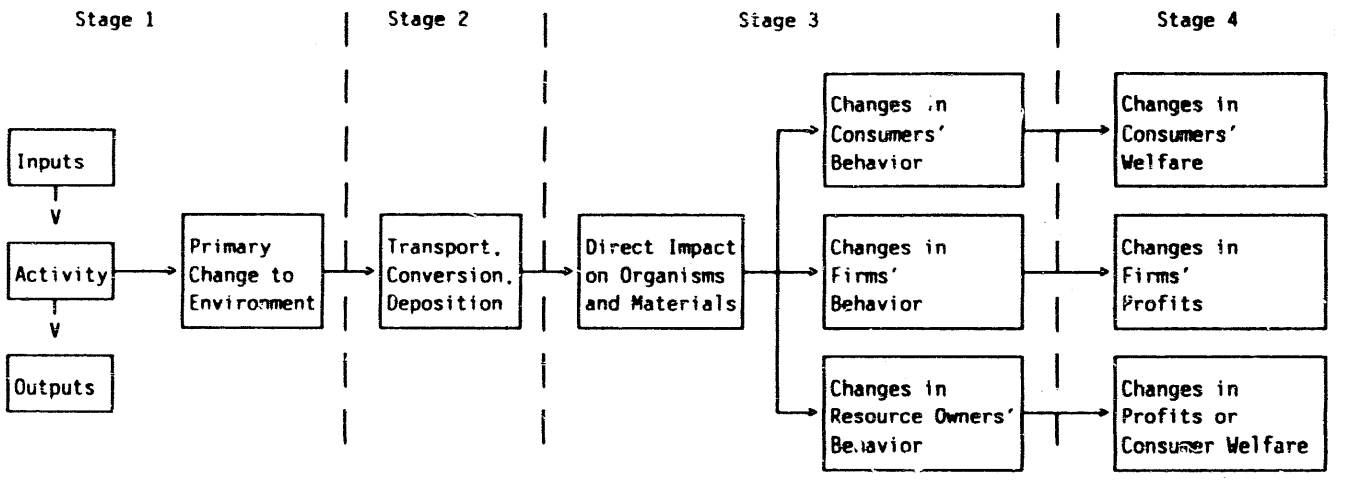

FIGURE 2.1. Stages in Valuation of Externalities

Stage 2 involves measuring the distributed effects (e.g., depositions) as precursors and pollutants are transported elsewhere. In the case of a coal plant, for example, one would be concerned about:

- the short-range deposition of volatile organic compounds (VOCs) and SO_2, which might affect human health
- the longer-range deposition of 1) ozone, which can adversely affect human health, crops and forests, and materials, and 2) acids, which can damage materials, aquatic ecosystems, and possibly forests
- the global dispersion of CO_2 and long-term buildup.

At this point, impacts can still be measured in physical terms, usually by the amount of the pollutant deposited. This stage of the valuation process requires modeling how the primary changes to the environment are transported through the environment and identifying the linkages between the primary disruption and affected systems. However, because of the complicated relationships involving the transport and chemical reactions associated with many pollutants, it may be very difficult (and expensive) to target the source of the pollutant. Furthermore, processes, such as those associated with powerplant pollutants, that combine transport phenomena and chemical reactions are often extremely difficult to simulate adequately.[a] In the case of air pollution, simulating the transport process for point-source pollutants over relatively short distances can be done for some pollutants by using "plume" models. These models are described briefly in Chapter 3. More work needs to be done on modeling the transport and conversion mechanisms for non-air-quality impacts.

In Stage 3, the effects of the environmental disruption on affected systems and their responses are measured. Most often, the direct physical and biophysical impacts of externalities are not directly observable and can only be estimated as statistical events. For example, inhaled sulfur compounds may cause lung damage in certain people. Although it is unlikely that anyone can trace a particular health effect on a particular individual to the emissions

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(a) In the case of acid deposition, for example, very large computer models are required that can take up to several days to project the geographic distribution of acid deposition from a large number of plants under specific atmospheric conditions.

from a given powerplant, the increased morbidity of an affected population can be linked to increased pollutant levels. The data collection and analysis associated with the physical effects are not discussed in this report because they require biophysical analysis of exposures, dose-response functions, characteristics of affected populations, etc.[a]

This reports focuses primarily on how to measure the economic effects associated with environmental impacts. These economic effects can be determined by observing the behavioral response by firms, resource owners, and consumers. For example, the relative profitability of a crop may change sufficiently for the farmer to change his crop mix. In turn, prices of food items purchased by consumers might rise, causing consumers to adjust their purchasing patterns. By the same token, recreational anglers may react to increasing acidification of their favorite lakes by going elsewhere, or taking up golf.

In Stage 4, economic effects translate into changes in economic welfare. Once all the basic information is available, quantifying this last stage involves placing a monetary value on each of the effects examined in order to derive a total economic value for the externality, i.e., the costs associated with residual environmental damages or the benefits associated with reversing those damages.[b] Three types of economic effects are examined here. The first type of effect is market effects on goods that are bought and sold in markets, e.g., yield reductions of commercial crops and timber. The second is non-market effects, where the physical effect is on a resource which is not bought or sold in a market. The third is human health effects, which can fall into either of the other two categories but is sufficiently distinct and controversial to be put in a class by itself. Human health effects can be

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(a) Lee et al. (1990 Draft) review various studies and methodologies that have been applied to pieces of this process. [Lee, A. D., M. C. Baechler, J. M. Callaway, L. O. Foley, and C. S. Glantz. 1990 (Draft). Technical Information in Support of Bonneville's Quantification of Environmental Externalities. Pacific Northwest Laboratory, Richland, Washington.]

(b) Assuming that the damages of a pollutant are reversible, then the value of the damages associated with a specific change (e.g., materials deterioration) in the state of the environment is equal to the value of the benefits associated with reversing that change.

translated into economic effects by examining the "willingness to pay" of individuals to avoid morbidity/mortality-related risks (discussed in Chapter 4).

Theoretically, all of the above effects can be valued in dollar terms. However, a comprehensive evaluation of the economic impacts of environmental externalities can be a difficult undertaking. In practice, several steps can be taken to simplify the problem and still produce estimates that are sufficiently accurate and complete.

2.4 TWO APPROACHES TO ECONOMIC VALUATION

This report presents an overview of two generic theoretical approaches to valuing externalities (described in detail in Chapter 4). The first approach, the cost-based approach, values external effects based on the amount of money society is willing to give up either to regulate the production of an externality or to mitigate the damages from it. This approach uses marginal mitigation or control costs imposed by regulations as proxies for actual marginal damages. In most cases, the requirements take either explicit or implicit account of the location of the powerplant and the impacts on affected populations.

The logic behind this approach is that if regulations mitigate environmental disruptions at the economically efficient level, the amount that society is willing to pay at the margin to reduce environmental impacts equals the marginal damages associated with the resulting externalities. This approach does not go through the four stages of the ideal valuation process outlined in the previous section. Rather, it uses the primary control or mitigation levels, associated with Stage 1 outputs, and control or mitigation costs as a substitute for the combined value of the Stage 4 impacts.

While this approach is easier to implement than the second approach, it requires the questionable assumption that the regulatory process correctly requires controls that equate marginal control costs and damages. Although this probably occurs rarely in practice, the regulatory process typically does weigh costs and benefits in the decisionmaking steps that lead to regulations. As noted earlier, this approach has been used in almost all cases thus far

where an approach has been used to value powerplant externalities (see Chapter 5).

The damages-based approach involves estimating the actual economic damages (or the benefits of reducing damages) of external effects to determine the aggregate damages from a powerplant when the level of pollutants emitted is known. To address condition (2) in Section 2.1, this method attempts to quantify how much economic agent B would have to pay society at-large to compensate for the marginal value of the damage to society. Direct valuation should take into account all the linkages between the primary environmental changes caused by an activity and the eventual economic impacts. Ideally, this would entail gathering and analyzing information from all four stages described above. While this approach is on sound theoretical ground, accurate and complete quantification using this approach presents many analytic challenges. The methodology for a damages-based valuation outlined in this report focuses primarily on valuing economic impacts in Stages 3 and 4.

Existing regulatory and licensing processes already require certain data and information that may fulfill some of the data needs for externality valuation.[a] Major gaps, however, are probable in three areas: 1) parts of the fuel cycle other than electricity generation, 2) steps in externality valuation other than the primary environmental disruptions, and 3) cumulative impacts.

(a) An analysis of Oregon's processes and requirements demonstrated that existing processes in most states are likely to provide data and information adequate to partially assess powerplant externalities (Lee, Baechler, and Callaway 1990).

3.0 DATA REQUIREMENTS AND DISCUSSION OF PLUME DISPERSION MODELS

To include the costs of externalities in Bonneville's generating resource evaluations, a wide range of data and information about environmental impacts is needed. Compiling such information will require information from Bonneville, as well as from developers of proposed facilities, and should address all potentially significant impacts, regardless of where they fall in the fuel cycle. Information unique to the project should come from proposers; generic information for portions of the fuel cycle not directly linked to specific projects should be provided by Bonneville. During the solicitation process, it may be appropriate to request from proposers a limited set of information on project impacts in the form of a checklist. This information could be used to flag potentially significant impacts. After Bonneville conducts an initial screening, more detailed information of the type discussed here could be requested from remaining developers.

This chapter discusses some of the factors that should guide the collection of project data related to externalities. Because one of the major categories of impacts is likely to be air pollution, it also summarizes the characteristics of numerous models that might be used to analyze the dispersion of plumes from powerplants. Outputs from such models are necessary in the quantification of externalities.

3.1 DETERMINATION OF SIGNIFICANCE

Perhaps the most important step in evaluating environmental impacts is choosing which impacts to focus on. All powerplants are likely to result in some environmental effects. The nature and magnitude of these effects depend very much on specific project features, such as the fuels and technologies employed, and the location of the project. Bonneville should evaluate any <u>significant</u> impact, regardless of where it occurs in the fuel cycle.

The National Environmental Policy Act (NEPA) states that significance requires consideration of both the context and the intensity of an impact (40 CFR 1508.27). Context means the setting in which the impact occurs. Intensity refers to the severity of the impact. In judging which impacts are significant and clearly insignificant, decision makers must consider a number

of factors to assess the intensity of an impact within its unique context (see Alton, Dowty, and Schmidt 1989). A great deal of scientific uncertainty or substantial controversy about an impact tends to indicate a conclusion of significance. Other factors that should be considered include potential effects on human health; possible effects on unique geographical features, such as nearby cultural or historic resources, parklands, prime farmlands, wetlands, or wild and scenic rivers; whether seemingly insignificant individual actions result in a significant impact when taken cumulatively; and potential adverse effects to endangered or threatened species.

The externality quantification methodology proposed by the Northwest Power Planning Council (NWPPC 1986) partially addresses this issue by requiring estimation of a resource's impacts over its effective life. Previous analyses conducted for Bonneville have taken an approach similar to that described here by estimating impacts throughout the fuel cycle (see, for example, ECO 1983).

Several issues are associated with attempting a comprehensive account of powerplant externalities. First, a complete analysis of all the stages in the fuel cycle and all the steps illustrated in Figure 2.1 would require a large investment of resources unless much of the information is readily available.[a] Second, once the analysis extends beyond the electricity generation process, it becomes difficult to determine the extent to which environmental impacts have been internalized economically. This obviously poses a difficult and expensive task if required for all fuel-cycle stages and all possible resources.

Third, as effects become less directly attributable to a specific resource, they become more difficult to assess and the justification for including them becomes less defensible. The NWPPC quantification methodology

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(a) The potential environmental impacts associated with several generating resources including hydroelectric, combustion turbines, cogeneration, geothermal, biomass, municipal solid waste, and stationary diesels are discussed by Lee et al. (1990 Draft). [Lee, A. D., M. C. Baechler, J. M. Callaway, L. O. Foley, and C. S. Glantz. 1990 (Draft). Technical Information in Support of Bonneville's Quantification of Environmental Externalities. Pacific Northwest Laboratory, Richland, Washington.] See also Baechler et al. (1990).

appears to recognize this, stating that Bonneville ". . . is required to estimate all direct [quantifiable environmental] costs. . ." (NWPPC 1986), without mentioning indirect costs. A hierarchy of impacts exists for any powerplant and it can be described in terms such as "direct and indirect" impacts, or "primary, secondary, and tertiary" impacts. Problems arise with such distinctions in establishing the criteria for categorizing impacts and then applying them uniformly.

3.2 FUEL-CYCLE ANALYSIS

The fuel cycle can be broken down into six stages and each stage can in turn be broken down into pre-operation, operation, and post-operation phases. The first three stages, which directly involve providing fuel to a plant, are fuel extraction, preparation, and transport. These stages typically are most important during plant operation. The fourth stage is power generation. The most significant externalities in this stage, of course, are most likely to arise during plant operation. However, plant construction and decommissioning can, in some cases, entail substantial environmental externalities. The fifth stage, transmission and distribution, can involve externalities prior to operation and well into the future. The last stage involves externalities during the end-use of the electricity produced by the plant. It is included here for completeness; however, for practical purposes, it is not likely to vary across generating resources and is most relevant to demand-side management technologies.

The fuel extraction stage is important for most generating resources. If the fuel supply is dedicated to the powerplant being evaluated, then pre-operation impacts should be considered; if the fuel supply has already been developed and is for multiple uses and users, then it is less arguable that pre-operation impacts should be counted. Similar arguments hold for the operation and post-operation phases. Certain impacts, such as worker health effects, are likely to be included partially in the fuel costs, and others may be internalized through regulations and permitting or siting requirements. Residual effects may still remain, however, and they should be examined. In some cases, control measure costs will be available and they can serve as a proxy for marginal damages and, therefore, the economic value of

externalities. In other cases, previous studies may provide valid damage estimates and they can be used.

The fuel preparation and transport stages can be handled similarly. Fuel transport may have the potential for spills and accidents that should be considered in the externality evaluation. Many studies have been conducted on risk assessment and economic damages associated with fuel spills. Again, a determination must be made as to whether such costs should be attributed to the powerplant in question or whether the effects should be considered so indirect as to be beyond the appropriate scope of analysis.

The power generation stage tends to dominate the assessment of externalities. Bonneville has made considerable strides in addressing impacts during this stage, for a number of resources. The largest impacts and the main focus have been on health effects from air pollutants. Some impacts, however, have only recently started to receive attention, and considerable uncertainties exist about the best approach to quantify them and the proper value to attach to them. The effects of CO_2 are one example.

The electricity transmission and distribution (T&D) stage will be important for powerplants that require construction of any new T&D facilities. Fairly good techniques exist for quantifying most of the likely residual damages of such facilities. Scientific uncertainties remain, however, in the area of health effects. Also, the issue may arise of how much of the externalities should be charged to a specific powerplant if the additional T&D equipment can serve other generators and electricity transfer purposes.

When quantifying a specific powerplant's externalities at different points in the fuel cycle, as we noted earlier, only those marginal impacts from the plant should be counted. For example, a plant that uses a fuel readily available in the market in large quantities is unlikely to cause significant marginal impacts associated with fuel extraction. In addition, those impacts are likely to be distributed over many sites where fuel is extracted and it is virtually impossible to attribute those impacts correctly to a specific powerplant.

Some method will be required to prioritize and screen the stages and phases in the fuel cycle because there are nearly 100 possible, separate

points at which analyses can be conducted for each powerplant. A major study conducted for Bonneville screened effects based on NEPA's definition of environmentally significant effects and applied the authors' judgment in determining whether the effects would be economically significant (ECO 1986). The screening process involved three sequential steps and permitted judgment to be used where uncertainties were large or public concern might be high. For screening effects, Callaway and Currie (1989) present a framework that relies on similar principles.

It is not practical, nor do we believe necessary, to conduct each of these analyses for every proposed plant. Given the existing approaches and Bonneville's needs, Bonneville may want to consider establishing an incremental process involving prioritization, screening, reliance on available information, development of new information in critical areas, and development of appropriate analytic tools. Such an approach, designed to evolve over time, might include the following components:

1. Use available research results and information to establish prioritization and screening criteria for the fuel cycle stages and impact areas.

2. Rely on relevant estimates of damage costs where available and use control or mitigation costs where inadequate damage cost data are now available.

3. Conduct research in critical areas where environmental impacts and damage cost data can be improved and will have potentially wide applicability.

4. Develop analysis tools and modeling systems for especially important impacts.

5. Revise the criteria and quantification approaches as new and better data and information become available.

3.3 QUESTIONNAIRES

To gather information pertinent to the valuation process, PNL has developed two types of questionnaires to be filled out by the proposer of a generating facility. These questionnaires are based on similar materials used by the Orange and Rockland Utility to score and rank 13 different environmental attributes for a supply-side bid solicitation (Orange and

Rockland 1989). Included in this ranking is the assignment of points based on the severity of environmental effects.

The first type of questionnaire is broad in scope and is designed to gather information that may result from any proposed development (see Appendix B). For some proposals this may be all the information necessary. For proposals with rather specialized impacts, such as a hydroelectric generator, PNL developed a second set of questionnaires. These questionnaires cover municipal solid waste, transmission systems, wood biomass, hydroelectric generation, and cogeneration. The fact that an issue is addressed in the questionnaires does not imply that the project automatically results in a significant effect.

The questionnaires are designed to gather from developers information that is unique to their proposal. Examples of this type of information for the power generation portion of the fuel cycle include:

- land requirements for the generating plant
- control technology to be employed at the plant
- potential pollutants emitted by the plant
- effects on local land uses.

Developers would not be required to provide detailed information about generic portions of the fuel cycle. Generic means that the portion of the fuel cycle in question is not directly or exclusively linked to the proposed generating facility, or related to a specific location. Table 3.1 describes whether environmental information tends to be generic or specific for different resources at different stages of the fuel cycle. This table also illustrates which portions of the fuel cycle are likely to be applicable to different resources.

For the most part, the information needed for Bonneville's assessment will also be needed by the developer to perform engineering and financial viability analyses, as well as to meet state and local siting requirements. Bonneville should develop off-the-shelf references for assessing impacts from, or to, generic elements of the environment. Examples of these elements include surface coal mining of western coal; train transportation of western

TABLE 3.1. Summary of Generic and Specific Environmental Information Needs for Different Resources at Different Stages of the Fuel Cycle

	Stage of Fuel Cycle[a]														
	Fuel/Energy Source Extraction			Fuel/Energy Source Preparation			Fuel Transport			Power Generation			Transmission and Distribution		
Resource Type	Pre-Op.	Op.	Post Op.	Pre-Op.	Op.	Post Op.	Pre-Op.	Op.	Post Op.	Pre-Op.	Op.	Post Op.	Pre-Op.	Op.	Post Op.
Hydroelectric	N	N	N	N	N	N	N	N	N	S	S	S	S	S	S
Combustion Turbine	G	G	G	G	G	G	G	G	G	S	S	S	S	S	S
Cogeneration	G/S	G/S	G/S	G/S	G/S	G/S	G/S	G/S	G/S	S	S	S	S	S	S
Geothermal	S	S	S	S	S	S	N	N	N	S	S	S	S	S	S
Biomass	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S
Municipal Solid Waste	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S

(a) Key:
N -- probably not applicable
S -- information tends to be specific to proposals
G -- information tends to be generic
Pre-Op. -- pre-operation phase
Op. -- operation phase
Post-Op. -- post-operation phase.

coal, natural gas pipelines, and oil wells; and occupational hazards. Bonneville has previously produced this type of information in environmental documents.

The questionnaire may give Bonneville enough information to determine if proposed mitigation strategies are optimal from a societal or NEPA perspective. Although not necessarily required by law, Bonneville may wish to encourage a mitigation approach as part of a NEPA strategy. Furthermore, the cost of instituting mitigation may be less than the social cost of the impact if left unchecked. Such an investment in mitigation internalizes the cost of environmental impacts, possibly at much less expense than if the costs were spread externally throughout society, thus making the resource more competitive.

In addition to providing the information needed to quantify externalities, the inventory of data will provide preliminary information to plan the preparation of environmental documentation for compliance with federal, state and local laws. The actual preparation of environmental documents will probably require specific information in addition to that discussed here. The information discussed here should also be useful to help Bonneville determine if any of the external environmental effects can be internalized through the application of effective mitigation techniques. And finally, Bonneville can use the information to develop a database to use for quality assurance when evaluating new proposals.

3.4 PLUME DISPERSION MODELS

One of the first types of impacts that Bonneville is likely to analyze when evaluating alternative generating resources is air pollution-related health effects. Such impacts have been assessed in prior studies and they may be the predominant impacts with fossil-fueled plants. A key step in analyzing these impacts is determining how pollutants are dispersed after they have been

generated by a powerplant.[a] Table 3.2 summarizes 21 current atmospheric dispersion models.[b] All of the models presented in the table are dispersion models approved by the U.S. Environmental Protection Agency (EPA) or Nuclear Regulatory Commission (NRC). Unless otherwise noted, additional information on the models and references is available in EPA (1986). The models can all run on mainframe and minicomputers; most have PC versions or can be converted for PC operation. Those with existing PC versions are indicated.

Plume models can be divided into two major categories, Gaussian and non-Gaussian. Gaussian models operate under the assumption, based on classical diffusion theory, that in a cross-section through a plume of pollutant material, pollution concentrations exhibit a Gaussian distribution.[c] For most applications, this is a good assumption; Gaussian models are the most frequently used dispersion models.

Non-Gaussian models are based on a number of alternative methods for estimating the dispersion of pollutants.[d] Sophisticated non-Gaussian models can provide more accurate solutions for particular situations than can their simpler Gaussian counterparts. However, complex non-Gaussian models may be difficult to initialize, require more powerful computer systems, take longer to run, and require a higher level of operator training to properly use the model and interpret results. The use of sophisticated non-Gaussian models will increase as non-Gaussian modeling techniques improve as the capabilities of PCs and other small computers continue to expand, and as expert systems

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(a) Lee et al. (1990 Draft) discuss such models in the context of a more general modeling system that could characterize pollutant dispersion and ultimate impacts on affected populations. [Lee, A. D., M. C. Baechler, J. M. Callaway, L. O. Foley, and C. S. Glantz. 1990 (Draft). Technical Information in Support of Bonneville's Quantification of Environmental Externalities. Pacific Northwest Laboratory, Richland, Washington.]

(b) The discussion here focuses on models that can be used to assess human health impacts, but Bonneville must ultimately consider other impacts, such as those on materials and wildlife.

(c) Detailed information on Gaussian distributions is available in advanced calculus texts, in the user's guides of many Gaussian models, and in dispersion modeling texts such as Randerson (1984). See also Barr and Clements (1984).

(d) These methods involve K-theory, similarity theory, particle-in-cell techniques, and higher order closure methods (Barr and Clements 1984).

TABLE 3.2. SUMMARY OF PLUME DISPERSION MODELS

Model Name	Model Type	Domain	Input Data	Output Data	EPA Approved	PC Version?
Buoyant Line and Point Source Dispersion Model (BLP) Developed for aluminum smelters stationary line source plume rise and downwash effects.	Gaussian plume	Rural areas, modeling domains radius < 50 km, simple terrain, 1-h to 1-year averaging periods.	Source configuration and pollutant emission parameters; up to 50 point sources, 10 parallel line sources; hourly meteorological data.	Total pollutant concentrations, monthly and annual 1-, 3-, 24-h average pollutant concentrations on user-specified receptor grid of up to 100 points. Does not treat deposition processes, but allows linear decay of pollutants.	Yes, specific applications	No
Climatological Dispersion Model (CDM2) Designed to estimate urban long-term average pollutant concentrations.	Steady-state Gaussian plume	Simple terrain, modeling domain radius < 50 km, point and area pollution sources.	Source configuration and pollutant emission parameters; point and area sources; climatological data (joint frequency distributions); plume rise and stack-tip downwash can be computed for point sources.	Average pollutant concentrations at user-specified grid points for periods from 1 month to > 1 year. Does not treat deposition processes, but allows exponential decay of pollutants.	Yes, specific applications	Yes
Gaussian-Plume Multiple Source Air Quality Algorithm (RAM) Designed to estimate pollutant concentrations of relatively stable pollutants.	Steady-state Gaussian plume	Can be applied to short- or long-term problems. Simple terrain, modeling domains radius < 50 km, urban or rural environments.	Source configuration and pollutant emission parameters; user may define both point and area sources; hourly meteorological data; plume rise and stack-tip downwash can be computed for point sources.	1- to 24-h average pollutant concentrations and annual average pollutant concentrations at user-specified grid points or on gridded receptor array. Does not treat deposition processes, but allows exponential decay of pollutants. Building wake processes are not treated.	Yes, specific applications	No

TABLE 3.2. SUMMARY OF PLUME DISPERSION MODELS

Model Name	Model Type	Domain	Input Data	Output Data	EPA Approved	PC Version?
Industrial Source Complex Model (ISC) Designed to estimate pollutant concentrations from a wide variety of sources associated with industrial complexes.	Steady-state Gaussian plume	Can operate in short- and long-term modes. Appropriate for flat or rolling terrain, modeling domains radius < 50 km, urban or rural environments.	Source configuration and pollutant emission parameters; user can define point, line, area, and volume sources; in short-term mode (ISCST), uses hourly meteorological data to compute straightline plume transport; long-term mode (ISCLT) uses joint frequency distribution data to compute straightline plume transport; plume rise, stack-tip downwash, and building wake can be computed.	Short- and long-term averaged products at user-specified receptor locations and rings. Treats deposition processes and allows exponential decay of pollutants.	Yes, specific applications	Yes
Multiple Point Gaussian Dispersion Algorithm with Terrain Adjustment (MPTER) Designed to estimate pollutant concentrations from multiple point sources.	Steady-state Gaussian plume	Can operate in both short- and long-term modes. Appropriate for flat or rolling terrain, modeling domains radius < 50 km, urban or rural environments.	Source configuration and pollutant emission parameters; hourly meteorological data; plume rise and stack-tip downwash can be computed.	Short- and long-term averaged products at user-specified receptor locations. Does not treat deposition processes, but allows exponential decay of pollutants.	Yes, specific applications	Yes
Single Source (CRSTER) Model Designed to estimate pollutant concentra-	Steady-state Gaussian plume	Can operate in short- and long-term modes. Appropriate for flat or rolling terrain, modeling domains radius < 50 km,	Source configuration and pollutant emission parameters; hourly meteorological	Short- and long-term averaged products at up to five user-specified receptor rings.	Yes, specific applications	No

TABLE 3.2. SUMMARY OF PLUME DISPERSION MODELS

Model Name	Model Type	Domain	Input Data	Output Data	EPA Approved	PC Version?
tions from point sources.		urban or rural environments.	data; assumes no vertical variation in wind direction or speed; plume rise and stack-tip downwash can be computed.	Does not treat deposition processes, but allows exponential decay of pollutants.		
Urban Airshed Model (UAM) Computes ozone and other pollutant concentrations by simulating photochemical processes in urban atmosphere.	Urban scale, 3 dimensional, grid-type, numerical	Short-term model; simulations of conditions for 3 days or less. Model assumes ozone formation is direct result of emissions of oxides of nitrogen and volatile organic compounds.	Source configuration, pollutant emission parameters, initial boundary concentrations; hourly, gridded wind data for number of vertical layers; temperature structure of atmosphere, humidity, surface pressure, and gridded roughness lengths; computes plume rise, dry deposition, and surface vegetation uptake.	Computes gridded instantaneous concentration fields at user-specified time intervals and grid levels. Chemical transformation component uses the Carbon-Bond II Mechanism.	Yes, specific applications	On more powerful PCs
Air Resources Regional Pollution Assessment (ARRPA) Model Designed to compute air concentrations and surface dry deposition of sulfur dioxide and sulfate.	Medium/ long-range Gaussian segmented plume	Appropriate for transport distances from > than 10 km to > 50 km.	3-dimensional, meteorological output from National Weather Service's Boundary Layer Model; source configuration and pollutant emission parameters; hourly wind field components, potential temperature, and other meteorological data; plume rise is computed; allows spatial and temporal plume rise variation.	Short-term averaged products on gridded receptor array. Non-gridded receptors can be specified. Computes dry deposition and processes and oxidation of sulfur dioxide to sulfate.	Yes, case by case	Maybe

TABLE 3.2. SUMMARY OF PLUME DISPERSION MODELS

Model Name	Model Type	Domain	Input Data	Output Data	EPA Approved	PC Version?
ERT Visibility Model Designed to estimate visibility impairment caused by emissions from isolated point sources.	Gaussian plume	Visibility impairment results provided for user-specified lines of sight.	Source configuration and pollutant emission parameters; hourly meteorological data; key pollutant background concentrations, deposition velocities, chemical transformation rates; plume rise can be computed.	Parameters related to visibility impairment, including total calculated visual range reduction, and pollutant's contribution. Treats dry deposition and uses first-order transformations of sulfates and nitrates.	Yes, case by case	No
Integrated Model for Plumes and Atmospheric Chemistry in Complex Terrain (IMPACT) Designed to calculate the impact of pollutants from point or area sources.	Eulerian, 3 dimensional, finite-difference grid	Simple or complex terrain, point or areas sources.	Source configuration and pollutant emission parameters; hourly meteorological data for surface and elevated monitoring stations within and surrounding modeling domain; can use vertical profiles of pollutant concentration, terrain height data, and surface roughness data; plume rise is computed and chemical transformations considered using number of mechanisms; physical removal treated using exponential decay of pollutants.	Vertical and horizontal cross sections of pollutant concentrations averaged over periods specified by user. Can model any inert pollutant or a number of reactive compounds (e.g., oxides of sulfur, oxides of nitrogen, ozone, and hydrocarbons).	Yes, case by case	No
MESOPUFF II Designed to calculate concentrations of up to five pollutant species.	Short-term, regional scale, Gaussian puff model	Allows spatial and temporal variations in winds, but does not explicitly treat complex terrain.	Source configuration and pollutant emission parameters; hourly meteorological data from up to 25 surface stations and 10 upper air stations; plume rise can be computed.	Single simulation examines up to 5 pollutant species. Can model up to 25 point sources, 5 area sources. Uses gridded receptor field; allows user to specify additional receptor locations. Treats both wet (precipitation) and	Yes, case by case	No

TABLE 3.2. SUMMARY OF PLUME DISPERSION MODELS

Model Name	Model Type	Domain	Input Data	Output Data	EPA Approved	PC Version?
				dry deposition processes. Computes hourly chemical rate constants from results from photochemical simulation models.		
MESOI/MESORAD MESORAD is the radiological version of MESOI; includes algorithms that compute radiological dose for selected radionuclides. Developed for use by U.S. Department of Energy (DOE) and the NRC.	Gaussian puff dispersion models	Allow spatial and temporal variations in windfield, explicitly treat complex terrain.	Source configuration and pollutant emission parameters; meteorological data (15-min or hourly data typical) from up to 40 surface stations to compute near-surface wind field; upper-level wind data are provided from one station; plume rise can be computed.	Can accommodate four point sources with time-varying emission rates. Uses gridded field of receptors to provide graphical or numerical information on pollutant exposures, deposition, and radiological doses (for MESORAD). Treats both wet (precipitation) and dry deposition processes and allows exponential decay of reactive pollutants.	No, developed for DOE and NRC	Yes, user-friendly forms, menus, and output display programs
Mesoscale Transport Diffusion and Deposition Model for Industrial Sources (MTDDIS) Designed to simulate long-range transport.	Gaussian puff model	Allows spatial and temporal variations in winds, but does not explicitly treat complex terrain. Can be used for releases in simple through rolling terrain, to determine 3-h maximum and 24-h average pollutant concentrations.	Source configuration and pollutant emission parameters; hourly meteorological data from up to 10 surface stations and single upper air station; plume rise can be computed.	Can treat up to 10 point sources. User can specify up to 3 rectangular receptor grids. Treats both wet (precipitation) and dry deposition processes. Chemical transformations treated using exponential decay of pollutants.	Yes, case by case	No

TABLE 3.2. SUMMARY OF PLUME DISPERSION MODELS

Model Name	Model Type	Domain	Input Data	Output Data	EPA Approved	PC Version?
Offshore and Coastal Dispersion Model (OCD) Designed to estimate pollutant concentrations under special dispersion conditions found in coastal and offshore areas.	Steady-state Gaussian plume	Inland portion of modeling domain can have simple or complex topography. Point sources may be located offshore, on shoreline, or inland (within several kilometers of the shore).	Source configuration and pollutant emission parameters; hourly data to represent meteorological parameters, e.g., wind direction and speed, mixing height, water temperature, humidity (over water), and the vertical temperature gradient.	Short- and long-term averaged products at user-specified receptor locations and receptor grids.	Yes, case by case	No
PLMSTAR Air Quality Simulation Model Designed to simulate behavior and predict atmospheric concentrations of pollutants in chemically reactive plumes.	Mesoscale Lagrangian photochemical	Air parcel subdivided into 5-layer/9-column domain of computational cells, up to 250 point sources and unlimited area sources.	Source configuration and pollutant emission parameters; data on surface winds, winds aloft, temperature profiles, and other meteorological parameters; incorporates explicit terrain adjustment of wind field.	Pollutant concentrations at specified times and receptor locations. Emission processors allow up to 250 point sources and unlimited number of area sources. Photochemical algorithms can consider 62 reactions involving 38 species. Chemical transformations are computed by numerically integrating nonlinear kinetic rate equations. Dry deposition processes are computed.	Maybe, case by case	No
PLUVUE II -Plume Visibility Model Designed to estimate visibility effects of single-source particle, NO_x, SO_x, etc. emissions	Gaussian plume		Source configuration and pollutant emission parameters; assumes constant wind direction and wind speed during simulation; requires information on background pollutant concentrations. Plume rise can be computed.	Plume concentrations and visual effects at specified downwind distances for calculated or specified lines of sight. Treats dry deposition and chemistry of key pollutant compounds.	Maybe, case by case	No

TABLE 3.2. SUMMARY OF PLUME DISPERSION MODELS

Model Name	Model Type	Domain	Input Data	Output Data	EPA Approved	PC Version?
Point, Area, Line Source Algoritnm (PAL-DS) Intended to assess air quality impact of particular urban-type sources (e.g., airports, shopping centers, parking lots) over level terrain on scales of tens to hundreds of meters.	Short-term Gaussian plume	Level terrain	Source configuration and pollutant emission parameters; data on wind direction and speed, wind profile exponents, stability class, mixing height, and air temperature; up to 99 sources allowed and may be of six types: point, area, and four types of line sources; can compute plume rise, but not downwash.	Hourly concentration, hourly deposition flux, and average concentrations (for up to 24 h) for each source type at each receptor. Can compute dry deposition but does not handle chemical transformations.	Maybe, case by case	Yes
Random Walk Advection and Dispersion Model (RADM) Uses random-walk method to simulate atmospheric dispersion.	Lagrangian dispersion	Applicable for point and area sources. Computations conducted for each advection time step. Pollutant concentrations computed for particular time by summing mass of particles in volume around each receptor.	Source configuration and pollutant emission parameters; gridded meteorological data (i.e., wind direction, wind speed, stability class, temperature, and mixing height); vertical wind speed profile used to allow wind speeds to vary with height; can specify multiple point and area sources; can compute plume rise.	Average concentrations by receptor for user-specified averaging times or entire simulation. Can compute dry deposition and exponential decay of chemical compounds.	Maybe, case by case	No
Reactive Plume Model (RPM-II) Designed to estimate short-term concen-	Reactive plume	Offers user option of choosing various chemical kinetic mechanisms.	Source configuration and pollutant emission parameters; data on wind speeds as function of time and other meteorological parameters;	Short-term concentrations of primary and secondary pollutants at either user-	Maybe, case by case	No

TABLE 3.2. SUMMARY OF PLUME DISPERSION MODELS

Model Name	Model Type	Domain	Input Data	Output Data	EPA Approved	PC Version?
trations of primary and secondary pollutants resulting from point or area source emissions. Claims to offer more realistic treatment of entrainment process (by which ambient air mixes with the plume) through enhanced horizontal resolution within the plume.			wind direction data not used; requires user to specify initial concentration of pollutant species; user can specify single point, area, or volume source; can compute plume rise.	specified times or downwind distances. Can be run using the Carbon-Bond II Mechanism. Can handle other user input chemical kinetic mechanisms.		
Regional Transport Model (RTM-II) Used to estimate air pollution impacts from multiple point sources and area sources at large distances (hundreds to thousands of km). Can treat many different pollutant species in single simulation, although primarily configured for sulfur dioxide and sulfate.	Hybrid Eulerian grid and Lagrangian Gaussian puff		Source configuration and pollutant emission parameters; data on grid wind fields and precipitation at user-specified time intervals; other data requirements to define topography, land use, deposition velocities, initial boundary conditions, and other parameters; point and area sources can be specified at each grid point (up to a total of 500) within modeling domain; can compute plume rise.	Instantaneous and average concentration fields at user-specified time intervals. Cumulative wet and dry deposition values can be produced. For chemical transformations, explicitly treats linear sulfur dioxide oxidation.	Maybe, case by case	No

TABLE 3.2. SUMMARY OF PLUME DISPERSION MODELS

Model Name	Model Type	Domain	Input Data	Output Data	EPA Approved	PC Version?
VALLEY Model Designed to provide screening estimates of 24-h and annual pollutant concentrations in areas where elevation of neighboring terrain may exceed emission stack height.	Straight-line Gaussian plume	Estimates of pollutant concentrations very sensitive to elevation of receptor locations. EPA recommends use of other models, if more than simple screening required for complex terrains.	Source configuration and pollutant emission parameters; uses joint frequency distribution data from nearest meteorological monitoring site to represent dispersion conditions throughout modeling domain; plume rise can be computed and height adjusted according to terrain elevations and atmospheric stability; can treat up to 50 point and area sources.	Pollutant concentrations at 112 receptor locations arrayed on radial grid of variable size.	?	No

technology can be applied to initialize model runs and help interpret model results.

As part of its environmental impact modeling system, Bonneville must select an atmospheric dispersion model that is appropriate for the modeling objective, size of the modeling domain, local topography, available meteorological data, release characteristics, pollutant characteristics, computer resources, and user expertise. Bonneville must address each of these selection criteria and carefully define model requirements and computer capabilities before selecting a specific dispersion model or models to include in Bonneville's modeling system. Although PNL does not have enough information to effectively evaluate these criteria for Bonneville, the following assumptions most likely will apply in Bonneville's model selection:

- The dispersion model will be used to estimate the ground-level pollutant concentrations resulting from the routine operation of power plants.
- The model will need to consider offsite environmental impacts, in both simple and complex terrain settings, out to distances of 50 km from the release point.
- Both short- and long-term impacts will be studied; however, the emphasis will be on long-term impacts.
- Model execution time will need to be fairly rapid (less than 10 min) for most applications, although slower execution times will be acceptable for more sophisticated analyses (e.g., these analyses may be conducted using overnight, batch-mode runs).
- Climatological data will be required for some applications; hourly meteorological data sets (providing information on spatial and temporal variations) will be required for other applications.
- Pollution will come from point or area sources; emissions may occur from more than one point source and may vary with time. Time varying emissions may be handled in a single or multiple model runs.
- Pollutant emissions that are only indirectly related to the operation of powerplants (e.g., emissions from increased automobile traffic in the vicinity of the power plant) will generally not be considered.
- The model will need to consider plume rise, deposition processes, and some simple chemical transformations.
- Sources will be inland; special coastal dispersion models will not be needed.

- Heavy gases will not be studied; the model will not be used to simulate the accidental release of liquid natural gas, chlorine, or other heavy gases at power plants.

- The modeling system will be based on a PC workstation (e.g., IBM PS/2 Model 70 or 80).

- The modeling system will be used by technically capable people--scientists, engineers, and managers with some experience in interpreting environmental assessment data.

- A user's guide and a training manual will provide guidance on how to use the dispersion model, how to interpret results, and how to evaluate model performance.

Unfortunately, PNL is not aware of a single dispersion model, or system, that can meet all Bonneville's needs. PNL recommends that Bonneville develop a modeling system that incorporates pollutant dispersion analysis with emissions models, dose-response models, and economics impacts models. This system also should permit the user to choose from at least two dispersion models with differing capabilities.[a]

(a) See Lee et al. (1990 Draft) for further discussion. [Lee, A. D., M. C. Baechler, J. M. Callaway, L. O. Foley, and C. S. Glantz. 1990 (Draft). Technical Information in Support of Bonneville's Quantification of Environmental Externalities. Pacific Northwest Laboratory, Richland, Washington.]

4.0 TWO APPROACHES TO THE ECONOMIC VALUATION OF EXTERNALITIES

The objective of the externality valuation process is to accurately estimate the economic costs of the damages that should be attributed to every residual environmental disturbance associated with a powerplant. There are two generic theoretical approaches to this. The first approach, the cost-based approach (discussed in Section 4.1), involves using estimates of marginal mitigation or control costs to value residual effects. The second approach, the damages-based approach (discussed in Section 4.2) entails a complete listing and quantification of economic costs associated with each type of damage caused by the residual environmental effects.

4.1 THE COST-BASED APPROACH

The cost-based approach involves using estimates of marginal mitigation or control costs to value residual external effects. This approach does not require tracking effects through all the stages identified in Section 2.3 because the mitigation and control costs are assumed to reflect the ultimate economic costs of the damages. Although regulations theoretically could be designed to set economically optimal levels of reductions in environmental damage (marginal control costs equal marginal benefits), the level at which environmental damages are regulated is typically governed by the extent of the biophysical damages caused. Environmental assessments are used to establish the extent of damages and the effects of regulation on these damages. Economic considerations usually enter into a regulatory decision but may be secondary to health and environmental factors. Nevertheless, the relationship between levels required by regulations and control costs are important in deriving estimates of the costs associated with externalities.

4.1.1 Theoretical Rationale

Ideally, cost-based approaches analyze marginal benefit and marginal cost curves from the standpoint of determining the economically efficient level of emissions reductions. The curves are assumed to include both consumer and producer costs and benefits, and all the market and non-market effects discussed in Chapter 2.

The theoretical argument is based on the assumption that environmental impacts should be controlled to their economically efficient level, taking into account both control costs and the damage costs of uncontrolled impacts. In a marginal economics framework, marginal control costs increase and the marginal benefits of each additional reduction in environmental damages decrease as tighter and tighter controls are imposed. To satisfy the economic efficiency criterion, controls should be required up to the point where the marginal control cost equals the marginal benefits of reduced damages.

For a single powerplant in isolation, the intersection of the marginal control cost curve and marginal benefits curve for that plant determines the optimum control level (see Appendix A, Figure A.1). At levels of pollution abatement above the economically efficient level, the marginal cost systematically exceeds the marginal benefit. Society is worse off when less or more abatement occurs than the economically efficient level. However, this conclusion may change when the effects of individual plants are considered in combination with other plants already present.

Most discussions about powerplant environmental externalities and regulations tend to focus on the impacts of a single plant, with little explicit attention given to the consequences of assessing the impacts of this single plant in an environment where, in fact, many plants may be present. NEPA analyses, however, often address the "cumulative impacts" associated with particular projects, taking into account to some extent the contribution of a particular project to cumulative environmental disruptions. Analyzing a single source in isolation is often inadequate because it ignores the damages caused by residual emissions from other sources and assumes that the level of pollution abatement mandated by existing regulations applies to all sources uniformly.

When all existing sources of environmental damages are taken into account, different requirements emerge for individual sources. For example, in the case where one powerplant exists and an identical facility is being added, the marginal control cost and benefits curves should be based on both plants together (see Appendix A, Figure A.2). In this situation, cumulative impacts would be taken into account and, under these circumstances, it can be

shown that the optimal control level is tighter for the new plant than if it were analyzed in isolation.[a]

This result suggests that where existing pollution levels are higher, tighter controls on new plants are justified and the societal benefits are higher.[b] Since the incremental cost of damages caused by each new powerplant depends on the existing level of environmental damages, externality valuations should take into account such cumulative effects.

4.1.2 Mitigation and Control Costs

There are two types of cost-based approaches. The first determines the cost of mitigating the damages done by an externality, while the second focuses on the control costs of preventing an environmental externality at the point of production.

Mitigation approaches measure "defensive expenditures." Externalities pose a threat to individuals who, economic theory suggests, will engage in defensive behavior to avoid these damages. The economically "rational" individual should select a way of mitigating the damages that equates the marginal benefits with the marginal cost of the mitigation. Thus, in cases where mitigation is economically feasible, the marginal mitigation cost to the individual should equal the marginal damage to the individual.

Using this logic, changes in total mitigation costs or "defensive expenditures" to avoid the adverse effects of environmental externalities on the part of all affected economic agents can be used, under certain conditions, to measure the damages (or benefits) of increases (or decreases) in environmental externalities This approach has been used to estimate the benefits of programs to reduce soiling from particulates and non-melanoma skin cancers due to stratospheric ozone depletion; and several studies have used

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(a) Intuitively, pollution controls on new facilities should be tightest in regions where existing pollution levels are the highest. The Clean Air Act (42 USC 7401-7642) and Clean Water Act (33 USC 1342, Sec. 402) exemplify this concept through their tiered control technology requirements.

(b) This theoretical finding is supported empirically by recent arguments in California that certain out-of-state air quality damages should be valued at one-tenth their in-state value [California Energy Commission (CEC) 1989].

the cost of planting trees to offset increases in atmospheric carbon as a means of valuing the damages done by CO_2 buildup (Chernick and Caverhill 1989). The same type of approach generally lends itself to valuing the health effects of increased air pollution due to higher medical costs associated with increased morbidity.[a]

Although the theory underlying the use of "defensive expenditures" to value externalities is compelling, the method has two primary limitations and its use is appropriate only in certain circumstances. First, damages may exist for which there are either no economically feasible defensive measures; or, even if such measures do exist, they may be hard to observe and measure and only certain people may be able to afford them. Second, there are cases when mitigating actions often have subsidiary benefits that are not related to the specific pollutant, and thus the true benefits of mitigation may actually exceed the cost of damages being mitigated.

Despite these limitations, mitigation costs represent an important and, with some limitations, theoretically sound set of measures for valuing the damages of environmental externalities. In fact, most economists would probably be reluctant to call this a cost-based approach, preferring instead to emphasize the behavioral link between this approach and the more direct methods for valuing the damages caused by environmental externalities described in Section 4.2.

The second cost-based approach involves using estimates of the costs of reducing environmental externalities to their regulated levels at the source as a measure of the economic damages. Similar to the mitigation approach, this approach assumes that regulators regulate an environmental externality to the point where the marginal benefits to society of controlling the last unit of an externality equal the marginal control costs. In this framework, the value of the marginal control cost is identical to the value of the marginal benefit. Therefore, the marginal control cost can be used, appropriately and without error, to value small increases in the externality.

(a) Medical costs alone, however, are likely to underestimate the total costs associated with physical and mental health damages.

However, at least two major complications are associated with the use of this type of approach. First, it is unlikely that the regulatory process in the United States produces an optimal level of pollution based on social benefit-cost principles. Pollution regulation in this country involves several criteria that often make it difficult to determine the relationship between marginal benefits and marginal control costs at the regulated level of pollution.

Second is the complex task of assigning a single marginal cost estimate to a single source or pollution precursor. In the simplest case, a single source is assumed to emit a single pollutant, for which there is a well-defined optimal pollution rule. In the real world, however, regulating one pollutant or precursor may influence the levels of other pollutants. Allocating marginal control costs to a single pollutant is extremely difficult because one precursor alone or in combination with other pollutants may cause a variety of damages and because regulating one precursor may influence the effects of others.

PNL has not attempted to assess the accuracy of using marginal control costs as a proxy for damage costs. However, the assessments that have been done by others suggest that control costs provide a fairly good proxy (Chernick and Caverhill 1989, p. 38). As a practical matter, typical research and resource constraints often mean this approach is the only feasible way to set a value for certain externalities.

4.2 THE DAMAGES-BASED APPROACH

If pollution control regulations were driven strictly by economic optimization criteria, then the marginal cost of the required controls would equal the marginal benefits of reducing emissions by one additional unit. Under these conditions, the marginal value of the residual damages associated with an externality would be simply the marginal control cost. Since this optimal control condition rarely exists in practice, a more direct valuation approach needs to be developed.

4.2.1 Theoretical Background

The damages-based approach estimates the costs of damages, or the benefits of reducing damages, by examining changes in the welfare of economic agents who are in some sense "damaged" by the physical effects of the externality.[a] The basic purpose of the valuation method is to determine the actual amount of compensation that society is willing to accept (or pay) to tolerate (or prevent) the residual damages caused by a generating resource.[b] Determining these amounts involves valuing both market and non-market goods.

In theory, all of the damages associated with the effects of a specific source (or all of the benefits from regulating that specific source) can be quantified and then can be plotted to derive the marginal damage curve associated with the emissions of a specific pollutant from that source. The damages method of valuation is based on two basic models of economic behavior, one for consumer welfare and one for producer welfare.[c] Assessing total damages entails evaluating changes in both consumer and producer welfare. Valuing changes in producer welfare is relatively straightforward. Valuing changes in consumer welfare, however, is more complex.

Two welfare measures commonly used for consumers are willingness to pay (WTP) and willingness to accept (WTA) compensation.[d] Consumer WTP to prevent a decrease in welfare is defined in terms of the maximum amount of money a consumer would be willing to pay to avoid the change, before it happened. Consumer WTA compensation for a decrease in welfare is measured by

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(a) The discussion in this section typically focuses on air emissions, but the principles are general enough to be applied to any type of environmental changes.

(b) The basic principles of economic valuation are detailed in Just, Hueth and Schmitz (1982). The best discussion of the application of economic valuation to air pollution is contained in Brown and Plummer (1990).

(c) At the center of these models is a mathematical function that indicates levels of welfare: a utility function for consumers and a profit function for producers. Increases in the levels of these functions are taken as improvements in individual economic welfare. See Silverberg (1978) on the issues associated with developing money measures of utility.

(d) Consumer surplus has also been used to value welfare changes in some cases.

the minimum amount of money the individual would accept to tolerate the change, after it happened.[a]

To better understand the valuation process, Table 4.1 provides a relatively simple taxonomy that shows the relationship between different effects categories and the types of economic values that are associated with them for air pollution impacts. The economic values are as follows:

- Market Values - reflect the economic values of goods and services traded in markets
- Non-Market Use Values - reflect the economic value of (usually) environmental resources to users, such as recreational anglers
- Non-Market Non-Use Values - reflect the willingness-to-pay of non-users to protect or preserve (usually) environmental resources.[b]

The effects of air pollution are grouped into three major environmental categories: terrestrial, aquatic, and air. Terrestrial effects include those on "goods" such as commercial crops and forest recreation. Aquatic impacts include those on "goods" such as commercial fishing and recreational fishing. Finally, air impacts are related to the effects of air pollution on visibility and human health effects through air pathways.

In Table 4.1, an "X" indicates that the type of value in the column heading is relevant to the effect category in the corresponding row. For example, crops represent the case of an effect category that has market impacts only because losses in crop yields are valued through market prices. Effects on wildlife, on the other hand, can have three different valuation components depending on the resource affected. For example, the adverse

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(a) WTA and WTP are not generally equal for the same change in welfare; however, WTA for an increase in welfare from state A to state B is identical to WTP for a decrease in welfare from state B to state A. In that sense, the measures are symmetric and the damages of a state change are equal to the value of the benefits of the reverse state change.

(b) Health values are treated as non-market values in this framework. Note that health impacts of air pollution have both non-market use and non-use characteristics. The use characteristics relate to the direct effects of air pollution on morbidity and mortality as valued by the affected individuals, while the non-use characteristics of these impacts relate to the willingness to pay of loved ones, friends, etc., to avoid those health effects to others.

TABLE 4.1. A Taxonomy for Relating Different Types of Economic Values to Air Pollution Effects

Effects Categories	Type of Values		
		Non-Market	
	Market	Use	Non-Use
Terrestrial			
Crops	X		
Commercial Forests	X		
Forest-Based Recreation		X	X
Wildlife	X	X	X
Materials	X	X	X
Other Terrestrial Ecosystems		X	X
Aquatic			
Commercial Fishing	X		
Recreational Fishing		X	X
Other Water-Based Recreation	X	X	X
Health		X	X
Other Aquatic Ecosystems		X	X
Air			
Visibility		X	X
Health		X	X

effects of air pollution on the population of game species could influence market values through producers and consumers in commercial markets for affected species; these effects could also influence the welfare of users such as recreational hunters; and finally these effects could influence the welfare

of non-users who wanted to preserve the affected species for others in current and future generations. Note that in at least three effects categories all three types of economic values may be potentially involved.

From an applied standpoint, the taxonomy is far from complete. The type of tables necessary to characterize the valuation needs associated with a single type of pollutant from a single source would have many more rows to reflect the individual resources at risk under each effect category.

4.2.2 Market Values

WTP and WTA measures of the effects of pollution on the consumption of market goods can be obtained directly for market values. Evaluating the damages associated with a market effect of an externality, such as decreased crop yields associated with an increase in air pollution, entails comparing before and after supply and demand curves for the crop to derive the combined changes in consumer and producer welfare. Valuing the effects caused by changes in air pollution from a single source requires going through all the stages described in Section 2.3. For market goods, economists must be able to determine how the physical damage to affected resources alters market values. From a mechanistic standpoint, this is easiest to do for crops and is much harder to do, for example, for construction materials.

4.2.3 Non-Market Use Values

As Table 4.1 shows, non-market use values are relatively common because functional markets for environmental goods rarely exist. For non-market goods, indirect methods or direct questioning of individuals can be used to estimate WTP and WTA to value the effects of externalities. The latter method is referred to as contingent valuation (CV).

The principle of indirect valuation is the basis for travel cost methods to value recreational site damages and for hedonic methods that analyze property values and wage differentials as measures of pollution damages to the environment and human health. Travel cost methods relate differences in the costs of traveling to alternative sites to the environmental quality of the sites.

A major strength of travel cost methods is that they can be applied to a fairly large number of the effects categories in Table 4.1. These models have been used to calculate the benefits to individuals of improved water quality, to place values on specific types of sport fish, and to estimate the value of reducing acid rain in Adirondack lakes. Nevertheless, there are several unresolved issues regarding their application.[a] One is that welfare results obtained from travel cost models have been shown to be extremely sensitive to model specification and choice of estimation technique.

Hedonic methods are another technique used for indirect valuation of non-market use values. They relate the variation in the market price of a good or factor of production to variations in the characteristics of the good or factor. This approach is used in health economics to relate individual wage rates to variations in the characteristics of various occupations. The hedonic wage approach has also been used to show that interurban differences in wages correlate with air quality. The hedonic property value approach, which relates the variation in residential structure sales prices to variations in house characteristics, has also been used to value the effects of inter-urban variations in air quality. However, applications to other forms of pollution are limited.[b]

The major conceptual problem with hedonic methods is that changes in wages or property values cannot be used to measure changes in WTP or WTA, except under very restrictive conditions. Typically, hedonic studies to value environmental amenities have not attempted to assign values to specific environmental goods but have provided estimates of the marginal price of air pollution reduction or similar generic measures. With the exception of health effects, then, hedonic approaches are very difficult to apply to the individual effects areas in Table 4.1.

If either the assumptions that underlie the indirect approach are not satisfied or the data needed to apply the specific methods are not available, changes in WTP and WTA in response to changes in pollution levels must be

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(a) See Brown and Plummer (1990).
(b) Even in air-pollution applications, according to Brown and Plummer (1990, p.4-36), the state of the art is "in a relatively unsettled state."

obtained by directly questioning individuals about their behavior in hypothetical, or contingent, markets. The CV approach has been used to estimate individual WTP and WTA for visibility and has been applied to the valuation of air and water quality damages. However, a number of issues have been raised by economists and social psychologists regarding the CV method.[a]

The methods for valuing the non-market effects of changes in air pollution are not as well developed as the methods discussed for market values. A particular problem is that no straightforward formula can be used to apply these values to physical damages. While the results of direct and indirect methods can be transferred to other contexts, to do so usually requires the assumption that individuals and resources are distributed identically to how they were in the original studies.[b] A final problem involves aggregating non-market values. Simply adding up individual values in different effects areas will not, in general, provide a theoretically correct estimate of the total change in welfare, even for a single individual.

4.2.4 Non-Market Non-Use Values

Much evidence suggests that individuals who do not plan to "use" an environmental amenity may still be willing to pay some amount of money to prevent pollution damages, either 1) to preserve the environment for their own potential future use or 2) for other reasons not related to their own use. The first type of value is referred to in the literature as "option value."[c] The second type of value, or "existence value," is totally unrelated to use. It is defined in terms of the compensating payment which an individual would pay (or accept) to avoid (or live with) environmental damage when the cost of access to the resource is so high that the individual prefers not to use it (Callaway 1990).

(a) See Mitchell and Carson (1989) and Cummings et al. (1986).

(b) The valuation of market effects is complicated by questions related to the transferability of scientific information, but usually not the transferability of economic information where market information is available. The valuation of non-market effects is beset with both problems.

(c) As Smith (1987a and b) and Freeman (1988) point out, option value is actually a use value which takes into account uncertainty.

In the case of non-use values, CV methods must be used to determine how much money individuals are willing to pay (or accept) for hypothetical increases (or decreases) in environmental quality. Existence values have been estimated for a number of non-market goods, including scenic vistas, water quality, big game, and endangered species. Estimates of existence values associated with air pollution are limited to studies of acid rain effects in the Adirondacks and Norway.[a]

Recent reviews of the theoretical basis for existence values have concluded that although basically sound, the theory still has some internal inconsistencies that require further resolution.[b] These reviews also found that most existing empirical estimates of existence values are flawed and that more work is needed to develop CV protocols for revealing these values. The underlying theme in all of these works is that, for a variety of reasons, the non-use values obtained in existing studies are systematically biased upward. However, the magnitude of these biases cannot be determined.

4.2.5 Estimating Damages: Practice

Relatively few studies have used a comprehensive damages-based approach to determine the overall social costs of air pollution. Several region-level studies have used systems-based models to value acidic deposition damages in Europe and the United States. ADEPT, a model developed to look at the role which uncertainty from a variety of sources plays in acid rain risk assessments, is currently being extended to value external effects. However, models such as this are directly applicable only to regional emissions, transport, and deposition processes and are not directly applicable to single sources.

Two studies have attempted to estimate the social costs associated with specific types of technologies for producing electricity.[c] Hohmeyer (1988)

(a) See Kealy et al. (1987) and Navrud (1989). The estimates from these studies are large -- from $5 to around $40 per individual -- such that if cumulated over a large number of individuals the sum can be quite large.
(b) See Freeman (1988); Brown and Plummer (1990); and Callaway (1990).
(c) See Lee et al. (1990 Draft) for a detailed discussion of these studies. [Lee, A. D., M. C. Baechler, J. M. Callaway, L. O. Foley, and C. S. Glantz. 1990 (Draft). Technical Information in Support of Bonneville's Quantification of Environmental Externalities. Pacific Northwest Laboratory, Richland, Washington.]

used this approach in part to quantify the social costs of energy consumption in the Federal Republic of Germany. However, the large number of simplifying assumptions and the near total absence of information about linkages between physical damages and emissions and between physical damages and economic value result in very rough estimates.

The second study, the generic coal study, is actually one of several studies prepared for Bonneville, principally by ECO Northwest, that attempt to quantify and value the environmental impacts of different electrical generating technologies.[a] These studies are the best examples of the damages-based approach that PNL was able to find in our limited review of the literature on this subject. They are also the only studies PNL found that are potentially applicable to Bonneville's externality evaluation efforts.The analytical approach used in the coal study consisted of six steps:

1. Estimate the level of emissions from a generic coal plant.
2. Use a transport and diffusion model to estimate the ground-level concentrations of each pollutant due to emissions from the plant.
3. Estimate the magnitude and composition of the human population and resources at risk exposed to each pollutant.
4. Estimate dose-response coefficients to characterize the bio-physical damages due to exposure to each pollutant.
5. Apply the dose-response coefficients for each pollutant to the exposed population and other resources at risk to estimate bio-physical damages.
6. Estimate the monetary value of these damages.

Based on the discussion in Section 2.3, these steps are consistent with all of the stages and transformations that characterize environmental effects at the power generation level of the fuel cycle that need to be taken into account to value externalities.

(a) The generic coal study is ECO Northwest (ECO). 1987 (Draft). Generic Coal Study: Quantification and Valuation of Environmental Impacts. Draft Report Submitted to Bonneville Power Administration, Portland, Oregon. The other technologies include dual-fuel combustion turbines (ECO 1983) and five generating resources: cogeneration from biomass and municipal solid waste, geothermal, solar central stations, and wind turbines (ECO 1986).

4.3 CONCLUSIONS

While the damages-based approach is theoretically correct, its intensive information demands, coupled with limitations in the state of the science in economics and in the other disciplines required, raise serious questions about the accuracy of estimates obtained. In summary, the difficulties inherent in applying this approach are as follows:

- Accounting for external effects directly can be prohibitively expensive and difficult.
- Required models are in their infancy and require large amounts of computer time to obtain results.
- A great deal of conflicting information and uncertainty is associated with the bio-physical damages caused by many pollutants.
- Economic methods for estimating pollution damages are not well developed in many of the effects areas.
- Application of economic methods to value both market and non-market effects can involve significant uncertainties.
- Valuation of physical damages of even a single pollutant from a single source has never been done in a marginal damage function framework.
- Marginal damage estimates cannot be created by adding up the damages due to a small change in the level of a single pollutant over multiple damage categories (e.g., crops, recreational fishing, and visibility) unless interactions are taken into account between these effects in the utility and profit functions of consumers and producers, respectively.

For these reasons, many utility regulatory bodies have looked increasingly for proxy measures to use in valuing the environmental effects of new generating resources. Much of this attention has focused on using the costs of controlling pollutants as a proxy for marginal damages, as was discussed earlier.

5.0 STATUS OF EXTERNALITY VALUATIONS AND CONCLUSIONS

Although the economics literature is replete with theoretical models to assess the value of residual environmental damages, most of the theoretical models require data that thus far cannot be measured credibly. The practical models that have been developed based on theory tend to deal with only a small portion of the problem. Consequently, very little of the theoretical work has been incorporated into utility processes. This chapter summarizes state activities to date and presents conclusions for Bonneville's consideration in its efforts to place an economic value on powerplant externalities.

5.1 STATE ENVIRONMENTAL EXTERNALITY REQUIREMENTS

Historically, environmental externalities have been controlled by federal and state regulations to what were thought to be acceptable levels; however, residual damages have been largely ignored by utility planners as well as regulators. Recently, however, several states have taken initial steps to include externalities in their utilities' powerplant planning processes.

Table 5.1 summarizes the approaches several states have used thus far to account for environmental externalities. The lack of uniformity suggests that no single approach has proven superior. The genesis of much of this work is rooted in the Pacific Northwest Electric Power Planning and Conservation Act (16 U.S.C. 839a.,Sec.3), passed in 1980. That Act was one of the first laws to specify the cost-effectiveness criterion for resource evaluation and to include the quantification of environmental costs and benefits as part of that definition. The intervening 10 years have seen much attention and energy directed toward that effort. The last two years have seen a spate of Orders and Statutes with language referring to the necessity of accounting for environmental costs in the resource planning, and especially the competitive bidding, process.[a]

(a) According to Ottinger (1990), 26 states have such language on the books. A survey suggests that agencies in 17 states have developed approaches for incorporating these costs (Cohen et al. 1990). According to testimony given before the California Energy Commission (Knox 1990), even the Edison Electric Institute has advised the utility industry to factor global climate change into its planning processes.

TABLE 5.1. Status of Externalities Quantification in Selected States

State	Quantification Basis	How Requirements Are Imposed	Value
NY	Mitigation cost of different externalities	Through resource bid process	Up to 1.4 cents/kWh, 24% of avoided cost with quantity determined through scoring matrix
WI	Assumed benefits of noncombustion resources over combustion resources, based on NWPCC recommendation	Through least-cost planning	Automatic 15% credit for noncombustion resources
VT	Assumed benefits of demand-side management (DSM) options	Through integrated resource assessments	Deduct 5% from DSM costs for environmental benefits, and 10% for risk reduction
MA	Quantifiable external impacts	Through resource solicitation process	NEES adds up to 15% to resource cost based on matrix similar to ORU approach
ME	Uncertain	Proposed through cost-effectiveness evaluation of large DSM programs	No values specified
OR	Control costs (Pacific Power & Light)	Through least-cost planning	Depends on utility evaluation
CA	Control costs (probably)	Assessment of utility resource plans	Add 10-25% to generation costs (proposed)

PNL's review of these activities suggests that while there is no shortage of language and directives, actual rulings and enforcement orders requiring the utilities to include the social costs of environmental damage resulting from energy production are still rare. States in which a tool or methodology is actually being implemented are rarer still. Only three states--New York, Wisconsin, and Vermont--and the Northwest Power Planning Council have actually specified values to be used in such evaluations (see Foley and Lee 1990).

Wisconsin's and Vermont's approach has been to subjectively assess a cost credit for relatively benign resources such as conservation. New York has taken a different direction, directly incorporating environmental externalities into its utilities' bidding process by assigning points to environmental costs just as the utilities assign points to other attributes to be evaluated in the bid. The value (cents/kWh) associated with the environmental costs is added over the avoided cost. New York's approach goes further than any other state to include the costs of residual environmental damage.

Massachusetts and Oregon have ordered utilities to include externalities in resource costs for planning purposes without specifying how to do so. Massachusetts, however, is well on its way to implementing an approach similar to that adopted by New York. While California has probably done more serious analyses of this issue than any other state thus far, no ruling has been promulgated ordering utilities to include externalities in resource cost assessments.

In all these states, most externalities have been valued using control or mitigation costs. The difficulty of applying the damages-based approach and the pressing need to begin reflecting externalities in decisions that will affect society for many decades have required cost-based approaches to be used, at least initially.

5.2 SUMMARY AND CONCLUSIONS

It is becoming increasingly clear that externalities need to be incorporated into energy decisionmaking. The electric utility sector is an

important source of these externalities, and the activities outlined in the previous section indicate a growing response to this issue by utilities and the state agencies that regulate them. But, it is also clear that much remains to be done before externalities are appropriately incorporated into the utility planning process.

Approaches to date have relied heavily on control or mitigation costs, rather than direct estimates of damages, as the basis for quantifying impacts. None of the approaches implemented so far has looked beyond the basic impacts involved in power production to the incremental impacts due to the other stages of the fuel cycle, from fuel extraction, to construction, fuel preparation, fuel transport, transmission, waste disposal, and decommissioning.

More importantly, none of these approaches has explicitly addressed the cumulative impacts of environmental damages. However, even though little analysis has addressed how to properly account for the effect of multiple sources in valuing externalities from a new powerplant, evidence from the regulatory arena suggests that the theoretical arguments presented earlier are implicitly factored into regulations.

From our analysis, we present the following conclusions and suggestions for Bonneville's consideration in its valuation of externalities in the resource acquisition process:

- Possible externalities at all phases of the fuel cycle should be considered initially. Which phases are most important will depend on the resource type.

- The externality valuation process needs to be coordinated with other processes, such as NEPA, that address the environmental impacts of new resources. Part of the information required for valuing externalities should be available from NEPA and siting and permitting processes.

- Bonneville may need to distinguish between generic and plant-specific information and data required for individual powerplants. Developers should be required to provide plant-specific information and Bonneville should develop databases of generic information.

- Because the potential number of impacts is too large to be tractable for analysis in all cases and some impacts are insignificant, screening criteria and procedures should be developed to reduce the number of fuel cycle phases and types of impacts that have to be analyzed.

- Initially, Bonneville may have to rely for certain types of externalities on control or mitigation costs as proxies for the value of their damages.

- Available information on actual damage costs should be used, where possible, to value externalities. In critical areas, further studies may be necessary to expand the information base.

- Valuations of externalities should take into account the location of powerplants and cumulative environmental impacts.

- A modeling system should be developed that integrates models of the initial environmental disruptions caused by powerplants (e.g., air emissions) with dispersion models, dose-response models, and economic impacts models. DOE's Multimedia Environmental Pollutant Assessment System and EPA's Human Exposure Model are two candidate models for further development.[a]

(a) See Lee et al. (1990 Draft) for additional details. [Lee, A. D., M. C. Baechler, J. M. Callaway, L. O. Foley, and C. S. Glantz. 1990 (Draft). Technical Information in Support of Bonneville's Quantification of Environmental Externalities. Pacific Northwest Laboratory, Richland, Washington.]

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APPENDIX A

DETERMINING OPTIMAL CONTROL LEVELS

APPENDIX A

DETERMINING OPTIMAL CONTROL LEVELS

This appendix provides additional information on the theory and implications of controlling environmental damages at their economically optimal levels. It discusses the theory of optimal control and the impacts that multiple sources have on determining optimal control levels when more than one source of environmental damages are present. The discussion is particularly important in assessing cumulative environmental impacts.

A.1 THEORETICAL RATIONALE FOR COST-BASED APPROACHES

The underlying theoretical justification for using marginal control cost as a proxy measure for damages is the assumption that society's preferences for regulating pollutants are revealed by the amount of money its members are willing to give up at the margin to regulate the damages caused by environmental externalities. This approach assumes that the regulatory, legislative, or administrative processes weigh costs and benefits and set requirements based on an optimization that reflects society's preferences.

Two fundamental theoretical issues are associated with using a regulation cost-based approach to value environmental externalities. First, under what circumstances is the marginal control cost a good proxy for the marginal benefits of reducing those damages? Second, if marginal control costs and benefits differ substantially, under what circumstances will the marginal mitigation cost systematically understate or overstate the marginal benefits of reducing pollution emissions? Figure A.1 illustrates the principles underlying the process of determining the economically efficient level of emissions reductions. The level of pollution abatement is shown on the x-axis, and marginal costs and benefits ($ per unit of pollution abatement) are shown on the y-axis. This figure displays the situation for a single powerplant considered in isolation.

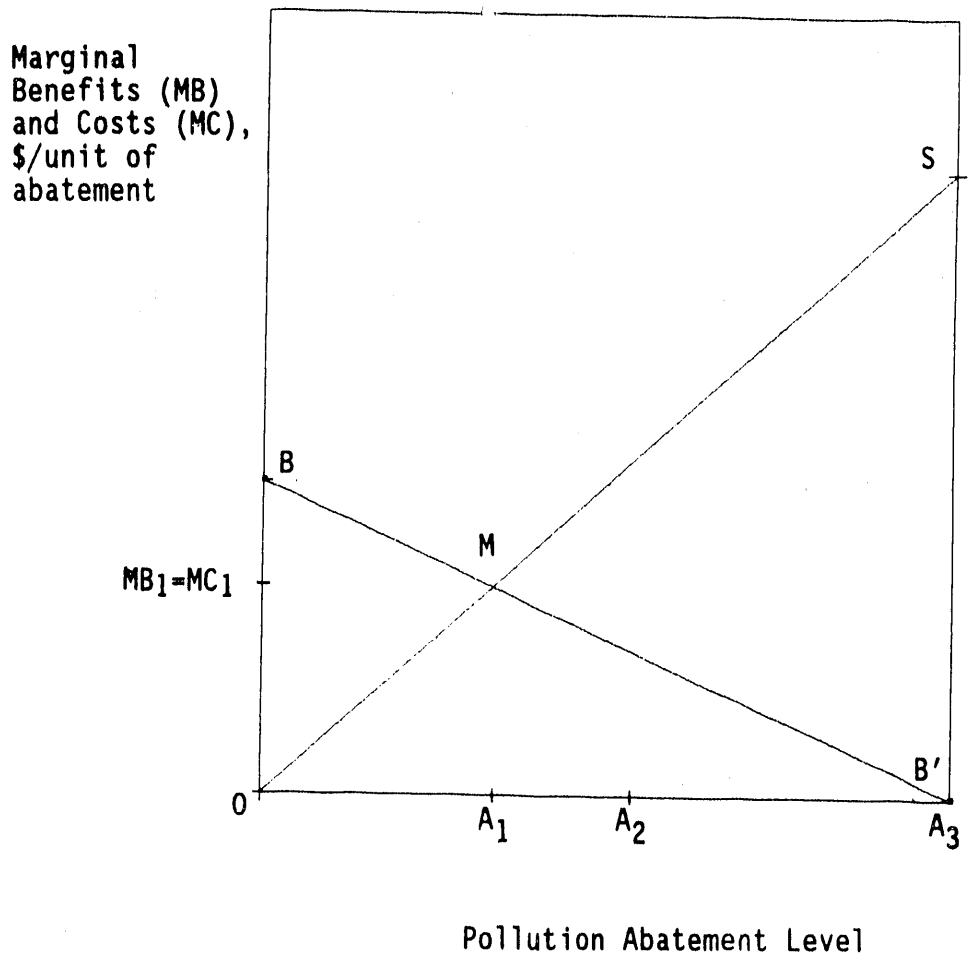

FIGURE A.1. Economically Efficient Pollution Abatement for a Single Powerplant

In Figure A.1 the line BB′ reflects the marginal benefits curve associated with reducing emissions of a pollutant from a single plant in a region from some maximum level, ignoring emissions from all other plants. This curve is downward sloping, reflecting the fact that the marginal benefits associated with the first unit of pollution abatement (for which the marginal value of damages is correspondingly high) is more valuable than subsequent units. The area under BB′ from the origin to any level of abatement is the total value of the benefits associated with that level of abatement.

The marginal abatement cost curve, OS, in Figure A.1, is upward sloping to represent the fact that the first unit of pollution abatement is less

expensive than subsequent units. The area under OS for any level of abatement is the total control cost associated with that level of abatement.

The difference between benefits and costs for any level of pollution abatement is simply the area under the curve BB′ between the origin and the abatement level minus the area under the curve OS. This difference increases from left to right up to abatement level A_1. The marginal benefit function and the marginal abatement cost function intersect at point M, corresponding to the abatement level A_1, which is the economically efficient level of pollution abatement.[a] At A_1 the marginal benefit of reducing the last unit of pollution from the maximum value is just equal to the marginal cost of abatement, at $MB_1 = MC_1$, on the vertical axis.

To illustrate the implications of the figure, note what happens for an abatement level, such as A_2, that is higher than the optimum. The corresponding marginal abatement cost is above the marginal benefits associated with A_2 and the difference is indicated by the distance between BB′ and OS at A_2. Thus, the higher the level of pollution abatement beyond the economically efficient level, the wider the divergence between marginal control cost and the marginal benefits of abatement. As for abatement levels lower than A_1, the difference between marginal benefits and costs declines for higher levels of abatement. In the extreme case where one eliminates all of the residual emissions from the source, the marginal benefit is equal to zero and the marginal abatement cost is at its maximum, A_3.[b]

(a) Total benefits minus total control costs, for any level of abatement, equal the area under the benefits curve to the left of the abatement level minus the area under the control cost curve. This quantity clearly increases from the left up to the point where the two curves intersect. To the right of the intersection, marginal costs exceed marginal benefits so the benefits minus costs decrease as the abatement level increases. The maximum value, thus, is for the abatement level where the two curves intersect.

(b) Assuming that the optimum level of pollution abatement is A_1, then the additional cost of eliminating the residual emissions is equal to the area A_1MSA_3; the additional benefits associated with eliminating the residual emissions are equal to the smaller area A_1MA_3; and the triangular area A_3MS is a measure of the net cost to society of eliminating the remaining emissions from the plant.

A.2 THEORETICAL ANALYSIS OF MULTIPLE SOURCES

In the real world, many sources disrupt the environment simultaneously. The previous section looked at the simplified case of regulating a single source in isolation. This section adds the reality of multiple sources to the theory presented there.

Figure A.2 illustrates the marginal benefit and abatement cost functions for two identical sources, using identical-pollution abatement technologies. The marginal benefit function associated with abating the pollution from each plant, in isolation, is shown by the line B_1B_1'. The marginal benefit function for single plants is assumed to be independent, meaning that the effects of pollution from the two plants are cumulative but not interactive. The marginal pollution abatement cost function for each plant is shown by the line OS_1[(a)].

The aggregate marginal benefit and cost curves are shown by B_2B_2' and OS_2, respectively. The aggregate marginal benefit function for both plants together, B_2B_2', is constructed by assuming that the same linear relationship exists between pollution abatement and marginal benefits as it does in B_1B_1', but that the amount of pollution to be abated has doubled. The aggregate pollution abatement marginal cost curve is shown by the line OS_2. Since the pollution abatement technologies at each marginal control cost can be applied to the two sources, rather than the one source represented by OS_1, the amount of abatement that can be achieved at each marginal control cost is doubled. OS_2 is constructed by horizontally summing the quantity of pollution abatement from two sources, holding marginal cost constant.

As shown in the previous section, the economically efficient level of pollution abatement for a single source in isolation is at A_1, where $MB_1=MC_1$. If both plants were regulated optimally together, however, the optimum level of pollution abatement occurs at the point where B_2B_2' and OS_2 intersect. In

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(a) The curve is not continuous beyond S, since this is the marginal cost associated with reducing the maximum feasible amount of pollution. Thus, the true marginal abatement cost curve is vertical above the marginal cost of MC_{max}.

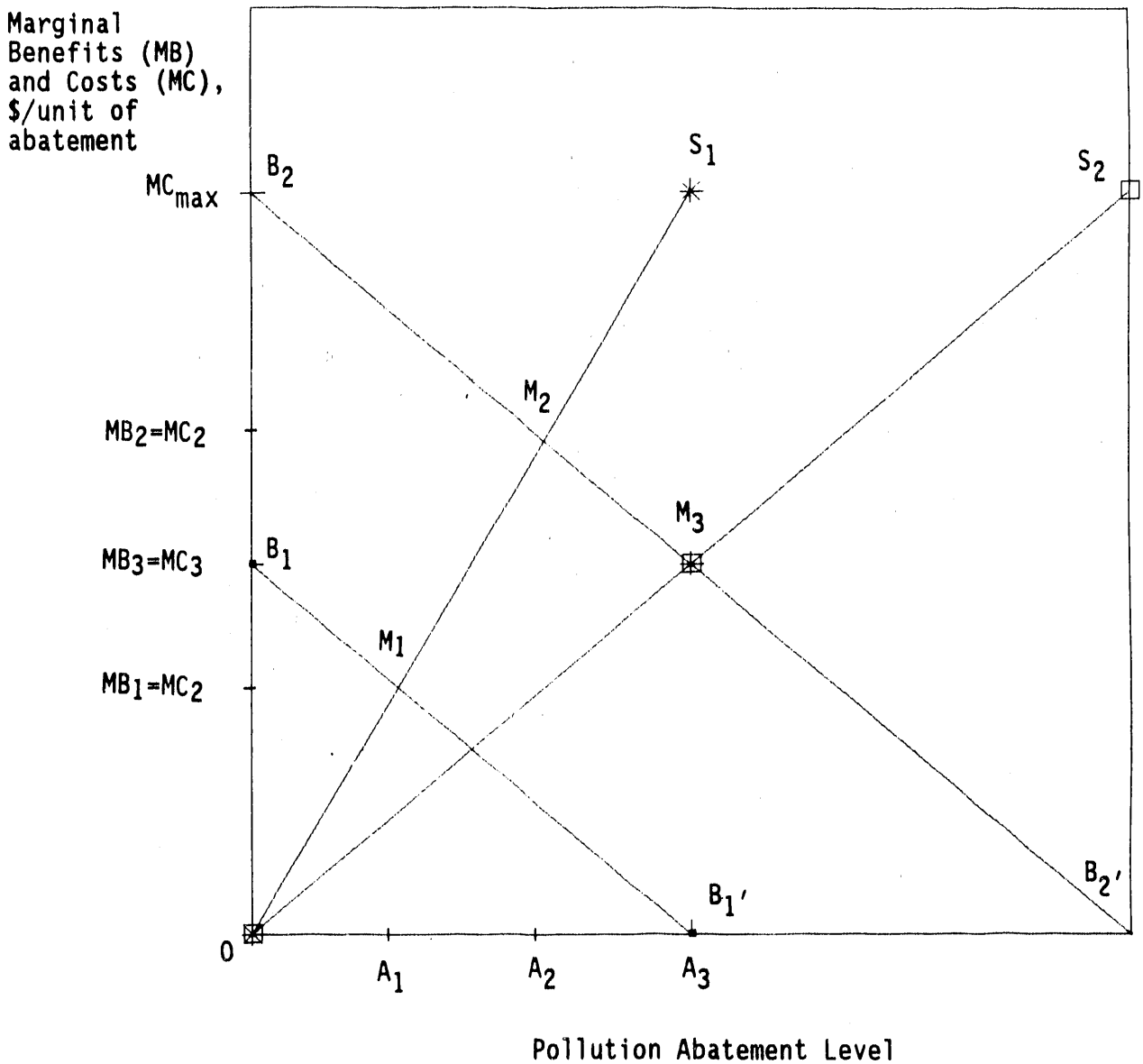

FIGURE A.2. Economically Efficient Pollution Abatement for Two Powerplants

this case, the optimal level of pollution abatement increases to A_3, where $MB_3=MC_3$, that is at a higher marginal cost (and marginal benefit). Thus, as the number of sources to be regulated increases, both the total amount of pollution abated and the amount abated from each source increas and so do the marginal cost and marginal benefits of eliminating the last unit of regulated pollutants.

At the same time, the amount of residual pollution emitted from each source decreases. In the one source case, residual pollution is equal to the distance $B_1' - A_1$. Regulating the two sources together optimally, each source is regulated at half of A_3, leaving residual pollutants from each plant equal to the distance $B_1' - A_3/2$. Residual pollution from each plant decreases by an amount equal to $A_3/2 - A_1$.

This argument can be extended to show that if more sources are added and they are regulated together optimally, the optimal control cost converges. As the number of sources increases, the optimal marginal abatement cost approaches the cost to abate the maximum amount of pollution from a single plant and the amount of pollution abated from the last source approaches the maximum amount of pollution created by the source. Thus, for a very large number of plants (i.e, the cumulative pollution levels are high), the optimum amount to abate from each plant approaches the individual source maximum (i.e., distance OB_1') at a corresponding maximum marginal cost (equal to a corresponding maximum marginal benefit) of MC_{max}.

As the number of sources and cumulative pollution levels increases, the criterion of economic efficiency would require that controls be installed to reduce pollution the maximum amount possible. This theoretical concept is consistent with regulatory requirements that impose tighter, and more expensive, controls in regions where the total pollution levels are the highest. This observation presents a theoretical justification for environmental regulations aimed at controlling cumulative environmental impacts.

Figure A.2 can be used to analyze a case where there are unregulated sources of pollution in the region. Two sources are assumed, one regulated and the other not. The marginal benefit curve for both sources together is given by B_2B_2'. However, since only one source is to be regulated, the relevant marginal control cost curve is OS_1, not OS_2. Under these conditions, the marginal benefit of A_1 units of pollution abatement (the optimum level if the plant is considered in isolation) is MB_1' (the marginal benefits on B_2B_2' at abatement level A_1), which is much higher than the marginal cost, MC_1. Therefore, it will "pay" society to reduce some more of the residual pollution from the one source, in this case to the level A_2, where the marginal cost

curve for the single plant, OS_1, intersects the combined marginal benefits curve, B_2B_2', and $MB_2 = MC_2$. If the aggregate marginal benefit curve included several more unregulated plants, this would shift the curve $B_2B'_2$ even further to the right, such that it might be optimal[a] to eliminate all of the residual pollution from the one regulated source.

To summarize, the main points of the preceding analysis are the following:

1. The marginal cost of regulating the emissions from a single plant, when optimized in isolation, generally understates the optimal marginal benefits and marginal cost associated with reducing emissions from a number of sources in a region when cumulative impacts are considered. This result holds whether or not all sources are regulated.

2. The larger the number of unregulated sources in a region, the more the marginal cost of regulating the emissions from a single plant, when optimized in isolation, understates the aggregated marginal benefits.

3. As the number of sources in a region increases, the optimum amount of pollution that should be eliminated from each plant increases. Where the number of plants is very large, it may be economically efficient to eliminate almost all the residual pollution from each source. This theoretical result provides an economic efficiency justification for imposing tighter requirements as the number of plants and total pollution increase.

These observations have important implications for both regulations and the cost-based approach for valuing externalities. Regulations already do, in some cases, place tighter control requirements on sources of environmental damages in areas where existing damages are relatively large. The theoretical arguments presented here provide an economic rationale for taking cumulative impacts into account in regulations aimed at controlling environmental damages. The theory provides some guidance for regulators who are charged with establishing such requirements.

In terms of valuing externalities based on control costs, this discussion emphasizes the need to account for cumulative impacts in determining what marginal control cost is an appropriate reflection of

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(a) Here, optimal means given that the other plants cannot be regulated for some reason technical or legal reason. The result raises obvious questions about the fairness of such policies, given the high cost to the single source.

societal costs. Simply using some typical control cost will not reflect the actual societal costs in all cases. In regions where existing pollution levels are high, the theoretical arguments presented here suggest that reducing externalities from a new powerplant to very low levels may be justified, and the appropriate control costs may be those associated with the most extreme controls available.

Two other points are important. First, optimum control levels will change over time as other sources of environmental damages are added to a region. Consequently, socially optimum controls will vary with time, and using a single type of control and its associated cost to value externalities will eventually misrepresent the actual societal damages. Second, controls on environmental damages should take into account all sources of the damages. As damage levels increase, the optimum control level for new powerplants, given no requirements to modify existing sources, will increase to point of maximum possible controls. However, if possibilities of controlling all existing and new sources are considered, then the controls required on new powerplants might be reduced and the optimum marginal control costs might be less than if only the new plant were considered. This approach would minimize the necessary control expenditures required to reach an optimum level of externalities.

APPENDIX B

GENERAL ENVIRONMENTAL QUESTIONNAIRE

GENERAL ENVIRONMENTAL QUESTIONNAIRE

1. Description of Proposed Generating Facility (Provide a description of the proposed facility. Include engineering data describing the type, capacity, capacity factors, fuel, fuel source, cooling source, emissions, heat rate, mitigation devices, precipitators and other relevant data.)

1.1 Is the proposal for an all new facility? ____Yes ____No

If an expansion of an existing project is planned, describe the existing plant: _____

_____

_____

Describe the expansion: _____

_____

_____

2. Land Use and Related Issues

These questions address issues related to land use. Attach a U.S. Geographic Survey map showing the proposed site and the area within a one mile radius. Attach a zoning map showing land use designations for the site and the pertinent planning agency's jurisdiction (city or county).

2.1 Check the best description of present on-site land use:

____urban ____industrial ____commercial

____residential ____rural (non-farm) ____forest

____agriculture ____other (describe)_____

_____

_____

2.2 Total site acreage: _____

Project area to be developed?

_____ acres initially

_____ acres ultimately

2.3 Proposed site land use inventory:

Land Use Type	Present Acreage	Acreage After Completion
meadow or brushland (non-farm)	_____	_____
forest	_____	_____
agriculture (orchards, cropland, pasture)	_____	_____
wetlands	_____	_____
surface water		
lakes and ponds	_____	_____
rivers and streams	_____	_____
bare earth (rock, earth, or fill)	_____	_____
roads and paved surfaces	_____	_____
buildings and covers	_____	_____
other (describe_____	_____	_____

_____)

2.4 What are the predominant land use(s) and zoning classifications within a 1 mile radius of the proposed site?

_____

_____

_____

2.5 What is the current zoning classification(s) for the site?

_____

2.6 What is the proposed zoning classification(s) for the site?

_____

2.7 Has the proposed facility been found to be consistent with local land use plans and zoning requirements? ____Yes ____No
What is the name of the agency and the contact person who made such a determination?

_____

_____

_____

2.8 Is any on-site agricultural land classified as "prime and unique farmland" by the Soil Conservation Service? ____Yes ____No

2.9 Is the proposed facility located within a designated coastal zone? ____Yes ____No

If yes, has the proposed facility been found to be consistent with coastal zone management plans? ____Yes ____No

What is the name of the agency and the contact person who made such a determination?

_____

_____

_____

2.10 Will vehicle traffic visiting the new facility affect local traffic patterns? ____Yes ____No

How was this determination reached? _____

_____

Will new roads on public lands be required to support the proposed facility? ____Yes ____No

How long will the new roads be? _____miles

Will the new roads require any structures such as bridges or tunnels? ____Yes ____No

2.11 Is the facility site located within a 100-year floodplain? ____Yes ____No

2.12 Will the proposed facility increase on-site ambient noise levels?
____Yes ____No

What is the average existing decibel level at the property line, at the point closest to the proposed facility? _____ dB

If the plant was built, what is the expected average decibel level at the property line, at the point closest to the proposed facility?
_____ dB

2.13 Does the proposed site adjoin, or is it near any residential neighborhoods? ____Yes ____No

Is the proposed facility visible from the residences? ____Yes ____No

Is noise from the proposed facility audible at the residences?
____Yes ____No

2.14 Does the proposed site adjoin, or is it near any commercial neighborhoods? ____Yes ____No

Is the proposed facility visible from any commercial establishments?
____Yes ____No

Is noise from the proposed facility audible at any commercial establishments? ____Yes ____No

2.15 Does the proposed facility site adjoin or contain, or is the facility near, a building, site, or district characterized as follows:

Listed or eligible for the National Register of Historic Places
____Yes ____No

With cultural significance to American Indians ____Yes ____No

Listed on the Register of National Natural Landmarks ____Yes ____No

A national, state, or local park or wilderness area ____Yes ____No

A national, state, or local wildlife refuge ____Yes ____No

A river designated as a national or state Wild and Scenic River
____Yes ____No

If yes, name the locations(s): _____

_____

_____

Is the proposed facility visible to people visiting the location(s)?
____Yes ____No

Will noise from the facility be audible to people visiting the location(s)? ____Yes ____No

What is the distance from the facility to the location(s) at their closest points? _____miles and feet

Will the location(s) be disrupted in any way? ____Yes ____No

If yes, please describe: _____

_____

_____

2.16 Is the proposed facility site, or land adjoining the site, now used by the community as an open space or recreation area? ____Yes ____No

If yes, please describe how the space is used? _____

_____

_____

2.17 Are there hunting, fishing, or shellfish collecting opportunities on or adjoining the proposed site? ____Yes ____No

If yes, please describe: _____

_____

_____

2.18 Does the proposed site now include or adjoin scenic views known to be important to the community? ____Yes ____No

If yes, please describe: _____

_____

_____

2.19 Does the proposed site include any distinct land forms such as cliffs, dunes, or other unique geological formations? ____Yes ____No

If yes, please describe: _____

_____

_____

2.20 Is the proposed facility visible from a high exposure transportation corridor, such as an interstate freeway, state highway, or Amtrak train route? ____Yes ____No

If yes, please describe: _____

_____

_____

What is the distance from the facility to the transportation corridor at their closest points? _____(miles and feet)

2.21 Are there visually similar projects within the vicinity of the proposed site? ____Yes ____No

If yes, please describe the site(s): _____

_____

_____

What is the distance from the proposed facility to nearby visually similar facilities? _____

_____

_____

2.22 Is the proposed facility visible on a seasonal basis (e.g. will the facility be screened by summer foliage but visible at other times)? ____Yes ____No

2.23 Will the proposed facility interfere with radio, television or other electronic media? ____Yes ____No

3. <u>Fish and Wildlife</u>

3.1 Does the proposed project site or adjoining areas contain any species of plant or animal life that is identified as threatened or endangered? ____Yes ____No

How was this determination made? _____

_____

_____

3.2 Will the proposed facility modify critical habitat as listed by the Secretary of the Interior? ____Yes ____No

3.3 Will pollution or heat emissions from the proposed facility affect fish or wildlife? ____Yes ____No

3.4 Will aquatic organisms be entrained with water intake? ____Yes ____No

3.5 Will aquatic organisms be impinged by water intake? ____Yes ____No

3.6. Will discharge of water, heat, or pollutants affect the distribution, abundance, or movement of aquatic animals or plants? ____Yes ____No

How was this determination made? _____

_____

_____

3.7 Will the proposed facility interfere with a resident or migratory bird population? ____Yes ____No

How was this determination made? _____

_____

_____

3.8 List the species of fish and wildlife that may be impacted from the proposed facility. Include and identify those affected by construction activities and plant operation.

_____

_____

_____

4. Water Quality

4.1 Does this proposal include a structure or work in navigable water?
____Yes ____No

4.2 Will dredging occur during construction? ____Yes ____No

If yes, please describe the location and extent of dredging: _____

_____

_____

4.3 What is the depth of the water table? _____ (feet)

4.4 Is the proposed site located over a primary, principal, or sole source aquifer? ____Yes ____No

4.5 Is subsurface liquid waste disposal involved? ____Yes ____No

If yes, please describe the types of waste involved and any treatment techniques that will be employed?

_____

_____

_____

4.6 Will water supply be drawn from wells? ____Yes ____No

If yes, indicate pumping capacity? _____ (gallons per minute)

4.7 Is surface liquid waste disposal involved? ____Yes ____No

If yes, indicate the type of treatment that will be used: _____

_____

_____

Anticipated types and volume of discharges (show units):

Rather than filling in the blanks below a copy of EPA Application Form 2D - New Sources and New Dischargers: Application for Permit to Discharge Process Wastewater - may be attached.

Discharge	Daily Average Flow	Daily Maximum Flow
Flow (gpm)	_____	_____
pH	_____	_____
Temperature	_____	_____
Biochemical Oxygen Demand	_____	_____
Total Suspended Solids	_____	_____
Chemical Oxygen Demand	_____	_____
Total Organic Carbon	_____	_____
Oil and Grease	_____	_____
Ammonia	_____	_____
Total Residual Chlorine	_____	_____
Cooling Water	_____	_____

List other pollutants as per Table II, Table III, Table IV and Table V; 40 CFR 122, Appendix D.

_____	_____	_____
_____	_____	_____
_____	_____	_____

Name of water body where effluent will be discharged: _____

_____

Volume of flow on standing surface area of receiving body: _____

_____

4.8 Will condenser cooling water be discharged? ____Yes ____No

If yes, what is the average and maximum temperature: _____

_____

4.9 Will the surface area of an existing water body be increased or decreased by the proposed facility? ____Yes ____No

If yes, please describe: _____

_____

_____

4.10 Have computer models of the effects of discharges to surface waters been completed? ____Yes ____No

4.11 Will wastes be treated on-site? ____Yes ____No

If yes, please describe the treatment: _____

_____

_____

If no, where will wastes be treated? _____

_____

_____

4.12 Have you discussed the proposed facility with local or state agencies with jurisdiction for water quality? ____Yes ____No

If yes, please identify the name of the person and the agency that you have contacted: _____

_____

5. Air Quality

5.1 Will the proposed facility comply with National Ambient Air Quality Standards for criteria pollutants? ____Yes ____No

Identify the method used to model emissions and dispersion. Identify key assumptions such as stack height, emission quantities, meterological data, and terrain data:

_____

_____

_____

Attach a copy of the analysis.

5.2 Provide an estimate of expected air emissions:

Air Emission	Peak lbs/hour	Average lbs/hour	Peak lbs/kWh	Average lbs/kWh
Particulates	_____	_____	_____	_____
Sulfur Dioxide	_____	_____	_____	_____
Nitrogen Oxides	_____	_____	_____	_____
Carbon Monoxide	_____	_____	_____	_____
Carbon Dioxide	_____	_____	_____	_____
Hydrogen Sulfide	_____	_____	_____	_____
Other Hazardous or Toxic Pollutants				
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____

5.3 Does the proposed facility comply with PSD (prevention of significant deterioration) requirements? ____Yes ____No

Please explain how this determination was made: _____

_____

_____

5.4 Has a risk assessment been done of the effects of potential hazardous or toxic emissions? ____Yes ____No

If yes, please attach a copy of the analysis.

5.5 Will air emissions from the proposed facility affect class I areas, such as national parks and wilderness areas? ____Yes ____No

5.6 Please describe the air pollution control technologies to be employed at the proposed facility:

_____

_____

_____

5.7 Have you discussed the proposed facility with local or state agencies with jurisdiction for air quality? ____Yes ____No

If yes, please identify the name and phone number of the person and the agency that you have contacted:

_____

_____

6. Solid and Hazardous Waste

6.1 Will the proposed facility generate solid waste? ____Yes ____No

If yes, please describe the contents of the waste: _____

_____

_____

How much waste will be produced? _____

_____

_____

How will the waste be disposed of? _____

_____

_____

6.2 Will the proposed facility generate toxic or hazardous wastes (as defined by the US EPA)? ____Yes ____No
If yes, please describe the contents of the waste: _____

_____

_____

How much waste will be produced? _____

_____

_____

How will the waste be stored? _____

_____

_____

How will the waste be transported? _____

_____

_____

How will the waste be disposed of? _____

_____

_____

6.3. Has hazardous or toxic waste ever been stored or disposed of on the proposed facility site? ____Yes ____No

How was this determination made? _____

_____

_____

END

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