Studies of the Environmental Costs of Electricity

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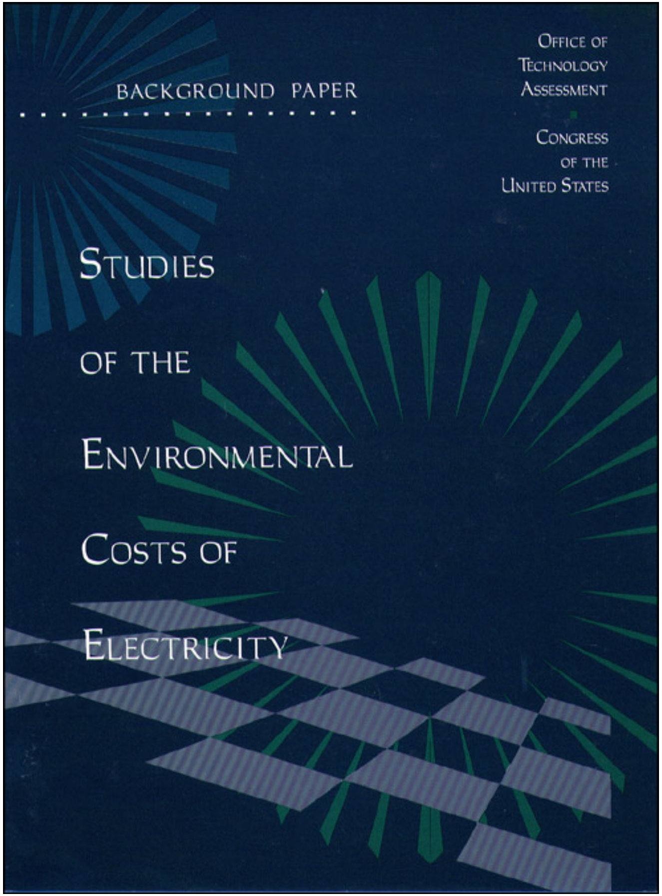

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Foreword

Studies of the Environmental Costs of Electricity examines studies that assign monetary value to the environmental effects of energy technologies. Quantitative analysis of environmental effects has been an important feature of energy policy for several decades, and growing numbers of studies attempt to integrate these analyses into an overall framework that allows comparison of the environmental effects of different technologies for generating electricity.

Because of the large size and scope of environmental cost studies, however, they necessarily involve a large number of assumptions. These assumptions have been the focus of contentious debate in the analytical and policy communities. While changing a study's assumptions can profoundly affect its results, there is currently no agreement on the most appropriate set of assumptions. This does not imply that all assumptions are equally valid, but indicates that assumptions often reflect deeply held values of participants in policy debates.

This report was prepared in response to a request by the House Committee on Science, Space, and Technology. The report examines a set of environmental cost studies, compares and contrasts their methods and assumptions, and discusses how they could be made more useful to federal policy makers. In contrast to other studies in this area, OTA'S report explores the close ties between values, assumptions, and quantitative results and the implications of these ties for policymaking.

OTA appreciates the participation of many individuals without whose help this report would not have been possible. OTA received generous assistance from workshop participants and reviewers who offered valuable information and comments. The contents of the report itself, however, are the sole responsibility of OTA.

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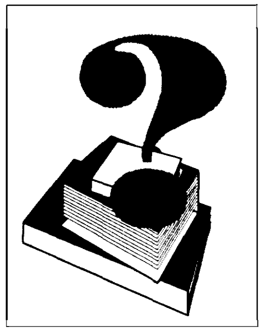
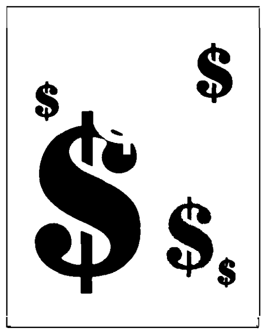
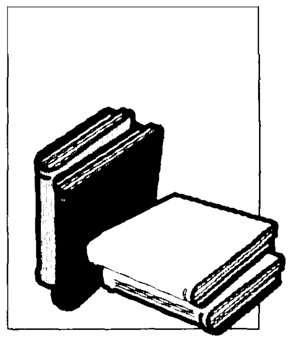




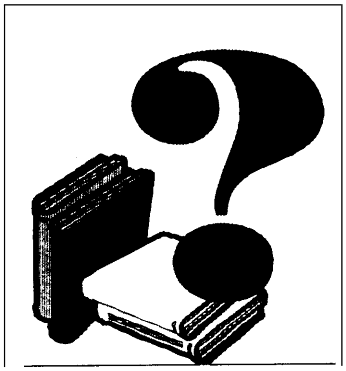


Summary 1

In the past two decades, studies of energy technologies increasingly have focused on quantifying environmental effects. In particular, many studies have attempted to estimate the *environmental cost* of different electricity generating technologies —the monetary value of the environmental effects—so that environmental concerns can be incorporated more easily into public and private decisionmaking.

These environmental cost studies have attracted the attention of a variety of legislators and regulators. Although few measures have been enacted with the intent of directly passing environmental costs onto consumers, several state and federal actions require that these costs be estimated and considered by utilities. For example, 29 states require utilities to consider environmental costs in some way when they choose among electricity supply options, and many other states are considering such measures. Several federal statutes also mandate that utilities or agencies estimate environmental costs.

Credible and accurate information about environmental costs could be a critical component of future state and federal policies. Several new studies will be released within the next year (see chapter 2 for details), and these new studies, as well as previously completed studies, could help federal policy makers make choices about the use of current electricity technologies and the level of support warranted for new or improved technologies. They also could allow quantification of the potential benefits associated with electricity technologies that have fewer environmental impacts (e.g., solar and wind energy) and technologies that reduce energy use (e.g., energy-efficient appliances). This is particularly important given that many of these alternative technologies currently cost more than traditional technologies.



BOX 1-1: The OTA Report in Context

This report examines the methodology, findings, and implications of studies that estimate the environmental costs of electricity production. Specifically, it:

- explains the principles behind estimates of environmental costs and the terms used to discuss such estimates,
- summarizes and compares existing estimates of environmental costs and the methods of arriving at those estimates,
- characterizes and analyzes the reasons for differences in estimates, particularly the assumptions and values that underlie different estimates, and
- discusses challenges associated with using current estimates in policymaking.

In contrast to many other reports on environmental cost studies, this report focuses on the studies' assumptions and values. The House Committee on Science, Space, and Technology, which requested this report, asked OTA to examine the fundamental assumptions and values that underlie debates over environmental costs and to explore their implications for policymaking.

The study focuses on environmental cost estimates for electricity generation because this area has produced substantial regulatory and legislative activity. It does not consider other types of costs (e.g., government subsidies and economic effects), nor does it consider other sectors of the economy concerned with energy (e.g., transportation).[1]

OTA did not attempt to make its own estimates of the environmental costs of electricity. The study's request explicitly excluded such estimates, and OTA finds that generally accepted estimates would be difficult, if not impossible, to achieve at this time.

In addition, this study does not discuss specific policy instruments. The use of specific policy instruments is largely separate from the estimation of environmental costs. Another OTA study is currently reviewing a variety of new approaches to environmental regulation.[2]

[1] Another OTA study does examine the social costs of transportation: U.S. Congress, Office of Technology Assessment, *Saving Energy in the U.S. Transportation System*, OTA-ETI-589 (Washington, DC: U.S. Government Printing Office, July 1994).

[2] U.S. Congress, Office of Technology Assessment, *Rethinking Environmental Regulation* (Washington, DC: U.S. Government Printing Office, forthcoming),

SOURCE Office of Technology Assessment, 1994.

The Office of Technology Assessment (OTA) has examined several studies of the environmental costs of electricity (see box 1-1). This report reviews the studies' results, methods, and assumptions in an effort to determine whether there are generally accepted approaches to estimating environmental costs and whether the studies have converged upon similar conclusions. The report does not provide a detailed discussion of how the findings of these studies might be incorporated into policy. Where policy relevance is discussed, it is primarily from a federal perspective.

OTA concludes that no clear consensus exists on quantitative estimates of environmental costs of electricity, or on methodologies for making those estimates. The methods of these studies, and the estimates themselves, vary widely. The differing methods and results have produced a contentious technical debate among analysts and policymakers who wish to use the results of environmental cost studies. Many of these differences can be addressed through further research and analysis. Some critical disagreements over methodology, however, mask deeper disputes over values, basic policy goals, and the intended role of environmental cost studies. It is unlikely that these disputes can be resolved by technical analysis or scientific research. Instead, these disagreements are more likely to be successfully addressed through public debates in the policy arena.

This report summarizes several existing and ongoing studies, discusses several major methodological disputes and the assumptions underlying them, and attempts to characterize the different frameworks of assumptions. Understanding these frameworks can help policymakers understand both current and future studies, avoid unintentionally accepting the embedded assumptions of studies, and make the best use of the information the studies provide.

STUDIES OF ENVIRONMENTAL COSTS

Environmental cost studies usually compare the effects of several different energy sources (e.g., coal, oil, nuclear, and solar). The studies catalog the emissions from power plants (e.g., sulfur dioxide (SO_2) and carbon dioxide (CO_2) and then estimate the costs associated with those emissions. Cost estimates can be made by either: 1) evaluating the health and environmental impacts from those emissions and estimating the monetary cost of those impacts or 2) examining the cost of currently mandated measures to control those emissions or to mitigate their effects. To estimate an energy source's total environmental cost, each study adds together the damages from all environmental effects attributed to a particular source.

OTA examined eight environmental cost studies for this report (see table 1-1). The studies were selected based on their comprehensiveness, their influence, and the extent of their methodological discussion. Two of the studies (one sponsored by the U.S. Department of Energy and one sponsored by New York State) are in progress and are expected to be completed by the end of 1994. The six other studies had been completed by 1991. There are several other recent and ongoing studies in addition to those that OTA examined in detail for this request. All of these studies are discussed in chapter 2.

On the basis of a review of the methodology and estimates of these eight studies, OTA found that:

- *Cost estimates are difficult to combine or compare.* Studies use very different methods of estimating, categorizing, and reporting results. These methods are so different that in-depth comparison of quantitative results is extremely difficult. In general, only broad comparisons are possible.
- *Cost estimates are variable and uncertain.* Estimates made by different studies vary greatly. For example, cost estimates for the same energy source can vary between nearly zero and a value greater than current electricity prices. All studies note that their results contain substantial uncertainty. Not all studies include explicit estimates of this uncertainty, but when uncertainty ranges are given, they are often as large or larger than the estimates themselves. At least one category of costs, those associated with global warming, is potentially large, but the costs are impossible to estimate with certainty.
- *A single category of effects often dominates the cost estimates. The* studies examined by OTA made more than 50 separate estimates of the environmental costs associated with particular energy sources. In more than 80 percent of these estimates, a single category of damages accounted for the majority of the cost estimate. In one study, for example, damages associated with SO_2 accounted for more than 60 percent of the total damages associated with one type of coal-fired power plant. This observation may facilitate the use of these studies for policymaking because dominant effects may point to areas where additional legislative or regulatory attention is warranted.

METHODS FOR VALUING ENVIRONMENTAL COSTS

Valuation is the process of taking an environmental impact (e.g., number of deaths or acres of damaged forest) and estimating a monetary value for that impact. Other phases of environmental cost studies besides valuation (e.g., estimating long-term health and ecological effects) are important and are often the focus of debate, but studies involving these other phases have been part of

TABLE 1-1: Environmental Cost Studies Reviewed by OTA

Authors	Sponsors	Title	Date
Resources for the Future; Oak Ridge National Laboratories	U.S. Department of Energy; Commission of the European Communities	External Costs and Benefits of Fuel Cycles	(forthcoming)
RCG/Hagler, Bailly, Inc.	New York State Energy Research and Development Authority; Empire State Electric Energy Research Corp.; Electric Power Research Institute	New York State Environmental Externalities Cost Study	(forthcoming)
Richard Ottinger et al. (Pace University Center for Environmental Legal Studies)	New York State Energy Research and Development Authority; U.S. Department of Energy	Environmental Costs of Electricity	1990
Stephen Bernow et al. (Tellus Institute)	Several state energy agencies and utility regulatory bodies (Vermont, Massachusetts, California, and Rhode Island)	Valuation of Environmental Externalities for Energy Planning and Operations	1990
Paul Chernick and Emily Caverhill (PLC, Inc.)	Boston Gas Co.; filed with the Massachusetts Department of Public Utilities	The Valuation of Externalities from Energy Production, Delivery, and Use	1989
Olav Hohmeyer (Fraunhofer-Institute for Systems and Innovation Research, Germany)	Commission of the European Communities	Social Costs of Energy Consumption	1988
ECO Northwest; Biosystems Analysis; Nero and Associates	Bonneville Power Administration; U.S. Department of Energy	(Several, see chapter 2 for details)	1983-1987
Michael Shuman and Ralph Cavanagh (Natural Resources Defense Council)	Northwest Conservation Act Coalition	A Model Electric Power and Conservation Plan for the Pacific Northwest: Environmental Costs	1982

NOTE Sponsors do not necessarily endorse or agree with a study's findings, particularly in the case of government agencies. Several other studies exist, See chapter 2 for additional details.

SOURCE Off Ice of Technology Assessment, 1994

legislative policy debates for some time. In contrast, valuation is relatively new to the policy arena and deserves special attention.

At least five valuation methods are used in current environmental cost studies. *Market valuation* uses existing market prices to estimate damages. *Contingent valuation* elicits estimates from consumers by the use of survey techniques. *Hedonic valuation* examines existing market prices to detect implicit valuation of environmental factors by consumers. *Control cost valuation* examines existing regulatory decisions to detect implicit valuation of environmental **factors by** government regulators. *Mitigation cost* ***valuution*** examines the cost of preventing or repairing environmental damages. Details of these methods can be found in chapter 3.

Disputes over valuation methods mostly center around the utility and accuracy of different types of evidence. For example, some methods (e.g., market and hedonic valuation) draw their information from consumer choices, whereas other methods draw information from the decisions of elected and appointed government officials (e.g., control cost valuation). Analysts and others disagree strongly about the proper method of estimating environmental costs and about whether such valuation is even useful.

ASSUMPTIONS IN ENVIRONMENTAL COST STUDIES

To make quantitative estimates of environmental costs, studies must make a large number of assumptions. Some of these assumptions involve valuation methods, others involve how to handle uncertainty or whether currently regulated effects should be included in cost estimates. Different assumptions can include or exclude whole classes of effects, and can lead to dramatically different numerical estimates for the effects that are included.

Environmental cost studies are not the only type of study in which assumptions affect results; all quantitative analyses are conducted within a general framework of assumptions and values. Environmental cost studies, however, include a particularly large number of assumptions. Attempting to estimate environmental costs necessarily uses the results of many other, more limited, component studies—for example, studies of emissions generation, transport, and deposition; environmental impacts; risk assessment; and economic valuation. Environmental cost studies incorporate the strengths and weaknesses of these component studies. As a result, environmental cost studies face an array of vexing problems that have emerged from the past two decades of research in environmental science, social science, engineering, and economics. They generally require a larger number of assumptions, contain greater uncertainties in their results, and engender more controversy than do studies of a more limited scope.

There are no obvious criteria to use in selecting a set of best assumptions for all purposes or for all policy makers. Specific assumptions draw criticism and support from different analysts, but most are not obviously flawed. Instead, these assumptions embody different goals and values that may be more or less appropriate to different purposes and policy makers. Because no single set of assumptions matches the goals and values of most parties, consensus estimates of environmental costs are not possible.

The impact of the assumptions and values implicit in different estimates is large enough that isolated quantitative estimates of environmental costs are nearly meaningless. Such estimates become meaningful only in the context of a study's assumptions and of the environmental effects that are included. This conclusion indicates that isolated quantitative estimates of environmental cost studies should not be presented as the final results of a study. This practice improperly focuses attention only on the numerical results, rather than on explaining those results in the context of the study's assumptions.

Investigating the assumptions that underlie these different estimates can help explain why the estimates differ and can also help to clarify broader debates over the environmental costs of energy. On the basis of the methodology of environmental cost studies, position papers by stakeholders, and a workshop convened for this study, OTA identified several frameworks of goals and values (see chapter 4 for details). These frameworks can be characterized by the answers to fundamental questions such as:

- *What is the goal of environmental policy?* Environmental cost studies are most frequently associated with the goal of economic efficiency. Other implicit and explicit goals assumed in environmental cost debates include equity, sustainability, and protection of health and safety.
- *What is the role of environmental cost studies in energy policy? These* studies can be used to quantify economic corrections to energy markets, facilitate compensation for environmental damages, or guide government regulation to protect health or encourage sustainability.
- *How is value determined?* Valuation can be based on consumers acting in markets, legislators and regulators acting in political systems, scientists studying ecological systems, or government officials acting in legal settings.

Different answers to these questions lead to different assumptions about what effects to include, how to value those effects, and how to handle uncertainty. These assumptions, in turn, can lead to widely divergent estimates of the environmental costs of electricity generation. All studies make these assumptions based on frameworks of goals and values, and these frameworks are often the focus of substantial disagreement. Rather than helping to resolve political and social debates, current environmental cost studies often reflect different positions in these debates.

ROLES FOR ENVIRONMENTAL COST STUDIES IN POLICYMAKING

Given that assumptions and values are so important to the methods and results of environmental cost studies, what role can such studies serve in developing federal policy?

Current Laws and Regulations

Several federal laws and regulations already require some examination of environmental cost. For example, consideration of environmental cost is required under the Pacific Northwest Electric Power Planning and Conservation Act of 1980 (Public Law 96-501). The Clean Air Act Amendments of 1990 (Public Law 101-549) require the Environmental Protection Agency (EPA) Administrator to conduct a comprehensive analysis of the effects of the act on the public health, economy, and environment of the United States. The Energy Policy Act of 1992 (Public Law 102-486) requires the Secretary of Energy to develop a least-cost national energy strategy that considers the economic, energy, environmental, and social costs of various energy technologies.

Some pending federal legislation has a connection to environmental cost issues. For example, much of the debate over whether to elevate the EPA to cabinet-level status has concerned whether the new agency would be required to perform cost-benefit analyses of proposed regulations. Some EPA regulations directly address the environmental effects of energy, and environmental cost studies hold the promise of helping to quantify regulatory benefits. EPA conceivably could conduct or use many different types of studies of costs and benefits. Some of these studies lack the complexity of studies that assess the environmental cost of energy, but the difficulties, challenges, and opportunities presented by environmental cost studies may provide useful analogs for broader questions about the quantitative study of EPA regulations.

In addition to federal policies, many state regulatory commissions require some quantitative or qualitative use of environmental cost estimates. Nineteen states require utilities to consider quantitative estimates of environmental costs. Requirements in another 10 states and the District of Columbia mandate the use of qualitative criteria that attempt to account for environmental costs.

Making Studies More Useful to Federal Policymakers

For federal policymakers, use of environmental cost studies offers both pitfalls and opportunities. Pitfalls include the unknowing acceptance of assumptions and values embedded within the studies' quantitative analysis. Opportunities include using environmental cost studies as a way to explore the importance of specific assumptions and as a way to gain useful insights into setting environmental priorities.

Moving Beyond Evaluation

In one way, at least, federal policymakers may find a mismatch between their own goals and those embodied in currently available studies of the environmental costs of electricity. Many of the assumptions in currently available studies stem from an emphasis on the goals of state utility commissions. In particular, these studies often assume that the important decisions involve choosing among available electricity generating technologies, rather than attempting to alter the relevant environmental effects of those technologies. Federal policy often involves the latter, through laws and regulations concerning pollution control technologies, mining and transportation safety, waste disposal, and impact mitigation.

One consequence of the existing focus on choosing among different generating technologies is that studies often report aggregate values that indicate total environmental costs. Such results are useful to state regulatory commissions that wish to affect how utilities add new generating capacity. However, they are of limited use to federal legislators and regulators, who have a wider array of pol icy measures available. If studies are not relevant to the design and management of electricity generating technologies, then federal policy makers may not be able to use the studies effectively or they may choose to ignore them entirely.

In contrast, if environmental cost studies present disaggregated results, then they could prove more useful to federal policy makers. They could assist legislators and regulators with setting priorities and designing efficient and effective regulatory programs. For example, if future studies analyze and report the relative importance of different effects as prominently as current studies report total environmental costs, then future studies could help support priority-setting activities in both regulatory programs and research and development activities.

Emphasizing Nonquantitative Results

Environmental cost studies often focus on what appears to be the "bottom line'' —the monetary value of env ironmental effects. In many cases, this is the most speculative and controversial aspect of the study, and effects that are not monetized are often ignored. In contrast, focusing on the earlier components of the study (e.g., the emissions and impacts stages) would emphasize aspects that are most amenable to scientific and technical resolution.

Monetization is useful, but its very nature allows the results of environmental cost studies to be reported in a highly aggregated form. This encourages use of the results without the full understanding of the assumptions and values that underlie them. Placing greater emphasis on reporting the results of earlier phases of the analysis (e.g., emissions and impacts assessments), and on clearly explaining the assumptions and values that underlie the estimates of monetary damages, would greatly assist the federal decisionmakers who may use the studies.

Informing Legislative Decisionmaking

At least for the near term, use of environmental cost studies on the federal level is likely to engender continued disputes over methodology and results. As is the case with current studies, much of the controversy over future studies will likely be due to fundamental differences in assumptions and the associated frameworks of goals and values, rather than specific findings of a given study. For policymakers, accepting and using the quantitative findings of a particular study of environmental costs implies accepting the goals and values embedded in that study.

Some analysts believe recent studies (e.g., DOE/EC and New York State) are converging on a common set of methods and their results should be preferred over those of other studies. In several ways, these recent studies do represent advances over older studies because they review a larger body of literature, they are often more systematic in their survey of emissions and environmental impacts, and several elements of their technical methodology are more sophisticated.

However, this methodological sophistication may be less important than the studies' basic assumptions, many of which depend on policy goals and values that are beyond the purview of analysts. These recent studies *do* make a relatively consistent set of assumptions. For example, these studies value environmental effects using only damage cost approaches (see chapter 3) and they employ relatively high standards of proof about what emissions and impacts should be included in environmental cost estimates. However, whether these assumptions represent objectively "better" choices depends on the goals and values of policymakers who use these studies, rather than on the opinions of analysts.

Technical and methodological critiques of environmental cost studies are important, but they are not the only important critiques. A study may be technically excellent and still not meet the needs of Congress and of executive branch agencies. If a study's values and assumptions differ radically from those of the relevant policy makers, then they may reject the study on those grounds alone. Such an action would not be "ignoring science" but would constitute the legitimate exercise of the policy makers' public responsibilities. In contrast, if a study's values and assumptions are made clear and match those of the relevant decisionmakers, then the study may be able to provide valuable insights of a sort that other analyses cannot.

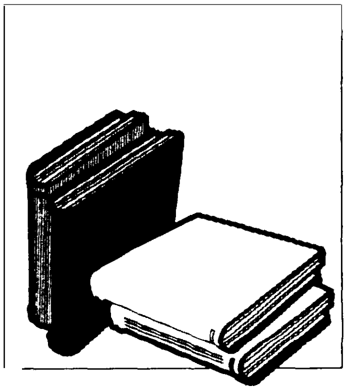
Studies of Environmental Costs 2

Much of the technical debate over the environmental costs of electricity concerns a set of quantitative studies. These studies were conducted mostly within the past two decades, and they attempt to evaluate the environmental costs associated with different electricity generating technologies. The studies serve as focal points for discussion. Their methodology, assumptions, results, and recommendations are being examined and challenged by various stakeholders.

In many cases, the methods and assumptions of these studies reflect the underlying values of the analysts who conduct the studies and the groups that sponsor them. These values often lie at the heart of disagreements over estimates of environmental costs. Understanding the technical methodology and assumptions of environmental cost studies can help to clarify the values that are at issue.

This chapter covers three areas. First, it discusses the general structure and purpose of environmental cost studies. Second, it summarizes the history and quantitative conclusions of a selected group of studies. Third, it compares and contrasts the selected studies in an effort to identify similarities and differences.

This chapter does not provide a detailed explanation of the methodological issues surrounding environmental cost studies or a detailed analysis of which methods are more or less appropriate. This report focuses on different issues—the values and assumptions that underlie estimates of environmental costs and the implications for using these studies in policymaking. These topics are discussed at greater length in chapters 3 and 4.



THE PURPOSE AND STRUCTURE OF ENVIRONMENTAL COST STUDIES

Environmental cost studies are a relatively recent phenomenon.[1] The earliest studies that compared several energy sources date from the 1970s, but nearly all studies of current interest date from the 1980s and 1990s.

Many other studies exist that analyze other types of costs (see box 2-1), but particular attention has focused on the environmental costs of electricity. One reason is that such studies have a built-in audience of government officials who regulate the environmental effects of electricity generation at both the state and federal levels. State and federal agencies have funded several studies, and many states have set policies based on the studies' results. Another reason is that, to conduct an environmental cost study, a large body of scientific research on environmental effects must exist or must be created. Such an extensive base of research may not exist in other areas.

Environmental cost studies are structured to facilitate comparison of energy sources by using monetary values to summarize the environmental effects of each source. A study examines a range of environmental effects (e.g., health impacts of air pollution and ecological damage resulting from mining operations) of several energy sources (e.g., coal, nuclear, and solar), and applies the same general methods to each source. The cost of each effect is quantified using a monetary value and then, for each source, the monetary values are added together to estimate the total cost of the environmental effects associated with that energy source.

Environmental cost studies generally make estimates for several electricity generating technologies, including coal, nuclear, natural gas, oil, hydroelectric, solar, and wind.[2] In addition, several forms of each technology are often evaluated. For example, fossil fuel plants may use different technologies for pollution control, and there are several approaches to generating electricity from solar energy. Because each of these technologies can produce different environmental effects, studies often treat them separately.

Environmental cost studies trace environmental effects through at least three related stages (see figure 2-1):[3,4]

- Identifying emissions—the environmental releases of byproducts of generation and use of electricity. For example, air emissions from

[1] For a general introduction, see Harold M. Hubbard, "The Real Cost of Energy," *Scientific American,* April 1991, pp. 36-42. For a more in-depth treatment, see Temple, Barker & Sloane, Inc. and Electric Power Research Institute, *Environmental Externalities: An Overview of Theory and Practice, CU/EN-7294* (Palo Alto, CA: May 1991). For a technical introduction to economic theory and practice of environmental cost studies, see G.M. Brown, Jr. and J.M. Callaway, U.S. National Acid Precipitation Assessment Program, "Report 27: Methods for Valuing Acidic Deposition and Air Pollution Effects," *Acidic Deposition: State of Science and Technology, Volume IV: Control Technologies, Future Emissions, and Effects Valuation* (Washington, DC: U.S. Government Printing Office, September 1990). For an extensive bibliography, see Consumer Energy Council of America, *Incorporating Environmental Externalities Into Utility Planning: Seeking a Cost-Effective Means of Assuring Environmental Quality* (Washington, DC: July 1993).

[2] Some studies even discuss the environment costs of energy efficiency measures. For example, Ottinger mentions two possible effects: 1) indoor air quality may decline when buildings are weatherized, and 2) increased efficiency may lower a region's peak energy demand and shift load from gas-fired peaking turbines to base-load coal or oil plants. Richard L. Ottinger et al., Pace University Center for Environmental Legal Studies, *Environmental Costs of Electricity (New* York, NY: Oceana Publications, 1990).

[3] Adapted from the discussion in: Oak Ridge National Laboratory and Resources for the Future, *U.S.-EC Fuel Cycle Study: Background Document to the Approach and Issues*, ORNL/M-2500 *(Oak* Ridge, TN: Oak Ridge National Laboratory, November 1992). Early reviews of externality studies also explicitly cite a similar structure. For example, Holdren establishes a four-step process: 1) sources, 2) insults, 3) stresses, 4) consequences. John P. Holdren, *Integrated Assessment for Energy-Related Environmental Standards: A Summary of Issues and Findings,* LBL-12779 (Berkeley, CA: Lawrence Berkeley Laboratory, October 1980).

[4] There is no entirely satisfactory taxonomy of externalities. They can be categorized by pollutant, by source, by impact, or by fuel cycle phase (e.g., mining, processing, generation, use). See Andrew Stirling, "Regulating the Electricity Supply Industry By Valuing Environmental Effects: How Much Is the Emperor Wearing," *Futures,* December 1992, pp. 1024-1047.

BOX 2-1: Types of Studies Not Covered in This Report

This report focuses exclusively on the environmental costs of electricity generation, but several other types of related studies exist. Some studies focus on nonenvironmental costs of energy. For example, federal energy subsidies represent a nonenvironmental cost.[1] Tax dollars are used to pay the costs of federal loan guarantees, energy assistance programs, research and development, energy services, and funding of some administrative agencies. Energy consumers do not pay directly for these subsidies, instead, all U.S. taxpayers bear the costs of these programs. Although nearly all taxpayers use the energy sources affected by federal subsidies (and vice versa), users do not pay for those subsidies in proportion to the amount of energy they use, Other nonenvironmental costs include induced public expenditures (e.g., defense costs) and economic effects (e.g., production, employment, and trade balance).

Several other studies examine benefits as well as costs.[2] For example, energy generation facilities can increase employment. Whether an effect is a cost or a benefit can depend on factors other than the effect itself. For example, additional jobs created by an electricity generating facility could be an economic benefit to an area with high unemployment. Alternatively, that same job creation could be a cost to an area with labor shortages.[3]

Finally, some studies focus on topics other than electricity. For example, a number of studies examine various costs of transportation that may not be completely included in prices (e.g., subsidized parking and roads, vulnerability to oil supply disruptions, congestion, and accidents).[4] Some of these effects are energy-related (e. g., vulnerability to oil supply disruptions), but most of the effects examined by these other studies have little direct bearing on electricity generation.

[1] U.S. Department of Energy, Energy Information Administration, *Federal Energy Subsidies. Direct and Indirect Interventions in Energy Markets,* SR/EMEU/92-02 (Washington, DC: November 1992); and Douglas N. Koplow, *Federal Energy Subsidies" Energy, Environmental, and Fiscal Impacts* (Washington, DC Alliance To Save Energy, April 1993).

[2] The terms costs and *benefits* are used differently in different contexts, Deaths attributable to air pollution can be termed a cost of energy generation; preventing those deaths can also be termed a benefit of air pollution regulations. This report generally conforms to the first usage

[3] Ajay K Sanghi, "Should Economic Impacts Be Treated as Externalities?" *The Electricity Journal,* March 1991, PP 54-59

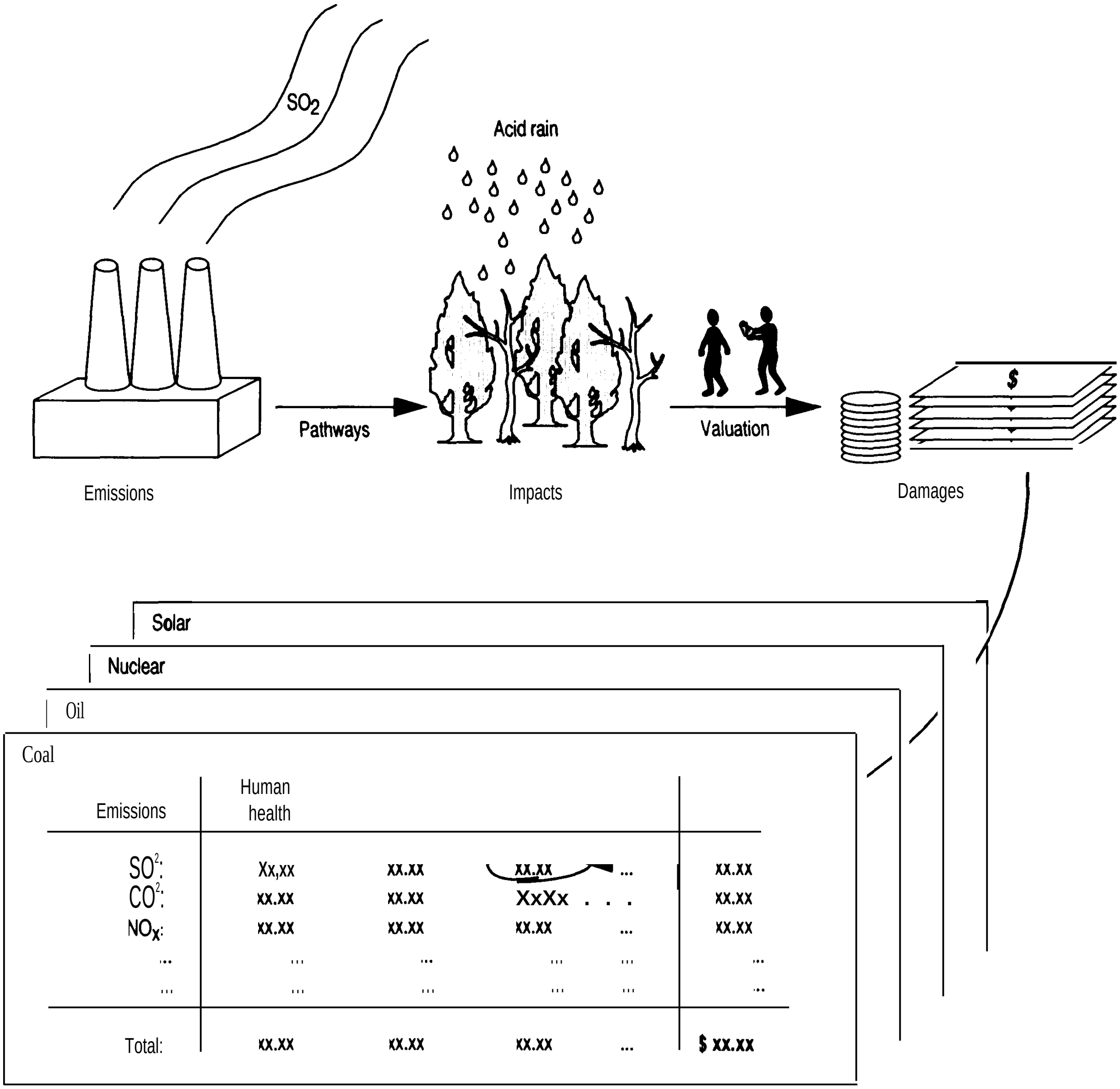
[4] U S Congress, Office of Technology Assessment, *Saving Energy in the U.S. Transportation System,* OTA-ETI-589 (Washington, DC U S Government Printing Office, July 1994), U S Congress, Congressional Research Service, "The External Costs of 011 Used in Transportation," June 3, 1992; James J. MacKenzie et al., *The Going Rate: What/? Really Costs To Drive* (Washington, DC: World Resources Institute, June 1992); David L. Greene and Paul N. Leiby, *The Social Costs to the U.S. of the Monopolization of the World Oil Market, 1972-1991, ORNL-6744* (Oak Ridge, TN Oak Ridge National Laboratory, March 1993), and Peter Miller and John Moffet, *The Price of Mobility Uncovering the Hidden Costs of Transportation* (New York, NY: Natural Resources Defense Council, October 1993).

SOURCE Office of Technology Assessment, 1994

burning fossil fuels include SO_2, CO_2, and particulates. See table 2-1 for additional examples.

- Identifying and evaluating impacts—the physical or socioeconomic effects of emissions on human health (e.g., cancer and emphysema), property (e.g., loss of commercial fishing or erosion of stonework by acid rain), and ecological systems (e.g., decreases in biodiversity). See table 2-1 for additional examples.
- Evaluating *damages-the* monetary value of impacts. To the extent that environmental costing focuses on reducing all environmental impacts to a single scale (e.g., dollars), evaluating damages becomes a necessary step in the analysis.

FIGURE 2-1: The Process of Estimating the Environmental Costs of Energy



NOTE: This figure does not show the process for studies that relyexclusivelyon damage costing approaches (see chapters3 and 4 foradescription) It also does not show the process of analyzing whether some damages are included in current electricity prices, a step that most existing studies have not taken.

SOURCE Office of Technology Assessment, 1994

TABLE 2-1: Examples of Emissions and Impacts

Emissions
Air emissions: SO_x, NO_x, CO_x, particulate, trace elements, air toxics
Waste generation: Toxic, radioactive, solid, liquid
Radiation
Electromagnetic fields (EMF)
Thermal
Noise
Pesticide use around power lines
Runoff from mining, processing, and fuel storage
Impacts
Human deaths and illness: accidents, cancer, respiratory illness, acute poisoning
Reduced production of crops, timber, or fisheries
Degradation of structures from atmospheric pollutants
Lost recreational opportunities
Degraded visibility
Loss of habitat and biodiversity
Use of land, water, and minerals

NOTE The lists are not comprehensive Not all impacts are tied to emissions or pathways.

SOURCE Office of Technology Assessment, 1994

Environmental cost studies use emissions to estimate impacts. Emissions travel through *pathways* to create an environmental impact. For example, some studies estimate trace emissions of SO_2 through the pathway of acid rain to the eventual environmental impacts on forest ecosystems (see figure 2-l). In addition to emission-related impacts, studies make estimates of impacts that arise independent of emissions. For example, some accidental deaths and injuries result from coal mining.

Next, environmental cost studies use impacts to estimate monetary damages. Impacts are converted to damages through a process of *valuation.* For example, the monetary damages associated with a lost forest ecosystem can be valued by surveying nearby residents who use the forest for recreation (see figure 2-l). It is not always possible to attach monetary damages to impacts. Some impacts are left out of damage estimates either because estimating damages is too difficult or because the damages are assumed to be negligible.

Although these three stages are common to many studies, they are far from universal. First, some analysts advocate adding another stage to environmental cost studies-evaluating whether damages represent an economic *externality (see* box 2-2). They argue that merely assessing damages provides only part of the information that is important for policymaking. Second, some environmental cost studies do not derive damages based on impacts, but instead make damage estimates based on existing legislative, regulatory, and judicial decisions. These valuation methods, referred to as *control cost methods, are* covered in more detail in chapter 3.

SELECTED STUDIES

OTA selected eight environmental cost studies to examine for this report (see tables 2-2 and 2-3). There are several other recent and ongoing studies in addition to those that OTA examined in detail (see box 2-3). The eight selected studies demonstrate both the promise and problems of environmental cost studies. The studies were selected based on the following criteria:

- *Comprehensiveness:* Each study covers a range of energy sources and environmental effects.
- *lnfluence:* Each study continues to influence current thinking of analysts and decisionmakers.[5]

[5] For example, one study (Inhaber, 1978) was excluded on this bask. The Inhaber report has been strongly criticized for a variety of errors (e.g., Holdren, 1979) and has little influence on current thinking. Herbert Inhaber, *Risk of Energy Production,* AECB-1119/REV-2 (Ottawa, Canada: Atomic Energy Control Board, November 1978); and John P. Holdren et al., *Risk of Renewable Energy Sources: A Critique of the Inhaber Report,* ERG 79-3 (Berkeley, CA: University of California, Energy and Resources Group, June 1979).

BOX 2-2: Economic Theory of Environmental Costs

Economists have devised a formal theory of environmental costs, They define some environmental effects as externalities-costs imposed on society that are not included in the prices of the goods or services. These costs are external, or outside, the existing system of energy pricing, By adding externalities to the market costs of energy, an analyst can estimate the total cost or social cost of energy.

Some externalities have been avoided through environmental controls. Many environmental effects are well documented and have resulted in environmental statutes, such as the Clean Air Act, Because there are serious consequences for violating the statutes, utilities have installed pollution control equipment to control emissions. Some of the cost of this equipment is passed on to consumers.

Other externalities have been included-or internalized—-in energy prices. For example, many analysts believe that wages in some industries (e.g., mining and construction) compensate workers for the relatively higher risks they may bear. Wages of workers in these industries are included in the market prices of energy, Other examples include settlements mandated by court verdicts in cases of environmental damage and the costs of purchasing $S0_2$ emissions permits under the Clean Air Act. These costs are incorporated into prices and thus partially or completely internalize the externalities,

Some environmental effects are not considered to be externalities. Environmental effects may remain even after an externality has been fully internalized. For example, suppose a power plant releases an air pollutant that is currently unregulated. If the pollutant has an environmental cost of $5 per ton, one way of internalizing these costs is to charge utilities $5 for every ton of the pollutant their plants emit. Such a tax would cause utilities to install pollution-control equipment-up to the point that the equipment costs more than the emissions it prevents, Some residual emissions would remain because they are too costly to prevent. At this point, it is cheaper for the utility to pay the tax than to control the remaining emissions.

Some critics of applying environmental costs argue that current regulations completely internalize the environmental costs for many pollutants. If regulations implicitly or explicitly balance social costs and benefits, then emissions have been reduced to an "optimal" level and the costs of that reduction are passed on to energy consumers. If regulations do *not* accurately balance social costs and benefits, then some environmental externalities may remain (if standards are set too low) or an economic externality may be created (if standards are set too high).

However, other analysts point out that, even if existing regulations balance costs and benefits, the remaining emissions still may represent an externality. Consider two different methods of reducing emissions of a pollutant to the same level. One method is an emission tax, set at a level equal to the marginal damages caused by the pollutant. ' Under this method, a utility will: 1) reduce emissions up to the point where the cost of control is equal to the cost of the tax, and 2) pay the tax on the remaining emissions. The utility either eliminates emissions or pays for the damages those emissions cause, An alternative method of regulating a pollutant is a mandated cap on emissions, set so marginal costs and benefits are equal. Under this method, a utility will reduce its emissions to the mandated level, In contrast to the first method, the utility will not incur any costs for its remaining emissions. Under this method, the utility eliminates some of its emissions, but does not pay for the damages caused by the remaining emissions. In the latter case, the damages represent an externality.

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[1] The term *marginal damages* refers to the damages associated with the "next" quantity of pollutant, rather than the average damages associated with all previous quantities. Because the costs and benefits of controlling emissions of pollutants can change with the amount already controlled, it is important to *examine marginal*, rather than average, values See chapter 4 for additional explanation,

BOX 2-2 (cont'd.): Economic Theory of Environmental Costs

Some environmental effects of energy remain largely unregulated. If the environmental damages from such pollutants exist, they represent clear examples of externalities. For example, the $C0_2$ emissions of electric utilities are thought to contribute to global warming, but these emissions are not regulated on the federal level, Several state public utility commissions (PUCs) have recognized the potential of future damages associated with $C0_2$ emissions as an externality, and they require that utilities consider $C0_2$ emissions during new capacity planning. To the extent that global warming is a serious environmental threat, unregulated $C0_2$ emissions represent an externality-a cost of energy use not included in the market price.

SOURCE Office of Technology Assessment, 1994.

- *Methodological discussion:* Each study presents a substantive discussion of the methods used to create its estimates.[6]

Despite these similarities, the studies also differ in many respects:

- *Analysts and sponsors:* Groups that conducted studies include academic groups, consulting firms, research organizations, environmental groups, and government laboratories (e.g., respectively, Pace University Center for Environmental Legal Studies, RCG/Hagler Bailly Inc., Resources for the Future, Natural Resources Defense Council, and Oak Ridge National Laboratory). Sponsors include utilities, state governments, citizens' groups, and federal agencies (e.g., respectively, Boston Gas Co., New York State, Northwest Conservation Act Coalition, and the U.S. Department of Energy).
- *Age: The* oldest study was published in 1982. The newest studies (New York State and DOW EC) are due to be completed in late 1994. In the intervening years, there have been new developments in valuation methodology, available data, and understanding of pollutant emissions, transport, and health effects.
- *Size and complexity:* Some studies are relatively short and simple (e.g., Shuman and Cavanagh's estimates are presented in less than 60 pages). Others are quite long and complex (e.g., Pace's analysis runs more than 700 pages).
- *Energy sources:* Some studies deal only with fossil fuels (e.g., coal, oil and natural gas). Other studies estimate costs for a range of other sources (e.g., nuclear, solar, wind, biomass) as well as energy -efficiency measures.
- Methods: Methods vary widely among studies (this topic is dealt within greater detail in chapters 3 and 4).
- *Environmental: effects: The* studies do not all cover the same environmental effects. Some studies deal almost exclusively with air emis-

[6] For example, one frequently cited study (Schilberg et al., 1989) was excluded on this basis. The study cited and compared a number of estimates, but did not contain extensive methodological discussion of its own. Gayatri M. Schilberg et al., "Valuing Reductions in Air Emissions and Incorporating Into Electric Resource Planning: Theoretical and Quantitative Aspects," California Energy Commission Docket 88-ER-8, JBS Energy, *Inc.*, report prepared for the Independent Energy Producers, Sacramento, CA, Aug. 25, 1989.

TABLE 2-2: Major Studies of the Environmental Cost of Ele

Name	Date	Authors	Sponsors	Comments
U.S. Department of Energy (DOE) and Commission of the European Communities (EC)	(forthcoming)	Resources for the Future Oak Ridge National Laboratories	U.S. Department of Energy; Commission of the European Communities	Unfinished. Resources: $3 million and 36 months.
New York State	(forthcoming)	RCG/Hagler, Bailly, Inc.	New York State Energy Research and Development Authority; Empire State Electric Energy Research Corp. Electric Power Research Institute	Unfinished. Resources: $1.75 million and 36 months. Will rely partially on DOE\EC results.
Pace	1990	Richard Ottinger, et al. Pace University Center for Environmental Legal Studies	New York State Energy Research and Development Authority; U.S. Department of Energy	
Tellus Insitutute	1990/1991	Stephen Bernow et al. Tellus Institute	Several state energy agencies and utility regulatory bodies (Vermont, Massachusetts, California, and Rhode Island)	Limited to air emissions of fossil fuels. Specific to California and Northeastern Us.
Chernick and Caverhill	1989	Paul Chernick and Emily Caverhill PLC, inc.	Boston Gas Co.; filed with the Massachusetts Department of Public Utilities	
Hohmeyer	1988	Olav Hohmeyer Fraunhofer-Institute for Systems and Innovation Research, Federal Republic of Germany	Commission of the European Communities	Specific to the former Federal Republic of Germany.
Bonneville Power Administration (BPA)	1983-1987	ECO Northwest Biosystems Analysis Nero and Associates	Bonneville Power Administration; U.S. Department of Energy	Seven studies, each on a different source (e.g., coal, nuclear).
Shuman and Cavanagh	1982	Michael Shuman and Ralph Cavanagh, Natural Resources Defense Council	Northwest Conservation Act Coalition	Specific to Northwest U.S.

NOTE' Names reflect terms commonly used to refer to the study in subsequent literature. Sponsors do not necessarily endorse or agree with a study's findings, particularly in the case of government agencies Studies were selected based their comprehensiveness, influence, and methodological discussion. Several other studies exist that do not meet one or more of OTA'S selection criteria. See box 2-3 for recent studies not reviewed in this report.

SOURCE. Office of Technology Assessment ,1994

TABLE 2-3: Characteristics of Selected Studie

	DOE-EC *(unfinlshed)*	New York State *(unfinished)*	Pace	Tellus	Chernick and Caverhill	Hohmeyer	BPA	Shuman and Cavanagh
Sources monetized	coal oil natural gas nuclear solar (PV) wind hydroelectric biomass conservation	coal (4) oil **(3)** natural gas **(3)** nuclear **(2)** biomass MSW hydroelectric (2) wind solar (2)	coal (4) oil (4) natural gas **(3)** nuclear solar wind biomass efficiency	coal (4) oil (7) natural gas (3)	coal (4) oil (4) natural gas (4)	fossil fuels nuclear solar (PV) wind	coal **(2)** oil natural gas nuclear biomass MSW geothermal solar (central) wind hydroelectric	coal nuclear wind solar (hot water) efficiency
Sources discussed, but not monetized	—	demand-side management	waste-to-energy hydroelectric geothermal	—	—	—	—	—
Emissions with monetized impacts	(not **available)**	SO_2 NO_x particulate nitrates lead mercury ozone acid aerosols air toxics water pollution radiation solid waste	SO_x NO_x CO_2 particulate radiation nuclear accidents noise	SO_2 NO_x N_2O CO_2 CO particulate volatile organics	SO_2 NO_x CO_2 CH_4 marine oil spills	**air pollutants** CO_2 nuclear accidents indust. accidents noise	(varies)	air pollutants CO_2 radiation nuclear accidents indust. accidents transp. accidents
Monetized impacts	(not available)	human health property damage crop damage fisheries damage land use visibility	human health property damage global warming crop damage land use visibility	(not applicable)	human health property damage global warming ecosystem damage crop damage livestock timber visibility	human health property damage global warming ecosystem damage land use	(varies)	human health property damage global warming proliferation

TABLE 2–3 (cont'd.): Characteristics of Selected Studies

	DOE-EC *(unfinished)*	New York State *(unfinished)*	Pace	Tellus	Chernick and Caverhill	Hohmeyar	BPA	Shurnan and Cavanagh
Effects quantified but not monetized	(not available)	energy security	acid rain; water use and pollution; thermal pollution; land use; solid waste; methane;	—	particulate;	—	(varies)	—
Effects noted but not quantified	(not available)	CO_2	ecosystem effects; non-routine nuclear emissions; damage to historical monuments; livestock; forestry; electro-magnetic fields	water pollution, noise, traffic	air toxics; carbon monoxide; ozone; electro-magnetic fields; herbicide use on transmission rights-of-way; land use; waste disposal; water pollution; thermal pollution; N_2O; indoor air pollution	species loss; routine nuclear emissions; damage to historical monuments; production of intermediate goods used in energy generation; impacts of stages of fuel cycle besides generation	(varies)	water consumption; recreation losses; fish and wildlife mortality; aesthetic damage; transmission and distribution
Stages or activities monetized	emphasis on generation	mining fuel processing transportation generation	generation decommissioning	generation (air emissions)	**generation**	generation	(varies)	extraction transportation generation
Valuation methods	(damage cost)	(damage cost)	market contingent hedonic mitigation cost	control cost mitigation cost	market control cost mitigation cost	market hedonic mitigation cost	(varies)	market hedonic control cost

NOTES: Numbers in parentheses in "Sources" indicate the number of different systems within the general source category that were considered (e.g., "Coal (3)" indicates that the study estimated environmental costs for three different types of coal plants). When effects are listed as "quantified but not monetized, " monetization may have been discussed, but the study produced no specific monetization estimate. Not all emissions, impacts, or effects were necessarily estimated for all energy sources, The Pace study discusses hydroelectric, but does not estimate monetized environmental costs for this source. Information in some studies had to be adapted to fit the structure of this chart. Valuation techniques based on damage costs include market, contingent, and hedonic valuation. Human health includes both public and occupational impacts. Some studies estimate nonenvironmental costs such as subsidies and macroeconomic effects; these are not included in this chart. The source listed as "efficiency" denotes several different approaches; Pace evaluated demand-side management; Shuman and Cavanaugh evaluated household weatherization. Valuation methods are discussed in greater detail in chapter 3.

SOURCE: Office of Technology Assessment, 1994.

BOX 2-3: Recent and Ongoing Studies Not Reviewed in This Report

The following studies were identified in the course of OTA'S analysis but are not extensively reviewed in the body of this report Each is briefly discussed below and its Implications for the report are explored

Studies

Nevada: These two studies were prepared by National Economic Research Associates, Inc. (NERA) for two Nevada utilities (Sierra Pacific Power Co, and Nevada Power Co),[1] The studies estimate environmental costs for five conventional air pollutants (PM-1 O, NO_x, SO_x, VOC, CO). In addition, estimates are made for environmental costs associated with four greenhouse gases (CO_2, CO, methane, and N_20) These latter estimates are based on estimates made by other studies and the reports note they are highly speculative. All estimates are given in terms of dollars per pound of pollutant. The study does not derive overall environmental costs associated with particular power or plant types. In this way, the Nevada studies differ from the studies reviewed in the body of the report.

Australia: This study was prepared by RCG/Hagler, Bailly, Inc. and SRC Australia Pty Ltd. as part of a larger project to evaluate and develop externalities policy for Victoria, a province in Australia.[2] The project was commissioned by the Victorian Department of Energy and Minerals and also sponsored by the Commonwealth Department of Environment, Sport and Territories, the State Electricity Commission of Victoria, the Gas and Fuel Corp. of Victoria, and the Renewable Energy Authority Victoria. Environmental cost estimates were made for particulate, nitrogen oxides, sulfur dioxide, ozone, air toxics, wastewater discharge, solid waste, and greenhouse gases. Estimates also were made of the socioeconomic benefits. The estimates are specific to the Latrobe Valley, a particular geographic region in Victoria, Although the report focuses on estimates in terms of dollars per pound of pollutant, the costs of one specific power plant are provided.

Wisconsin/Minnesota: These two studies have been prepared by RTI and NERA for U.S. utilities in Wisconsin and Minnesota. In both cases, the studies have not been made public by their sponsors, due to their use in pending rate cases before state regulatory commissions. They will be released by the end of 1994.

California Energy Commission: For several years, the California Energy Commission (CEC) has sought to quantify environmental costs of constructing new generating facilities. These analyses have been part of the Energy Report process, a formal process that includes adopting environmental cost estimates to be used for energy planning. The 1992 Energy Report process used values based on estimates made by Regional Economic Research, Inc. This research recently has been compiled into a single document.[3]

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1 National Economic Research Associates, *Final Report. External Costs of Electric Utility Resource Selection m Nevada,* report prepared for the Nevada Power Co (Cambridge, MA March 1993), National Economic Research Associates, *Final Report External Costs of Electric Utility Resource Selection m Northern* Nevada, report prepared for Sierra Pacific Power Co (Cambridge, MA December 1993)

2 RCG/Hagler, Bailly, Inc and SRC Australia Pty Ltd., *Externality Policy Development Project: Energy Sector, Consultants' Summary Report for the Victorian Study* (East Melbourne, Victoria Department of Energy and Minerals, October 1993)

3 Mark A Thayer et al , Regional Economic Research, "The Air Quality Valuation Model, " draft report, Apr 21, 1994

(continued)

BOX 2-3 (cont'd.): Recent and Ongoing Studies Not Reviewed in This Report

Implications

The Nevada, Australia, Wisconsin, Minnesota, and CEC studies are not discussed elsewhere in this report. In the case of the Wisconsin and Minnesota studies, they could not be discussed because sufficient information was not available, In the case of the Nevada, Australia, and CEC studies, they provide only limited results. The Nevada studies provide cost estimates for air emissions only, and do not provide comparative figures for different types of power plants. The Australia study provides estimates for a more comprehensive set of effects, but only applies those figures to evaluating the overall costs of a single type of plant (a coal-fired power plant). The CEC study provides estimates only for air emissions and only for a limited number of generating technologies that are being considered in California.

Results from these newer studies do not alter OTA'S overall findings, The estimates of environmental cost studies still vary widely, depending on the values and assumptions embedded within the studies. Differences in these values and assumptions are unlikely to be resolved by technical studies, Accepting the results of a particular study involves the implicit or explicit acceptance of a large set of assumptions about what effects to include and how to value those effects,

Results of these newer studies confirm several of OTA'S findings. First, their cost estimates are generally far lower than many previous studies. The two Nevada studies make cost estimates associated with different air emissions that are between 30 percent and less than 1 percent of similar cost estimates of the Tellus and Pace studies. Similarly, the Australia study estimates the environmental cost of an existing coal plant as between 0.0013 and 2.3 cents/kWh, with a central estimate of 0.0020 cents/kWh. By comparison, the Tellus and Pace studies make estimates ranging between 3 and 10 cents/kWh. These results reinforce the conclusion that cost estimates are extremely variable. Second, results of these newer studies differ from results of other studies in ways discussed in chapter 4. In comparison with many other studies, these newer studies are more restrictive in the categories of costs that are included and in how those costs are valued. Consequently, their cost estimates are lower than those of many earlier studies,

SOURCE. Office of Technology Assessment, 1994,

sions of fossil fuels, others include emissions such as oil spills and impacts such as nuclear war.[7]

- *Categorization of effects:* Several of the studies categorize environmental effects by emissions, presenting results for SO_2, CO_2, NO_X, and other emissions and then adding them to obtain overall estimates of environmental costs (e.g., Pace, Tellus, and Chernick and Caverhill). Other studies categorize effects by type of impact such as flora, fauna, human, and climate impacts (e.g., Hohmeyer).
- *Technology specificity:* Some studies group a number of different technologies into a single category. For example, Hohmeyer's study produces only a single estimate of environmental costs for all fossil fuels. In contrast, other studies (e.g., Pace, Chernick and Caverhill) differentiate estimates based on generation tech-

[7] One study (Shuman and Cavanagh) includes the risk of nuclear war in its high-end estimates of environmental costs associated with nuclear power. They contend that use of nuclear power increases the proliferation of nuclear weapons, and proliferation increases the risk of nuclear war. Michael Shuman and Ralph Cavanagh, *A Model Conservation and Electric Power Plan for the Pacific Northwest, Appendix 2: Environmental Costs* (Seattle, WA: Northwest Conservation Act Coalition, November 1982).

nology (e.g., oil combustion turbine) and by the sulfur content of fuels.

- *Location specificity:* Some studies are specific to a particular region of the country, whereas others are intended to be more general. Highly specific studies calculate impacts based on assumptions about population densities, particularly sensitive or resistant ecosystems, or transport or deposition of pollutants. Several studies have chosen specific sites to evaluate, in order to be able to make specific assumptions about the exposed population and the surrounding ecological conditions.[8,9]

Despite these differences, it is tempting to look for common conclusions, or to average numerical results, in an effort to obtain conclusions with greater validity than those of a single study. However, the differences among the studies make it difficult to compare their results in a meaningful way. Taken together, these studies point more toward the diversity of approaches to evaluating environmental costs than toward common conclusions.

Each study is discussed briefly below. Each completed study is accompanied by a table presenting its quantitative results. The results are presented first in a way that is as close to the original study as possible—the cost figures have not been rounded or recalculated.[10] In addition to the original figures, a set of adjusted figures in 1990 dollars is given for each study to facilitate inflation-adjusted comparisons.

Additional discussion of methodological issues is presented in chapters 3 and 4. The studies reviewed below are used to illustrate that discussion.

Department of Energy/Commission of the European Communities

The DOE/EC study is a major ongoing study initiated in February 1991 by the U.S. Department of Energy (DOE) and the Commission of the European Communities (EC). The two organizations agreed to support a study to develop a comparative analytical methodology and the best range of estimates of external costs for eight fuel cycles and four conservation options.[11] The eight fuel cycles are coal, oil, natural gas, uranium, biomass, hydroelectric, photovoltaic, and wind. The study is expected to conclude in late 1994.

Responsibilities for the analytical work have been split between U.S. and European research teams. The teams share lead responsibilities for the nuclear study. The U.S. leads the coal, oil, natural gas, biomass, and hydroelectric studies. The EC leads the conservation, photovoltaic, and wind studies. DOE's portion of the study was contracted to Oak Ridge National Laboratory (ORNL) and Resources for the Future (RFF).[12,13] The EC organized a similar study team.

In November 1992, the U.S. contractors issued a report that summarized progress to date and detailed modifications made to the initial DOE/EC agreement.[14] The 1992 report remains the only

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8 For example, the studies by DOE/EC and BPA.

9 For an extensive discussion of this issue, and approaches to extending findings from one location to other locations, see Alan J. Krupnick, "Benefit Transfer and Valuation of Environmental Improvements," *Resources*, vol. 110, winter 1993, pp. 1-7.

10 Some analysts have recalculated cost estimates so that they refer to a set of standard power plants. No such recalculation was attempted here. For an example of such recalculation, see Jonathan Koomey, *Comparative Analysis of Monetary Estimates of External Environmental Costs Associated With Combustion of Fossil* Fuels, LBL-28313 (Berkeley, CA: Lawrence Berkeley Laboratory, July 1990).

11 The Federal Energy Regulatory Commission is also a sponsor of the U.S. portion of the study.

12 Oak Ridge National Laboratory is a federally owned, contractor-operated laboratory. Resources for the Future is an independent nonprofit organization that conducts research on the development, conservation, and use of natural resources and on the quality of the environment.

13 As with most reports contracted for by DOE, the study's conclusions will not necessarily represent the views of its sponsors.

14 Oak Ridge National Laboratory and Resources for the Future, op.cit., footnote 3.

publicly available document on the DOE/EC study. However, in January 1993, DOE circulated a draft report for peer review. In August 1993, peer review was complete and the report was returned to ORNL and RFF for modifications. The coal-specific report is expected to be issued in September 1994, with the remaining reports (on oil, natural gas, hydroelectric, biomass, and nuclear) to be completed by the end of 1994.[15]

The DOE/EC study is not completed, but many details of its methodology are available. The study is using damage cost approaches (see chapter 3)-one of the first times damage costing has been used exclusively in a major study of the environmental costs of electricity. Its component reports plan to cover a broad range of fuel cycles and stages of energy production (e.g., mining, transportation, use, and waste disposal). Each fuel cycle report will focus on one or two actual plants, in an effort to produce specific and defensible results.

New York State

The New York State study is a major ongoing study that began in December 1991. It was undertaken in response to an order from New York Public Service Commission, and its goal is to develop a methodology and computer model that will permit estimation of environmental costs. The model will apply to new electricity generating plants, relicensed plants, and electricity demand management options in the state of New York.

The study is a joint effort of four organizations: the New York State Department of Public Service, the New York State Energy Research and Development Authority, the New York State electric utilities through the Empire State Electric Energy Research Corp. (ESEERCO), and the Electric Power Research Institute (EPRI).[16] The latter three organizations are funding the $1.75-million project.

The project is managed by a five-member board of representatives from the four organizations and one representative from Resources for the Future, an independent expert selected by the four other members. The management board directs the work of two contractors: the research contractor (RCG/Hagler, Bailly, Inc.) and the coordinating contractor (Industrial Economics, Inc.).

The project will produce four separate reports: 1) a critical review of existing research that screens a large number of possible emissions and impacts, 2) a recommended methodology, 3) a computer model and manual, and 4) case studies that represent applications of the model. The first report was completed in December 1993 and became available to the public in May 1994.[17] The other reports are expected to be finished by the end of 1994.

The first report screens different possible environmental effects for inclusion in the final computer model. The report reviews a large number of emissions and impacts, and it categorizes them based on initial judgments of the size of their associated damages and their ability to be accurately quantified. Later reports will concentrate on the emissions and impacts judged to be both large and amenable to quantification.

Among the studies reviewed by OTA, the New York State study is unique because of its intended output. The study will produce a software-based model that runs on personal computers. The software will permit users to modify the values of model parameters (e.g., levels of emissions and costs per unit of emission) and will produce estimates based on those values. All other studies reviewed in this report provide only a printed

[15] Paul Carrier, Department of Energy, personal communications, January, April, May, and July 1994.

[16] EPRI's participation is limited to the first phase of the study (see below).

[17] RCG/Hagler, Bailly, Inc., "New York State Environmental Externalities Cost Study Report 1: Externalities Screening and Recommendaions," ESEERCO Project EP91-50, December 1993.

report with environmental cost estimates based on a single, or at least limited, set of parameter values.[18]

Pace

The Pace study is one of the best known and most frequently cited studies of environmental costs. The study was prepared for the New York State Energy Research and Development Authority and the U.S. Department of Energy, and it was published in 1990.[19] The study is wide-ranging, covering different energy sources (e.g., coal, oil, natural gas, nuclear, renewable, waste-to-energy systems, demand-side management) and environmental effects (e.g., air and water pollution, global warming, acid rain, land use). The report also includes a brief discussion of policy tools on both the state and federal levels.

Quantitative results of the study are summarized in table 2-4. The study concludes that environmental costs associated with coal, oil, and nuclear are highest, costs associated with natural gas are somewhat lower, and costs associated with renewable sources (solar, wind, and biomass) and demand-side management are substantially lower.

The Pace study explicitly notes several classes of environmental costs excluded from the analysis, generally due to uncertainty or lack of data. For fossil fuels, it excludes greenhouse gases such as methane and N_2O; air toxics; water use, land use, and solid waste disposal; and environmental costs associated with fuel extraction, transportation, and processing. For nuclear power, it excludes extraction and transportation of uranium. Due to the exclusion of these environmental costs, the authors believe their estimates are more likely to be underestimates than overestimates.

The Pace study summarizes, critiques, and evaluates much of the existing literature. These estimates are then combined to produce illustrative estimates. However, the authors note that some of the studies they reviewed were inadequately documented and substantively deficient. The authors caution that the quantitative results of the study should not be cited as definitive estimates, but rather indicate the order-of-magnitude of results and should be a useful starting point for further research.

Tellus

The Tellus study represents work published in 1990 and 1991 by Stephen Bernow, Donald Marron, and Bruce Biewald of the Tellus Institute, an independent, nonprofit research and consulting organization. The Tellus work is not a single study, but instead is comprised of several estimates produced for state regulatory commissions and state energy agencies. A 1990 report summarizes this previous work and describes the estimates and methodology concisely. In addition, a 1991 journal article applies the results of the 1990 report to estimate overall environmental costs for several combinations of generating technologies and fuels.[20]

The study differs from other environmental cost studies in two important respects. First, the Tellus study only provides estimates of the costs of air emissions. Costs of other types of emissions (e.g., radiation), and impacts (e.g., industrial and transportation accidents) are not estimated. Air emissions are relevant only to the burning of fossil

[18] One study not reviewed in this report does include a computer model: Mark A. Thayer et al., *The Air Quality Valuation Model* (San Diego, CA: Regional Economic Research, Inc., Apr. 21, 1994).

[19] Ottinger et al., op. cit., footnote 2.

[20] Stephen Bernow and Donald Marron, *Valuation of Environmental Externalities for Energy Planning and Operations, May 1990 Update* (Boston, MA: Tellus Institute, May 18, 1990); and Stephen Bemow et al., "Full-Cost Dispatch: Incorporating Environmental Externalities in Electric System Operation," *The Electricity Journal*, March 1991, pp. 20-33.

TABLE 2-4: Pace's Estimates of Environmental Costs

By emission type		
Type	cost, $/lb (1989)	Cost, $/lb (1990)
SO_2	2.03	2.13
Particulate	1.19	1.25
NO_x	0.82	0.86
CO_2	0.0068	0.0071

By plant type		
Plant	Cost, $/kWh (1989)	Cost, ¢/kWh (1990)
Coal		
Existing boiler (1 .2% S)	6.8	7.1
AFBC (1 .1% S)	3.3	3.5
IGCC (0.45% S)	2.8	2.9
NSPS	4.5	4.7
Oil		
Boiler (0.5% S)	3.2	3.3
Boiler (1% S)	4.5	4.7
Boiler (2.2% S)	7.9	8.3
Combustion turbine (1% S)	3.0	3.1
Natural Gas		
Existing steam plant	1.2	1.3
Combined cycle	1.1	1.1
BACT	0.8	0.8
Nuclear	2.91	3.05
Renewab/es		
Solar	0-0,4	0-0.4
Wind	0-0.1	0-0.1
Biomass	0-0.7	0-0.7
Demand-side Management	0.0	0.0

NOTE: Values in 1989 dollars and cents are reported in the study. Values in 1990 dollars and cents are adjusted using the consumer price index The values reported above for various emission types are listed by Ottinger et al. as "rough starting points"; in several cases (SO_2, NO_x, and particulate), the authors contend that the damages "could be much higher."' Values for acid deposition, electromagnetic fields, and land and water use impacts were not estimated due to inadequate data. Most plant types for fossil fuels list the sulfur content of the fuel (e.g., 1,2% S).

The study derived values for various plant types from thevaluesfor emission types Thestudyfoundthat waste-to-energy plants were likely to have fairly large environmental impacts, but they concluded that more research was needed before a quantified estimate could be made,

KEY: NSPS = New source performance standards: IGCC = Integrated gas combined cycle: AFBC = Atmospheric fluidized bed combustion BACT = Best available control technology

SOURCE: Richard L. Ottinger et al., Pace University Center for Environmental Legal Studies, *Environmental Costs of Electricity* (New York, NY: Oceana Publications, 1990).

fuels (coal, oil, and natural gas) and these are the only sources for which Tellus generates estimates.[21] A summary of the Tellus estimates is provided in table 2-5.

Second, the Tellus study is unique because of its exclusive reliance on a valuation method known as *control costing.*[22] It derives all esti-

[21] Despite these limitations, the Tellus study is an important one to consider. It strongly defends the use of control cost approaches, and its results have influenced the actions of several state regulatory commissions.

[22] Other studies make occasional use of control cost valuation. Tellus is the only study to rely exclusively on control costing.

TABLE 2-5: Tellus' Estimates of Environmental ^

By emission type

Type	Northeast U.S. cost, $/lb (1989)	southern California cost, $/lb (1989)	Northeast U.S. cost, $/lb (1990)	Southern California cost, $/lb (1990)
NO_x	3.50	131.00	3.7	137.29
SO_x	0.75	37.50	0.79	39.30
Volatile organic gases	2,65	14.50	2.78	15.20
Particulate	2.00	24.00	2.10	25.15
CO	0.43	0.43	0.45	0.45
CO_2	0.011	0.011	0.012	0.012
CH_4	0.11	0.11	0.12	0.12
N_2O	1.98	1.98	2.08	2.08

By plant type

Plant	Cost, ¢/kWh (1990)
coal	
FGD	4.47
2.37°A sulfur	7.00
1.83°A sulfur	9.97
0.82% sulfur	6.05
Oil	
Steam, 1 .5% sulfur	5.55
Steam, 1 .3% sulfur	3.92
Steam, 1 .0% sulfur	4.08
Steam, 0.75% sulfur	3.54
Steam, 0.70% sulfur	3.86
Steam, 0.30% sulfur	4.44
Combustion turbine	6.04
Natural Gas	
Steam	2.37
Combustion turbine	4.22
Combined cycle	1.68

NOTE: Values by emission are from Bernow and Marron, 1990. Differences in cost estimates between the Northest United States and Southern California result from differences in applicable state laws. Estimates for NO_x and CO include both ambient air quality and greenhouse warming impacts; volatile organic gases include both volatile organic compounds and reactive organic gases; particulate include both total suspended particulates and PM1O. Values by plant type are from Bernowet al., 1991 (table 5) and are based on power plants operating in the Northeastern United States. FGD = flue-gas desulfurization.

SOURCES. Stephen S. Bernow and Donald B. Marron, *Valuation of Environment/ Externalities for EnergyP/arming and Operations, May 1990 Update* (Boston, MA. Tellus Institute, May 18, 1990); and Stephen Bernow et al., "Full-Cost Dispatch' Incorporating Environmental Externalities in Electric System Operation," *The Electricity Journal*, March 1991, pp. 20-33.

mates of environmental costs from the costs imposed by existing legislation.[23] It estimates the costs of compliance with existing regulations, and then uses these values to indicate a "revealed preference" of regulators—a cost that regulators are willing to impose on utility customers to control emissions. Control costing is covered in more detail in chapter 3.

[23] There is one exception. Environmental costs associated with c@ emissions were estimated using the cost of mitigating the damages from global warming.

The control costing approach used in the Tellus study results in varying estimates for the environmental costs of emissions in different areas of the country. In several cases, estimates of the environmental costs associated with air emissions in the Northeast are substantially lower than estimates for the costs associated with air emissions in Southern California. This difference results from California's more stringent emission standards. California's standards impose higher costs on utilities and their customers, thus resulting in a higher estimate of environmental costs associated with particular emissions.

Chernick and Caverhill

The Chernick and Caverhill study was produced in 1989 by Paul Chernick and Emily Caverhill of PLC, Inc.,[24] a consulting firm in Boston, Massachusetts.[25] The study was sponsored by the Boston Gas Co. and filed with the Massachusetts Department of Public Utilities. It targets issues important to New England and the northeastern United States, and is not intended to provide results applicable to the entire United States. It estimates environmental costs for coal, oil, and gas-fired generators. It makes no estimates of the environmental costs associated with other sources, such as nuclear, hydroelectric, solar, and wind power.

Chernick and Caverhill make estimates by combining several sources of information. They examine estimates from previous environmental cost studies (e.g., for $S0_2$ and NO_x),26 from information about the costs mandated by various environmental regulations (e.g., for $S0_2$ and NO_x), and from the costs of mitigation (e.g., for $C0_2$, CH_4, and marine oil spills). For each emission, they examine the range of estimates offered by each method, and then choose what they feel to be a plausible value.

The study estimates values for two general categories of environmental effects: air emissions ($S0_2$, NO_x, $C0_2$, and CH_4) and marine oil spills. In addition, estimates are made of the environmental costs associated with the macroeconomic effects of oil imports. The report also lists a set of other environmental costs as identified, but not quantified: additional air emissions (air toxics, CO, particulate, and ozone) and a variety of noncombustion-related environmental costs (e.g., electromagnetic radiation, pesticide use on transmission rights-of-way, water and thermal pollution, indoor air pollution, and accidental injuries and deaths in extraction and transportation).

Table 2-6 presents a summary of the study's results on environmental costs. The report contends that estimates of environmental costs are more likely to be underestimates than overestimates. Overall, the study estimates the environmental costs associated with natural gas to be somewhat lower than those associated with coal and oil.

Hohmeyer

The Hohmeyer study was published in 1988 by Olav Hohmeyer, then an economist and deputy head of the Department of Technical Change at the Fraunhofer-Institute for Systems and Innovation Research in the Federal Republic of Germany.[27] It was sponsored by the Commission of the European Communities.

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24 The company is now named Resource Insight, Inc.

25 Paul Chernick and Emily Caverhill, PLC, Inc., "The Valuation of Externalities From Energy Production, Delivery, and Use: Fall 1989 Update," A Report to the Boston Gas Co., Dec. 22, 1989. Although entitled an "update," this report is the primary document referred to by other studies and analysts in the area, and appears to contain the primary methodological content.

26 In particular, Chernick and Caverhill use several studies conducted for the Bonneville Power Administration (BPA) (see below). In many cases, the authors adapt the BPA calculations to add effects they feel were left out of the original calculations.

27 Olav Hohmeyer, *Social Costs of Energy Consumption: External Effects of Electricity Generation in the Federal Republic of* Germany (Berlin, Germany: Springer-Verlag, 1988).

[redacted] [redacted]

By emission type		
Type	**Cost, $/lb (1988)**	**Cost, $/lb (1990)**
SO_2	0.88	0.96
NOx	1.50	1.64
CO_2	0.011	0.012
CH_4	0.35	0.38
Marine 011 spills	o.20/MMBTU	o.22/MMBTU
By plant type		
Plant	**Cost, ¢/kwh (1988)**	Cost¢ **¢/kWh (1990)**
Coal		
Existing (1 .2% S)	5.7	6.2
AFBC	3.8	4.1
IGCC	3.2	3.5
NSPS	4.9	5.3
Oil		
Existing steam plant (0.5% S)	3.6	3.9
Existing steam plant (1% S)	4.3	4.7
Existing steam plant (2.2% S)	5.8	6.3
Combustion turbine (0.3% S)	5.0	5.5
Natural Gas		
Existing steam plant	1.9	2.1
Combined cycle	1.9	2.1
NSPS	1.6	1.7
BACT	1.28	1.40

NOTE MBTU = 1,000 BTU Values in 1988 dollars and cents are reported in the study. Values in 1990 dollars and cents are adjusted using the consumer price index Values are specific to the Northeast. The authors felt that the values reported above are "more likely to be understated than overstated " (p 96) Values for many other classes of costs were not estimated, due to their inability to quantify them with any certainty

Valuesforod-fired generators were adjusted to *exclude* an oil import premium that was included in the report's final estimates This premium reflects the national economic cost of oil imports It includes costs associated with vulnerabilities to interruptions and price swings, increases in inflation, and deterioration of the balance of payments In contrast to every other effect estimated, the 011 import premium is nonenvironmental.

The study derives values for for various plant types from the values for emission types. In addition to the combustion-related emissions, 00007 pounds of NO_x were included for each source to account for emissions during transportation No cost estimates were made for some combustion emissions (air toxics, CO, particulates, and ozone) and for some noncombustion related effects (e g., electromagnetic radiation, solid waste generation, water and thermal pollution, and accidental deaths and injuries).

Values for new coal and gas plants (NSPS, IGCC, AFBC, and BACT) are specific to New England

KEY. NSPS = New source performance standards, IGCC = Integrated gas combined cycle; AFBC = Atmospheric fluidized bed combustion, BACT = Best available control technology.

SOURCE Paul Chernick and Emily Caverhill, PLC, Inc , "The Valuation of Externalities from Energy Productlon, Delivery, and Use: Fall 1989 Update, " A Report to the Boston Gas Co , Dec. 22, 1989.

The study is specific to the Federal Republic of Germany. However, it is worth considering because it is widely cited and generated substantial interest in the United States when it was released. Its methodology is explained fairly carefully in the text of the study, and Hohmeyer maintains the general approach is valid for any market-based economy.

The study explicitly compares renewable energy resources, such as solar and wind, with conventional energy sources, such as coal and nuclear. It focuses on costs in the following categories: environmental effects, subsidies, depletion of nonrenewable resources, and public expenditures (R&D support, induced expenditures, and subsidies).

TABLE 2-7: Hohmeyer's Estimates of Environmental Costs

	Envirwwnental effects by plant type	
Plant	**Cost, DM/kWh (1982)**	**Cost, ¢/kWh (1990)**
Fossil fuels	0.0114-0.0609	0.78-4.153
Nuclear	0.0120-0.1200	0.82-8.18
Solar	**0.0044**	**0.30**
Wind	O.0001	**0.007**

NOTE: Values in 1982 Deutsche Marks are reported in the study. Values in 1982 cents were converted using a conversion rate of 2DMn — a rough value suggested by Hohmeyer during presentations on the study. Values m 1990 dollars are adjusted using the consumer price index. Values are specific to the Federal Republic of Germany. Values for some classes of effects were not estimated. Estimates for nuclear reactors excludes breeder reactors.

Values presented here are for environmental costs only, Estimates of public expenditures and resource depletion costs that are included m the study are not included in this table.

SOURCE: Olav Hohmeyer, Social *Costs of Energy Consumption: External Effects of Electricity Generation in the Federal Republic of Germany* (Berlin, Germany: Springer-Verlag, 1988).

Its cost estimates are based on several sources. Some estimates come directly from other studies that value specific categories of effects (e.g., human health effects of air pollution). Other estimates involve direct calculations based on damages (e.g., estimating the probability of, and health effects from, a nuclear accident and multiplying by the monetary value of a life). Finally, a few estimates involve the costs of mitigating environmental damages (e.g., the costs of avoiding the effects of sea level rise brought on by global warming).

The study explicitly notes several classes of environmental costs are not quantified. These include "psycho-social" costs of deaths and illness, health care costs, species loss, environmental effects of intermediate goods used to produce and operate energy systems, some costs of climatic changes, environmental costs of routine operation of nuclear plants, and aesthetic and land-use effects of renewable energy. The author contends that data gaps and uncertainties (which prevented some effects from being quantified or monetized) placed renewable energy sources at a disadvantage.

Table 2-7 summarizes the quantitative results of Hohmeyer's study. Overall, the study estimates that the environmental costs of coal and nuclear power are substantially larger than those of solar and wind power. The report notes that the quantitative results should be interpreted as a first approximation that can be useful for policy. Further, the report claims that where uncertainty existed, the assumptions were least favorable to the report's eventual conclusion (that the environmental costs of renewable sources are considerably lower than those of conventional sources).

I Bonneville Power Administration

The Bonneville Power Administration (BPA) study was undertaken to comply with the provisions of the Pacific Northwest Electric Power Planning and Conservation Act, passed in 1980. The act requires the Bonneville Power Administration and the Northwest Power Planning Council to pursue a planning process that gives priority to cost-effective energy options when planning new energy generation capacity. The act requires that evaluations of cost-effectiveness include quantifiable environmental costs that are directly attributable to energy conservation measures or new energy resources.[28]

zs~is same **act** motivated a coalition of environmental, labor, ratepayer, and citizens' groups to produce a separate **study (see Shuman and** Cavanagh, below).

TABLE 2-8: BPA's Estimates of Environmental Costs

By plant type		
Plant	**Cost (¢/kWh)**	**Cost (1990 ¢/kWh)**
Coal	0.064-0.956	0.072-1.081
Oil		
Combustion turbine	**0.03**	0.04
Natural Gas		
Combustion turbine	**0.087**	0.108
Nuclear	**0.000837-0.0126**	0.001142-0.0172
Hydroelectric	**0.769-1.074**	1,049-1,465
Biomass	-0.011-0.49	-0.013-0.56
Municipal Solid Waste	-3,18-41.664	-3.66-47.9852
Geothermal	0-0.0188	0-0,0217
Solar	0	0
Wind	0	0

NOTE: The separate BPA studies differ substantially, so the estimates for different energy sources are not strictly comparable. Years of the estimates vary: coal=1987, oil and natural gas = 1984, nuclear and hydroelectric = 1982, biomass, MSW, geothermal, solar, and wind = 1986. The coal estimates are drawn from the generic, rather than the site-specific, study. Range of coal estimates reflects a range of possible plant locations; range of nuclear estimates reflects a range of possible valuation techniques; range of hydroelectric estimates reflects a range of possible valuation techniques and discount rates; range of biomass, municipal solid waste, and geothermal estimates represents uncertainty in effects and valuation. Negative values indicate a net environmental benefit. Estimates reported here only include the studies' estimates of environmental costs and benefits, not estimates of socioeconomic and infrastructure costs and benefits that are included in some of the studies. In addition, the damages associated with the consumptive use of water are not included in the nuclear estimates.

SOURCES: ECO Northwest et al., "Generic Coal Study: Quantification and Valuation of Environmental Impacts," report commissioned by Bonneville Power Administration, Jan. 31, 1987; ECO Northwest et al., "Final Report: Economic Analysis of the Environmental Effects of the Coal-Fired Electric Generator at Boardman, Oregon," report commissioned by the Bonneville Power Administration, Dec. 29, 1983; ECO Northwest et al., "Estimating Environmental Costs and Benefits for Five Generating Resources," report commissioned by the Bonneville Power Administration, March 1986; Biosystems Analysis, Inc., "Final Report: Methods for Valuation of Environmental Costs and Benefits of Hydroelectric Facilities, A Case Study of the Sultan River Project," report commissioned by Bonneville Power Administration, June 1984; ECO Northwest et al., "Economic Analysis of the Environmental Effects of a Combustion-Turbine Generating Station at Frederickson Industrial Park, Pierce County, Washington: Final Report," report commissioned by Bonneville Power Administration, Mar. 26, 1984; and Nero and Associates, Inc., "Environmental Costs and Benefits Case Study: Nuclear Power Plant, Quantification and Economic Valuation of Selected Environmental Impacts/Effects," report prepared for the Bonneville Power Administration, Feb. 8, 1984.

The study consists of a set of six semi-independent studies, completed over a period of five years by three different contractors: ECO Northwest, Nero and Associates, and Biosystems Analysis.[29] The studies covered 10 different energy sources: coal (both a generic and a site-specific analysis), oil and natural gas (fueling combustion turbines), nuclear, hydroelectric, solar, wind, geothermal, biomass, and municipal solid waste. The quantitative results of the study are given in table 2-8.

[29]ECO Northwest et al., "Generic Coal Study: Quantification and Valuation of Environmental Impacts," report commissioned by Bonneville Power Administration, Jan. 31, 1987; ECO Northwest et al., "Estimating Environmental Costs and Benefits for Five Generating Resources," report commissioned by the Bonneville Power Administration, March 1986; ECO Northwest et al., "Economic Analysis of the Environmental Effects of a Combustion-Turbine Generating Station at Frederickson Industrial Park, Pierce County, Washington: Final Report," report commissioned by Bonneville Power Administration, Mar. 26, 1984; ECO Northwest et al., "Final Report: Economic Analysis of the Environmental Effects of the Coal-Fired Electric Generator at Boardman, Oregon," report commissioned by the Bonneville Power Administration, Dec. 29, 1983; Nero and Associates, Inc., "Environmental Costs and Benefits Case Study: Nuclear Power Plant, Quantification and Economic Valuation of Selected Environmental Impacts/Effects," report prepared for the Bonneville Power Administration, Feb. 8, 1984; and Biosystems Analysis, Inc., "Final Report: Methods for Valuation of Environmental Costs and Benefits of Hydroelectric Facilities, A Case Study of the Sultan River Project," report commissioned by Bonneville Power Administration, June 1984.

Although the studies are similar in the broad outlines of their methodology, they vary substantially in a number of factors, including the emissions considered and the specific valuation approaches used. As a result, the cost estimates associated with the energy sources cannot be compared with each other in the same way as estimates made by other studies.

| Shuman and Cavanagh

The Shuman and Cavanagh study was prepared in 1982 by Michael Shuman and Ralph Cavanagh of the Natural Resources Defense Council. It was prepared as part of a larger report-a comprehensive proposal for future power development in the Pacific Northwest-sponsored by the Northwest Conservation Act Coalition, an umbrella organization for 38 environmental, labor, ratepayer, and citizens' groups in the Pacific Northwest.[30] The environmental cost estimates are contained in appendix 2 of the larger report.[31]

The study examines some of the most significant environmental impacts of five different energy options: coal, nuclear, wind, solar water heating, and household weatherization. It estimates costs for occupational and public exposure to emissions; property and crop damage from emissions; occupational and nonoccupational accidents in extraction, transportation, and generation (including catastrophic nuclear accidents); and nuclear proliferation. The study does not address a variety of potential environmental costs such as water consumption, recreation losses, fish and wildlife mortality, aesthetic damage, and impacts from transmission and distribution facilities.

A summary of the study's quantitative findings is shown in table 2-9. Overall, the study estimates that the environmental costs of solar, wind, and weatherization are less than one-tenth of those associated with coal and nuclear. The authors believe their analysis to be conservative-the assumptions made in the study are least favorable to the eventual conclusions of the study (that coal and nuclear have high environmental costs relative to solar, wind, and conservation).

The study's explicit aim is to compare renewable sources of energy, such as solar and wind, with conventional sources such as coal and nuclear. The study's estimates of solar and wind were done largely in a relative way. For example, the health impacts of solar and wind were estimated by using the estimate for nuclear (excluding accidents, radon emissions, and proliferation). This decision reflected the authors' belief that the primary environmental costs of solar and wind were due to the construction of a large energy-producing facility and that those risks were similar for nuclear, solar, and wind. The study assumes that few environmental impacts are reflected in the economic costs of energy use, and that most environmental costs should be treated as economic externalities.

In their analysis, Shuman and Cavanagh felt it was best to preserve uncertainties in the range of estimates offered, rather than in what classes of environmental costs were included. As a result, they quantify environmental costs some other studies typically leave out. For example, estimates of coal environmental costs include the health effects and property damage resulting from climate change. These effects account for more than half of the total costs at the high end of the range that Shuman and Cavanagh give for coal power. Similarly, estimates of nuclear environmental costs include the health effects and property damage resulting from nuclear accidents, radon release, and weapons proliferation. These effects account for more than 99 percent of the high end of the range given for environmental costs associated with nuclear power.

SoRalph Cavmagh et ~]., A M~el Electric power and Consemation plan *for the Pacijc Northwest (Seattle,* WA: Northwest Conse!_vation Act Coalition, November 1982).

31 Shumm and Cavmagh, op. Cit., foomote 7.

TABLE 2-9: Shuman and Cavanagh's Estimates of Environmental Costs

By plant type

	Cost, ¢/kWh (1980)		Cost, ¢/kWh (1990)	
Plant	Midpoint range	Full range	Midpoint range	Full range
Coal	2-3	0.03-20.68	3-5	0.05-35.31
Nuclear	*2-3*	*0.05-30.24*	*3-5*	*0.09-51.64*
Solar and Wind	0-0.12	—	0-0.20	—
Weatherization	0	—	0	—

NOTE: Values in 1980 dollars are reported in the study. Values in 1990 dollars are adjusted using the consumer price index. Values are specific to the Pacific Northwest. Values for some classes of costs were not estimated.

SOURCE: Michael Shuman and Ralph Cavanagh, *A Model Conservation and Electric Power Plan for the Pacific Northwest, Appendix 2: Environmental Costs* (Seattle, WA: Northwest Conservation Act Coalition, November 1982).

COMPARING STUDIES

The final results of environmental cost studies cannot be validated, in the sense of being able to compare them with some objective reality. Other types of studies can, at least in principle, be compared with measurements of actual phenomena. For example, energy demand forecasts can be compared with actual demand experienced at a later date; models that estimate environmental transport of pollutants can be compared with measured concentrations of those pollutants. In contrast, environmental cost studies produce final results that cannot be compared with anything except results of other studies.

The difficulty with validating environmental cost studies places special importance on the ability to compare the results of several studies. This section discusses several conclusions based on a comparison of the studies reviewed in this chapter.

Estimates are Not Independent

None of the studies summarized above contain only original research. All of the studies assemble smaller studies of individual components such as the health impacts of particulate, the value attached to a human life, and the willingness to pay for pollution-free wilderness.[32] In addition, some analysts adapt calculations used in other studies to suit their own purposes. Studies nonetheless require substantial work on the part of their authors: they must develop an overall structure for the study; they must locate, critique, and select original studies; and they must combine those studies in a rigorous and defensible way.

This prevailing approach of assembling smaller pieces means that each study does not represent an independent estimate of environmental costs. The estimates, assumptions, and methods of one study are often used in subsequent studies, albeit in modified form. The body of literature on environmental costs thus represents an evolving set of related estimates rather than a set of completely independent ones.[33]

In addition, environmental cost studies are not always estimating the same thing. Each study has its own definition of what constitutes an environmental cost and its own assumptions about how the cost should be estimated. As a result, any two studies may actually be estimating quantities whose definitions only partially overlap.

These features of environmental cost studies have important implications for how the studies' quantitative estimates are used. When viewing a set of quantitative estimates, there is a temptation

[32] In a few cases, the studies conducted original research to supplement the other, smaller studies that they assembled to estimate environmental cost. For example, the BPA site-specific hydroelectric study conducted original valuation research.

[33] This should not be construed to mean, necessarily, that the externalities literature is converging on a single set of estimates or that more recent studies are always superior to older ones.

TABLE 2-10: Methods of Categorizing Environmental C

Method	Examples	Studies using as a major categorization method
Energy source	Coal, oil, nuclear, photovoltaics	Pace, Tellus, Chernick and Caverhill; Hohmeyer, BPA, Shuman and Cavanagh
Activity	Mining, transportation, fuel processing, generation, waste disposal, energy use	BPA (coal), Shuman and Cavanagh
Emission	$S0_2$, $C0_2$, NO_x, particulate, heat, noise	Pace, Tellus, Chernick and Caverhill
Impact	Human health, quality of life, climate, flora, fauna	Hohmeyer, BPA (coal and hydro), Shuman and Cavanagh
Manifestation	Species extinction, global warming, cancer	Shuman and Cavanagh

NOTE: It maybe possible to retrospectively apply different categorization schemes to published studies based on data they contain. However, for a study to be listed in the rightmost column, the method must be used explicitly in the study to organize the reported results, The DOE/EC and New York State studies are excluded because they are not yet completed,

SOURCE: Office of Technology Assessment, 1994.

simply to average the values, assuming that each value is an independent estimate of the same quantity. These conditions do not hold for the environmental cost estimates discussed in this chapter, and the estimates should not be averaged. Instead, individual studies need to be examined and their estimates compared.

| Studies Categorize Costs Differently

Unfortunately, interstudy comparisons are often problematic. Environmental cost studies employ a wide variety of methods for categorizing environmental costs (see table 2-10). Each method provides a different view of environmental costs. A single activity, such as the emission of carbon dioxide from a coal plant, can be categorized by many different characteristics, including the medium of the emission (air), the phase of the fuel cycle (generation), and the energy source (coal).

The differing categorization schemes employed by different studies make comparisons difficult. Nearly all studies categorize results by energy source (e.g., coal, nuclear, and hydroelectric). However, the components that make up these overall estimates are important to examine, and this is made substantially more difficult when the components are reported using different categorization schemes.

For example, the Pace study reports environmental costs associated with particular emissions (e.g., CO_2, SO_2, NO_x particulate) and then combines these with quantity estimates to estimate the environmental costs associated with each fossil fuel energy source (e.g., coal, oil, natural gas). In contrast, the BPA generic coal study categorizes effects by impact (e.g., human health, crops, livestock, timber, materials, ecosystems, and visibility).

If studies use a common framework, comparisons are easier. Analysts and readers could compare several studies side by side to understand their similarities and differences. In addition, a consistent framework allows researchers to alter an existing study to incorporate new data or assumptions. However, no categorization of environmental costs fits perfectly for all environmental effects and all technologies.[34]

Differences in categorization are understandable, given the diverse conditions and purposes under which the studies were assembled. How-

[34]Stirling, op. cit., footnote 4.

ever, the differences force policy makers to view existing studies as independent units of analysis, rather than flexible tools whose assumptions and numeric values can be interchanged to fit the policy makers' particular circumstances or interests. In contrast, the results of at least one pending study (New York State) will be embodied in computer software, which will allow many parameters of the study to be changed easily, although its basic structure will remain fixed.

One Effect Category Often Dominates

Although studies categorize environmental effects quite differently, a single category dominates most estimates of environmental cost. Specifically, in the eight studies reviewed by OTA, 55 quantitative estimates were produced that were broken down into several categories of effects. Of these, 46 (84 percent) had single categories that accounted for the majority (i.e., 50 percent or more) of the total estimate.[35]

For example, Pace makes estimates for 15 different generating technology and fuel combinations. Within each estimate, the study categorizes effects by emission (e.g., $S0_2$, NO_x, particulate, and $C0_2$). Pace produced an estimate of 4.72 cents/kWh for the environmental cost associated with coal plants meeting the new source performance standards (NSPS). In the case of this estimate, the effects associated with $S0_2$ accounted for 2.95 cents/kWh, or more than 60 percent of the total estimate.

There is some consistency in the effects that dominate. Three studies (Pace, Tellus, and Chernick and Caverhill) estimate costs for fossil fuels and categorize effects by emission. When a single category dominates in an estimate from these studies, the category is either $S0_2$ or $C0_2$. Similar conclusions are difficult to draw for nuclear and renewable energy sources because the studies are often less specific about how they categorize effects for these energy sources.

This dominance of single effects has important implications for policy makers. It points to the potential for environmental cost studies to be used for setting priorities. Although studies with different frameworks of assumptions may differ in their quantitative estimates of environmental costs, if there is agreement on dominant effects then the studies may provide valuable guidance for where legislative and regulatory efforts should be focused. Important questions of priorities would still remain, of course, including how to balance environmental programs against other important federal priorities, but focusing environmental efforts effectively is still an important victory.

Cost Estimates are Highly Variable

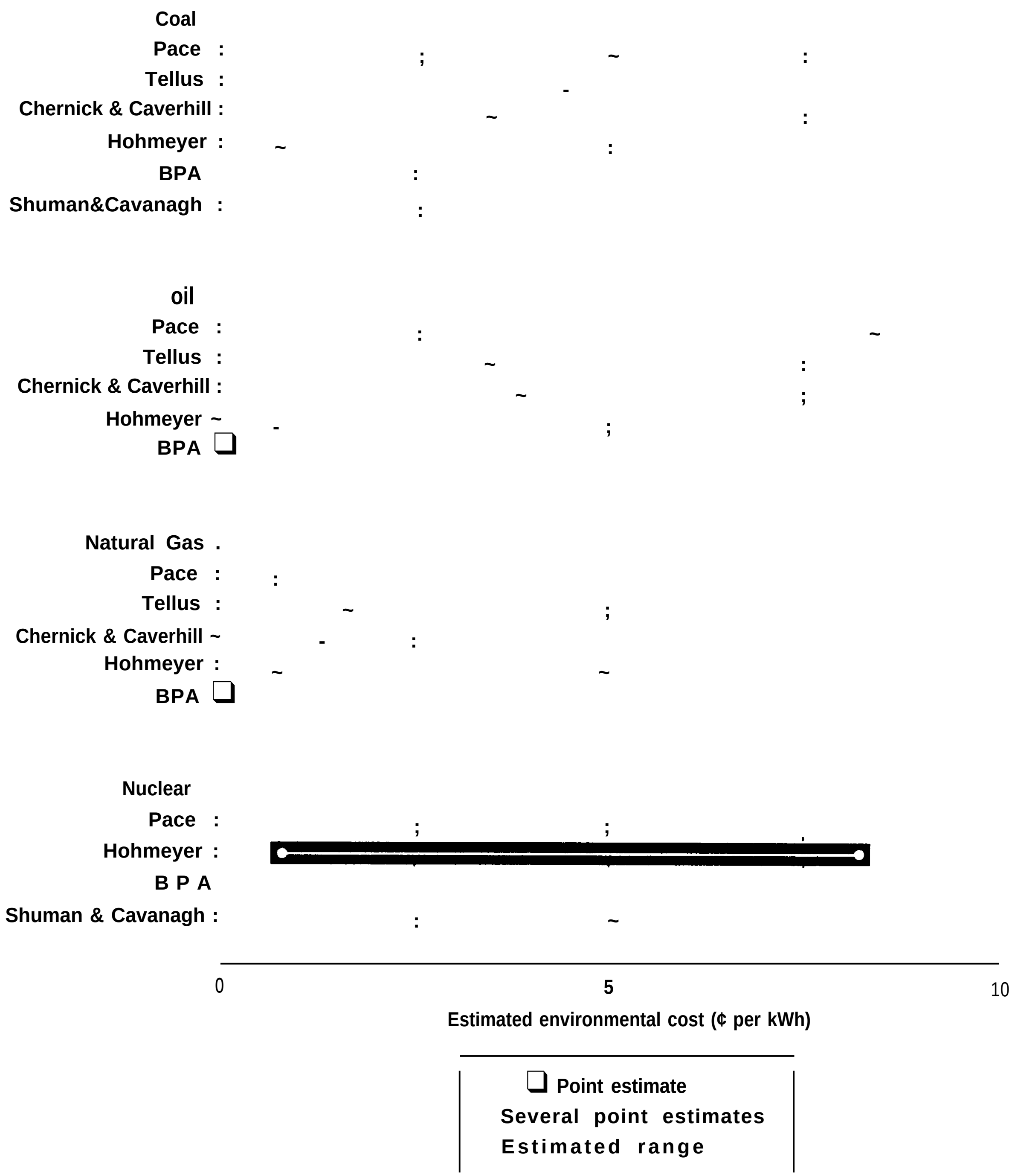
In some cases it is possible to compare results of different environmental cost studies .[36],[37] Despite these differences in categorization, rough comparison of results is still possible (see figures 2-2 and 2-3). Comparing these results indicates wide variation in cost estimates. Some estimates of environmental costs are nearly zero. In other cases, estimates are as high as 10 cents/kWh-costs that are larger than the electricity rates that average consumers currently pay. The wide variation in

[35] None of the studies actually make this calculation. The OTA numbers are derived by employing the primary categorization method used by each study. In some cases, not all of the estimates in the particular study were counted. For example, the BPA hydro study contained a wide range of estimates, but only two (the high and low estimates) were included in the 55 estimates used for this calculation. Similarly, estimates that include only a single category of effects were not counted. For example, Hohmeyer's estimate of nuclear environmental costs is based solely on accidents. This estimate was excluded from the 55 estimates used in the calculation.

[36] Nearly all studies produce results categorized by energy source (e.g., coal, nuclear, and solar). Even these results are categorized and reported indifferent ways. Hohmeyer presents one overall estimate for "fossil fuels," three studies (BPA, Shuman and Cavanagh, and Chernick and Caverhill) make distinct cost estimates for each fossil fuel source (coal, gas, and oil), and the remaining completed studies (Pace and Tellus) produce further distinctions among several different combinations of combustion technology and fuel.

[37] As noted earlier, some analyses have attempted to adjust for differences among the studies attributable to different technical assumptions, such as the heat rates and emission factors of power plants. For example, see Koomey, op. cit., footnote 10.

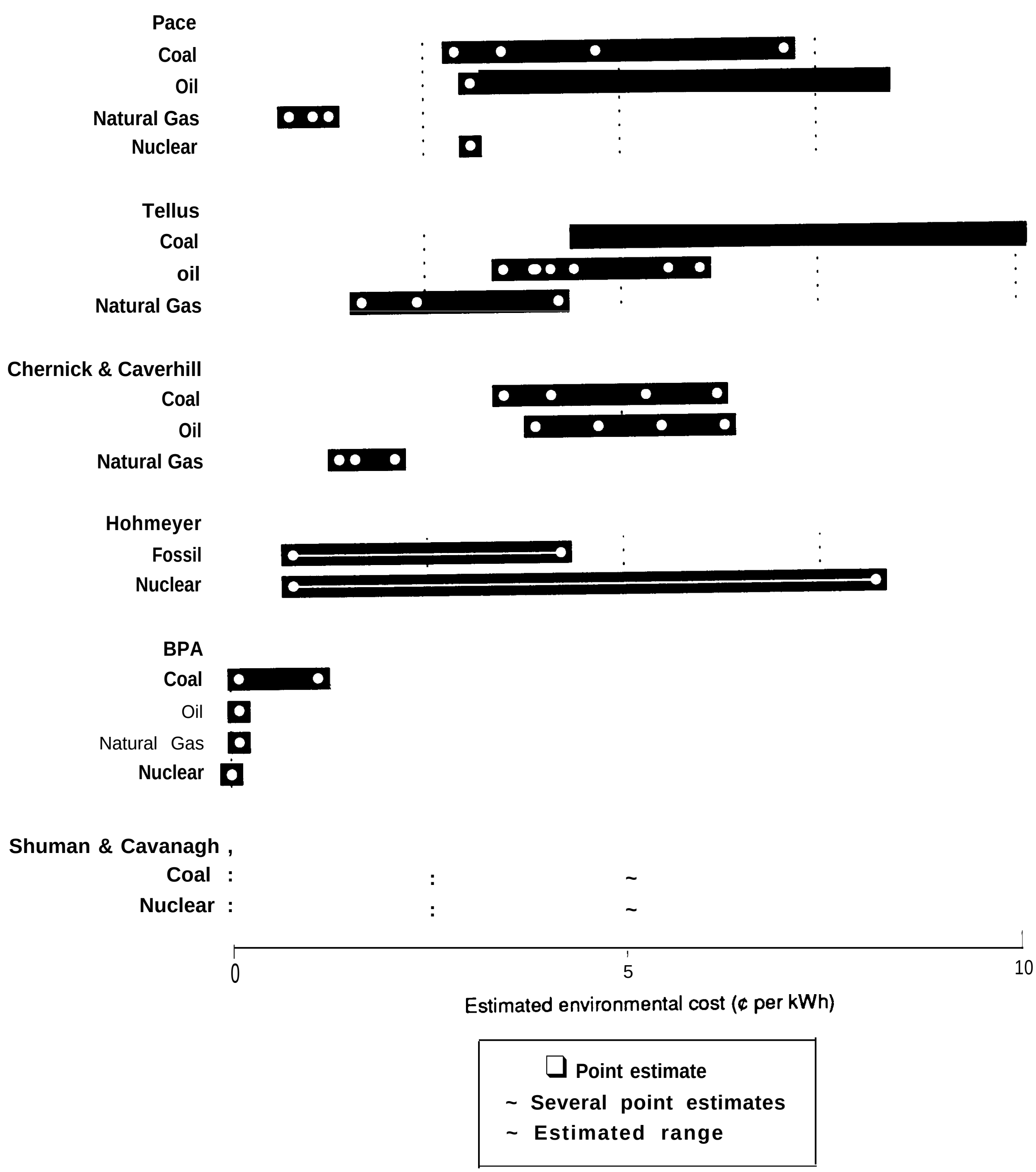
FIGURE 2-2: Results of Environmental Cost Studies Vary Widely (listed by generating technology)



NOTES: See text for full description of the difficulty of comparing environmental cost estimates, When several point estimates are given, each estimate is for a different specific generating technology (e.g., combustion turbine) or specific fuel (e g., oil with 1 % sulfur content). Hohmeyer gives only one estimated range for all fossil fuels (coal, oil, and gas). The Shuman and Cavanagh estimates are the "best estimate" ranges, Costs are given in 1990 cents per kilowatt-hour. Not all results are shown for each study.

SOURCE: Office of Technology Assessment, 1994

FIGURE 2-3: Results of Environmental Cost Studies Vary Widely (listed by study)



NOTES See text for full description of the difficulty of comparing environmental cost estimates When several point estimates are given, each estimate is for a different specific generating technology (e g , combustion turbine) or specific fuel (e g., 011 with 1 % sulfur content). Hohmeyer gives only one estimated range for all fossil fuels (coal, 011, and gas) The BPA estimates should not be directly compared because the individual studies used different methods and assumptions. The Shuman and Cavanagh estimates are the "best estimate" ranges. Costs are given in 1990 cents per kilowatt-hour Not all results are shown for each study quantitative estimates demonstrates there is no consensus about cost estimates among currently published environmental cost studies.

Cost Estimates are Highly Uncertain

Due to a variety of analytical difficulties and unknowns, all of the studies are cautious in their presentation of numerical estimates. First, some studies present broad ranges of possible values rather than specific numeric estimates (often called "point estimates"). For example, Hohmeyer, BPA, and Shuman and Cavanagh all use this method. Shuman and Cavanagh even go so far as to produce a "midpoint range" indicating values they think are most likely, and a "full range" for coal and nuclear indicating values they think are possible. Where ranges are presented, they are often quite large. The Hohmeyer high and low estimates vary by a factor of about five in the case of fossil fuels and 10 in the case of nuclear. Shuman and Cavanagh's full range high and low estimates differ by more than a factor of 500.

Second, some studies produce a point estimate and then attempt to evaluate the uncertainty associated with that estimate. Where uncertainty is evaluated, it is often quite large. For example, several of the BPA studies evaluate the uncertainty to be as large or larger than the estimate itself, indicating that the actual cost could be nearly zero or as much as twice the point estimate.[38]

Finally, most studies are careful to label their results "preliminary." This is due to various data gaps, uncertainties, methodological disputes, and the early stage of development of environmental cost analysis. Based on uncertainty estimates and cautions contained in the studies, and based on the large differences in the results of different studies, prospective users of environmental cost studies should assume that all estimates are highly uncertain and preliminary.

Conclusion

Many of these issues—independence, categorization, variability, and uncertainty-are closely related to the valuation phase of environmental cost studies. This phase takes quantitative estimates of environmental impacts and attempts to value them in monetary terms. Other study phases also bear on the issues discussed above, but valuation introduces additional dimensions and complications. The different methods of valuation are discussed the next chapter.

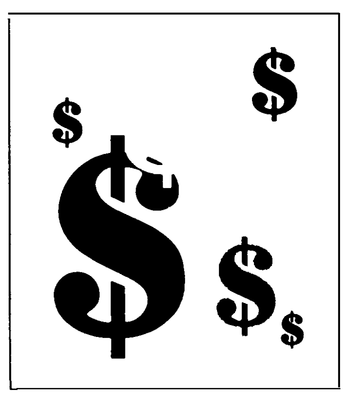
38 Specifically, the cost estimates for coal, oil, and natural gas are accompanied by uncertainty estimates. For coal, the standard deviation is estimated to be equal to the estimate itself. For oil and gas, the two standard deviations are estimated to be equal to the estimate itself. The standard deviation is a statistical quantity indicating the variability of an estimate. For a normal (or "bell shaped") distribution, approximately 95 percent of the possible values lie within two standard deviations of the mean value (the center of the distribution).

Methods for Valuing Environmental costs 3

Valuation is a method used in environmental cost studies to assign monetary values to the environmental effects of electricity production. Examples include finding the value individuals attach to reducing the risks of coal mining, improving urban air quality, or assuring clear visibility.

Valuation is a particularly important method to understand. Although environmental cost studies raise many other important methodological issues in addition to valuation (e.g., human risk assessment, extrapolation from animal studies, and estimates of transport and deposition of environmental pollutants), these methods have been well reviewed by other reports and are amenable to further scientific research. In contrast, disputes about valuation methods are relatively new to policy makers and appear less amenable to resolution by additional research. Differing assumptions of analysts strongly affect the choice to use monetary valuation at all, the choice of valuation method, and the way that method is applied. Because there is little or no consensus on these assumptions, valuation lies at the root of much of the controversy over the study and use of environmental costs.

At least five valuation methods are used in current environmental cost studies.[1] *Market valuation* uses existing market prices to estimate damages. *Contingent valuation* elicits estimates from consumers by the use of survey techniques. *Hedonic valuation* examines existing market prices to detect implicit valu-



1 All of these techniques assume a goal of *monetary* valuation. This almost always has been the goal of environmental cost studies. In theory, however, a study could analyze the "costs" of electricity generation in a more general, noneconomic sense. For additional discussion, see the section in chapter 4 on quantification and monetization.

ation of environmental factors by consumers. *Control cost valuation* examines existing regulatory decisions to detect implicit valuation of environmental factors by government regulators. *Mitigation cost valuation* examines the cost of repairing environmental damages to estimate the value of preventing such damages from occurring. Each valuation method is detailed in the following sections.[2]

MARKET VALUATION

In some cases, environmental impacts from energy production affect things that are bought and sold, and thus have a market price. For example, hydroelectric facilities can reduce salmon populations by hindering the upstream migration of adult salmon to spawn and the downstream migration of juvenile salmon toward the ocean. One method of estimating the cost of a reduced salmon population is to multiply the reduction by the market price of salmon.

Market valuation is used in several studies. For example, the Pace study uses market prices to value the corrosive impact of air pollution on materials and the potential property damage from a large nuclear accident. Similarly, the Bonneville Power Administration (BPA) studies use market valuation in several contexts, including valuing impacts on agriculture, fur trapping, and commercial forestry.

Market valuation has the advantage of relying on data that are readily available and fairly uncontroversial. Care must be taken to find prices that apply to the specific losses associated with energy generation (e.g., prices appropriate to the specific crops grown where emissions have their greatest impacts), but this difficulty is fairly easy to overcome.

Market valuation also has some subtle pitfalls. Market costs may be distorted because, like energy prices, they may not include all relevant costs. Many individuals would contend that forests have higher value than the commercial value of the timber, and that the value of some animal life is higher than the market price of their pelts. There is no generally accepted method to account for these effects, and attempting to do so could involve an analysis as large as the original environmental cost study. As a result, most studies that use market valuation do not attempt to adjust market price data to account for them.

The major limitation of market valuation is that not all environmental impacts of energy affect things that are bought and sold in markets. The value of items such as visibility, preservation of endangered species, and health impacts cannot be estimated using market valuation.[3] This limitation has led to the use of several other valuation techniques.

HEDONIC VALUATION

Hedonic valuation examines existing market prices for evidence of the value placed on particular environmental effects. For example, one way to estimate the value of a recreational area is to examine the travel costs borne voluntarily by those who visit the area. Similarly, one way to estimate the value associated with personal safety is to compare the wages of workers in hazardous occupations with those in occupations that are safer, but otherwise similar.

Several studies use hedonic valuation to estimate the value of environmental impacts. For example, the BPA studies for coal, oil, and gas use estimates that infer the value of visibility from property values. Pace uses those estimates as well. Similarly, the BPA hydroelectric study uses estimates based on the travel costs of hunters to value the loss of deer in the area to be flooded by a dam.

[2] This chapter is meant to introduce readers to various valuation techniques, not to be a detailed methodological critique. Detailed examinations of each method can be found in footnoted references in each section.

[3] "Visibility" refers t. the presence or absence of haze often produced by burning fossil fuel. Visibility problems are most commonly encountered over urban areas, but also have become an issue in scenic vistas such as those around the Grand Canyon.

Like market valuation, hedonic methods have the advantage of deriving from choices made by consumers. This avoids problems that may stem from inaccurate self-reporting--i.e., problems caused by individuals who say they place a particular value on an environmental impact, but who do not act consistently with that belief (seethe discussion of contingent valuation below).

Unlike market valuation, however, hedonic methods must adjust for all factors that influence price other than the object of study. For example, to determine the value of visibility by using property values, analysts must account for all the other reasons property values may vary (e.g., quality of home, access to services, proximity to workplaces). Although statistical techniques exist to account for these other influences, there are a great many practical and theoretical pitfalls to avoid.

In addition, prices may not accurately reflect how people value environmental effects. For example, wage differentials may not accurately reflect risks to workers. First, workers may be unaware of risks they face, and they may not demand higher wages to account for increased risk. Second, workers may be unable to bargain effectively to make their wages adequately compensate them for their risks. Barriers to job mobility may limit the opportunities of high-risk workers to change positions or occupations.[4]

CONTINGENT VALUATION

Contingent valuation (CV) consists of surveying individuals directly about the value they attach to environmental damages. A typical survey provides a respondent with information about a hypothetical program that will prevent future harm to the environment. The respondent then is asked how much he or she would be willing to pay, individually, to bring the program into existence. The questions can be couched in several different forms, such as a direct question, a series of questions about hypothetical economic tradeoffs, or a referendum—asking respondents whether they would vote for a particular tax increase to fund the program. In each case, the goal is to elicit an economic value that the individual attaches to the program, in as realistic a way as possible.

CV could be used to estimate willingness to pay for almost anything, including goods that are actively bought and sold in markets. However, the technique's greatest use is for estimating the value of goods and services that are not bought and sold in markets. Specifically, CV can be used to estimate what are called *non-use values (see* box 3-1).

CV has been actively studied for about 20 years. In the past five years there has been a dramatic increase in the number of academic studies and presentations on the topic,[5] and several comprehensive texts exist.[6] CV also has been employed in a variety of environmental cost studies. For example, the BPA hydroelectric study estimates the value of old-growth forest impacts by contingent valuation. The BPA oil and gas study uses evidence from contingent valuation studies to estimate the value of visibility. This estimate, in turn, is used by Pace. Finally, both the DOE/EC and the New York State studies expect to make use of CV to estimate the value of several environmental impacts that cannot be valued easily in other ways.

CV has some distinct advantages over other methods. First, it is the only method that can evaluate non-use values. As noted in box 3-1, non-use values can bean important source of environmental cost data. Second, citizens, not experts, produce the evaluation. Proponents of CV are quick to point out that the method has a strong undercurrent of democratic decisionmaking. Private citi-

[4] John P. Holdren, *Integrated Assessment for Energy-Related Environmental Standards: A Summary of Issues and Findings*, LBL-12779 (Berkeley, CA: Lawrence Berkeley Laboratory, October 1980).

[5] Kenneth Arrow et al., "Report of the NOAA Panel on Contingent Valuation," Jan. 11, 1993.

[6] For example, see Robert C. Mitchell and Richard T. Carson, *Using Surveys To Value Public Goods: The Contingent Valuation Method* (Washington, DC: Resources for the Future, 1989).

BOX 3-1: Non-Use Values

Some environmental resources are regularly used by individuals or groups. For example, wilderness **areas provide recreation for hikers and hunters—recreation that may be curtailed if the areas are harmed. The worth of this recreation is referred to as a "use value, " because individuals benefit from actually** using the wilderness area. Attaching monetary figures to use values can be challenging, but involves well-recognized principles in economics.

In addition to use values, economists have come to recognize that a person may value something, even if he or she does not intend to use it. This "non-use" value, also known as "passive-use" value, measures the worth ascribed to something that is *not* used. Non-use values have been divided into at least three categories: 1) option value-the value of preserving a resource for potential future use. For example, even though someone may not be considering an immediate visit to the Grand Canyon, he or she may wish to preserve the option for a future visit; 2) bequest value-the value of preserving a resource for future generations. Even though an individual may never expect to visit the Grand Canyon, he or she may wish to preserve that option for future generations; 3) existence value-the value of "knowing the resource exists. " Some individuals attach a value to the existence and protection of a resource, even if they never expect anyone to use it.

Non-use values have engendered substantial controversy, One reason is the difficulty of assessing them. Use values can be measured by an individual's behavior-how far a person travels to use a recreation area, for example. By definition, non-use values involve few outward signs. Surveying individuals about the value they place on environmental resources-called *contingent valauation* (CV)-generally is recognized as the only method of assessing all types of non-use values. Because the results of CV are difficult to check against behavior, observers are skeptical of their results

Another focus of controversy is the claim that non-use values can represent moral and ethical concerns. Some economists claim that individuals' responses to CV surveys represent more than just preferences that are commonly linked with market choices (e.g., tastes and fashion); in addition, they also represent moral and ethical beliefs of the individual. Others, such as philosopher Mark Sagoff, argue that such ethical and political choices are distinct from the preferences considered by economists and cannot be treated in the same way. These writers argue that economic preferences are concerned with personal benefit and are best resolved within markets; ethical choices are concerned with community good and are best resolved in a more public forum.

To summarize, few participants in environmental cost debates deny that non-use values exist, but there is substantial disagreement about how to measure non-use values reliably and about their proper role in public decisions.

SOURCES: Mark Sagoff, "Environmental Economics: An Epitaph," Resources, No. 111, spring 1993, pp. 2-7; Raymond J. Kopp, "Environmental Economics: Not Dead But Thriving, " Resources, No. 111, spring 1993, pp. 7-1 2; Oak Ridge National Laboratory and Resources for the Future, *U. S.-EC Fuel Cycle Study: Background Document to the Approach and Issues*, Report No. 1 on the External Costs and Benefits of Fuel Cycles: A Study by the U.S. Department of Energy and the Commission of the European Communities, ORNL/M-2500 (Oak Ridge, TN: Oak Ridge National Laboratory, November 1992).

zens, not experts who may be detached from the interests of the public, are asked to value the programs. This puts some of the decisionmaking power in the hands of those who ultimately will pay for the environmental control and mitigation programs (through taxes and/or higher product prices).

CV is far from universally accepted, however, and several criticisms have been made. First, results vary with how the questions are asked. Relatively subtle differences in wording, in the order questions are asked, or in the supporting evidence given, can substantially affect the answers of respondents. Second, some results are not consistent with basic tenets of economic theory. Economists expect that the value of a certain quantity of goods will increase as that quantity increases. For example, if someone is willing to pay a dollar for an apple, they should be willing to pay substantially more than a dollar for two apples. Respondents in CV studies have not always behaved as economists expect. In one study, the average willingness to pay to prevent 2,000 migratory birds from dying was as great as that for preventing 20,000 or 200,000 birds from dying.[7]

Third, studies sometimes appear to produce unreasonable answers. Some critics have argued that CV results should be dismissed merely because the implied value of environmental damages, when aggregated on a national level, are unreasonably large.[8] One reason for these large values is that respondents lack a meaningful budget constraint and the need to consider tradeoffs. Although respondents might report they are willing to spend $100 to prevent future oil spills, they may fail to account for all the other environmental programs they might be asked to fund or other, nonenvironmental uses for their funds. Particularly when such responses are hypothetical, as they are in CV, respondents may not meaningfully consider what expense they will forego to pay for such a contribution. One study estimating willingness to pay for protecting the Alaskan coast from oil spills showed that estimates varied substantially depending on whether such values were discussed independently ($85) or in the context of overall government spending ($0.29).[9]

Fourth, respondents may give "strategic" answers to survey questions that are intended to influence public agencies. A respondent might believe that, by stating a high value, he or she can encourage state or federal agencies to undertake the programs described in the survey. Alternatively, respondents may believe that, by stating a low value, they will reduce or avoid a future tax increase to pay for such programs.[10]

Finally, respondents may not fully understand or trust the information provided by the survey. The responses requested on CV surveys are unlike typical choices made by consumers. Environmental effects have impacts that go far beyond the respondent in both time and space. Evaluating environmental effects deals with topics (e.g., ecology, biology, atmospheric science) that are unfamiliar to most respondents, and few respondents have had the opportunity to see the effects of previous choices. Respondents also may not trust the given information. They may react based on an overall belief about environmental reporting (e.g., "those environmental problems are always exaggerated" or "the damage always ends up to be worse then we're initially led to believe"). In any of these cases, respondents may not be answering the question given, and they may not produce an accurate assessment of their willingness to pay.

To summarize, CV studies are subject to a variety of biases that are potentially troubling, and care needs to be taken in the design, conduct and reporting of studies. However, CV studies can

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[7] Arrow et al., op. cit., footnote 5.

[8] For example, see Charles J. DiBona, "Assessing Environmental Damage," *Issues in Science and Technology,* fall 1992, pp. 50-54.

[9] Charles River Associates, "Methodological Biases in Valuing Environmental Resource Damage," *CRA Review, December* 1992, pp. 1-4.

[10] Arrow et al., op. cit., footnote 5.

produce useful information for evaluating environmental costs, and CV appears to be the only method to assess non-use values, a potentially important component of these costs.[11]

CONTROL COST VALUATION

Control cost valuation infers the value of environmental impacts by examining the pattern of public decisions recorded in regulations, laws, and court rulings. By determining the cost of the controls mandated by these decisions, and their benefits in terms of environmental effects, the dollar value of those effects can be estimated. Control cost valuation is also termed "shadow pricing" or "revealed preference" valuation.

For example, the Tellus study uses control cost valuation to estimate the environmental cost associated with various air emissions, including NO_x, SO_x, and $C0_2$. To estimate each of these costs, the Tellus study takes cost estimates for various pollution control technologies whose use is mandated by federal or state regulation. The study then divides these costs by the emissions reductions (in pounds) that the technologies achieve. This calculation produces a cost per pound figure that is used as an estimate of the environmental cost per pound of emissions.

The major advantage of control cost valuation is its simplicity. Control costs can be calculated merely by dividing the cost of mandated controls by the emissions reduction achieved by the controls. The data for these two numbers are relatively uncontroversial and easy to obtain. In contrast, alternative methods require tracing emissions from generation (e.g., $S0_2$ from a coal plant), through intermediate pathways (acid rain), to eventual environmental impacts (forest damage). Then the impacts must be valued. That process introduces many uncertainties and potential analysis problems.

However, analysts point to a variety of failings associated with control cost valuation. First, it is criticized as representing circular reasoning. Many analysts believe one important goal of environmental cost analysis is to compare the costs and benefits of environmental regulations. If the cost of regulations (i.e., cost of environmental control technologies) is used to estimate the benefits (i.e., environmental costs avoided), then a meaningful comparison of costs and benefits is impossible. This argument is explored in more detail in chapter 4.

Second, control costs can vary widely. Studies of cost per life saved have indicated large variations in the values implied by the costs and benefits of different regulations. Critics of control cost valuation use this variation as evidence of problems with the method. If the values vary so widely, then regulations clearly do not represent a rigorous weighing of costs and benefits. However, some supporters of control cost valuation are not so troubled by these variations. Supporters argue that control costs indicate the *minimum* costs regulators are willing to impose. Because of this belief, studies that use control costs valuation often use the *highest* cost of control. 12

MITIGATION COST VALUATION

Like control cost valuation, mitigation cost valuation attempts to infer environmental costs from the costs of responses to environmental damage. In contrast to control cost valuation, however, mitigation cost valuation does not examine costs imposed by current regulations. Instead, it examines *prospective* mitigation costs under the presumption that additional environmental impacts

[11] These conclusions are supported *by* a review by the National Oceanographic and Atmospheric Administration's (NOAA) Panel on Contingent Valuation. The NOAA Panel's report gives a variety of guidelines for conducting accurate and useful CV studies. Arrow et al., op. cit., footnote 5.

[12] Paul Chernick and Emily Caverhill, PLC, Inc., "The Valuation of Externalities from Energy Production, Delivery, and Use: Fall 1989 Update," A Report to the Boston Gas Co., Dec. 22, 1989, p. 7.

should be avoided. Mitigation can involve reversing damages (e.g., treating diseases or replacing damaged goods) or intervening between intermediate and final environmental effects (e.g., "liming" mountain lakes to reverse the effects of acid rain).

Several studies use mitigation costs to estimate environmental costs. The Pace study uses mitigation costs to estimate the costs of $C0_2$ emissions—an area where cost estimates are notoriously difficult. It examines the costs associated with growing forests to capture and sequester carbon. Similarly, the Hohmeyer study uses mitigation costs to estimate the cost of $C0_2$ emissions. It estimates the costs of bolstering Germany's coastal defense works (e.g., dams and locks) to avoid the effects of an increase in worldwide sea levels that are thought to be one effect of global warming.

Mitigation cost and control cost valuation both have the advantage of simplicity and the disadvantage of being viewed as involving circular reasoning (see chapter 4 for details) .13

CONCLUSION

The differences among valuation techniques have been a source of substantial debate and controversy in the analytical community. The differences involve the types of evidence considered. Market and hedonic methods look at the purchasing decisions of individual consumers in actual markets, control cost valuation examines the decisions of government regulators, and contingent valuation examines the answers of survey respondents.

Perhaps the most contentious and long-standing debate over valuation methodology has been between supporters of valuation methods that are grouped under the label of *damage costing (i.e.,* market, hedonic, and contingent valuation) and valuation methods grouped under the label of *control costing* (i.e., control cost and mitigation cost valuation). This debate continues to dominate many discussions of environmental cost studies. It is covered in greater detail in chapter 4.

The debate over these differences sometimes obscures a basic fact: all valuation approaches involve assumptions about the legitimacy and appropriateness of different types of evidence. These decisions often depend on questions that are beyond the scope of an individual study, and instead depend on broad policy goals and how environmental cost studies are used to support those goals. This is the topic of the next chapter.

[13] One form of mitigation costing avoids the problem of circular reasoning. Studies that examine consumer behaviors intended to mitigate environmental effects (e.g., purchasing bottled water to avoid drinking potentially contaminated water) can indicate the value they assign to avoiding the environmental effect. However, most use of mitigation costing involves prospective actions intended to keep environmental resources in their current condition.

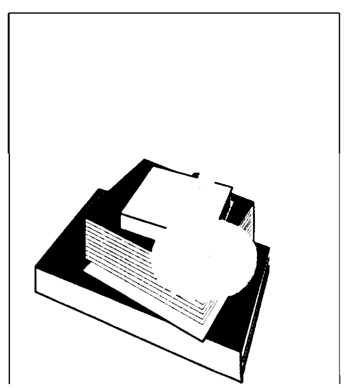
Assumptions in Environmental Cost Studies

4

The assumptions underlying any environmental cost study strongly influence both the overall structure of the study and its quantitative results. Varying assumptions can include or exclude entire classes of environmental effects from consideration. For example, the assumption that studies should evaluate only relatively certain effects could exclude the potential effects of CO_2 emissions on global climate. For effects that are included in a given study, different assumptions can lead to dramatically different numerical estimates of the value of those effects. For example, monetized estimates of damage to wilderness areas can vary greatly depending on the valuation technique. If a study uses only the commercial value of the area's timber, then the damage estimate may be quite low; if the study includes non-use values, recreation impacts, and endangered species impacts, then the estimate may be much larger.

Assumptions are an integral part of any environmental cost study.[1] This does not mean the studies are intentionally biased. Rather, every environmental cost study is conducted within a general framework of assumptions and values. When these frameworks are the focus of social and political debate, environmental cost studies can become the focus of substantial controversy—as they have in some cases.

Underlying assumptions are a particular problem in environmental cost studies. Estimating environmental costs requires



[1] Some studies are more explicit than others about identifying their value frameworks. For example, the Department of Energy/Commission of the European Communities (DOE/EC) study explicitly discusses the basis of the economic framework that it uses. Although it does not discuss this framework within the context of competing frameworks, it makes its own framework reasonably clear.

using results from many other types of environmental studies, including studies of emissions generation, transport, deposition; environmental impact; risk assessment; and economic valuation. Because of this broad scope, environmental cost studies face a vast array of vexing problems that have emerged in the past two decades of research in biology, engineering, economics, and social science (see table 4-l).

Because environmental cost studies employ the results of these smaller studies, they necessarily take on their assumptions and uncertainties, and then add assumptions and uncertainties of their own. As a result, studies of environmental costs are likely to require a larger number of assumptions, to yield results with greater uncertainties, and to engender more controversy than studies of more limited scope.

There is no clear agreement about the most relevant set of assumptions, and this lack of agreement is reflected in how actual studies are conducted. Different environmental cost studies use different assumptions about how to define environmental costs, how to value environmental effects, and how to handle uncertainty. The lack of agreement is discussed in numerous critiques of published studies. Economists, ecologists, regulators, and others frequently argue over the propriety of assumptions made in specific studies.

Several existing reviews of environmental cost studies examine these assumptions at some level of technical detail.[2] These critiques are useful to analysts who are interested in improving the methodology of future studies and to policy makers who wish to evaluate the findings of an individual study. However, from the standpoint of using these studies in federal policymaking it is important to realize that *all* environmental cost studies make assumptions that affect their results, and these assumptions often involve fundamental questions that lie within the purview of policymakers rather than analysts. These questions include:

- *What is the goal of environmental policy?* Environmental cost studies are most frequently associated with the goal of economic efliciency. Other implicit and explicit goals assumed in environmental cost debates include equity, sustainability, and protection of health and safety. *What is the role of environmental cost studies in energy policy? These* studies can be used to quantify economic corrections to energy markets, facilitate compensation for environmental damages, or guide government regulation to protect health or encourage sustainability.
- *How is value determined?* Valuation can be based on consumers acting in markets, legislators and regulators acting in political systems, scientists studying ecological systems, or government oflicials acting in legal settings.

A few reviews of environmental cost studies discuss the studies' underlying assumptions and values.[3] Many of the concepts in those reviews are discussed in this chapter. In addition, several other reviews of related areas have concluded that differences in assumptions underlie many of the disputes over quantitative studies of environmental issues (see box 4-1). Reviews of the health effects of air pollution, the economics of salmon preservation efforts, and the risks of the herbicide alachlor all identify the importance of studies' underlying values and assumptions.

Despite the findings of these reviews, explicit discussion of the fundamental questions that underlie the assumptions of environmental cost studies, and even a recognition that these ques-

[2] For example, see, Richard L. Ottinger et al., Pace University Center for Environmental Legal Studies, *Environmental Costs of Electricity* (New York, NY: Oceana Publications, 1990); Staff of the Federal Energy Regulatory Commission, *Report on Section 808: Renewable Energy and Energy Conservation Incentives of the Clean Air Act Amendments of 1990* (Washington, DC: December 1992).

[3] For example, Andrew Stirling, "Regulating the Electricity Supply Industry by Valuing Environmental Effects: How Much is the Emperor *Wearing, ''Futures,* December 1992, 1024- 1047; John P. Holdren, *Integrated Assessment for Energy-Related Environmental Standards: A* Summary *of Issues and* Findings, LBL-12779 (Berkeley, CA: Lawrence Berkeley Laboratory, October 1980).

TABLE 4-1: Fields and Selected Research Areas Used in Environmental Cost Studies

Fields	Selected rasearch araas
Economics	Determinants of value; methods of discounting.
Psychology	Perceived risk; accuracy of survey responses.
Biology and toxicology	Extrapolation of human health effects from animal studies.
Epidemiology	Health effects of pollutants.
Ecology	Systemic effects of pollutants; determinants and importance of biodiversity.
Sociology and anthropology	Cultural variations in value ascribed to environmental resources.
Atmospheric science	Transport and deposition of pollutants; long-term effects of carbon dioxide emissions.

SOURCE Off Ice of Technology Assessment, 1994

tions are important, is often absent from environmental cost analysis. Instead, the studies deal with the details of implementing the assumptions (e.g., the sources of data, the calculation techniques, and the intermediate results). Even if a study's authors discuss its assumptions at length, a technical analysis is unlikely to resolve the issues involved. In general, environmental cost studies *reflect,* rather than *address,* the political and social debates over these questions.

This chapter illustrates how many of the most controversial methods and assumptions of environmental cost studies are related to more fundamental questions. It discusses several major issues in environmental cost analysis and presents an overall framework to help organize and explain different sets of assumptions.

ISSUES AND UNDERLYING ASSUMPTIONS

Decisions about valuation and other methodologies do not take place in a vacuum. Such decisions are made in the context of assumptions about the goals of policy, the intent of the study, and what valuation is intended to achieve. Such assumptions become clearer in the context of debates over particular methodological issues. This section discusses selected issues, outlines the positions taken by different analysts, and identifies assumptions that lie at the core of each debate. Although other important issues may exist, the issues discussed here illustrate the importance of assumptions to the conduct and findings of environmental cost studies.

Quantification and Monetization

Environmental cost studies inevitably consider a collection of disparate effects. For example, evaluating the environmental costs associated with coal may involve combining occupational deaths and injuries from coal mining, chronic health effects of power plant emissions, ecological damage from global warming, property damage from acid rain, and resource depletion resulting from burning fossil fuels. Without a common set of units, these effects cannot easily be compared with each other or with the costs of controlling them-decisionmakers are left comparing "apples and oranges."[4]

The approach generally taken in environmental cost studies is to express all environmental effects in numeric form (quantification) and then to con-

[4]There is a growing body of work about decisions involving multiple objectives that cannot be easily compared (e.g., see Ralph L. Keeney, *Decisions With Multiple Objectives: Preferences and Value Tradeoffs* (Cambridge, England: Cambridge University Press, 1993). Several utilities are considering techniques that involve weighting and ranking impacts without explicit monetization (Robert L. San Martin, U.S. Department of Energy, personal communication, July 7, 1994). However, existing environmental cost studies do not employ these techniques.

BOX 4-1: Other Studies on the Importance of Values and Assumptions

Several independent studies have concluded that values and assumptions are fundamental to quantitative evaluations of environmental effects. Some of these studies are directly relevant to energy because they deal with a subset of the issues considered in environmental cost studies of energy (e.g., air pollution from fossil fuels and salmon losses from hydroelectric generation). To the extent that these smaller studies are strongly influenced by values and assumptions, then the results of energy studies will be as well. Other studies deal more generally with environmental effects of non-energy activites (e.g., alachlor),

The Health Benefits of Air Pollution Control

In 1989, the Congressional Research Service (CRS) undertook an extensive review of the health benefits of air pollution control within the context of the Clean Air Act (CAA). The study involved a review of literature, six CRS-contracted assessments of current knowledge and methods, and a colloquium at which the authors and commentators discussed the studies and their implications. The study concludes:

> . . . it is not currently feasible to produce an unambiguous evaluation of the health benefits of controlling air pollution . . . Estimates vary greatly, for two primary reasons: First, scientific uncertainties and data limitations necessarily result in estimates based on interpolations, projections, and assumptions. Second, the different professional orientations, personal values concerning environmental quality, and varying interpretations of the goals and procedures of the CAA lead assessors to differing views on what benefits mean, how they can be validly estimated, and what assumptions to make in the face of major uncertainties.

Endangered Species Act and the Pacific Northwest Salmon

Since 1984, researchers at Resources for the Future (RFF), a Washington-based independent research organization, have been studying the effects of hydropower on salmon populations in the Pacific Northwest. In summarizing some of RFF's recent experience with economic assessments of the costs and benefits of salmon preservation and restoration efforts, three researchers concluded:

> Traditional analyses do not easily capture or suitably address many of the different values associated with species preservation, ways-of-life, job-security, community stability, etc., particularly with the reductionist approach characteristic of most natural and social sciences . . . It is clear that all disciplines and much scientific analysis rest on a set of values which shape the focus and methodology of the analysis of many policy issues. The information of a single analysis is thus constrained by its value base. Particularly in the case of species preservation, the oftentimes narrowly-focused values of a reductionist approach are less-than-ideal information providers to a policy problem that begs for insight into multiple values.

The Risks of Alachlor

Researchers from the Institute for Risk Research at the University of Waterloo in Canada examined the Canadian debate over the risks of the chemical herbicide alachlor. In a 1991 study, they conclude:

> the debate over the risk of alachlor is *not* primarily a debate between those who accept the verdict of scientific risk estimation and those who do not. It is not a conflict between those who understand the "objective" risks of alachlor and those who are guided by an irrational "subjective" perception of its risks. Neither is it primarily a debate within science itself. Rather, it is primarily a political debat-a debate among different value frameworks, different ways of thinking about moral values, different conceptions of society, and different attitudes toward technology and toward risk-taking itself,

SOURCES: U.S. Congress, Congressional Research Service, *Health Benefits of Air Pollution Control: A Discussion,* 89-161 ENR (Washington, DC: Feb. 27, 1989, pp. 1-2); Jeffrey B. Hyman et al., Resources for the Future, "Dollars and Sense Under the Endangered Species Act: Incorporating Diverse Viewpoints in Recovery Planning for Pacific Northwest salmon," Discussion Paper QE93-11, 1993, p. 11; Conrad G. Brunk et al., *Value Assumptions in Risk Assessment: A Case Study of the Alachlor Controversy* (Waterloo, Canada: Wilfred Laurier Press, 1991) pp. 6-7, vert those numbers to a single unit of measure such as dollars (monetization).[5] The total monetary value of an energy source's environmental effects can then be compared easily with the total costs of other sources and with the costs of controlling those effects. If all effects of an energy source can be expressed in a monetary value, then two or more electricity generating technologies can be easily compared, and the option with the lowest total cost is clearly preferable. The costs of an energy source's environmental damages also can be compared with the costs of controlling those damages—helping to decide whether additional controls are warranted. If multiple units of measurement are used (e.g., dollars, lives, and acres of forest), then simple quantitative comparison becomes difficult or impossible.

All the studies discussed in this report quantify and monetize at least some of the effects they identify.[6] Several authors note that important classes of effects were either not quantified or not monetized in their studies. For example, Pace did not produce monetized estimates for impacts from greenhouse gases such as methane (CH_3) and nitrous oxide (N_20), air toxics, water use, land use, solid waste disposal, or the extraction and transportation of fossil and nuclear fuels. Similarly, Hohmeyer did not produce monetized estimates for impacts such as the psycho-social costs of deaths and illness, health care costs, the costs of losing biological species, certain costs of climatic changes, environmental costs of routine operation of nuclear plants, and aesthetic and land-use costs of renewable energy.

All of the studies reviewed in chapter 2 monetize the damages deemed reasonable by the study's authors. However, not all studies include the same damages. Damages may be excluded because a study's authors thought a damage was unquantifiable, or because they thought it was small enough to be ignored. Nearly every study explicitly notes broad classes of environmental costs that were not monetized.

Critiques of Quantification

Environmental cost studies focus on effects that can be expressed in quantitative terms. These terms are easier to discuss and handle analytically, and they can be presented in tables and graphs. The quantified results of environmental cost studies are almost always featured prominently when the results of studies are reported in technical literature and news accounts.

Accurate quantitative results can be among the most useful outcomes of an environmental cost study. If well presented, quantitative results can communicate a study's findings clearly, and they can give readers an idea of the relative magnitude of different sources of effects that have the same units of measure. Quantitative results also can be used easily by other analysts who are building on the work of the original study.

These advantages have led many analysts to pursue environmental cost studies—to quantify important environmental effects not currently quantified and thus not included in energy decisionmaking. Their success, however, has been incomplete. A variety of effects remains unquantifiable. Most environmental effects of energy sources have consequences that cannot be quantified.

Several analysts urge caution in the use of quantification and contend that nonquantitative results of environmental cost studies are at least as important as quantitative results.[7] Focusing only on quantitative results may construe the results of studies so narrowly that the studies' main points are missed. Underlying much of the environmental cost literature, however, is a strong drive to es-

5 This approach is, almost by definition, part of an environmental cost study.

6 Other studies of the environmental effects of energy sources rigorously avoid producing monetized estimates of any kind. For example, see John P. Holdren et al., "Environmental Aspects of Renewable Energy Sources," *Annual Review of Energy, vol. 5, 1980,* pp. 241-291.

7 See footnote 3.

timate and report quantitative results, often to the exclusion of nonquantitative ones.

Some studies (e.g., Shuman and Cavanagh) make an attempt to estimate even highly speculative effects, choosing to reflect the uncertainty in the ranges of the final results, rather than not include any estimates at all. Many other studies, however, only note that certain effects were not considered.

Critiques of Monetization

Monetization attaches estimates of value (most often expressed in dollars) to environmental effects. In general, these effects first have to be quantified in some way (e.g., days of lowered visibility or numbers of acres of forest affected). Then, a monetary value is attached to the quantified effect by using a valuation technique such as contingent valuation, hedonic valuation, or control costing (for details, see chapter 3).

Supporters argue that monetization is both a useful and inevitable part of energy decisionmaking. Considering no information about an environmental effect is equivalent to setting a value of zero.[8] Considering only qualitative information about an effect is equivalent to some quantitative value, although that value is never specified.[9]

However, the difficulties of monetizing environmental effects are so great that some analysts argue against it. The argue that the important characteristics of environmental effects include not only the expected harm,[10] but also a range of other measures:[11]

- *Probability and consequences:* Although the expected harm of two environmental effects may be equivalent, the characteristics of those harms' probability and consequences may differ substantially. For example, nuclear reactor accidents represent a large portion of the environmental costs of nuclear power in some studies. Such accidents are relatively unlikely, but could have extremely large consequences if they were to occur. Other risks (e.g., mining deaths and injuries) are relatively certain and have comparably small consequences. Comparing or combining these two risks can be problematic.
- *Distribution of damages across space, time, and classes of victims:* Where, when, and to whom impacts occur can affect how risks are perceived. For example, effects such as industrial accidents are immediate and affect only workers in a particular industry; global warming may remain a problem for centuries and may affect people who received little or no benefit from the electricity generation that led to the warming.
- *Degree of personal control: The* likelihood of some effects can be reduced by actions taken by affected individuals. For example, drivers can take extra care at railroad crossings to reduce their own likelihood of being killed or injured in rail accidents. Other effects, such as air pollution, are more difficult to avoid.
- *Degree of irreversibility:* Some environmental effects are reversible, others are not. For example, reduction of agricultural crop yields can be compensated for by production elsewhere; a unique ecosystem that is severely harmed by power plant emissions may be irreplaceable.

Because there is no generally accepted method for combining all of these characteristics into a

[8] Ottinger et al., op. cit., footnote 2, p. 14.

[9] Daniel Dodds and Jonathan Lesser, Monetization and *Quantification of Environmental Impacts,* State of Washington Interagency Task Force on Environmental Costs, Issue Paper ITF-3 (Olympia, WA: Washington State Energy Office, June 1992), pp. 84-85.

[10] *Expected harm* is usually defined as the probability of an event multiplied by its consequences. For example, if an accident has a 5 percent probability of Occurnng each year and would result in 200 deaths, then the expected harm would be 10 deaths/year.

[11] Holdren, op. cit., footnote 3, p. 243; John P. Holdren, "Energy Hazards: What To Measure, What To Compare," *Technology Review,* April 1982, p. 32-39,74-75.

single number,[12] some critics argue that monetizing and aggregating environmental effects are inappropriate tasks for analysts. Deciding how to weigh the different components of environmental effects is necessarily a matter of personal values as well as technical judgment. As a result, such decisions use as much political and social judgment as they do economic and ecological data.

Most critics of aggregation are not arguing that such valuations should never be made by anyone, only that such decisions should not be made by analysts.[13] Clearly, tradeoffs between environmental harms are necessary to make, but critics argue that such decisions should be made in public forums, not in analysts' offices.

Impacts

Merely because a factor cannot be quantified or monetized does not mean it is unimportant.[14] For many conventional sources of energy, some of the environmental effects that are potentially the most damaging are the ones most resistant to convincing quantification and monetization. For example, nearly all the environmental cost studies reviewed in chapter 2 either explicitly exclude estimates of the costs of global warming or they produce estimates they regard as highly speculative. When studies do make estimates of costs associated with global warming, however, it often represents the largest single category of costs.

Unfortunately, nonquantitative results of environmental cost studies are often ignored in preference to results that can be expressed in monetary terms. Quantified results are easy to cite and summarize, whereas nonquantitative results are difficult to convey without long quotations or textual summaries. As a result, monetized results may receive more attention in news coverage and summaries aimed at policy makers.

In such cases, the inability to quantify and monetize all environmental effects may lead users of environmental cost studies to underestimate the total effects of some energy sources. If important effects of some energy source are inherently difficult to quantify and the monetized results dominate the presentation of conclusions, then the study may provide an inaccurate picture, despite solid analysis.

In addition, in studies that do not monetize all effects, far more attention must be paid to how results are presented. Such studies present results that are much more multifaceted and disparate, and thus require analysts to explore approaches to presenting complex data simply and clearly.

Underlying Assumptions

Decisions about quantifying and monetizing environmental effects reflect assumptions about the policy goals that environmental cost studies are meant to support and the process by which decisions about the environment should be made. Studies conducted within an economic framework often assume that economic instruments (e.g., pollution taxes) are the policy tool of choice. From this perspective, monetizing environmental impacts and combining them into a single value is entirely appropriate. Establishing such instruments requires that all environmental effects be summarized in a single number-the economic value of those effects. With such an estimate in hand, almost all that remains for decisionmakers is to use these values to establish appropriate economic incentives for energy producers. In studies conducted in noneconomic frameworks, there is far less agreement and less focus on specific policy instruments.

Furthermore, different analysts appear to have different assumptions about the preferred process

[12] Stirling, op. cit., footnote 3, p. 1027-1029.

[13] Holdren, op. cit., footnote 11, p. 38.

14 Holdren calls this problem "confusing things that are countable with things that count." Ibid.

for making environmental decisions. Many supporters of monetizing environmental effects argue that individual preferences (expressed as monetary values) accurately summarize the overall value of any particular effect and that these estimates can be added (either across individual people or across individual effects) to reflect the overall environmental effects of an energy source. For example, an analyst might derive the cost associated with decreased visibility from coal emissions by determining an average individual willingness-to-pay from a survey of several thousand consumers and multiplying this by the total number of persons whose visibility would be affected. By conducting a similar process for each environmental effect, the analyst would add up all the costs and derive an overall estimate of damages for coal-fired generation.

However, some critics of monetization argue that choices about the environment are inherently a public function, not an activity that can be done outside of a public forum. [15] They claim that valuing the environment involves more than individuals acting as consumers and responding to surveys that estimate their willingness to pay for environmental improvements. Choices about the environment necessarily involve individuals acting as citizens involved in public debate, airing differing viewpoints, allowing individuals to become more fully informed, and finally choosing a course of action through a democratic process. To these critics, monetization usurps a public function.

Damage Costs vs. Control Costs

Environmental cost studies differ in the valuation methods used. Valuation methods are often divided into two categories-damage cost methods and control cost methods (see table 4-2). Damage cost methods trace the effects of energy generation from emissions to eventual environmental damages. The monetary value of those damages are then estimated using market, hedonic, and contingent valuation. In contrast, control cost methods circumvent this lengthy process by assuming that current environmental regulations implicitly value the environmental damages that regulations prevent. By examining the costs that legislative and regulatory bodies impose on utilities to prevent some environmental damages, analysts can estimate the value of the remaining damages.

TABLE 4-2: Categories of Valuation Methods

Category	Methods
Damage cost	Market valuation Hedonic valuation Contingent valuation
Control cost	Control cost valuation Mitigation cost valuation

SOURCE: Office of Technology Assessment, 1994.

Control cost methods have been pursued largely on pragmatic grounds. In most cases, control costs are substantially easier to estimate than damage costs. Most analysts who use control cost methods agree that damage costs would be preferable, but they contend that estimating damage costs is often hopelessly complex. Control costs are a “second-best” solution, they argue—a way of obtaining rough estimates without the immense analytical effort required to estimate damage costs.

Several studies use control cost methods to value environmental effects. The studies by Pace, Tellus, Chernick and Caverhill, Hohmeyer, and Shuman and Cavanagh all make at least some use of control cost methods, although the extent of use varies widely (see chapter 2 for details). Of the studies reviewed in detail by OTA, only the BPA, DOE/EC, and New York State studies make use of

[15] Mark Sagoff, *The Economy of the Earth: Philosophy, Law, and the Environment* (Cambridge, England: Cambridge University Press, 1988).

damage cost approaches exclusively.[16] Control costs also are used by many state regulatory commissions that have incorporated environmental costs into utility requirements.

Critiques

Studies that have used control cost approaches have drawn heavy criticism.[17] For example, critics argue that public decisions do not represent a consistent and rigorous weighing of costs and benefits. Several studies have indicated that different regulations result in widely varying costs per life saved.[18] Such evidence is used to bolster the claim that current regulations are not economically efficient. Regulators either lack the appropriate information or, as in the Clean Air Act, are barred from considering the costs of control. Thus, critics argue, the implicit values assigned by environmental regulations are likely to be incorrect.

Supporters of control cost methods argue that, although control costing is imperfect, it represents the only currently feasible way to evaluate most costs.[19] Damage cost methods require an understanding of the emission of pollutants, the transport of those pollutants, the exposure of humans and ecosystems, and the dose/response relationship of those exposed. This multiplies the number of assumptions that a study must make and leaves room for substantial bias and error.

In addition, the same problems that afflict estimates based on control costs afflict estimates based on damage costs. For example, studies of individual judgments about risks are notorious for finding seemingly "irrational" choices.[20] These choices presumably would be reflected in purchasing decisions and survey responses and thus would afflict damage cost methods such as hedonic and contingent valuation. This has been borne out in contingent valuation surveys, where actual responses do not match the theoretical predictions of optimal consumer behavior (see chapter 3).

In fact, it is arguable that methods based on "revealed preferences," whether they be the revealed preferences of regulators (e.g., control cost valuation) or consumers (e.g., hedonic valuation), are more likely to reveal accurate answers than contingent valuation estimates. Revealed preference methods, at least, have the benefit of operating under some budget constraints and requiring real actions on the part of participants. In contrast, contingent valuation operates mainly within a hypothetical realm of what respondents *say* that they would do under the given circumstances, and past surveys have often lacked a budget constraint.

In addition to these methodological problems, however, some critics believe that control cost methods have an even greater flaw. They argue that control cost methods are not just inaccurate, but are nonsensical because they assume precisely what they should be trying to evaluate—whether current environmental regulations are economically efficient. Because the goal of evaluating environmental costs is to balance the costs and

16Many studies make only limited use of control cost valuation. For example, the pace study uses control cost valuation solely to estimate damages for CO_2 emissions. Studies such as Pace nonetheless are labeled "control cost studies" by control cost critics. During reviews of draft versions of this report, several reviewers labeled the eight studies that OTA reviewed as "damage cost studies" or "control cost studies." However, there was little agreement in the assignment of those labels.

17For example, see Paul L. Joskow, "Weighing Environmental Externalities: Let's Do It Right!" *The Electricity Journal*, May 1992, pp. 53-67; Staff of the Federal Energy Regulatory Commission, op. cit., footnote 2.

18For example, see John F. Morrall, "A Review of the Record," *Regulation,* November/December 1986, pp. 25-34.

19Stephen Bernow and Donald Marron, *Valuation of Environmental Externalities for Energy Planning and Operations 1990, May 1990 Update* (Boston, MA: Tellus Institute, May 18, 1990); Paul Chernick and Emily Caverhill, "Methods of Valuing Environmental Externalities," *The Electricity Journal*, March 1991, pp. 46-53.

20In studies of either individual or regulatory decisionmaking, the definition of "rational" or "consistent" decisionmaking is often based on expected harm (e.g., probability times consequences).

benefits of environmental controls appropriately, they argue, then using control costs as a measure of environmental benefits entails circular reasoning.[21,22] To allow balancing of costs and benefits, the estimates of these two quantities should be arrived at independently.

Impacts

There is disagreement over the impact of using control cost methods rather than damage cost methods. Supporters of control costing often argue that the methods probably *underestimate* the value of environmental effects of energy. Critics of control costing often argue that the methods vastly *overestimate* their value.

Control cost methods could underestimate environmental costs for several reasons. First, existing regulations may be an environmental "bargain" in the sense that they cost far less than the nation's citizens would be willing to pay. Just because citizens support one level of spending on environmental control or restoration does not mean they would be unwilling to support even higher costs for the same programs. In this way, control cost supporters argue, control costs represent only a lower bound on the value of environmental effects .23 In most cases, then, control costs represent an underestimate. Second, some argue that current environmental regulations systematically undercontrol environmental effects due to political reasons.[24] If this is true, then control cost methods would systematically underestimate the value of environmental effects.

Conversely, some critics claim that control cost methods may overestimate environmental costs. First, according to these critics, current regulations already overcontrol some pollutants. Using control costs for these regulations overestimates the value of the remaining emissions. Second, using the *highest* cost of control, as some studies do,[25] purposely selects for high values. These values may be too high due to ignorance or miscalculation, not because of careful evaluation about the costs citizens are willing to pay to avoid environmental damages. Using the highest cost of control, critics argue, is likely to inflate environmental cost estimates artificially.

Underlying *Assumptions*

Part of the dispute over the use of control cost approaches stems from underlying disagreements over policy goals and how environmental cost studies should be used to support those policy goals.

Critics of control costing often assume a policy goal of economically efficient regulation.[26] In this framework, consideration of environmental costs represents a way of reforming environmental regulation—in particular, of reforming current command-and-control regulations with more market-based approaches, such as emissions taxes and tradable permits. This type of reform requires a balancing of economic costs and benefits. Within such a framework, the use of control cost methods appears to be nonsensical because it equates costs and benefits-using the costs of pollution controls to estimate the benefits associated with those controls.

Outside an economic framework, however, control costing appears far more acceptable. Sup-

21 Stirling, op. cit., footnote 3.

22 Joskow (op. cit., footnote 17, p. 64) states his conclusion quite clearly: "The highest cost of control methodology is meaningless, arbitrary and capricious. It is not a second-best method for measuring environmental damages. It is absolutely worthless!"

23 For this reason, some studies (e.g., Tellus) examine the control costs based on several regulations and then use the highest one as their estimate of the value of any particular environmental effect.

24 Ottinger et al., op. cit., footnote 2, p. 42.

25 E.g., Tellus.

26 E.g., Staff of FERC, op. cit., footnote 2, p. iii, 15; Joskow, op. cit. footnote 17, pp. 54, 61.

porters of control costs genera lly are interested in policy goals other than economic efficiency. Policy goals such as protection of health and safety, sustainability, and equity do not focus on balancing costs and benefits. In addition, supporters of control costs generally are more interested in the overall ability to compare the effects of energy sources than in implementing specific market incentives.[27] From these perspectives, **control costs** appear to be a more valid method for arriving at estimates of environmental costs. The fact that they derive from existing regulations is important only in evaluating their accuracy, not their overall legitimacy.

Of course, the fact that *some* uses exist for control cost methods does not excuse their use for purposes to which they are not suited. If the goal of a particular environmental cost analysis is to balance costs and benefits, then control cost methods *would* embody circular reasoning. However, it is equally mistaken to say that control cost methods have no place whatsoever in environmental cost analyses that have goals other than economic efficiency.

Another portion of the dispute over the use of control costing stems from underlying disagreements over *who* should be empowered to make valuation decisions.[28] Proponents of control cost methods point out that the technique is merely extending the coverage of previous decisions made by elected and appointed government officials. Proponents of damage cost methods often point out that their estimates come from studies of consumers (i.e., contingent and hedonic valuation). These methods allow individual citizens to express their will more directly.

This issue demonstrates the tight links between seemingly technical issues of environmental cost studies and deeply held values about society and decisionmaking. Valuation brings out issues of how environmental problems are viewed and issues about what groups are invested with the power to make decisions that affect the health of individuals and ecosystems.

I Average Effects vs. Marginal Effects

One approach to determining the environmental effects of individual generating plants is to consider their *average* effect. For example, to determine the $S0_2$ emissions of an oil-fired plant, an analyst might find out the emissions of a random sample of generating plants and find the average number of pounds of $S0_2$ emitted per kilowatt-hour of electricity that reaches consumers. Similarly, an analyst attempting to determine the environmental impact of a pound of $S0_2$ might find the overall damages attributed to $S0_2$ emissions and then divide by the total number of pounds of the pollutant known to be emitted.

Another approach is to consider the *marginal* effect of an individual generating plant. For decisionmakers who are deciding whether to build an oil-fired plant, the relevant figure is how much $S0_2$ will be emitted by the new plant, not by the average plant that is now operating. The average figure will include old plants that are just a few years from retirement as well as new plants that were just constructed. Similarly, the environmental impacts associated with an *additional* pound of $S0_2$ maybe substantially different from the *average* damage.

These examples illustrate the difference between average and marginal effects. Economists are quick to point out that, for most decisions, it is the marginal effects that matter. For policy decisions such as building new power plants, taxing pollutants, and setting emissions limits, the marginal effects indicate what marginal benefits could be achieved by the measures.

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[27] Chernick and Caverhill, op. cit., footnote 19.

[28] Shuman and Cavanagh note: "The controversy over the 'true' value of human life may mask an intractable *moral* question about who should make the decision." Michael Shuman and Ralph Cavanagh, *A Model Conservation and Electric Power Plan for the Pacific Northwest*, Appendix 2 (Seattle, WA: Northwest Conservation Act Coalition, November 1982).

Marginal analysis does not always involve determining the emissions of new plants. Estimating the marginal cost might also be used for other purposes, such as determining which existing power plants to dispatch,[29] determining appropriate compensation for those who live near existing plants, or determining what plants to remove from service.

A special case of this problem is location specificity. Some studies attempt to produce national average estimates of the environmental costs associated with different types of generating plants. However, local conditions can vary greatly. Factors such as weather, surrounding ecosystems, and population density all are important inputs to environmental cost calculations.[30] Some studies have dealt with this problem by limiting the study to a relatively homogeneous region; for example, Shuman and Cavanagh focus on the Pacific Northwest. Other studies produce different estimates for different sites. For example, the BPA generic coal study provides six different estimates of environmental costs based on geographic location and the population of nearby cities.[31]

Critiques

Some environmental cost studies have been criticized for looking only at average effects. Critics argue this misrepresents the options available to decisionmakers. Decisionmakers (whether economic, regulatory, or legislative) can only affect energy generation *at the margin (e.g.,* by choosing what plants to construct, modify, or shut down).

The issue of marginal effects is particularly important to economists, but ecologists also argue for considering marginal effects. Ecological responses are often nonlinear.[32] Although little ecological damage may have resulted from current levels of pollution, additional amounts can have effects that are dramatically worse. Thus, ecologists argue, considering average effects of pollution may substantially underestimate the effects of some pollutants.

Most studies to date have examined average effects. In general, this has been because of the difficulty of examining marginal effects. There is great uncertainty in the estimation of average effects; marginal effects represent an even greater analytical challenge. However, a few studies have examined site-specific numbers. The DOE/EC study is focusing on specific sites in an effort to avoid this problem. Other studies have emphasized the environmental effects of *new* plants in an effort to avoid some of the pitfalls of considering average effects.

Impacts

The impact of considering average rather than marginal effects depends on the effect being examined. Considering average ecological effects probably lowers environmental cost estimates. Current levels of pollution maybe assimilated by the environment in ways that increased levels could not be. Similarly, if thresholds exist for ecological and human health effects from certain pollutants, then increasing pollutant levels might

[29] Stephen Bemow et al., "Full-Cost Dispatch: Incorporating Environmental Externalities in Electric System Operation," *The Electricity Journal,* March 1991, pp. 20-33.

[30] Ottinger et al., Op. cit., footnote 2, pp. 68-69; Alan Krupnick, "The Social Costs of Fuel Cycles: Lessons Learned," Discussion Paper QE93-04 (Washington, DC: Resources for the Future, 1993), p. 15.

[31] ECO Northwest *et a]., Generic Coal Study: Quantification and Valuation of Environmental Impacts,* report commissioned by Bonneville Power Administration, Jan. 31, 1987.

[32] In this context, *nonlinearity* refers to how an ecological system responds to different levels of pollutants. For many ecological systems, adding a certain amount of a pollutant can have a small or a large effect, depending on the current level of pollutants already in the system.

cross those thresholds, resulting in ecological and human health effects that were not present previously.[33]

The impact of considering emissions from average electric generating plants is less certain. In general, newer plants are cleaner than plants based on older technology, but plant location matters as well. A specific plant may have higher or lower emissions depending on how its location compares with that of the generating plants used in the calculations of average environmental costs.

Underlying Assumptions

Arguments about the relative merits of considering average and marginal costs rest on assumptions about the role of environmental cost studies in policy. Analysts concerned with economic efficiency are likely to focus on the importance of marginal analysis when considering power plants and other technological infrastructure. In this view, considering average costs will raise environmental cost estimates artificially because, for example, new plants are cleaner than old ones.

Analysts concerned with sustainability are more likely to focus on the importance of considering marginal effects on ecosystems. In this view, considering average costs will lower environmental cost estimates artificially because, for example, it will not account for the probability of crossing some unknown threshold-beyond which an ecological system cannot assimilate additional pollutants.

Internalization

When examining environmental costs, economists are particularly concerned with *internalization.* Every environmental cost analysis attempts to quantify environmental damages in monetary terms, but economists generally go a step further to ask whether existing environmental regulations already *internalize,* or account for, these damages (see box 2-2 for the economic theory of externalities and internalization).

Many existing environmental cost studies largely ignore the question of internalization. Of the six completed studies reviewed by OTA, none systematically considers whether current regulations have internalized some or all environmental costs. The ongoing DOE/EC study will carefully delineate between damages and externalities for each damage pathway.[34] The ongoing New York State study has determined that a few classes of environmental damages were already internalized and excluded them from further consideration.

Critiques

When reviewing environmental cost studies, utility and industry representatives often respond by citing the large number of environmental regulations with which they already comply. A large number of existing regulations control human health and environmental impacts of mining, construction, transportation, and electricity generation activities.

Some critics of current environmental cost studies argue that, if a pollutant is currently regulated, and utilities are in compliance with that regulation, then no economic externality can exist. This argument generally is made from one of two perspectives. One perspective is that current regulations accurately weigh environmental costs and benefits. This is the same assumption that some economists criticize when it is used to justify control costing. However, to the extent that current regulations *do* balance costs and benefits, it can be argued that the regulations internalize the environmental costs associated with the pollutants they regulate. An alternative perspective is that some current regulations require that pollutants be reduced to levels where no significant health effects

[33] It is possible, though probably unlikely, that considering average costs rather than marginal costs would *increase* estimates of environmental costs. For example, there may be situations where "the damage is done" and the marginal damages might be less than the average damages.

[34] Pathways are the links between *emissions* and *impacts* (see figure 2-1).

occur. For example, the criteria for setting standards under the Clean Air Act is to "protect health with a margin of safety." By this reasoning, electricity utilities in compliance with standards should not produce *any* significant health effects, let alone effects that can be considered to be externalities.

Several responses are made to the argument that current regulations completely internalize environmental costs. First, existing regulations neither eliminate environmental effects entirely, nor do they effectively balance them against control costs. Health effects remain even after regulation and those effects are not always accurately balanced against the costs of control.[35] Some argue more broadly that relatively few environmental impacts are reflected in the market costs of energy, so largely ignoring internalization is appropriate.[3G]

Second, some supporters of environmental cost studies reject a strict definition of externalities. They argue that it is important to understand the environmental effects of energy regardless of whether they are "internalized." Third, some economists argue that, in some cases, current regulations are largely irrelevant to determining externalities. Instead, studies can use the marginal environmental damages as a reasonable estimate of externalities.[37] Consistent with this conclusion, some studies, such as the Pace study, argue it is important to consider the costs of residual emissions—those emissions that remain after regulations have been imposed.

Impacts

Assuming that current regulations eliminate all externalities certainly would produce lower estimates of environmental cost. When studies assume that regulated pollutants still can produce externalities, they will include a larger number of effects than if they used a more restrictive definition. For example, risks of occupational deaths and injuries are assumed, by at least some analysts, to be compensated for by increased wages in hazardous industries. If environmental costs are defined as only those effects that are not already included in market prices, then occupational deaths can logically be excluded from total cost estimates. If environmental costs are defined more broadly as ***all*** environmental effects, however, then occupational risks should be included, and cost estimates will increase.

Underlying Assumptions

The issue of whether internalization is important depends upon assumptions of what policies environmental cost studies are intended to support. Estimating the monetary value of environmental damages associated with energy production, something all environmental cost studies do, addresses one question: What is the monetary value of the environmental effects of energy? Evaluating whether those damages are already internalized helps to address another question: What should we do about it? Both questions are important, but a study does not necessarily need to answer the second question in order to be useful.

To achieve a policy goal of economic efficiency, assessing the current degree of internalization is vital. Estimates of uninternalized environmental costs are necessary to achieving economic efficiency through economic instruments such as pollution taxes. Without analyzing the degree of

[35] Krupnick, op. cit., footnote 30.

[36] Shuman and Cavanagh, op. cit., footnote 28, p. 1.

[37] In cases where existing regulations are based on "command and control" and not economic incentives, the correct monetary amount 10 add to private costs is equal to marginal damages. A. Myrick Freeman III, et al., "Accounting for Environmental Costs in Electric Utility Resource Supply Planning," Discussion Paper QE92-14 (Washington, DC: Resources for the Future, 1992).

internalization achieved by current regulations, it would not be clear where to set pollution taxes.[38]

If, however, the intent of an environmental cost study is to support different policy goals, then the degree of internalization may be less important. For example, to inform policies concerned with equity, it would be important to know *who* is affected by pollutants, even if the effects of those pollutants are fully internalized in an economic sense. Merely because utilities are taxed for the pollutants they generate, for example, says nothing about whether those affected by the pollutants are compensated.

Thus, for purposes other than economic efficiency, it can be useful for studies to estimate the costs of environmental effects, regardless of whether those effects are already internalized. Furthermore, estimating such costs is necessary before economic externalities can be estimated. In this sense, investigating and detailing all environmental effects is useful regardless of the policy goal.

Managing Uncertainty

Environmental effects differ in the certainty with which they can be established. Some effects are fairly well understood. For example, mining accidents are a known risk of coal-fired electricity generation. Accurate statistics have been kept for decades and the frequency and magnitude of the risk are well understood. Other risks are less certain. For example, the probability and consequences of large-scale nuclear reactor accidents are still the subject of substantial debate.

How to estimate and represent uncertainty is a persistent problem for many types of quantitative studies, but it can be a particular problem for environmental cost studies.[39] The data and relationships used in environmental cost studies are often uncertain, and this uncertainty propagates throughout the study and affects the final results. Furthermore, uncertainty tends to increase as the study moves from inputs to final results (e.g., from emissions to valuation).

Systematic treatment of quantitative uncertainty is not easy. The uncertainty of each piece of input data must be assessed, and then these uncertainties must be combined in a credible way. Analytical methods that combine uncertainties often make fairly large assumptions (e.g., that the uncertainty associated with one piece of input data is independent of the uncertainty associated with others). Even with these assumptions, however, the combination of many uncertain inputs is analytically challenging.,[40,41]

Critiques

Analysts differ on how to handle uncertainty. Some analysts argue for a restrictive stance on which effects to include. They exclude uncertain effects because they are too speculative and are likely to artificially inflate estimates of environmental costs. Other analysts are fairly liberal about which effects to include. They include un-

38 An added complication is that internalization represents a moving target. Environmental laws and regulations are frequently altered, SO an analysis can become outdated quickly.

39 However, uncertainty is not unique to environmental cost studies. Other areas of utility planning and regulation encounter this problem as well. Paul Chernick, *From Here to Efficiency: Securing Demand-Management Resources, Volume 5, Quantifying the Benefits of Demand Management* (Boston, MA: Resource Insight, Inc., January 1993).

@For additional discussion of this problem, see M. Granger Morgan and Max Henrion, *Uncertainty: A Guide to Dealing With Uncertainty in Quantitative Risk and Policy Analysis* (Cambridge, England: Cambridge University Press, 1990).

41 The DOE/EC study is making an extensive effort to rigorously deal with uncertainty. The approach used in the study is intended both to allow quantitative uncertainty estimates and to provide qualitative information to potential decisionmakers. See Oak Ridge National Laboratory and Resources for the Future, *U. S.-EC Fuel Cycle Study: Background Document to the Approach and Issues*, Report No. 1 on the External Costs and Benefits of Fuel Cycles: A Study by the U.S. Department of Energy and the Commission of the European Communities, ORNL/M-2500, November 1992, pp. 2-23-2-26.

certain effects because of concerns about grossly underestimating the true effects of energy production. Finally, some studies give a range of estimates, reflecting different thresholds of uncertainty.

For example, studies differ in whether they consider potential damages from global warming caused by greenhouse gas emissions. Some studies, such as the New York State study, have concluded that the uncertainties of estimating damages associated with CO_2 are so great that they will not attempt an estimate and will instead assign a default value of zero.[42] Other studies, such as Shuman and Cavanagh, assign a highly uncertain value to the damages, varying between zero and more than half of the total damages associated with coal generation.

Many current environmental cost studies do not systematically consider uncertainty throughout their calculations. In general, the studies make point estimates of potentially uncertain data and uncertainty is only discussed in the report's text, not indicated in the reports' quantitative results .43 Point estimates are rarely rounded to reflect their rough level of accuracy.

Impacts

A study's approach to uncertainty can have significant effects on results. Including uncertain environmental effects can only increase the estimates of environmental costs. Ignoring the issue of uncertainty may make the studies useless from a policy standpoint. If the cost differences between energy sources are significantly smaller than the range of uncertainty of the estimates, then the estimates will be of little value. Whether this is true of current estimates is difficult to say, given the way in which many current studies handle uncertainty. Readers are left with a clear idea of the studies' "best guesses," but little quantitative idea of the possible range of results.

Underlying Assumptions

Approaches to resolving uncertainty vary greatly and rest at least partially on value judgments of the analysts involved. For some, a lack of evidence indicates relative safety—if risks were present, then research would have indicated their presence. To others, a lack of evidence indicates how little is known about potential risks—if information is lacking, then research may be overlooking important risks.[44]

For example, a recent survey of 22 experts on the economic impact of global warming demonstrates the different reactions to uncertain evidence.[45] Quantitative studies are unable to predict the consequences of global warming with a high degree of certainty, so the survey sought to collect the subjective estimates of various experts. Their collective judgment might produce estimates of impacts to be used in quantitative models. However, the survey indicated afar more interesting result. The subjective estimates of different groups varied widely: mainstream economists expressed little concern about potential impacts and were confident that human societies would adapt handily to the changes. In contrast, natural scientists expressed great concern about potentially large and irreversible destruction of life-sustaining ecosystems.

Discounting

Discount rates are used to compare economic costs and benefits that occur at different times. A

42 RCG/Hagler, Bailly, InC., "New York State Environmental Externalities Cost Study Report 1: Externalities Screening and Recommendations," ESEERCOPro@ctEP91 -50, December 1993, p. iii. The study's computer model will allow users to insert their own value for CO_2 damages.

43 When the DOE-EC studies are released, they may be an important exception.

44 Harold P. Green, "The Risk-Benefit Calculus In Safety Determinations," *George Washington University Law Review*, vol. *43, No. 3*, March 1975, pp. 791-808.

45 William D. Nordhaus, "Expert Opinion on Climatic Change," American *Scientist*, January-February]994, pp. 45-51.

positive discount rate indicates that a cost of $10 that will be incurred in five years is worth less than $10 today. How much more depends on the discount rate. For example, if the discount rate is 3 percent, a $10 expenditure five years in the future is only equivalent to $8.59 today.

The practice of discounting can reflect many concerns. First, discounting can reflect a fundamental human tendency. People would rather have a good now than later. Second, it can account for the productive nature of some resources. Between now and some future time, some resources can be productive, generating revenue for their owners. Resources such as farmland and livestock meet this criterion. Third, discounting can reflect risk and uncertainty about the future. The practice of charging interest on loans is a recognition of the business risks associated with investments. Fourth, discounting can be used to adjust for technological change. Environmental damages in the future may be less harmful than today because new technologies will be developed to mitigate them.

Environmental cost studies use discount rates to adjust some cost estimates. For example, Shuman and Cavanagh's study uses a 1 percent discount rate for property damage and a discount rate of zero for human lives. In general, environmental cost studies have applied discounting to only a few, long-term effects of electricity generation. These include the global warming effects of CO_2 emissions and the long-term risks of nuclear waste. Because these impacts are often a significant component of total environmental cost, discounting can be an important issue. However, discounting does not affect the majority of impact categories, either because the impact is relatively prompt (e.g., oil spills), because studies do not apply discounting to them (e.g., human deaths and injuries), or because a valuation technique is used that avoids discounting entirely (e.g., control cost valuation).

Critiques

There are several views on how discount rates should be used to value environmental resources. Some economists and utility experts argue for using rates similar to those used by utilities for valuing capital investments (e.g., 6 to 8 percent).[46] This provides a consistent basis for utility resource selection decisions, but it also has the effect of reducing the value of damages that occur far into the future (e.g., global warming or nuclear waste storage) to nearly zero.

Many environmentalists argue for using relatively low discount rates. Low discount rates have the advantage of treating future generations equally to our own, but they also may cause relatively certain, near-term effects to be ignored in favor of more uncertain, long-term effects. Future generations may have new technologies and knowledge that will cheaply and easily deal with long-term environmental threats such as global warming or nuclear waste storage.

Impacts

High discount rates will produce lower damage estimates because they reduce the costs associated with environmental impacts that occur in the future. For example, a high discount rate will decrease the importance of the impacts of global warming. The BPA generic coal study explicitly ignores the impacts of global warming for this reason.[47] Conversely, low discount rates will result in higher damage estimates.

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[46] Ottinger et al., op. cit., footnote 2.

[47] They calculate that, even if global *Wining damages are $5* trillion, because the damages will occur 100 years from now, the amount attributable to a single coal plant (after discounting at 3 percent) is less than $8,300 per year (this calculation assumes that coal is only responsible for 33 percent of all CO_2 emissions, and that a single plant consumes only 0.001 percent of all coal consumed in the world). The study ignores this amount because it would add less than 1 percent to the total environmental costs that the study attributes to a generic coal plant. ECO Northwest et al., op. cit., footnote31, pp. 4-7.

Underlying Assumptions

Some disputes over discount rates can be traced to assumptions about the relative importance of natural resources (e.g., forests, lakes, and animals) and technological resources (e.g., roads, dams, and machinery). Applying discount rates to environmental impacts implies an equivalence between natural and technological resources. The ability to trade off natural and technological capital has been strongly disputed by some ecologists. For example, some argue that natural and technological capital can be more clearly seen as *complements* than as substitutes—implying that we need both to make use of either.[48,49] Although funds used to construct technological systems can be banked and spent at a later time, the same cannot be said of human lives and the important characteristics of ecosystems. Similarly, once some ecological systems are consumed, they may be difficult or impossible to regain.

Discounting also raises questions of how much reliance can be placed on technological solutions to current and future environmental problems. Advocates of high discount rates sometimes argue that technological progress will find solutions to future environmental harms. Those who advocate low rates do not wish to depend on future progress to mitigate harms that could be prevented today.

I Conclusions

These issues do not exhaust the list of situations where disputes can be based on underlying assumptions and values, but they provide a starting point. Each of these issues can affect the outcome of a environmental cost study, and how each issue is resolved depends largely on an analyst underlying assumptions. The "right" assumptions for an environmental cost study are not clear, and current debates over environmental cost studies are doing little to resolve them. Instead, discussions of the technical details of individual studies often hide disagreements over basic assumptions.

FRAMEWORKS

The discussion above indicates the wide variety of issues that affect environmental cost studies and the diversity of assumptions that affect how analysts resolve those issues. The assumptions occur at many different levels of analysis. One way of understanding these assumptions is to divide them into three levels: first, the fundamental goals the study is intended to support; second, the general strategies used to frame the study; and third, the specific methods the study uses to make its estimates.

Table 4-3 provides examples of these frameworks. The positions outlined are extreme, and rarely adopted in unalloyed form, but they help illustrate different frameworks, the connections within individual frameworks, and the broad spectrum of possible assumptions that underlie environmental cost studies.

| Goals

Analysis of environmental cost issues does not take place in a vacuum. Nearly every analysis begins with a particular view of problems not fully addressed by current policies. For example, economic analysis of environmental questions often begins by examining why current markets fail to control environmental effects. Analysis of the same issues by environmental groups often begins by noting emerging global environmental threats that are linked to energy use.

These problems often are translated into an implicit or explicit policy goal. Economic efficiency is nearly always the presumed goal of economic analyses of environmental cost problems. Public protection is a traditional goal of much existing environmental regulation. Sustainability is quick-

[48] Here the term *complements* is used in an economic sense. complements are defined by economists as items whose consumption is closely related. Computer keyboards and monitors are complements—when purchases of one rises or falls, the purchases of the other moves similarly.

[49] Robert Costanza and Herman Daly, "Natural Capital and Sustainable Development," *Conservation Biology,* vol. *6, 1992,* pp. 37-46.

TABLE 4-3: Frameworks of Assumptions

Goals		Strategies		Methods	
Policy goal	**What is the source of environmental problems?**	**Role of environmental cost studies in energy policy**	**What are environmental costs?**	**Valuation approach**	**What is value?**
Economic efficiency	Markets do not capture all the important information for energy decisionmaking by producers and consumers. Existing regulations are inefficient.	Quantify the necessary corrections to energy markets so that all important decisionmaking information can be contained in prices. Compare the total costs and benefits of a specific policy.	Externalities—environmental effects that are not reflected in current energy prices and that are economically quantifiable.	Consumers acting in markets.	An amount that consumers are willing to pay for an environmental good or service.
Protection of public health and safety	Energy technologies have created risks to the public that are preventable.	Indicate where government action is necessary to minimize the health and safety impacts of energy production.	*Unintended* side effects of energy use.	Legislators and regulators acting in political systems.	One measure of the importance of an environmental effect.
Ecological sustainability	Existing energy use is not ecologically sustainable because individual consumers act according to their own narrow self-interest, instead of considering the impacts of their actions on the whole ecosystem.	Indicate where government action is necessary to make energy production sustainable.	Effects on global or local ecosystems that are not apparent or are not of interest to individual consumers.	Scientists acting in scientific settings.	An indicator that can be used to communicate ecological importance.
Equity	Disparities in political and economic power exist between different members of society. Powerful individuals attempt to push adverse effects onto others while retaining the positive effects for themselves.	Indicate situations where inequities occur and quantify the damages in order to facilitate compensation.	Adverse effects of energy use that are not borne by those who benefit.	Legislators, regulators, judges, and juries acting in political and legal systems.	An amount that provides just compensation and that punishes unjust actions.

SOURCE: Office of Technology Assessment, 1994.

ly becoming the predominant goal underlying many analyses that take an environmental perspective. Equity has recently emerged as a concern about environmental impacts

These policy goals are not mutually exclusive, and few analysts would explicitly advocate pursuing only one of them. However, single policy goals are often implicitly assumed without substantial attention to other goals. Such an approach is understandable because combining several policy goals is difficult and requires an overarching organization that needs to be explained and defended. Such an activity goes beyond the scope of most environmental cost studies.

Most existing environmental cost studies fall primarily within a framework of protecting public health and safety. The studies are aimed at identifying environmental effects of energy to indicate where government action is necessary. They broadly consider all environmental effects of energy, without substantial concern about whether such effects have already been, in a strict economic sense, internalized by existing regulations.

These studies and their use by state regulatory commissions have been strongly criticized for misunderstanding economic concepts. For example, questions have been raised about the use of control costing, not accounting for currently internalized effects, and using average instead of marginal effects. Partially in response to these criticisms, the ongoing DOE/EC study falls predominantly within a framework of economic efficiency. The study's authors take pains to explain the specifics of this policy goal, and they point out how current studies fail to inform such a policy goal adequately.

Few, if any, studies have approached environmental issues from a framework of equity. However, environmental equity has been the focus of intense attention recently, and casual readers of environmental cost studies often assume that the studies are primarily concerned with equity. In addition, equity is of great concern to federal policymakers, particularly Congress.

I Strategies and Methods

Policy goals often translate fairly directly into other important assumptions in environmental cost studies. Some of these assumptions concern a study's strategy (i.e., what role is envisioned for the study in energy policy). Other assumptions concern methodology (i.e., how the study assigns value to environmental effects).

Frameworks based on economic efficiency can appear to offer a complete basis for policy, providing an extremely clear, although limited, role for policymakers. Economics provides a theoretical description of environmental problems (market failures), a quantitative strategy for informing policy (estimating externalities), methods for carrying out that strategy (e.g., contingent valuation), and a set of policy tools (e.g., pollution taxes). Critics of exclusively economic approaches argue, however, that economics is far from a complete system. Other important goals such as sustainability and equity are not directly addressed by economics, and they can be difficult to integrate with economic goals.

Most proponents of economic approaches argue for a more moderate position—that economic information supports the creation of policies that are economically efficient, and that also achieve other ends such as equity or sustainability. Such a view, however, presupposes that environmental cost studies provide relatively technical and unbiased information to policymakers-casting policymakers as the arbiters and integrators of information. However, as indicated above, environmental cost studies themselves often embody, rather than inform, decisions about assumptions and values.

In addition, the tendency of some environmental cost studies has been to push the boundaries of technical analysis outward, attempting to subsume progressively larger set of issues within a quantitative framework. Such quantitative treatment can be appealing to policy makers faced with difficult decisions. Because economic efficiency goals are more easily treated quantitatively, there is a danger they may effectively override other goals and become the de facto basis for policy.

Careful assessment of the policy role for environmental cost studies is needed, particularly given current and future attempts to use these studies on the federal level. How are environmental cost studies used in federal and state policymaking? What challenges await if they become more widely used on the federal level? How can they be conducted to best meet the needs of policymakers? These questions are considered in the next chapter.

Roles for Environmental Cost Studies in Policymaking 5

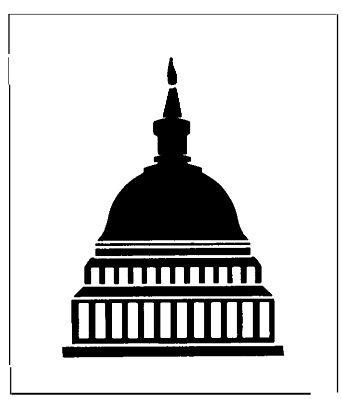
This chapter discusses the current state and federal policies that require the evaluation or use of environmental costs, and it outlines how environmental cost studies can be made more useful to federal policy makers. It explains some of the links between environmental cost studies and policy and some of the difficulties of applying current studies to federal policymaking. Although current studies are not being used extensively on the federal level, several new studies soon will be released, and there is likely to be increased debate over whether to consider the findings of these future studies when developing federal policy.[1] Increased use of environmental cost studies presents federal policy makers with both pitfalls and opportunities.

CURRENT LAWS AND REGULATIONS

Several policies at the federal and state levels involve explicit consideration of environmental costs. They demonstrate the variety of approaches to environmental costing and the ways current studies are used.

Federal Laws

The federal government incorporates environmental cost concepts into a wide variety of legislation and regulations.[2] These include the Energy Policy Act of 1992 (Public Law 102-486,



[1] For an excellent review of the stakeholders and their positions, see J. M. Fang and P. S. Galen, *Issues and Methods in Incorporating Environmental Externalities into the Integrated Resource Planning Process*, NREL/TP-461-6684 (Golden, CO: National Renewable Energy Laboratory, forthcoming).

[2] For a discussion of taxes and user fees that appear to consider environmental costs, see box 5-1.

BOX 5–1: Environmental Costs and Federal Revenue

Concerns about the federal budget deficit and the existing tax structure have prompted close examination of alternative methods of raising revenue, including environmental taxes. Such taxes could include energy-related policies such as carbon taxes and gasoline taxes, and nonenergy policies such as charges for municipal solid waste collection, congestion taxes on urban highways, and taxes on toxic chemical emissions.

Proposals for environmental taxes cite several advantages, First, they offer a source of federal revenue to address the budget deficit. Alternatively, they could be used in a revenue-neutral manner, to shift away from taxing “goods” (such as income) and toward taxing “bads” (such as pollution). In either case, the taxes would reduce emissions of the taxed pollutants (such as $C0_2$) or reduce consumption of the taxed goods (such as gasoline).

For example, the Clinton Administration proposed a BTU tax in early 1993. The proposal would have imposed a base rate of 25.7 cents per million BTUs on coal, natural gas, nuclear power, hydroelectricity, home heating oil, liquefied petroleum gases and imported electricity. An additional tax of **34,2 cents per** million BTUs would have been imposed on gasoline and other refined petroleum products, The measure was designed to raise $50 billion between 1994 and 1997, as well as **reduce emissions** of $C0_2$ and cut imports of oil.

Even prior to these measures, however, the federal government collected some revenue from environmental sources, in 1992, the federal government collected an estimated $7.6 billion in revenues from natural resources and environment-related sources (see table below), about half of one percent of the federal budget, While these federal revenues are not directly related to environmental damage, they do reflect charges for natural resource depletion (in the case of the leasing and land use fees) and indirect pollution (in the case of the environmental penalties and CFC taxes).

Sources of Federal Revenues from the Environment (1992)

Amount (billion $)	Source
2,8	Leasing and extraction of oil, natural gas, and minerals
2.0	Penalties and recoveries from environmental cleanup
1,6	Fees from timber harvesting, grazing, and other land use
0662	Taxes on chlorofluorocarbons

SOURCE Council on Environmental Quaility, *Environmental Quality: 23rd Annual Report of the Council on Environmental Quality* (Washington, DC: U.S. Government Printing Office, 1993).

Environmental taxes can be an unstable revenue source, however. To the extent that environmental taxes discourage pollution, they also reduce the revenue that they generate. Unless the tax rate is proportionally increased, the tax receipts will decline. If this effect is relatively mild and temporary, it may represent more of a start-up problem than a long-term liability of environmental taxes. If, however, it is feasible to completely eliminate a taxed pollutant, then the revenue source will disappear entirely.

SOURCES: Robert Repetto et al,, *Green Fees: How a Tax Shift* Can work *for the Environrnent and the Economy,* (Washington, DC: World Resources Institute, November 1992); and Margaret Kriz, “A Green Tax?” *National Journal,* **Apr. 17,** *1993,* pp. 917-920,

the Clean Air Act Amendments of 1990 (Public Law 101-549, the Pacific Northwest Electric Power Planning and Conservation Act of 1980 (Public Law 96-501), and certain pending legislation.

The Energy Policy Act of 1992

This act requires the Secretary of Energy to develop a least-cost energy strategy to promote energy efficiency and limit the emission of carbon dioxide ($C0_2$) and other greenhouse gases. In developing the strategy, the Secretary is directed to "take into consideration the economic, energy, social, environmental, and competitive costs and benefits . . . of his choices."[3] Assumptions are explicitly identified as an important component of the least-cost energy strategy. The act states that" the Secretary shall include in the least-cost energy strategy an identification of all of the assumptions used in developing the strategy and priorities thereunder, and the reasons for such assumptions."[4]

The Clean Air Act Amendments of 1990

The 1990 Clean Air Act Amendments (CAAA) requires that the Environmental Protection Agency (EPA) conduct periodic, comprehensive analyses of the costs, benefits, and other effects of the act.[5] In considering benefits, the analysis is to include all economic, public health, and environmental benefits of efforts to comply with provisions of the act.[6] The amendments specifically reference quantitative studies of environmental benefits, noting that in cases where numerical values are assigned to the act's benefits, a default assumption of a zero value shall not be used, unless it is supported by specific data. This is intended to combat the practice of counting only the effects that can be quantified and assuming that all unquantified effects are unimportant (and thus have a zero value). EPA is also directed to assess how the benefits of the act are measured in order to ensure that damage to human health and the environment is accurately measured and taken into account.

The Pacific Northwest Electric Power Planning Act of 1980

This act requires that the Northwest Power Planning Council develop a methodology for determining quantifiable environmental costs and benefits, and apply it to help determine the total system cost of energy resources.[7] The act resulted in the studies commissioned by the Bonneville Power Administration (BPA), as well as the Shuman and Cavanagh study, which was supported by a set of environmental, citizens, labor, and ratepayer groups.

Pending legislation

In addition to the policies discussed above, Congress currently is considering some measures with a connection to environmental cost analysis. For example, much of the debate over whether to elevate the EPA to cabinet-level status has concerned whether the new agency would be required to perform cost-benefit analysis of proposed regulations. Proponents of a larger role for risk assessment in EPA decisionmaking argue it would help the agency set priorities and ensure that regulations are cost-effective. Opponents argue that requiring quantitative risk assessments will leave the agency inflexible and open to endless scientific debate.[8] Although environmental cost studies of electricity generation represent only a small subset of proposed EPA studies, they highlight some of the issues and controversies likely to surround broader use of cost-benefit analysis for evaluating regulations.

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[3] 42 U.S.C. § 13382(@.

[4] 42 U.S.C. § *13382(e).*

[5] 42 U.S.C. § *7612(a)* and (b).

[6] The terminology here can be confusing. The amendments refer to the "environmental benefits" of the Clean Air Act, whereas most studies refer to the "environmental costs" of energy production. The terms are practically equivalent, although there is a subtle difference; environmental costs of energy production refers to those effects that could be avoided through additional pollution controls; environmental benefits of existing regulations refers to those effects that are already avoided with existing controls. In either case, the analytical approaches are similar.

[7] 16 U.S.C. § 839.

[8] G. *Lee,* "Analyzing *Risk Assessment at EpA," The Washington Post*, Mar. *8, 1994, p.* A17.

I State Laws and Regulations

Estimates of environmental costs are important 10 a variety of state energy policies. Many state policies require that electric utilities consider environmental costs in some way when they choose among electricity supply options (see figure 5-1).[9] Nineteen states require utilities to use quantitative estimates of environmental costs, including such measures as adding monetary amounts to prices based on emissions per ton of pollutant.[10] An additional 10 states and the District of Columbia require the use of qualitative criteria that attempt to account for environmental costs.[11] Qualitative requirements include such measures as listing various environmental impacts in proposals for new generating capacity. Three other states have legislative or regulatory activities in process that may lead to requirements for quantitative or qualitative consideration of environmental costs.[12]

MAKING STUDIES MORE USEFUL IN FEDERAL POLICYMAKING

When environmental cost studies are used in future federal energy policy, they will be subject 10 continuing disputes over methodology and results. Among these disputes are those over which methods are preferable in theory and which are possible in practice. Such disputes are responsible for some, although not all, of the controversy over using control cost approaches rather than damage cost approaches, using average rather than marginal costs, and assessing the degree of internalization (see chapter 4 for an extended discussion).

More importantly, however, disputes will continue because of differing assumptions about goals, strategies, and methods. As described in chapter 4, many of the most contentious issues surrounding current environmental cost studies can be traced back to differences in underlying assumptions. These assumptions are more likely to be *reflected in,* rather than *resolved by,* current studies. Consequently, users of environmental cost studies need to evaluate the studies' assumptions carefully, lest they unintentionally accept assumptions that do not match their own.

Technical and methodological critiques of social cost studies are important, but they are not the only important critiques. A study may be technically excellent, yet not meet the needs of Congress and executive branch agencies. The values and assumptions of any particular study may or may not overlap with those of particular policy makers. If a study's values and assumptions differ radically from those of the relevant decisionmakers, they may reject the study on those grounds alone. Such an action would not be "ignoring science" but would constitute the legitimate exercise of these policymakers' public responsibilities.

I Moving Beyond Evaluation

Consideration of the assumptions that underlie environmental cost estimates is particularly important for federal policymakers because the assumptions of some current studies may not be relevant to their needs. Some current studies assume a context of state public utility commissions (PUCs) and their regulation of utilities. In many cases, PUCs have funded the studies, or their actions prompted other organizations such as utilities, utility groups, and environmental groups to fund them.

As a result, existing studies tend to be cast largely in an evaluative role—that is, they help decisionmakers choose among a fixed set of alterna-

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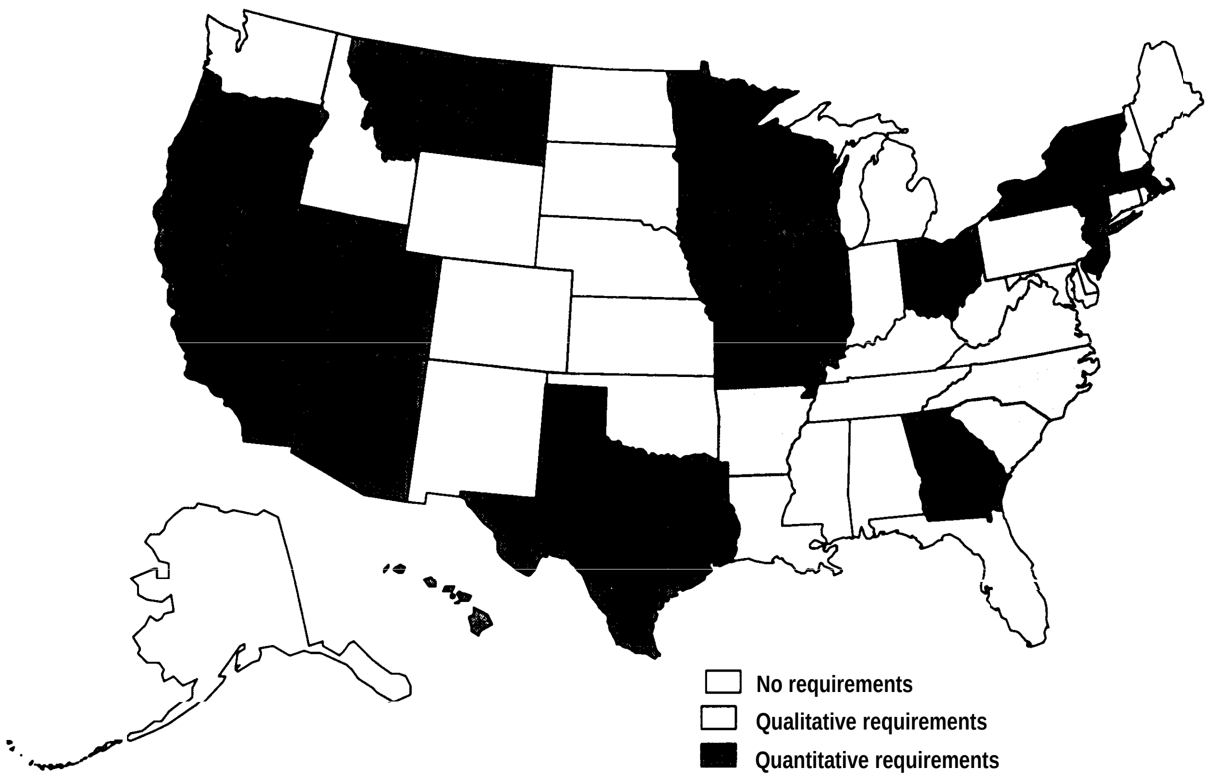
9 Information about specific state regulations is drawn from Fang and Galen, op. cit, footnote 1.

10 Seven states (California, Massachusetts, Minnesota, Nevada, New York, Oregon, and Wisconsin) specify monetary values by emission. One state (New Jersey) specifies a monetary amount by energy type (e.g., electricity or gas). Two states (Iowa and Vermont) specify percentage values by energy type. Nine states (Arizona, Georgia, Hawaii, Illinois, Missouri, Montana, Ohio, Texas, and Utah) require a quantitative approach without specifying the method.

11 Arkansas, Colorado, Connecticut, Delaware, Idaho, North Carolina, Pennsylvania, South Carolina, Washington, and West Virginia.

12 Kansas, Oklahoma, and New Mexico.

FIGURE 5-1: State Public Utility Commission Requirements for Utility Consideration of Environmental Costs



NOTE: Iowa, Oklahoma, and New Mexico have requirements under consideration. The District of Columbia has qualitative requirements.

SOURCE: Adapted from J.M. Fang and P.S. Galen, *Issues and Methods in Incorporating Environmental Externalities into the Integrated Resource Planning Process,* NREL/TP-461-6684,Golden, CO: National Renewable Energy Laboratory, forthcoming.

tives for electricity generation. PUCs are largely concerned with influencing utilities' decision-making processes, and environmental cost studies have been used to inform PUC efforts. In some cases, this influence is explicit; some states require utilities to add certain monetary values, derived from environmental cost studies, to the estimated production costs of new facilities when the utilities consider capacity expansion. In other cases, this influence is implicit; some states require utilities to derive and use their own cost values. In both situations, the emphasis has been on deriving a total cost figure that is used to choose among electricity generating technologies.

The characteristics of energy technologies are substantially more malleable than implied by the current use of environmental cost studies. Choices about pollution control technologies, mining and transportation safety, power plant siting, waste disposal, and impact mitigation approaches all affect the overall environmental costs of particular energy sources. All these ways to affect the design and management of energy technologies are open to federal (and state) legislators and regulators, although current studies generally are not oriented toward informing such approaches. Because of this, existing environmental cost studies may give a mistaken impression of the opportunities for minimizing the environmental costs of electricity generation.

For example, risks to workers in energy-related industries can contribute to high overall figures for the environmental cost of electricity generation. These figures may indicate that an energy source relies on inherently hazardous operations, but it also may indicate that safety practices in those industries are not as well developed as in others. The appropriate policy decision may be not to reduce use of the energy sources that rely cn the hazardous industry, but instead to increase efforts to understand and control the industry's hazards.[13]

In the past, the breadth of policy opportunities has not been lost on federal legislators and regulators. During the past two decades, Congress and federal regulatory agencies have become active] y involved in the technological design of electrical.y generating technologies-particularly by mandating air pollution control equipment and by funding research in improved technologies. This approach to federal regulation has alarmed some observers and is partly responsible for the increased interest in alternatives to command-and-control regulations. This, in turn, has increased interest in economic approaches to environmental control and in studies of environmental costs.

In many ways, the use of environmental cost studies is analogous to the use of another type of environmental assessment that has recently gained popularity-life-cycle assessment (LCA). LCAs attempt to quantify the total environmental damage attributable to a particular product because of its production, use, and disposal. They allow two products to be compared based on their environmental characteristics. For example, LCAs have been conducted for disposable and cloth diapers, paper and styrofoam cups, and plastic and paper shopping bags. After several years of debate, recent reports have concluded that LCAs are more useful as a tool for examining and improving design and production processes than they are as a method of selecting products with superior environmental characteristics.[14] Similarly, one important role for environmental cost studies is to suggest how electricity generating technologies can be changed so they are more acceptable to society, rather than merely to indicate they should be used to a greater or lesser degree.

| Emphasizing Nonquantitative Results

The impact of the assumptions and values implicit in different estimates is large enough that isolated quantitative estimates of environmental cost are nearly meaningless. Such estimates become meaningful only in the context of a study's assumptions and of the environmental effects that are included and excluded. This conclusion indicates that isolated quantitative estimates of environmental cost studies should not be presented as the final results of a study. This practice improperly focuses attention on the numerical results, rather than on the study's assumptions.

Analysts themselves are often aware of the limitations of their methods, but that awareness does not always affect how studies are reported and used. For example, most environmental cost studies to date have emphasized the tentative nature of their own quantitative estimates, the classes of effects they did not consider, and the importance of additional research. After the studies are published, however, their results are often stripped of this important context and merely portrayed in numerical form.

Environmental cost studies often focus on what appears to be the "bottom line' '—the monetary value of environmental effects. In many cases, this is the most speculative and controversial aspect of the study, and effects that are not monetized are often ignored. In contrast, focusing on the earlier components of the study (e.g., the emissions and impacts stages) would emphasize aspects that are most amenable to scientific and technical resolution.

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[13] John P. Holdren, "Energy Hazards: What To Measure, What To Compare," Technology *Review*, April 1982, P. 74.

[14] U.S. Congress, Office of Technology Assessment, *Green Products by Design: Choices for a Cleaner Environment,* OTA-E-541 *(Washington,* DC: Government Printing Office, September 1992).

This does not imply that monetization is a fundamentally flawed enterprise. However, by its very nature, monetization allows results of environmental cost studies to be reported in a highly aggregated form. This encourages use of results without full understanding of the assumptions and values that underlie them. Placing greater emphasis on reporting results of earlier phases of the analysis (e.g., emissions and impacts assessments), and on clearly explaining the assumptions and values that underlie estimates of monetary damages, would help make the studies more valuable for use in federal policymaking.

Informing Legislative Decisionmaking

A focus on disaggregated results and on explaining assumptions and values is important for reasons beyond mere accurate reporting or analytical convenience. Decisions about values are not the province of technical analysis. Instead, they belong in a public arena to be debated and decided by citizens and their publicly elected officials. Only when quantitative analyses clearly identify their underlying assumptions and values can they inform and enlighten public debate.

If the assumptions and embedded values of environmental cost studies are explained carefully, and if summary results present both quantitative and qualitative aspects, they can be useful for legislative purposes. Quantitative aspects include not only final environmental cost estimates, but also disaggregated results showing the relative importance of various factors to the final estimate, sensitivity analyses showing how the results vary when important inputs are varied, and an analysis of the uncertainty associated with important quantitative values. Qualitative aspects include identifying emissions that account for the majority of the impacts in specific impact categories, identifying alternative assumptions that will substantially alter the quantitative results, and identifying how the results compare with other similar studies. Clearly, this approach to analyzing and presenting environmental cost estimates poses a substantial challenge. However, without such an approach, environmental cost studies may prove to be of little use to policymakers.

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