Draft Submission

Social Cost of Energy Generation

**Submitted to:
Pacific Gas and Electric**

**Submitted by:
Meridian Corporation**

January 5, 1990

Contract No. Z-19-0-218-89

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

TABLE OF CONTENTS

	PAGE
EXECUTIVE SUMMARY	i
CHAPTER	
I. INTRODUCTION	1
II. SOCIAL COSTS	3
- Overview	3
- Environmental Effects	10
- Economic Effects	12
III. A REVIEW OF METHODS FOR QUANTIFYING SOCIAL COSTS	13
- Overview	13
- Difficulties Inherent in Methodological Approaches to Valuing Social Costs	15
- Lessons Learned	17
- Need for More Information	19
- Review of Analytical Techniques	21
- Description and Characterization of Impacts	22
- Ranking and Weighting of Social Costs	25
- Cost of Control or Abatement	28
- Full Costing of Externalities	31
- Strengths and Weaknesses of Methods	33
IV. A REVIEW OF METHODS FOR INTEGRATING SOCIAL COSTS INTO UTILITY BIDDING SYSTEMS	38
- Overview	38
- Conceptual Role of Externalities in Bidding Systems	39
- Review of Implementation Methods	41
- Quota Systems	41
- Point Systems	41
- Simple Rules of Thumb	42
- Abatement Cost Approaches	43
- Full Costing	43
- Ranking and Weighting	43
- Application of these Methods into Utility Bidding	45
- Different Methods of Accounting for Attributes Affect Outcomes	51
- Utility and Regulatory Perspectives	52

V.	REVIEW OF CURRENT REGULATORY EFFORTS	56
	- State Efforts	56
	- Federal Efforts	58
	- Trade Groups	59
VI.	SUMMARY AND CONCLUSIONS	60
	Appendix A - Assessment Options	A-1
	Appendix B - Social Cost Estimates	B-1

LIST OF EXHIBITS

	PAGE
1. Hypothetical Pollution Control and Social Cost Relationships	5
2. External Effects Throughout the Fuel Cycle	8
3. Social Cost Parameters	9
4. Social Costs and Technology Cost Effectiveness	14
5. The Impact Valuation Process	18
6. Describe and Characterize	23
7. Ranking and Weighting	26
8. Cost of Control or Abatement	29
9. Full Costing	32
10. Summary of Methodologies	34
11. Methodologies to Estimate Social Costs	35
12. Trade-Offs Between these Approaches	37
13. Misallocation with External Costs	40
14. Implementation Framework: Social Costs and Utility Bidding Systems	44
14a. TBS Worksheet	50
15. Three Intrinsic Boundary Issues	63
16. Analysis, Implementation and Boundary Issues	66
17. The Impact of Valuing Social Costs	71

EXECUTIVE SUMMARY

Historically, the market price of conventional energy has not fully accounted for all the resultant costs imposed on society. However, the attention paid to these costs -- or social costs -- is now growing rapidly. There are multiple influences behind this increasing concern including: economic growth and a concomitant expansion in electricity demand and its environmental impacts; a greater scientific understanding of environmental impacts; and improved methods of estimating the resultant costs of impacts. The emergence of institutional mechanisms such as least cost planning and competitive bidding are also influencing this shift in priorities. Coinciding with these factors is a much broader range of technological choices available (at varying costs) to mitigate many externalities.

The purpose of this effort was to review the concept of social costs and identify the procedural and methodological approaches to the problem of quantifying and pricing externalities. The various methodologies fell into four broad categories ranging from assessments based principally on value judgements of environmental and social impacts to attempts at full quantification and valuation of social costs. The methodologies were described in considerable detail. The pros and cons of different methods were described as well as their potential implications for the utility industry and PG&E.

A number of approaches were discussed that could be used to translate these values into an environmental attribute that can be employed in the utility competitive bidding process. Three efforts to account for social costs, either under way or under consideration by various utilities and/or regulatory bodies, were reviewed. Ultimately, the selection of a particular methodology to account for social costs may not be as important as the care taken in defining a final implementation methodology. As demonstrated by a recent study, the choice of a particular bidding framework has significant influence over final technology choices.

Valuing the externalities associated with energy production will ultimately require the resolution of much larger conceptual issues. These include societal definitions of the total value of electric power, the capability and capacity of utilities to conduct research into external costs to society and implement the actions implied by such research, and the existence and strength of regulatory mandates that will largely dictate which methodologies are implemented.

In addition, five studies were examined in detail to begin the process of developing a range of estimates for social costs by various categories of emissions and power sources. Major conclusions are summarized below, with further explanation following:

- Regulatory direction and/or intervention may limit PG&E's choice of a methodology and its implementation, and will certainly impact the relevance of PG&E's involvement in social cost analysis. Many of the key variables affecting the choice of a methodology are simply beyond PG&E's purview.
- Because regulatory uncertainties exist, PG&E should structure its methodology in a manner that is designed to influence the larger policy context in which social cost valuations must be considered. PG&E may wish to devise an approach to social costing that can be presented as an alternative or as a point of departure for other levels of policy making that may supersede PG&E.
- Based on our analysis of the strengths and weaknesses of the various methodologies, and the current uncertainties with regard to utilities' role in implementing social costs analyses, we recommend the development of a hybrid ranking and weighting approach (similar to the Temple Barker Sloane approach) at this time. This approach is relatively inexpensive, can incorporate and help rationalize existing data on social costs, and if properly implemented, can provide both reasonable estimates of social costs as well as help develop a policy consensus on the implications of externalities for energy production.
- Once PG&E has implemented a social costing methodology, they may elect to determine how different methods of accounting for externalities could affect future resource decisions. Once an approach to valuing social costs is implemented, it is important to see if the results imply significant changes, or if they will have relatively little impact on resource acquisition decisions.
- The changing regulatory environment, and specifically the growth of independent power producers that must be considered in competitive bidding systems, has heightened the importance of factors such as operational characteristics, viability, diversity, and flexibility at the same time that pressures are increasing to consider social costs.

I. INTRODUCTION

This report is intended to provide a general understanding of the social costs associated with electric power generation. Based on a thorough review of recent literature on the subject, the report describes how these social costs can be most fully and accurately evaluated, and discusses important considerations in applying this information within the competitive bidding process.

Further, information is presented that recognizes the utility's need to effectively plan within the changing regulatory environment. Regulatory changes have already led to increased purchases from independent power producers (IPPs). The Energy Information Administration projects the need for 110 Gigawatts (GW) of new capacity by the year 2000. Of this amount, 37 GW is under construction or planned by traditional utilities. Another 27 GW is expected to be supplied by capacity additions at existing utilities, and the remaining 46 GW, which has not been committed, will be supplied by either traditional utilities or by IPPs. Competitive bidding for the selection of IPPs has introduced numerous economic, legal, and technical questions that complicate the evaluation of these power sources.

This report acknowledges several approaches to ameliorating environmental effects that call for increased substitution of electricity for other sources. The California Energy Commission, for example, is currently examining scenarios calling for greatly increased demand side management, for industrial electrification amounting to 15,000 to 25,000 GW per year in Southern California. They postulate that a 50% rate of vehicle electrification would result in an estimated 5,000 to 12,000 megawatts additional load for 8-10 hours per day. At the same time, they state that reducing CO₂ emissions by 10% of what would otherwise be produced in the years 1990 to 2009 could be difficult to carry out in the face of continued strong demand growth and the trend of increasing CO₂ driven by increasing gas-fired generation.

At this time, utilities and regulators are both working to effectively address the complex issues on incorporating social costs into a pricing or bidding structure. The central challenge is to identify and value external or social costs, and account for them in a competitive bidding environment. The influence of social costs on the utility resource mix simultaneously requires that greater attention be paid to factors of risk and resource availability.

Following the introduction, Chapter II addresses the external/environmental effects on a general level -- defining terms and characterizing impacts and their relative magnitude. The essential theory behind externalities will be explored and attention will be given to the sources of externalities, their dynamics, and their resulting impacts.

Chapter III will then explore some of the specific considerations that must be made when performing any in-depth analysis of externalities. These considerations include boundaries and jurisdictions, as well as political and procedural points. This is followed by a description of four general approaches for calculating the costs of externalities and countering negative impacts, providing an overview of their relative strengths and weaknesses. In developing this chapter, 14 publications were reviewed and assessed for

their contribution to the particular challenges faced by PG&E. These publications range from general approaches for analyzing externalities to very specific cost estimates for environmental damages. Reviews of these publications are included in Appendix A. The chapter will then explore considerations for integrating these approaches into the utility competitive bidding process.

Chapter IV describes the integration of this information into the bidding framework, focusing on concerns to utilities including risk, dispatchability, and resource mix. Chapter V reviews current regulatory efforts in the area of social costs.

Finally, Chapter VI provides a summary of conclusions and recommendations for further study.

II. SOCIAL COSTS

OVERVIEW

Historically, the market price of conventional energy sources has not fully accounted for all the costs imposed on society. This situation is changing however, as increased attention is being paid to externalities. The shift toward including external or social costs can be traced to the greater awareness and concern of the environmental impacts of energy production as well as increased understanding of the nature and extent of external impacts. The emergence of institutional mechanisms such as least cost planning and competitive bidding is also influencing this shift in priorities. Coinciding with these factors is a much broader range of technological choices now available (at varying costs) to mitigate many externalities.

Definition of Terms :

For this analysis, external costs or social costs relate to any unpriced impacts created in the process of electric power generation. As the brunt of these effects is borne by society, they are termed "social costs." Private costs are those that are *internalized*, or contained within a particular transaction -- these costs are represented by prices in the marketplace. The total costs are the sum of private and social costs, and represent the "true" or full cost of the product or service consumed. While generally negative, such costs or impacts may also include positive features. Externalities are additive, and the total, or net cost of a product may be very different than the apparent market price.

The Source of Social Costs :

Social costs stem from the failure of private market prices to convey the total costs -- environmental, financial, or qualitative -- resulting from purchases. Part of this is a problem of perception and information, as individuals may not be able to clearly observe all of the unintended results of their actions.

This premise was succinctly described by Garritt Hardin as "The Tragedy of the Commons." In this analogy, "The Commons" -- an 1800's village green -- represents the global environment as an eminently public resource. As such, the Commons is freely available to the public as grazing land. Nearby residents would individually find that the marginal private benefit (to themselves) of grazing their animals there was greater than the marginal private cost (to themselves), even though the total social cost (to the community) eventually proved to be infinite: the Commons was destroyed through overgrazing. Even when faced with this fate, no individual resident would stand to gain from voluntarily limiting the use of the free grazing land.

When applied to electric utilities, the premise holds true. All consumers stand to benefit from an inexpensive power supply, and the least expensive sources will be sought in the marketplace. Even though the external effects of power generation are not evident, they still impose costs on society. As social costs increase in magnitude, the marginal benefit of inexpensive power is overcome as the total costs become unacceptable.

The Dynamics of Social Costs :

Social costs persist because private and social costs remain unaligned and create a cost/benefit dilemma. Such costs become evident because common property resources (such as air, water, and other natural resources) do not have an infinite capacity to absorb the effects of use. Even when the sources of social costs are identified, access rights to common property resources preclude a simple solution.

As an example, consider two enterprises situated on a river. The first produces steel, while the second, downstream, operates a resort hotel. Both enterprises use the river at no charge, but in different ways. The steel firm uses it to discharge waste, while the resort uses it to attract customers seeking water recreation. This situation is graphically represented in Exhibit 1. As the quantity of emissions increases, so do the costs to the owners/users of the resort. Reducing the social costs for the resort is possible only at some cost to the steel mill -- either through some treatment of the effluent, reduced production of steel, or another disposal method. Since the river is a common property resource and neither party has a greater claim on the resource, the economically optimum level of emissions is where the total of social and control costs is at a minimum. At this level, neither social costs nor control costs are eliminated entirely, but the external costs of using the river are equally distributed.

If these enterprises were owned by the same person, and the relative costs were considered, the quantity of emissions would be at this minimum total cost point. When there are different owners, however, an economically efficient use of the water is unlikely to result. The steel mill sells a product at a price lower than its total cost to society. The resort bears the social costs by virtue of the fact that it is downstream.

By leaving these pollution impacts unpriced in market transactions, several results occur :

- Only the private costs are represented, so the price of products that contribute to pollution is lower.
- Demand for the commodity increases because of the apparently lower price.
- More pollution is produced than would be otherwise in a full consideration of the costs and benefits of production.

Exhibit 1. Hypothetical Pollution Control and Social Cost Relationship

CPGE15

- There are no incentives to search for ways to reduce pollution per unit of output until pollution reaches intolerable levels.
- Reprocessing and reuse are discouraged since the use of the river as disposal alternative is so inexpensive.
- Other polluters may be attracted to the river as a disposal site

Thus, while the costs created solely by the steel operation may fall most directly upon the resort operation, and the benefits will be realized primarily by the owners and customers of the steel mill, the market imperfection resulting from free access to the river creates multiple effects throughout the economy.

Such a dynamic resists a natural solution. In this example, the conflict could be resolved through regulatory intervention :

A tax on the steel producer would internalize costs back into the production of steel and would persuade the steel plant owner to reduce the output of steel and pollution. Reduced output would require higher prices per unit of steel if the owner wished to attain his previous level of profit. The avoidance of the tax would also create an incentive to explore disposal alternatives less costly than the tax.

A legislated ceiling on the permitted discharge into the river, set at a level that regulators believed reflected the lowest total cost to both parties, would accomplish much the same objective. Such a ceiling would presumably be enforced by a fine for exceeding the limit, or by granting the resort owner the legal right to sue for damages.

The Effects of Social Costs :

The example of the steel mill and the resort is a simplification. Virtually all market decisions lead to some kind of social cost, creating a complex web of interacting effects. The effects may take many forms, but all are costs :

The effects may be paid currently as a direct financial cost; for example, as higher costs for health care or clean water. They may be paid indirectly, as in reducing the recreational benefit enjoyed by fisherman on a polluted stream. Such costs may be paid by consumers of the product that created the external effect, but not perceived as part of the purchase.

Costs may be displaced to another market whose participants do not consume the product that leads to externalities (thus suffering the costs without enjoying any of the benefits).

As some costs are not apparent, either in their creation or payment, they may be transferred to a later time or another generation.

Not accounting for external costs leads to the relative overproduction of certain products that impose costs on society. External costs can also significantly affect the order in which purchases are made and resources which are selected and developed. It is believed that by accounting for external costs, power project selection and development may be affected.

Social Costs in the Utility Sector :

While many links are not yet clearly defined, there are potentially significant social costs stemming from the production of electric power. The true depth and breadth of social costs resulting from the electric power sector are a function of the interconnections between our ecosystems and economies. Because externalities are manifested through such complex interrelationships, they tend to have very broad, diverse impacts that seemingly multiply with closer examination.

The more obvious effects -- for instance, smokestack emissions observable in the power generation process itself -- understate the complexity of social costs found in the electric power sector. Exhibit 2 illustrates a broader set of effects throughout the entire fuel cycle. There are numerous stages at which market decisions are made with essentially incomplete information, resulting in potential social costs. These social costs result in a net reduction in the welfare of individuals and society as a whole. Since these costs are not represented in the price of power, individuals have no way to explicitly value them, and the costs remain unaccounted for in market decisions.

The social costs related to power production fall into two general categories : environmental and economic. Exhibit 3 provides an illustrative list that may result to some degree from the production of electricity and gas services. This list is not intended to be comprehensive nor is it meant to cast judgment on which effects should be considered or ignored. It does, however, indicate the broad variety of issues that are not considered in market prices.

Exhibit 2 External Effects Throughout the Fuel Cycle

Exhibit 3

SOCIAL COST PARAMETERS

ENVIRONMENTAL ISSUES

Acid Rain
Global Warming
Air Pollution
Water Pollution
Toxic/Nonradioactive Waste
Radioactive Waste/Accident
Electric and Magnetic Fields
Noise Pollution
Accidents
Work/Home Environment
Resource Depletion
Land Use/Productivity
Solid Waste
Endangered Species
Aesthetic Qualities
Religious or Cultural Values

ECONOMIC ISSUES

Employment
Tourism
Insurance Costs
Safety/Security Costs
Transportation Costs
Savings
Employment

Depletion of Nonrenewable Resources

-Natural Gas
-Crude Oil
-Coal
-Nuclear

Subsidies and Goods and Services Supplied Publicly

-Public Disaster Provisions (nuclear)
-Public expenditures for environmental administration and control
-Emission monitoring
-Radioactivity monitoring
-Cost of Publicly Provided Infrastructure
Fossil Fuels
Nuclear
-Monetary Subsidies (direct)
Hard coal
Oil and gas
Nuclear energy
Accelerated depreciation
-Public R&D Transfers
Renewable energy sources
Nuclear energy
Fossil fuels
-Strategic Reserves

ENVIRONMENTAL EFFECTS :

Environmental concerns have technical, economic, and policy dimensions. This section provides a brief overview of environmental externalities and their sources, the relative contribution by electrical generation, and possible mitigation or avoidance options. Greater attention is given to individual fuel sources in Chapter III.

Acid Rain and Air Pollution :

Gaseous and particulate emissions are a major external cost of the industry, transportation, and electric power sectors. Emission impacts are a function of concentration, accumulation, and interaction; few individual air pollutants have significant impacts individually or in small doses. Airborne residuals can affect climate, visibility, vegetation, materials, and human health. They may also be transported considerable distances, resulting in both interstate and international controversy.

Acid rain results mainly from sulphur dioxides (SO_2) and nitrogen oxides (NO_x) released in fossil fuel combustion. About 75% of sulphur dioxide and nitrogen oxide emissions in the U.S. comes from electric power production. The impacts relate to relative emissions type and quantity, and vary with the fuels and technologies used in different parts of the country.

Global Warming :

CO_2 , in particular, and other gases which cause atmospheric warming, are an inescapable result of fossil fuel combustion, and are increasingly feared to be responsible for the gradual warming of the planet. These gases permit solar energy to penetrate the earth's atmosphere but, like a greenhouse, inhibit the release of this heat back out into space.

CO_2 is believed to contribute approximately 50% to the effect. The U.S. produces about 25% of the total global emissions of CO_2 . Because electric power production in the U.S. accounts for about 35% of U.S. production of CO_2 , it is responsible for about 7.5% of world CO_2 emissions.

In California, oil combustion contributes to about 72% of the state's CO_2 emissions, and natural gas combustion accounts for about 27%. California utilities emit about 10% of the state's CO_2 emissions.

The validity of the greenhouse effect concept is still highly controversial. Nevertheless, its impacts could include major changes in the level of precipitation, a rise in sea level and intrusion of salt water into delta and estuary systems. Summertime temperatures may increase, resulting in higher peak electricity demand, which could occur at a time when hydroelectric sources (which currently comprise about 30% of California's electric energy) are diminished due to less rainfall and snowpack.

The likelihood and degree of the greenhouse effect depends to some degree on our near-term energy sources, and to a large degree on scientific unknowns. While complex computer models have been created to predict effects, it is still not clear exactly what the atmospheric response will be, and to what degree the thermal mass of the oceans will mitigate effects. Still subject to considerable debate is the actual timing and magnitude of the effect. Of critical importance is the rate at which changes occur. Rapid temperature change could strain social and political institutions, and ecological damages could be enormous, if not irreversible. The interactive effects between global warming and acid rain could exacerbate widespread damage.

Land and Water Use Impacts :

Due to the wide variety of impacts among coal, oil, gas, and nuclear powered generating sources, and even among plants of the same fuel type, it is difficult to measure land and water use impacts on a per kilowatt hour (kWh) or installed capacity basis.

Land uses include storage and disposal areas as well as other areas committed for various uses but left relatively undisturbed. A nuclear power plant may serve as a virtually permanent commitment on a parcel of property. Certain renewable energy technologies, including array photovoltaics, wind generation, and crop land for biomass energy vary in their land use impacts depending on whether there are other simultaneous uses. And while hydropower sources are often thought to be environmentally benign, they entail large land use impacts.

Water use impacts are primarily a function of their use in energy production for cooling, and include thermal pollution and evaporative losses. Certain forms of pollution control equipment, in particular, have significant water requirements.

Although demand for land and water for particular uses and function of energy production can be quantified on a fairly standardized basis, many of the impacts will be very site-specific. For instance, measured impacts on fish habitat or aesthetics can vary depending on whether the plant is located on and using a pristine trout stream in a wilderness area, or on a drainage ditch in a remote industrial park. The most extreme land use impacts are precluded by siting and environmental impacts constraints, and the cost of more stringent environmental controls may be useful as an indicator of the implicit value of avoiding environmental impacts. There is ample room for debate over aesthetic and other considerations in any plant siting. In some cases the best value that can be attributed to these factors takes the form of a description of the magnitude and types of impacts likely to be associated with different options (i.e., thermal discharges from nuclear and fossil plants, aesthetic objections to certain solar and wind technologies, etc.).

Other Effects :

There are a number of other impacts associated in different ways with electricity generating technologies such as noise, radio frequency interference, odors, indoor air

pollution, solid waste, and hazardous materials. Although these impacts are important, they evade characterization as environmental impacts and have been less thoroughly researched and valued.

ECONOMIC EFFECTS

Other social costs result from institutional intervention in the marketplace. These effects may take the form of direct costs -- such as subsidies, government agency outlays, or tax advantages -- that act as incentives for the support of activities deemed socially beneficial. While such direct expenditures or reductions in government revenue can be clearly identified as costs to society, they are generally paid through additional taxation and are not apparent in the market transactions they relate to. A 1985 study for the Center for Renewable Resources calculated that these costs were approximately \$28 billion annually, with about half of these expenditures being made for the nuclear industry.

Other economic effects may be more difficult to quantify. Consider, for example, the sale of public energy assets below market value; the cost of the strategic petroleum reserve; part of the costs of maintaining a rapid deployment force; and federal insurance for the nuclear industry; all have social costs of some form. Other effects may also be wholly or partially deferred to a later time, as in the case of nuclear waste disposal and nuclear plant decommissioning.

Many economic effects resulting from electricity and gas production are the result of local dislocations associated with siting, building and operating facilities within a local community. Major construction projects in particular may create a noticeable "boomtown" effect. Influxes of money and workers into remote areas can increase the need for schools, health care, roads, waste disposal, recreational facilities, and other infrastructure that is not accounted for in the cost of the project. Changes in the population and in the backgrounds of community members can create social and psychological impacts that alter residents' perception of their community, either positively or negatively. Finally, concern over the externalities associated with a project, whether well-founded or not, create very real changes in the public's valuation of their surroundings and environment.

III. A REVIEW OF METHODS FOR QUANTIFYING SOCIAL COSTS

OVERVIEW

This chapter reviews numerous methods that are being developed or practiced to account for social costs in considering future energy options. If a utility's goal is to provide an electric system at the lowest social cost and to ensure economically efficient electrical energy resource decisions, then it is necessary to quantify and, to the extent possible, price the environmental externalities created by energy resources.

By explicitly considering social costs, the potential effects on resource decisions can be very real. A Bonneville Power Administration publication states that "only a fraction of a cent per kilowatt-hour may separate a cost-effective resource from one that is not; the inclusion of environmental costs could easily tip the balance." Thus the selection of a particular method to account for these societal costs could have important ramifications for a utility's future generation mix.

A 1988 study completed by Olav Hohmeyer from the Federal Republic of Germany, for the Commission of European Communities identified the societal costs of West Germany's coal and nuclear options and concluded that if the externalities were included, the cost of coal production would be increased by 80 percent and the current cost of nuclear power would increase threefold. Another salient feature of Hohmeyer's approach is his description of the ultimate effect of external impacts in terms of the delay they impose of the development of many of the renewable energy technologies that could mitigate many external costs of fossil fuels. (See Exhibit 4 and footnote)¹.

In the United States, several utilities and utility commissions are currently examining the societal cost issue. Most notable is the Bonneville Power Administration (BPA) which has, for a number of years, performed an "Environmental-Cost Analysis" required under the Pacific Northwest Electric Power Planning Act of 1980 which specifically requires that environmental costs be quantified and priced and included in the system costs of proposed energy resources. Several studies have been undertaken aimed at quantifying the

¹ The costs of conventional energy are gradually increasing due to, for example, rising exploration and mining costs, while the costs of the new technology based on renewable energy resources are decreasing considerably over time due to technological knowledge. These costs are projected to intersect at time(o), when the renewable energy conventional energy technologies will be equally attractive on a cost basis. By including the social costs related to conventional energy, the intersection points shifts to time(i). (From "*Social Costs of Energy Generation - How Does Wind Compare*," Paper presented at the conference "*Windpower 89*," September 24-27, 1989, San Francisco, California, by Olav Hohmeyer.)

Exhibit 4

Social Cost and Technology Cost-Effectiveness

environmental costs of coal, nuclear, hydropower, geothermal, wind, solar, combustion-turbine, cogeneration, and conservation resources. Research has addressed the valuation of most significant environmental effects including health effects, fish and wildlife, visibility, agricultural impacts, recreation, aesthetic values, as well as economic effects from "boomtown" and infrastructural effects when power plants are built which can place greater demands on public services such as schools, hospitals, fire departments, and police protection. Other utilities, state energy offices, and public service commissions are examining these issues around the country, the most notable being California, New York, Massachusetts and Wisconsin.

DIFFICULTIES INHERENT IN METHODOLOGICAL APPROACHES TO VALUING SOCIAL COSTS

A review of current literature revealed some of the pitfalls and difficulties in valuing social impacts. The difficulty for utilities in including social costs in resource decisions by utilities is in establishing values for environmental effects that are not traded in markets, and therefore, have no established price. A Bonneville Power Administration report on performing Environmental-Cost Analysis refers to some inherent difficulties in the process:

Estimating the financial costs of power production is not always easy. But estimating environmental costs and benefits is always a tricky business. For example, if smoke from a power plant obscures views, creates respiratory problems or becomes acid rain, you've got environmental effects. But how do you measure those effects? And how do you attach economic values? Power production has always created environmental effects, but, in the past, most were not explicitly valued."

While a number of techniques exists for valuing social costs, a recent Electric Power Research Institute (EPRI) report examining available measures and methods for assessing environmental damages (related to air pollution) states that these estimates may be less accurate than previously supposed. In fact, substantial uncertainty and disagreement exist about the following questions:

- What are the appropriate economic measures (data needs) for environmental damage and benefits?
- What economic assessment methods are applicable to specific environmental issues?
- How should societal responses (adjustments) to environmental damage be incorporated into the overall assessment? and
- What level of confidence can be attached to estimates of environmental benefits?

For example, the EPRI document discusses that a simple damage function approach which links some level of pollution to a measurable physical response may not be wholly adequate as it does not include individual behavioral responses to changed environmental quality. The authors state that :

"While many environmental, and natural resources, such as air quality, are public goods that are not exchanged in markets, that doesn't mean that these resources, as public goods, do not have value. People may change their recreation patterns or move their residences due to characteristics of the environment. Similarly, firms often choose locations based upon the availability of unpriced environmental amenities."

While the damage cost function method involves the straightforward calculation of damages by multiplying the unit market price or replacement cost of a commodity (e.g., fish in a lake) by the number of units of the commodity impacts, other methods take into account that individuals are aware of pollution-caused damage and are thus capable of responding to these damages. Economists have relied on "indirect links" to measure willingness to pay for environmental quality through such techniques as hedonic property value and travel costs measurement approaches. On the other hand, if this information is not available, economists have elicited willingness to pay values through "direct links" through surveys and interviews using contingent valuation measurement approaches.

It is interesting BPA documents which do incorporate more of these rigorous research methods have disclaimers for various data points and cost calculations, such as for visibility:

"The value of visibility was estimated by the Resource Environmental Economics Laboratory [1981] at the University of Wyoming. The evaluations come from a series of contingent evaluation questions on visibility performed by the University of Wyoming over the last ten years, and a set of property value studies estimating the value of air pollution. Neither of these sources of evaluation are perfectly matched with the visibility issue in this study. The contingent valuation questions were asked entirely in the Southwest and were primarily in conjunction with sites in National Parks and Monuments. The property value studies come from large urban areas, none in the Northwest. The contingent valuation results are plagued by nonresponses, questionnaire bias, poor sampling procedures, and strategic bias. The property value studies are troubled by pollution measurement error, aggregation, and omitted variables. Further, it is difficult to determine what fraction of the value of clean air to attribute to visibility as opposed to soiling, material damage, and health effects. Thus the existing methodologies are not entirely satisfactory and none of the existing studies directly pertains to the Northwest. A final difficulty with visibility is that the evaluation may not be linear across the observable range of visibility. Thus, what people are willing to pay to go from low visibility to high visibility may not reflect what they would pay for a slight improvement. The proposed valuation of \$10 per kilometer-year per person makes the additional assumption of linearity. The true value probably ranges between \$0 and \$20."

Some authors have cautioned against trying to put too much information into one value and state that environmental analysis can easily be abused by opponents or proponents of a given technology if the many uncertainties in the analysis are collapsed into a single cost figure:

"Environmental analyses can easily be abused by proponents or opponents of a given technology if the many uncertainties in the analysis are collapsed into a single cost figure. At almost every stage of an environmental analysis loom huge regions of uncertainty within which an analyst can pick particular points to suit their own biases. Preservation of these uncertainties, however, renders such arbitrary choices unnecessary. While this does not mean that an environmental analysis should embrace every numerical estimate, no matter how implausible, it should nevertheless try to preserve legitimate uncertainties wherever possible."

It's interesting that Shuman and Cavanaugh advocate developing a range of plausible environmental costs for various energy production technologies as this approach is very similar to the estimates of social costs we developed in Appendix B.

LESSONS LEARNED

While the previous discussion accounts for some of the weakness and difficulties in examining social costs, a great deal has been learned to date. BPA has found many resource costs such as health effects and biological damage to crops and forests from coal are fairly straightforward to quantify. In fact, BPA studies indicate that the 80 to 95 percent of local economic damage attributable to fossil fuel combustion is accounted for by health risks. Even with low sulfur coal and remote siting in the west, coal plants can be expected to impose levelized environmental costs of between 2-10 mills per kWh just for health risks. And this does not include costs associated with acid rain, ozone depletion, and global warming.

The environmental effects associated with air pollution are well-known. The economic costs of those effects is less understood, but appear to be increasing. One study from Rowe and Chestnut on air pollution in California found that health damage accounted for about 60 percent of the total measured economic harm caused by failing to meet the air quality standards (in addition to damage to agriculture and forestry. An economic assessment of the health benefits from improvement in air quality in the South Coast Air Basin California found that the best conservative estimate of the economic benefit of better health is \$.94 billion to \$14.3 billion.

The economic cost of environmental impacts is highly variable depending on the source type and the characteristics of the site where the source is located. BPA estimates are perhaps the most complete and thorough data is available through their case studies of plants as well as generic studies. Their studies follow a rigorous 5-step sequence (see Exhibit 5) valuation process which include: 1) identifying the environmental impact; 2)

Exhibit 5

The Impact Valuation Process (Bonneville Power Administration)

accounting for pollutant dispersion in the environment, 3) determining exposure levels by parts of the ecosystems: people, materials, vegetation contact; 4) calculating the dose-response function, i.e., following exposure to a pollutant a response such as slower plant growth, respiratory ailments, or death, etc.; and 5) valuation of the change in the environmental service, e.g., the cost of losing fish in terms of lost benefits provided such as food and recreation.

In a letter to the Chairman of the Solar Energy Society, Shepard Buchanan, the project manager of the BPA projects on social costs, referred to a recent conference on Societal Costs, stating:

Geothermal, wind, solar, and conservation resources have environmental costs approaching zero when significant local concerns are mitigated, as they nearly always can be. Cogeneration and combustion-turbine resources have low costs depending on the fuel used and the location. Natural gas and biomass have the lowest costs, oil is higher. Combustion turbines and cogeneration costs are in the range of 1-5 mill per kWh range. Cogeneration from solid waste creates huge health risk costs in the range of several cents per kWh. As with all resources, site characteristics such as the size of the exposed population have a strong influence on the magnitude of costs."

On the other hand, Buchanan states that based on existing information nuclear environmental costs are perhaps the most difficult to quantify. Many costs are unknown - such as the environmental cost of waste disposal and plant decommissioning -- while others defy quantification -- such as the threat of nuclear proliferation or plant sabotage.

NEED FOR MORE INFORMATION

Buchanan believes that "the general level of knowledge in this area is limited" and that "little effort has been devoted by the utility industry to this problem. (He also believes that DOE, EPA, and state agencies also have major responsibilities in this area). He maintains that much additional research is required and believes that "the most compelling areas for research are not in the economic arena per se, but in the medical, biological, and climatological fields." He continues:

"For example, economists have done considerable research in the value of a health risk and impute those values with a good deal of confidence. However, much remains to be done in the quantification of those health risks. The greatest uncertainty is not in the value of a health risk, but in its nature and size. Effects of pollutants to air and water need a much better understanding to predict effects on flora and fauna; as with health risks, the problem is not valuing predictable environmental effects but predicting those effects in the first place.... The most pressing needs are in the areas of health, global warming, acid rain and waste disposal."

On the other hand, others conclude that both scientific and economic research is necessary. For example, the recent California study on an economic assessment of the health benefits from improvements in air quality in the South Coast Air Basin states:

"The modeling of human exposure, particularly on a regional basis, is still a relatively young science which in turn depends on the emerging field of microenvironmental studies. Such studies attempt to characterize human exposure for the full range of outdoor, indoor, and in-vehicle environments encountered in typical human activities. An area for concern for future valuation work is related to the aggravation and increased incidence of chronic respiratory disease. Impacts in terms of chronic respiratory diseases have been identified for PM-10 and for ozone. Only preliminary attempts have been made to value these long-term endpoints, however, based upon assumptions about the numbers and severity of illness. Should this damage category or one similar to it, be included in any epidemiological analysis, more economic work is needed. The recommended levels of analysis would be to better define the degree of impact implied, obtain improved COI value measures, and tie the non-COI impacts to other symptoms for which values exist to determine an appropriate total value range."

And this is only one of the methodological gaps they mention related to the need for improved economic values.

As public utility commissions attempt to include social costs into the resource allocation process, methodologies are being developed for the inclusion of these costs. A recent Issue Paper from the Northwest Planning Council on the topic of accounting for environmental consequences of electricity resources during the power planning process perhaps best summarized the whole dilemma by stating that:

"While there are clear theoretical, as well as legal reasons to incorporate external costs into resource cost estimates, the thorough and accurate quantification of such estimates is a herculean task, riddled with significant gaps in knowledge and laden with value judgments. In fact, there may not be a wholly accurate answer that can be derived or agreed upon. However, there may be research and knowledge, even if simply descriptive, that would help the Council identify possible environmental impacts, assess their significance, and account more fully for them in its decision-making."

The Council then lays out a series of assessment options for them to begin to examine this issue ranging from updating current descriptive information to conducting primary and secondary research in an attempt to answer the myriad questions surrounding all impacts of resources. They state that most of the options are not mutually exclusive and that the Council could decide to pursue various combinations of the proposed options.

REVIEW OF ANALYTICAL TECHNIQUES

The Council's series of assessment options provides a good analytical framework for reviewing techniques that are being used to examine social costs. In the following sections, a similar approach used in which methods were categorized by their similarities in approach is outlined as follows:

- 1. Description and Characterization of Impacts**
- 2. Relative Ranking of Social Costs**
- 3. Costing of Control Efforts**
- 4. Full Costing of Externalities**

This grouping describes a continuum of the detail and effort involved in the evaluation of social cost, and like the Council, the continuum is not always consistent and categories are not always exclusive. Some are written from an environmentalist perspective, and were designed to make a point more than to serve as a basis for competitive bidding. Others are more rigorous in their treatment of methodological issues, but fall far short in providing the types of information that would be needed for full application. A major divergence also occurs between the Costing of Control Efforts and the Full Costing of Externalities approaches. While they both have an important costing element, they attempt to address externalities from two wholly different perspectives.

For each category of documents, a brief summary will be presented as well as an examination of the methodology, if any, that it presents. Strengths and weakness of these documents follow the section of what the authors feel contribute to the topic of externalities, and then a conclusion of the pros and cons of the methods presented in the document. It should be noted that new methods and approaches are being developed to examine this issue. Moreover, the review of these documents are not meant to be a judgement of the document's merits, but rather its contribution to the valuation of social costs. (An expanded description of each study is located in the Appendix).

1) DESCRIPTION AND CHARACTERIZATION OF IMPACTS

DESCRIPTION: This category is similar to The Northwest Power Planning Council Assessment Option 1 which states that such efforts "would not delve into pathways or valuations of the environmental effects, but would simply describe and characterize the impacts". The resulting descriptions of environmental effects might include: description of the primary effect (e.g., release of sulfur oxides); significant consequences (e.g., lake acidification, forest dieback, property degradation, human health effects); and means and effectiveness of mitigation (e.g., scrubbers, low sulfur coal), but did not specifically calculate costs. The NWPP also states that this information would assist in flagging environmental problems that have not been adequately addressed by regulating agencies or the Council and therefore may merit further attention.

This type of cost comparison is depicted in Exhibit 6. While "Resource B" would generally be selected by the market, the inclusion of additional information permits a renewed consideration of "Resource A".

Although this category does not include any work on the valuation of impacts, those studies that describe and characterize impacts were deemed important, and were therefore included.

SUMMARY OF STUDIES: The first study, Environmental Effects of Electricity Generation, develops estimates on air pollutants for the generation stage for electric generating technologies and makes general recommendations for environmental strategies, e.g., increased efficiency, substitution of cleaner technologies for older, less efficient ones, increased waste heat utilization, and increased pursuit of renewable energy technologies.

The second set of studies, Energy Systems Emissions and Materiel Requirements and Environmental Emissions from Energy Technology Systems: The Total Fuel Cycle, improves state-of-the art knowledge by quantifying and comparing emissions from up to 14 generating technologies using a life-cycle approach. It points out the environmental advantage of a material-intensive technology such as photovoltaics compared with a fuel-intensive system such as coal.

The third is a model which has been developed compiling standard energy and emission-related data for fuel cycles of various energy systems which provide space heating and electricity. The objective is to provide a computerized data base to provide a method for comparative assessment of energy systems, based on one unit of delivered energy, and to develop options for integrating non-comparative and qualitative impacts of energy systems into the decision-making process. The authors stress that this model is descriptive rather than prescriptive and is not meant to free decision makers from their responsibility to value environmental effects, but is to enhance available information and present it in a form that can support the decision process.

OBSERVATIONS AND UTILITY IMPLICATIONS : The importance of this approach cannot be underestimated, as it forms the basis for any detailed analysis of externalities. Efforts such as these are required to determine the full range of effects. However, these

Exhibit 6

Describe and Characterize

methodologies are not prescriptive in terms of amelioration methods. The approach can only deal with nonquantifiable issues in the most general of terms. Such an approach may end up overwhelming the decision-making process with a flood of new information without prescribing methods for trading off dissimilar attributes.

This research could be used to develop qualitative information and then combined with making a subjective rank ordering of resources by environmental impact, which is what the Northwest Power Planning Council ultimately decided to do.

2) RANKING AND WEIGHTING OF SOCIAL COSTS

DESCRIPTION : The studies in this category describe ranking various energy resources to reveal which resources are most or least environmentally damaging. Such approaches may simply use qualitative or subjective judgement to aid in ranking resources, or may rely on quite rigorous cost information. Through the use of adjustment factors or adders, divergent impacts are weighted to explicitly rank resources. This approach is depicted in Exhibit 7, where the relative total costs of two resource are compared.

SUMMARY OF STUDIES: The first study is a methodology developed by CEC designed to take advantage of early land use planning and environmental impact analysis methods. They pursue an exhaustive list of costs, including the usual private costs (capital, operation, and fuel) as well as government subsidies, environmental impacts, and issues of economic development and system reliability/security. The authors deliberately take a qualitative approach by developing a relative ranking scale to establish broad boundary limits rather than making specific cost assumptions.

The second study in this category was developed by Temple, Barker, and Sloane, Inc. (TBS) for New England Electric. The TBS study goes a step further than the CEC work by attempting to specifically evaluate characteristics in a ranking and weighting to fit a bidding framework. The TBS methodology is a highly developed ranking and weighting scheme and attempts to simultaneously consider a number of disparate environmental and operating characteristics.

In developing this approach, TBS reviewed a number of qualitative and quantitative methods. They decided to value environmental categories and develop weights for other characteristics through a combination of simple Delphi survey techniques and a limited amount of existing environmental costing data. Eleven surveys were completed by environmental professionals both at the primary level (where respondents weighted individual environmental effects) and the secondary level (where respondents assessed the total environmental score). They found that while sources used to develop factor weights were not necessarily consistent in the implied or stated weights, they did exhibit consistency in the relative weighting of environmental issues.

The third methodology reviewed for this category was a study performed by the Bonneville Power Authority to evaluate five generating resources. They relied on very rigorous costing methods to evaluate a broad range of external effects, and arranged the information to display the effect it would have on power source selection. This approach essentially worked in reverse from a sampling of existing sources to develop a sensitivity test, or set of "switch points," that explicitly showed how large social costs would have to be before resources switched place in the least-cost portfolio.

OBSERVATIONS AND UTILITY IMPLICATIONS : Because of the difficulties involved in full costing measures (see following sections) the attempt to develop relative values for resource options may be the best way to build consensus on the weighting of different resources in a bidding scheme. In practical terms, any evaluation of social costs may have

Exhibit 7

Ranking and Weighting

Is this distance
positive or
negative?

RESOURCE A

RESOURCE B

to be translated in some fashion through ranking or weighting approaches, particularly since many operational characteristics (such as dispatchability, diversity, and reliability) may be difficult to accurately represent through dollar values.

The amount of subjectivity in such approaches may vary enormously. While ranking and weighting techniques may simplify the bidding process, they may obscure a significant amount of detail. The apparent objectivity of the resulting framework may create a false sense of accuracy. The potential pitfalls in arranging information in this way will depend on whether the results are rigidly prescriptive or merely suggestive.

Such ranking may be applicable within a relevant range. The relative weights or ranks developed are somewhat a function of the existing resource mix and will not remain static as new resources with different characteristics are selected.

3) COST OF CONTROL or ABATEMENT

DESCRIPTION: This option, rather than actually attempting to calculate the costs of environmental effects resulting from power production, starts with basic assumptions about the preferred level of damage. It then ranks power sources in terms of the costs required for the emission control technologies needed to meet those assumed or accepted standards. Thus, current (or proposed) emission standards are used as a proxy for the social costs. Conversely, if control costs are not known with accuracy, or are not regulated, the estimated costs of abating emissions through another approach may be substituted. In the case of CO₂, for instance, the cost of reforestation to absorb CO₂ will serve as a proxy. For other emissions, abatement through the purchase of offsets may be less expensive than scrubber technologies. Such an approach essentially depends on administratively defined levels of desired emissions, and is depicted in Exhibit 8.

SUMMARY OF STUDIES: This approach, being applied in New York in varying degrees by the State Energy Office and Public Service Commission, is the use of abatement costs as indirect measures of the values of air quality impacts. According to this line of thinking, optimal air quality control policy sets emission limits where the marginal cost of abatement are equal to the marginal benefits (where these benefits are conceptually the same as the external costs associated with the emission). Thus, the abatement costs associated with a given emission (say, NO_x) can be used as a proxy for the external costs of the emission. In this case, the cost of control or abatement of various stack emissions was used as a comparison to environmental damage estimates from other sources to iterate a probable cost for damage.

Some authors, Sebold et al., give some reasons as to why there are a variety of conceptual and practical problems associated with this use of abatement costs:

"First, any reasonable approach to valuing air quality impacts must recognize the variation in the value of changes in air quality across air basins resulting from differences in air chemistry, topography, geography, and target populations. However, air quality standards (abatement levels) are generally set at the national level. Even if these national standards are based on careful calculations of costs and benefits, it is highly unlikely that the resultant abatement levels are optimal in each air basin. This means that abatement costs may be well above the benefits of abatement (the external costs of the emissions) in some air basins and considerably below in others. Second, even within an air basin, the abatement cost for a given emission may vary significantly across sources. For instance, NERA (1988) has estimated the cost of NO_x controls in California's South Coast Air Basin to range from \$8,800 per ton for petroleum refineries to \$42,600 per ton for electric utilities. Assuming that the external cost of a ton of NO_x is the same across sources within a basin (and all other factors remain constant), it is unclear which abatement cost level (if any) should be chosen to reflect the external social costs of this emission."

Exhibit 8

Cost of Control or Abatement

29

OBSERVATIONS AND UTILITY IMPLICATIONS: While this approach has strong merits, its assumption that current control standards accurately reflect social costs is in some ways a default mechanism. However, the information on control costs is much more straightforward, clearly definable, and generally more easily available than specific information on the value of environmental damage. An added benefit is that the parameters of the impacts considered are very clearly defined.

In the case of CO₂, the absence of current impacts makes it very difficult to quantify possible effects, but information on amelioration through reforestation can be used to develop benchmarks. Even if full damage costs are never known, a reasonable inference can be made as to whether the damage costs are greater, or less than, the known cost of reforestation. Finally, the use of emission standards may underestimate costs, as emission damages and affected populations -- and thus the economic costs -- vary considerably across air basins.

4) FULL COSTING OF EXTERNALITIES

DESCRIPTION : This assessment option involves developing methods of identifying the environmental impacts of alternative generating resources and developing a rigorous means of valuing the associated damages. Such costs may then be used to develop, for example, environmental credits for particularly benign resources, or conversely, a cost penalty for key unmitigated pollutants. This approach of comparing two or more resources by a detailed and consistent tally of social costs is depicted in Exhibit 9.

SUMMARY OF STUDIES : These full costing studies vary in detail and intent. Full costing efforts are an ongoing effort at the Bonneville Power Authority, and their efforts are among the most rigorous. They examine impacts, dispersion, exposure, and valuation in a number of site-specific and generic studies on valuing the social costs associated with power plants.

A recent memo from BPA summarizes their findings on cost ranges, and indicate that 80 to 95 percent of local economic damage attributable to fossil fuel combustion is accounted for by health risks. Even with low sulfur coal and remote siting in the West, coal plants can be expected to impose levelized environmental costs of between 2-10 mills per kWh for health risks alone. This does not include costs associated with acid rain, ozone depletion, and global warming.

As stated earlier, Olav Hohmeyer of the Fraunhofer Institute in West Germany completed a detailed full costing study of impacts in that country in 1988. One of the most salient features of his analysis is the delay imposed on the development of many renewable energy technologies that results from the failure to account for the social costs of conventional energy sources:

Shuman and Cavanaugh, in writing a power and conservation plan for the Pacific Northwest, point out some of the possible pitfalls in full costing. They state that preserving legitimate uncertainties is better than ignoring them, and that "environmental analysis can easily be abused by opponents or proponents of a given technology if the many uncertainties in the analysis are collapsed into a single cost figure."

The Electric Power Research Institute performed a review of methodologies in this category and determined that simple damage control cost figures do not include behavioral responses, and accurate accounting for social costs requires the application of methods such as hedonic pricing and contingent evaluation.

OBSERVATIONS AND UTILITY IMPLICATIONS : One inherent difficulty in this approach is reaching a consensus on which cost measures to include and in what detail. Even if all aspects and theoretical links are known, it is difficult and expensive to produce accurate data to fill in the theoretical framework. This results in a need to make tradeoffs between the veracity of the selected methodology, staffing, and budget constraints.

Exhibit 9

Full Costing

As in "cost of control" approaches, the economic cost of energy-induced environmental impacts is highly variable depending on the resource type and the site characteristics.

STRENGTHS AND WEAKNESSES OF METHODS

Any and all of the methodological categories described in this paper can result in useful approaches to the problem of accounting for externalities. Within any of these categories, the individual design of the methodology remains most important. The value of a particular methodology ultimately depends on the assumptions made, the level of detail required, and the care taken in putting it all together. A summary of the methodologies reviewed in this report is included as Exhibits 10 and 11, and some of these will be elaborated upon further in Chapter IV.

A visual representation of the four categories of methodologies presented is included in Exhibit 12. In this diagram, two of the most important characteristics of the methodologies graphically represent some of the trade-offs inherent in the selection of a methodology. The X-axis represents the relative cost and complexity of the method, while the Y-axis scales the relative degree of accuracy (or avoidance of subjectivity that approach provides).

"Description and Characterization of Impacts" methodologies are relatively low on both scales. Such approaches are relatively simple, but provide few answers to the many questions they raise.

"Ranking and Weighting" schemes introduce more complexity, but presumably provide some guidance in how resource options stack up against each other. Most of the increase in apparent "accuracy" is a function of increased subjectivity, and thus may be suspect. However, the careful design of such a methodology can provide a consistent approach to the complete unbundling of a disparate range of attributes.

"Cost of Control" techniques lend themselves very well to the problem of awarding price factors to certain attributes. Avoiding the subjectivity of ranking and weighting essentially requires deferring judgment to the will of regulatory bodies, but results in an effective translation of the regulatory mandate. However, certain attributes may still need to be described through ranking and weighting approaches.

"Full Costing" approaches -- the most expensive and complex-- purport to provide the most accurate view of the true cost of power. The implicit question raised is whether the marginal increase in accuracy is worth the increase in complexity (a complex trade-off problem).

Describe and Characterize

Ranking and Weighting

Cost of Control

Full Costing

Exhibit 11

METHODOLOGIES TO ESTIMATE SOCIAL COSTS

Describe and Characterize

1. **Environmental Effects of Electricity Generation** - Describes the range and types of environmental impacts associated with electricity generation from various primary energy sources in both qualitative and quantitative terms.
2. **Energy System Emissions and Material Requirements and Environmental Emissions from Energy Technology Systems** - Quantifies and compares life-cycle emissions from various power generating technologies.
3. **Environmental Analysis of Energy Systems: The Total Emissions Model for Integrated Systems** - Fuel cycle energy and emissions data to assess and compare various energy systems.

Ranking and Weighting

1. **The Social Benefits and Costs of Electricity Generation and End-Use Technologies** - Focuses on the need for improved energy planning to incorporate social benefits and costs from generating technologies. Uses weighting criteria to value both the important and magnitude of various impacts.
2. **Integrating Environmental Externalities into Resource Planning at New England Electric** - Develop a hybrid approach to weight environmental impacts.

Cost of Abatement

1. **Energy and Cleaner Air: Costs of Reducing Emissions** - Attempts to relate emissions abatement technologies and their costs.
2. **Environmental Externality Issue Report** - An evaluation of approaches to valuing environmental impacts and incorporating those values into state-level energy planning.
3. **Case 88-E-241 Proceedings on Motion of the Commission as to the Guidelines for Bidding to Meet Future Electricity Capacity Needs of Orange and Rockland Utilities** - A study of how environmental factors should be incorporated in the competitive bidding rate structure.

Full Costing

1. **Social Costs of Energy Consumption - Externalities of Electricity Generation in the Federal Republic of Germany.** Monetizes environmental and economic costs upon society to demonstrate the need for internalizing social costs of electricity generation.
2. **Social Cost Priority Matrix - Ranks survey-generated energy and environmental concerns.** Also attempts to quantify associated social costs.
3. **Testimony and Exhibits of Michael Nicklas before the North Carolina Utility Commission or Least - Cost Integrated Resource Planning - Utilizes a limited set of clearly quantifiable societal costs to determine least-cost power.**
4. **Estimating Environmental Costs and Benefits for Five Generating Resources - Estimates the economic value of environmental impacts from renewable technology power generating. Identifies and analyzes impacts, then calculates the present value of expected environmental impacts.**
5. **A Model Electric Power and Conservation Plan for the Pacific Northwest - Uses low discount rates to analyze generic yet significant environmental impacts of coal, nuclear, and wind powered generation as well as solar water heating and household weatherization.**
6. **A Methodology for Integrating Air Quality Impacts into Energy Resource Planning - This is a review of the conceptual role of social costs in the competitive bidding process. Recommends values for air quality impacts and integrates these values into bid rating structures.**

Exhibit 12

Trade-offs Between These Approaches

Accuracy or Reduction of Subjectivity

Cost and Complexity

IV. A REVIEW OF METHODS FOR INTEGRATING SOCIAL COSTS INTO UTILITY BIDDING SYSTEMS

OVERVIEW

Competitive bidding for new electric generation by private power producers is becoming an increasingly important feature of utility resource planning and represents a major departure from the historical practices of the electric utility industry in which new generating resources were constructed by vertically-integrated utilities. Competitive power procurement may fundamentally reshape the market for power producing technologies.

Capacity bidding systems are now being developed in a number of states as a means of implementing least-cost resource planning. In some states, multiattribute systems, which take into account externalities as well as direct financial resources costs, are being considered as a means of improving allocation.

The design of bid evaluation systems is a challenging task because it requires the explicit valuation of many "non-price" factors of utility planning. Bidding systems require that these non-price factors or attributes which had not been previously priced in the market such as fuel diversity and risk, dispatchability, and environmental impacts be valued explicitly and independently. The multiple attributes are then simultaneously evaluated in order to arrive at the best outcome for long-term power contracts. The design of bidding systems allows the utility to retain an overriding influence in the final selection of a generating system.

There are several reports which concerned the use of procedures to incorporate environmental externalities into utility bidding systems. Specific examples included: 1) the Orange and Rockland utility located in New York and how it became a test bed for methodologies based on conflicting beliefs for the valuation of the environmental block; 2) prepared the development of a methodology to value air quality impacts for the California Energy Commission by Sebold et al., which could be used to incorporate full cost mechanisms into utility bidding schemes; and 3) the New England Electric Utilities development of a methodology for incorporating environmental externalities into the bidding process. Another report, *Evaluation Methods in Competitive Bidding for Electric Power*, by Kahn et al., examined the overall complexity of bidding systems, its nuances and how different methods could affect ultimate outcomes, e.g., the allocation of points for "non-price factors."

The following sections provide a conceptual overview of externalities in bidding systems as well as a discussion of the implementation techniques considered by states and utilities attempting to achieve this integration. The reviewed options include:

1. Quota Systems
2. Point Systems
3. Rules of Thumb
4. Abatement Control Approaches
5. Full Costing Approaches
6. Ranking and Weighting Systems

These overview discussions are followed by specific approaches that could be used or are being used to develop a value for an environmental attribute in bidding systems. Finally, the chapter concludes that different methods of accounting for attributes in bidding systems can affect final outcomes, and therefore, technology selections.

CONCEPTUAL ROLE OF EXTERNALITIES IN BIDDING SYSTEMS

Sebold discusses the conceptual role of externalities in bidding systems. This is presented in Exhibit 13 and described here:

"In the upper panel, we show a total resource requirement as a horizontal distance. This requirement would normally be identified in advance of the request for bids, and would take the form of some number of megawatts of total capacity. Suppose for simplicity that only two kinds of generating resources are available, so that the total resource requirement must be equal to the sum of the chosen capacities of the two resources. This assumption allows us to use the horizontal axis of Figure 1 to depict amounts of resource A (measured by left to right) and resource B (indicated from right to left). Suppose resource B has no externalities. Under this restrictive assumption, the marginal social and private costs of using the resource will be equal. In accord with standard assumption, the marginal private social cost of B rises as more of the resource is used (i.e., as we move from right to left in the diagram). Assume on the other hand that resource A gives rise to significant external cost. Then its marginal social cost will lie above its marginal private cost, as shown in the figure.

The lower panel shows the total social and private social costs of satisfying the given resource requirement. In a capacity bidding setting where external costs are ignored, the competitive mix of resources indicated in Figure 1 will be chosen. It will be the mix that minimizes the total *private* cost of meeting the capacity need, and will be determined where the marginal *private* costs of the two resources are equal. However, the minimization of total *social* costs requires a different mix. The optimal mix (from the social perspective) is found where the marginal *social* costs of the two resources are equalized. As shown, this optimal mix will entail less of resource A and more of B than the competitive solution."

Sebold also believes that achieving the optimal mix essentially requires considering social costs, rather than only private costs, when assessing resource bids. In order to take external costs into consideration, of course, some reasonably reliable means are needed of adding these costs to private costs. In formal terms, this means that ways must be developed of

Exhibit 13

Misallocation with External Costs

estimating dollar values of these externalities, so that they can be added to bid prices, and, thus, in the jargon of academic literature, "internalized" into the decision process.

REVIEW OF IMPLEMENTATION METHODS

1. QUOTA SYSTEMS

This option -- also known as the rule-based approach -- involves the design of bidding systems so that a certain portion of capacity requirements are filled by technologies with relatively favorable external effects (e.g., environmentally benign technologies, or those which improve the diversity of the fuel mix, or those with strong employment impacts. While Sebold et. al say that this approach is fairly easy to implement, they believe that it neither avoids or solves the problem of valuation. In terms of Exhibit 13, it assumes that the planner knows the optimal mix of resources; however, they believe that this mix cannot be estimated without information about the values of important external costs.

The bulk of the analysis goes into determining quota levels and there is little room for give-and-take in later stages. While this approach is fairly easy to implement, it sidesteps the problem of valuation and can create serious distortion. By making the assumption that the optimal mix of resources is known, the (relatively) positive aspects of particular resource options are exaggerated without equally considering their (relative) shortcomings. The optimal mix cannot be estimated without information about the values of important external costs.

Rules can be used to encourage bids for technologies that have certain perceived benefits. For instance, the Wisconsin PUC chose a rule-based approach when it elected to give noncombustion resources like hydro and conservation a 15 percent advantage. Rules can also be used to limit the absolute amount of a particular resource that would be accepted in a portfolio or in a resource bid. However, such approaches may preclude established forms of energy prematurely, and do not solve the problem of how to select dissimilar or even similar proposals in a bid.

2. POINT SYSTEMS

A few bidding systems have been designed so that points are allocated to technologies on the basis of their associated externalities. The subjectivity of many external and non-price effects suggest that they should be reduced to a point score through a consistent methodology. Final choices are simplified at the expense of subjectivity, and this may be acceptable.

According to Sebold, planners faced with monetary bids and point scores for each resource option are still faced with determining trade-offs between points and price. He states:

"Suppose two resources are bid, one at the cost of \$700 per MW and the other at

\$600 per MW. Suppose also that the first resource receives a point score of 5, and that the second has a score of 7 (where higher scores are better). The choice between these two options depends upon the dollar value of points, which in turn depends on the valuation of the externalities underlying the point scores. Point systems don't answer questions concerning valuation, they merely rephrase them."

Despite reducing bid factors to points, methodologies must be evaluated to ensure that the nominal weight awarded to a category does in fact survive methodological processing in its intended form and that categories do not cancel themselves out in such a way to render the actual weight meaningless. Kahn et al., has shown that despite the point systems for these externalities, many decisions basically are made on the basis of price. (This is discussed further in the section on Different Methods for Accounting for Attributes in Bidding Systems Affect Final Outcomes).

3. SIMPLE RULES OF THUMB

Sebold et al. state that perhaps as a natural reaction to the complexity of the problem some individuals have suggested the use of simple rules of thumb for valuation. For instance, some in the California debate have suggested that air quality impacts be quantified in terms of single primary emissions, NO_x, and that a rough reference value of this emissions (say \$20,000 per ton) be used for valuation. Insofar as there are several variations on this kind of approach, Sebold states it is difficult to list specific problems with it. He offers two general points:

"Rough rules of thumb that deal with single emissions (e.g., NO_x) are extremely narrow, and may really further distort resource decisions. Generating resources tend to have different "relative mixes" of emissions. Focusing on a single emission may minimize some adverse environmental impacts while exacerbating others. The result far worse, rather than better than that which could be obtained by ignoring air quality impact altogether.

Rules of thumb that ignore variations in external costs across air basins are partially useful. External costs vary substantially across air basins due to differences in air chemistry, topography, weather, subject populations and other factors. This happens for two general reasons. First, a given primary emission may have very different impacts on air quality in different basins. For instance, NO_x emissions may significantly aggravate ozone concentrations in one air basin, yet have little or no impact on ozone in another. Second, a given change in air quality (e.g., ozone levels, visibility, etc.) will have different economic values in different basins because of differences in affected populations of people, animals, plants, and materials. The value of a change in visibility, for instance, depends partly on the size and characteristics of the affected human population."

(Some of these difficulties were discussed in the preceding chapter on methodologies for valuing damages).

4. ABATEMENT COST APPROACHES

One approach being used in New York is the use of abatement costs as indirect measures of the values of air quality impacts. According to this line of thinking, optimal air quality control policy sets emission limits where the marginal costs of abatement are equal to the marginal benefits (where these benefits are conceptually the same as the external costs associated with the emission). Thus, the abatement costs associated with a given emission (say, NO_x) can be used as a proxy for the external costs of the emission. Sebold et al., say that this approach sounds attractive in that it uses generally available information and is applicable to a wide variety of emissions. As pointed out in the earlier chapter, there are also some weaknesses with this approach which include the fact that control costs are based on national standards and these standards might have different effects in different air basins. Thus, abatement costs may be well above the benefits of abatement (the external cost of the emission) in some air basins and considerably below in others. In addition, the abatement cost for a given emissions may vary significantly across sources. It may be cheaper to use some methods of abatement than others, yet if the value of an external ton of NO_x is the same across sources within a basin, it is unclear which abatement level (if any) should be chosen to reflect the external social costs of this emission.

5. ECONOMIC VALUATION OF DAMAGE COSTS (FULL COSTING)

This approach is to identify environmental impacts of alternative generating resources and to develop a rigorous means of valuing the associated damages. While this can be a herculean task as discussed in the earlier chapter, some (Sebold et al.) suggest an approach that they believe is feasible given the existing state of the art with respect to economic valuations. They outline an approach for valuing air quality impacts which is discussed later in this chapter.

6. RANKING AND WEIGHTING

This final approach was developed by New England Electric which hired Temple, Barker, and Sloane, Inc. to develop a methodology for incorporating the effects of environmental externalities into the resource planning process and the development of NEESPLAN: 1990. This approach includes both qualitative and quantitative aspects in order to arrive at a highly developed ranking and weighting system. The approach examined attempts to integrate a number of items which evaluate disparate environmental characteristics in order to minimize subjectivity. The methodology depends on experts' opinions and while the results are still relatively subjective, there is consistency in the relative weighting and environmental issues.

The choice of the implementation method selected will affect the translation of social costs into the bidding framework and ultimately technology choice. Determining the best method for doing this that permits implementation while preserving the essence of social cost values, will depend on utilities' experience with these methods and their relative capabilities and resources. The best framework for doing so is still open to interpretation (depicted in Exhibit 14). Several applications are discussed in the following section.

Exhibit 14

Implementation Framework: Social Costs and Utility Bidding Systems

APPLICATION OF THESE METHODS INTO UTILITY BIDDING

This section reviews several approaches for applying these methods into utility bidding: 1) The New York/Orange and Rockland case which uses cost of control; 2) Sebold and Thayer's approach to the possible use of full costing procedures; and, 3) New England Electric Utility approach which uses a ranking and weighting approach.

1. Proceedings on Motion of the New York Public Service Commission as to the Guidelines for Bidding to Meet Future Capacity Needs of Orange and Rockland Utilities (USE OF COST OF CONTROL TECHNIQUES)

Perhaps the most notable example of a process where state energy office and PSC officials worked together to arrive at inclusion of environmental externalities for a utility bidding system is the recent outcome of the recent New York State Public Service Commission ruling concerning Orange and Rockland, a New York utility.

In June 1988, the New York State Public Service Commission (NYSPSC) requested (in Opinion 88-15) that the state's electric utilities file a Draft Environmental Impact Statement (DGEIS) in order to assess the potential environmental impact of utility bidding procedures. This utility became a test bed for methodologies including environmental externalities in utility bidding systems.

This began an evolutionary process. Orange and Rockland had originally proposed a 10 percent environmental block for bid evaluation. However, the State Energy Office, had developed data based on a 200 MW coal-fired plant meeting New Source Performance Standards (NSPS) for several control cost scenarios ranging from mixed control to advanced control technologies that indicated that environmental effects comprised 20-30 percent of avoided costs, and that bid scoring should reserve that amount for environmental effects. They estimated that air emissions alone were in excess of 8-24 percent of avoided cost, and recommended reserving 40-80 percent of the environmental block for NO_x, SO_x, and CO₂ emissions.

The issues then faced by NYSPSC staff included determining the appropriate weight to assign to environmental effects, and within this environmental block, the most appropriate methods for apportioning weights among individual environmental factors.

Both NYSPSC and the New York State Energy Office (NYSEO) assumed that new projects would comply with Federal New Source Performance Standards. For most air impacts, abatement costs for meeting NSPS were thus used as a proxy for the value of environmental damages. Other costs were developed using estimates from other sources. These costs were used as guidelines to confirm the size of the components of the environmental block, modifying what had been a more subjective ranking and weighting scheme. Their figures are as follows :

<u>Effect</u>	<u>Cost per kWh (Proxy)</u>
Sulphur Oxides	0.25
Nitrogen Oxides	0.55
Carbon Dioxide	0.10
<u>Particulates</u>	<u>0.005</u>
Total Air Emissions	0.905
Water Discharges	0.10
<u>Land Use Impacts</u>	<u>0.40</u>
Total cost	1.405 cents/kWh

By assuming that winning bids would come in at no more than the company's avoided cost of 6.42 cents per kWh, environmental externalities were calculated to be about 24% of average cost. This price factor was then reinterpreted into a point factor that could be integrated into Orange and Rockland's existing point system. The final NYSPSC recommendation was for an environmental block sized at 24% of the price score (not the total score) where the price score comprised 47% of the total score.

While the NYSPSC acknowledges that their conclusions do not form a complete methodology, and that additional efforts are necessary to ensure consistency in applying the methodology across different utilities, the NYSPSC also agreed that it was not in the state's best interests to assume the full cost of its CO₂ emissions until it received some assurances that other states would follow suit. They also expressed concern that premature use of very high estimates would offer a disproportionate advantage to gas-fired over coal generation. They did, however, recommend that New York utilities initially take small, unilateral steps as preparation for the imposition of more stringent requirements at a later date.

The strength of the New York-Orange and Rockland methodology is that it eliminates the problem of comparing price and point factors by essentially reducing them both to one price factor (even though they are later reconverted to points). Also, the size of the environmental block that should be considered in a bidding process is automatically defined by the components of the price factors themselves, and different resource options can be compared on a consistent basis. Thus, all factors that can be reduced to price are included in a price block where they may be compared consistently with price factors of competing resources. Non-price factors (such as dispatchability, fuel diversity, risk, etc.) are considered in a separate block.

However, the major shortcoming is one of subjectivity. The use of abatement costs as a proxy for environmental costs is wholly dependent on the level of environmental control that is considered "sufficient," whether it be legislated emission limits or an academic best guess. While such a methodology could very quickly accommodate a new set of emission requirements, its focus is on targets rather than actual costing information.

2. ***A Methodology for Integrating Air Quality Impacts into Energy Resource Planning***, Frederick D. Sebold and Mark A. Thayer of Regional Economic Research, Inc. (San Diego, California) undertaken for the California Energy Commission. (USE OF FULL COSTING TECHNIQUES)

This paper by Sebold et al., which was prepared for the California Energy Commission, reviews the conceptual role of externalities in utility bidding systems and makes recommendations for valuating air quality impacts and integrating these values in bidding systems.

Sebold et al., suggest a methodology to approach the economic valuation of damage costs as follows:

1. They believe that a large body of literature already exists on dose-response relations and that the dollar value of physical impacts can be estimated from this information. They discuss the resource approach, contingent valuation (willingness to pay), and revealed preference methods.
2. They recommend the construction of reference values of external costs, e.g., the air quality impacts per unit, the physical dose-response functions, and the dollar values of key physical responses. Impacts are measured as the dollar value of a one-unit ton change in each emission in each air basin.
3. The next step is the integration of reference values into the bidding system:
 - Each technology/resource offered in the auction would be reviewed and a set of emission factors would be determined. These factors would indicate the level of emissions per ton for each of the subject emissions.
 - These values would be multiplied times the reference value (dollar values per ton) for each emission for the basins in question, to get an estimate of the external costs associated with the resource per ton.
 - An assumed capacity factor and resource lifetime would then be used to translate this value into the implied external cost per kW of capacity.
 - Finally, the external cost per kW would be added to the bid price of the resource in question.

They assert that the information exists, and that while assembling the information

in useful form would be complex, it results in a practical yet rigorous methodology that they feel is superior to other methods. Sebold and Thayer make the very important observation that environmental effects may be site-specific, making it difficult to evaluate them generically. Moreover, that the economic value of an environmental effect may vary depending on where it originates also has broad implications. For certain impacts in some areas -- those that have health or material damage implications, or occur in areas where the dose-response relationship is already high -- using a generic cost would underestimate the actual impact. Other impacts, such as CO₂, have no localized impacts in the short run, and generic worldwide costs may be the more effective proxy.

Such an approach would be costly and time-consuming, and would only be fairly applicable if it were performed consistently over a very large area. If only air impacts were to be considered, the proposed methodology could be workable. However, applying the method to a significantly broader set of concerns might make the process too onerous for practical application. Little guidance is suggested regarding the integration of results into the bidding process; however, since their methods would deliver strict price results, integration should not be very difficult.

3. Integrating Environmental Externalities into Resource Planning at New England Electric (RANKING AND WEIGHTING)

In Massachusetts, the Department of Public Utilities (Document 86-36-F) ordered the state's electric utilities to consider environmental effects in their resource planning process. During the summer of 1989, various Massachusetts utilities, regulators, and selected individuals with environmental concerns met in a collaborative series of meetings to review environmental effects of power production and attempt to agree on proposed approaches to the problem. The environmental groups preferred full costing methods, while utilities embraced ranking and weighting methods.

As previously noted, New England Electric hired Temple, Barker and Sloane, Inc. to develop a methodology for incorporating these effects into the resource planning process and the development of NEESPLAN II: 1990.

TBS compared a wide range of qualitative and quantitative approaches and arrived at what they termed a "hybrid approach." The TBS approach borrows much of the "cost of control" as a proxy for environmental impacts methodology used in Orange and Rockland, but rather than using this, they generated environmental categorizations and weights through Delphi survey techniques and from existing data related to regulatory requirements mandating various emissions levels. A limited number of surveys (11) were completed by environmental professionals at both the primary level (where respondents weighed individual environmental effects) and the secondary level (where they assessed the total environmental score).

TBS and NEES determined some ground rules that formed the basis for their methodology as follows:

- externalities are best characterized as "issues"; i.e., global warming or acid rain rather than specific emissions
- externalities should be considered from society's, not the utility's, point of view
- only environmental externalities occurring in the operating stage would be considered initially
- movement toward full costing was a desirable long-term goal

Ten environmental issues were selected from their surveys and included: global warming, acid rain, land use, solid waste, water use/quality, emissions to air, aesthetics, indoor air quality, fuel issues and ozone. (This approach was somewhat similar to the ASES priority matrix in that questionnaires were sent out to various experts to list and rank what they thought were the foremost environmental concerns.)

Each environmental issue set was then broken down into one or more sub-issues. For example, acid rain was broken down by sulfur oxides and nitrogen oxides, with the least amount of points being given for those technologies that pollute less (with least points being the best). Similarly, for land use, a generating system that would use pristine land would receive higher points (for relatively greater impacts) than land that was currently used for industrial purposes (a relatively lower impact). The relative weighting of issues was determined by compiling information from studies and reports, Delphi polling of experts, and the use of weights determined in previous methodologies. Its one-page evaluation sheet provides a simple but succinct evaluation of a resource option. (Exhibit 14a presents the worksheet that resulted from their work).

Factors Contributing to Score for Environmental Attribute

The factors contributing to scores for individual issues were compiled depending on the characteristics that best described their impact :

Regulatory:

If the factor could be described by legislated limits (such as NSPS), then the scoring scale related to the degree that a resource met that limit. For instance, the highest emission level of any realistic Massachusetts power source option determined the upper limit of the global warming category, and received a "4," whereas a source with no emissions would receive "0."

Range of options:

This normalizes impacts in the range relevant to utilities; i.e., actual weight of emissions per kWh.

ISSUES AND CONTRIBUTING FACTORS

Environmental Concern Weight	Issue	Contributing Factor Weight	Factor	(Least) -----> Impact -----> (Most)					Issue Impact Score
				0	1	2	3	4	
9%	Global Warming	100%	Carbon Dioxide (lb/kWh)	0	0.63	1.25	1.88	2.5	
14%	Acid Rain	50%	Sulfur Dioxide (lb/mmBtu)	0	0.3	0.6	0.9	1.2	
		50%	Nitrogen Oxides (lb/mmBtu)	0	0.15	0.3	0.45	0.6	
7%	Land Use	*	Amount (acres)	0	2000	4000	* multiply "amount" score by "character" score to calculate impact		
			Character	industrial	res/com/farm	pristine			
14%	Solid Waste	100%	Overall Assessment (lb/kWh)	0	0.05	0.1	0.15	0.2	
			Adjustment						
16%	Water Use/Quality	20%	Amount (gallons/kWh)	0	150	300	450	600	
		40%	Attributes of Input Water	no water used	minor loss of recreational area	minor loss of habitat	major loss of recreational area	major loss of habitat	
		30%	Thermal Attributes of Receiving Water	no change		receiving water with minor thermal change		receiving water with major thermal change	
		10%	Chemical Attributes of Receiving Water	no change		receiving water with minor chemical change		receiving water with major chemical change	
16%	Emissions to Air	25%	Air Toxics (fuel type)	no fuel		natural gas		coal or oil	
		25%	Particulates (lb/mmBtu)	0	0.0075	0.015	0.0225	0.03	
		25%	Sulfur Dioxide (lb/mmBtu)	0	0.3	0.6	0.9	1.2	
		25%	Nitrogen Oxides (lb/mmBtu)	0	0.15	0.3	0.45	0.6	
2%	Aesthetics	40%	Visual Effects	not visible or obtrusive	seasonally visible	visible from major roads	visible from recreation areas	visible from sensitive areas	
		40%	Noise	no noise	below nighttime ambient	below daytime, above nighttime	above daytime ambient	meets property line limit	
		20%	Signal Interference (households affected)	0	10	20	30	40	
2%	Indoor Air Quality	10%	Creation	reduces production		no effect		increases production	
		90%	Retention (air changes)	increases number		no effect		reduces number	
4%	Fuel Issues	100%	Overall Assessment	no fuel		natural gas		coal/oil	
16%	Ozone	45%	VOCs (lb/mmBtu)	0	0.0015	0.003	0.0045	0.006	
		45%	Nitrogen Oxides (lb/mmBtu)	0	0.15	0.3	0.45	0.6	
		10%	CFCs	no release				CFCs released	

Root cause:

This scale is an attempt to simplify effects by reducing them to their root cause, and is used primarily for assessing fuel issues.

Adjustment:

This method allows subjective adjustments to account for mitigating effects.

Grading:

This approach allows a subjective "minor - to - major" assessment comprised of broad issues (such as water/air use) that are made up of a large number of dissimilar elements.

State of the Art : This method recognizes that the lack of information on certain issues (they cite indoor air quality) precludes precision, but subjective evaluation is a reasonable proxy.

Reference to the Work of Others :

This method is essentially the borrowing of other work pertaining to ranking of impacts. For instance, in the case of aesthetics, they borrowed the ratings filed by Orange and Rockland in New York.

TBS adopted this method because they believed that full costing was not yet possible although they state that movement towards full costing is a desirable long-term goal. They found that while sources used to develop factor weights were not necessarily consistent in their implied or stated weights, they did exhibit consistency in the relative weighting of environmental issues.

The TBS methodology is a highly developed ranking and weighting scheme, and attempts to integrate a number of approaches to evaluating disparate environmental characteristics in order to minimize subjectivity. Its limitations include that while the methodology purports to borrow some of the strengths of the Orange and Rockland approach, it does not, however, actually consider impact factors on any kind of price or cost-related basis, and is consequently much more arbitrary. The methodology depends on a limited number of expert opinions, and the results are relatively subjective. Available information on the method does not specify the size of the environmental block, nor how it is considered in overall bid evaluation.

DIFFERENT METHODS OF ACCOUNTING FOR ATTRIBUTES AFFECT OUTCOMES

Kahn compares and evaluates several bid systems to determine the impact of the methodology chosen on the technology selections that result. In a California conference on competitive bidding, a hypothetical auction was held in which five technologies were competing: gas-fired cogeneration, gas-fired combined cycle, biomass, geothermal, and small

hydro. From the results of that workshop, Kahn found that the approach taken to scoring and ranking projects can affect the outcome of projects selected. He notes significant differences in the "nominal" weights assigned to price and other factors compared to real weights, or the weight that actually influences outcomes.

For example, he found that two systems that placed very different nominal weights on price (50 percent of Orange and Rockland Utilities vs. 70 percent of Niagara Mohawk) effectively ranked bids in them in the same order as a price-only system. This indicates that different methods of accounting for these non-price factors can affect future resource decisions.

Kahn seems dissatisfied with current tendencies to allocate environmental blocks within bidding procedures:

"The environmental credit concept does not incorporate competitive effects in pollution control strategies and provides few incentive for lower cost methods of achieving environmental goals. At present, there has been very little discussion of how to incorporate environmental goals into competitive bidding through means other than the environmental credit approach."

However, he found it difficult to reconcile accounting for social costs to effectively articulate environmental impacts in a form that can be accurately assessed in the competitive bidding process:

"Many of the benefits associated with... reduced environmental insult are related to the valuing of public goods rather than private goods. Because the power auction process is primarily a procurement for private consumer benefit, it is not clear what weight should be given to the public benefits associated with choices made in the process."

Despite his difficulties in resolving these larger issues, Kahn's observations regarding nominal weights are very important. They warn against including a multitude of complex factors that are effectively cancelled out by the systems. In essence he is advocating critical review of the methods to incorporate social cost factors to determine their effect on project selection.

UTILITY AND REGULATORY PERSPECTIVES ON SOCIAL COSTS

True least-cost planning conceptually requires consideration of externalities. The first step in to internalizing social or external costs is to understand them; the next step is identify and quantify them. Attempting to fully describe the entire range of effects in the electric power process is difficult in itself. Placing a value on each individual effect is considerably more difficult, particularly because external costs fall outside the normal market pricing system; there is often little real market-cost information available to use as guidance. It may be necessary to devise entirely new methods of collecting and assessing information, while certain factors may resist quantification and may require relatively

subjective assessments. In the process of accounting for social costs, there are specific boundaries that need to be defined and considerations that need to be addressed. These boundaries and considerations are important regardless of which methods are used to value social costs, and may be relatively independent of the approaches used to implement social costs in the bidding process.

Deciding which impacts and costs to consider is most difficult. The breadth and depth of the categories selected for evaluation and the way in which they are defined have a tremendous impact on the outcome of any evaluation of social costs. Accurately attributing costs to their sources is not yet a finely developed science, and this may influence which parameters are selected. The specific definitions or assumptions made introduce significant complexity into the calculation of social costs, and will later determine the rate at which social costs are traded off against others and will thus affect which impacts are mitigated. Responsibility for assessing social costs is often hazily defined, creating complications for both utilities and regulators. Each will tend to define parameters for social costing differently.

Some analysts such as Hohmeyer believe that incorporating social costs into energy planning may best be accomplished through a tax or penalty that is equal to or greater than the cost of the social cost. However, few of the methodologies reviewed suggest that such direct fashion payment is necessary. Bidding systems represent one way to incorporate social costs into the utility decision-making process to determine if and how social costs change the order in which resources are selected. While this may result in the selection of power sources that have higher energy and/or capacity costs, the lower social costs of the newly prioritized sources should result in a true least-cost resource mix.

The Utility Challenge

From the utility business perspective, resource decisions based on social costs must be evaluated in terms of their real contribution and impacts in a world where many other externalities are consistently ignored. A business that invests in pollution control equipment of its own volition would not be as competitive as others that do not take social costs into account, making it difficult to continue to represent those costs. If this resulted in any loss of market share, competitors would assume that share, eventually bringing output and externalities back up to previous levels.

The assumptions made in evaluating social costs may lead to the reduction of certain social costs, but this reduction could be translated into other negative costs or effects. For instance, methodologies that give overly generous credit to environmentally benign technologies may result in a resource mix that is environmentally cleaner but less reliable. Thus, paying increased attention to one set of social costs increases the need to accurately assess non-price factors such as risk, dispatchability, curtailability, and diversity. These factors ultimately affect not only the utility but the ratepayer as well.

In considering social costs, practicality and accuracy are of paramount importance.

No methodology is useful if it is so complex that it obscures the realities behind decisions. Likewise, something that depends only on subjective or relative factors fails to effectively deal with the economic nature of social costs. The goal is to narrow methodology choices down to the most relevant factors that can be cogently represented in a selection methodology. In achieving that goal, utilities are faced with several questions :

- To what degree do utilities contribute to overall social costs?
- How much is the cost of power distorted by social costs?
- What kinds of resources -- financial or otherwise -- are needed to accomplish the task of social costing?
- Can the information be translated into price or cost, and can that information in turn be effectively applied within the bidding environment?
- Does the use of this information create other effects that are reflected in profitability, competitiveness, market share, or other risks?
- Are requirements set by regulators consistent and capable of implementation?

Questions of utility responsibility for social costs, and their ability to effectively address them, must be answered before social costs can be reduced through utility planning.

The Regulatory Challenge

From the regulatory perspective, the definition of the characteristics used to define social costs raises significant questions as well. The CEC has stated that their criteria are to: minimize total system economic costs (production and capital costs, reliability, and operations), account for uncertainty, preserve environmental quality, maintain a sound economy, conserve resources, and protect public health and safety. While the items on this menu are not mutually exclusive, maximizing all of them at the same time is an enormous challenge.

While contexts for reducing social costs need to be created, definitions set by a utility may be overridden by regulatory bodies, whose decisions may in turn be overridden by national or global political requirements. Whether social costs are considered on a regional, state, national, or global scale will have very different results. Considering only the social costs that occur with a utility's service area fails to account for any localized impacts resulting from power imported from generation sources located outside the service territory, and likewise ignores the effects of emission exports. A state such as California, which receives relatively fewer pollutants from other sources, does not have as great a need to count imported external costs. Other areas, such as Eastern Canada or New England, which are suffering from acid rain largely produced in the Midwest, are already attempting

to mobilize political resources to ensure that exporting impacts carries some prohibition or penalty.

States producing or burning large quantities of coal could resist efforts to ameliorate large CO₂ discharges by defining new bidding methodologies to give minimal consideration of the potential damage due to CO₂ emissions. States that produce or use little coal -- such as California -- might not be adversely affected if CO₂ emissions receive a heavy weighing in mandated national standards. However, if such standards are implemented solely within California, the implications for regional inter-competitiveness are enormous. The California Energy Commission has stated that :

"If we adopt a social value for CO₂ emissions for electricity and if these values result in higher costs of electricity to consumers, this may have perverse effects. For example, higher rates might cause large customers to switch to self-generation fired by the cheapest fuel (probably gas) or might lead customers to choose to locate their new facilities in another state which produces electricity without CO₂ guidelines."

Thus, one possible outcome is that efforts to account for social costs are circumvented, and the intended reduction in emissions is thwarted. The other result could be the loss of business opportunity and income, accompanied by a transfer -- rather than reduction -- of emissions to another region. Regulatory attempts to account for social costs must carefully define boundaries, or run the risk of unintended effects. For example, in order to meet their sulphur emission targets, Ontario Hydro has agreed to purchase power from Illinois Power, which burns high-sulphur coal. Ironically, these emissions tend to find their way towards Canada, which has more severe acid rain problems than Illinois. Ontario has met the required target, but not the intent of the acid rain legislation. In this case, inadequate definition of the necessary boundaries has resulted in a situation where externalities were increased rather than reduced.

Similarly, attempts to reduce emissions can result in disincentives to demand side management if they are described in terms of emission rate limits rather than emission caps or ceilings. Under an emission ceiling, lower emissions resulting from DSM can account for the same reduction in social costs as scrubbers or fuel switching. Since DSM reduces total emissions by reducing the number of hours that existing plants operate, but does not change the rate emission from that plant when it operates. Thus, if emission reductions resulting from DSM are to be properly accounted for, and provide an accurate incentive to consider DSM options, emission ceilings rather than rate requirements are likely to result in the intended outcome. Such boundary issues -- regarding source, effect, and jurisdiction -- are likely to become more important over time as issues are politicized and as mitigation attempts are pursued on a piecemeal, rather than multilateral basis.

V. REVIEW OF CURRENT REGULATORY EFFORTS

This section provides a review of regulatory efforts to examine social cost issues.

STATE EFFORTS

Several utilities and public utility commissions are responding to the increasing national concern over the environmental impacts of electric supply sources by explicitly including environmental externalities in the bid ranking process.

Vermont :

The governor of Vermont and a coalition of environmental groups, have developed a program to identify new resources to offset the proposed early retirement of their Yankee nuclear plant, and developed a schedule of goals for reducing greenhouse gases and acid rain precursors by 15% below current levels by the year 2000.

Oregon :

For a number of years, the Bonneville Power Administration has performed an Environmental-Cost Analysis which they utilize in assessing future options.

California :

A Joint Committee on Energy Regulation and the Environment was recently formed by the state's legislature. Technical experts have been commissioned to develop white papers in three areas:

- #1. Electricity resources and environmental impacts
- #2. Energy efficiency as a coordinated environmental/energy strategy
- #3. Integrated solutions to energy, air quality, and vehicle problems

A public forum is scheduled to be held in California in February 1990 which will examine these issues with utilities and other interested parties.

New York :

New York has set a goal of reducing carbon dioxide emissions 20% by 2008. The state energy plan also recommends a 2.5% annual reduction in energy consumption per dollar of gross product. Although the PSC recognizes that many externalities are still not included, they have begun assessing specific environmental impacts.

● *Case 88-E-241 - Proceedings on Motion of the Commission as to the Guidelines for Bidding to Meet Future Electricity Capacity Needs of Orange and Rockland Utilities.*

In this document, air emission and other external costs are assigned an economic value in cents per kWh, e.g., sulfur oxides at 0.25 cents/kWh; NO_x at 0.55 cents/kWh; and CO₂ at 0.1 cents/kWh. The total costs of environmental externalities are 1.405 cents/kWh. These costs were then transposed into points as part of a scoring formula (e.g., 15 points in the Orange and Rockland utility). Such scoring is emerging as a suggested approach for other New York utilities.

Massachusetts :

In Massachusetts D.P.U. 86-36-F, all electric utilities in the state were instructed to include consideration of externalities (primarily environmental) in their planning processes, but did not specify any particular approach. During the summer of 1989, Massachusetts utilities, regulators, and environmental groups entered a collaborative process to explore responses to this directive. In this process, the Conservation Law Foundation expressed its desire to see full costing methods pursued, while the major utilities preferred ranking and weighting approaches.

In December 1989, the Massachusetts D.P.U. issued 86-36-G, which suggested, but did not require, that environmental considerations should receive a 25% adder in the planning process. Technical review of this directive is underway, and the D.P.U. has asked for comments from utilities. They hope that their least-cost planning process will be complete by 1991, and will incorporate environmental considerations.

Wisconsin :

● The Wisconsin Public Service Commission is very progressive in terms of assessing long term supply and demand requirements for generation capacity and what impacts those requirements will have on utilities and their customers. In 1976, the state passed the "Power Plant Site Act" to provide a means for comprehensive, rational, long-term planning to best meet the state's future electricity requirements. The Act calls for the PSC to develop a plan every two to three years and it gives the PSC broad authority on how to proceed with the development of each plan. The PSC is advanced in both its level of planning and its incorporation of non-economic issues into each plan. Each plan then serves to form somewhat of an ongoing statewide

model for meeting future generation and transmission needs as well standards for cost environmental impact, etc. As such, utility proposals for additional generation capacity or transmission lines must be consistent with prior PSC plans.

- Initially the plans focused on future demand, capacity additions, and transmission requirements. Increasingly, however, they have incorporated environmental issues into the overall planning process. The state considers the role of the environment to be an integral piece of the long-term plan. The PSC, in previous plans, has addressed the environmental impact of nuclear-powered generation as well as coal-fired generation. Currently, they are looking at more broad and long-term environmental effects. This means analyzing various supply and demand options, life cycle costs and the resulting environmental impacts.
- In addition, the PSC is considering the inclusion of social cost issues into the competitive bidding process. However, in this current effort the PSC is at a very preliminary stage. It is first trying to determine if incorporating social costs into the bidding process is reasonable or effective. If so, it will then attempt to determine the best method for doing so. Progress in this area is not expected in the near term.

FEDERAL EFFORTS

At the federal level, no attempt has been made to quantify social costs which are directly attributable to electric utilities. However, as part of the National Energy Strategy and associated public hearings, there has been an expressed need for social cost methods and for incorporating these costs in the evaluation of power-producing technologies. In addition, the Department of the Interior and the Environmental Protection Agency currently have contractors estimating social costs of selecting technologies. It is evident, that as federal efforts continue, the tools for assessing environmental effects will improve.

Federal efforts in this area have focused on analyzing general effects that President Bush's Clean Air proposal would have on the environment and industry. For example:

- The Environmental Protection Agency (EPA) is performing a number of studies in response to the Bush proposal. However, these studies have focused primarily on the cost of abatement to meet the proposal's requirements as well as the resulting reduction in emissions. The issues of concern include acid rain, global warming, and visibility. No action is foreseen to assess full social costs.

- The National Acidic Precipitation Assessment Program (NAPAP), part of the Council on Environmental Quality, is a federal interagency group whose mission is to assess the range of federal studies regarding acid rain and report its findings to the Congress. As with EPA, a large part of their recent work has involved reviewing the President's Clean Air proposal as well as other federal efforts surrounding that proposal. They have not performed a comprehensive analysis of the impact of acid rain generated social costs on the economy. Moreover, they do not foresee such a study in the near term. A comprehensive national level analysis would introduce many variables, uncertainties and subjective decisions in its development. Therefore the validity of such an analysis would be seriously questioned.

TRADE GROUPS

In response to the administration's Clean Air proposal last session, several members of Congress introduced alternative clean air legislation. As the number of clean air legislation possibilities has grown, so has the likelihood of passage of a clean air bill. As a result, a few trade groups (such as National Association of Manufacturers, Edison Electric Institute, and the American Gas Association) have begun to perform their own assessments of the impact clean air legislation will have on their respective industries. Some trade groups have also performed their own analyses on the impact their industries have on current emissions and what role they can play in reducing harmful emissions in the future. To date, none of these studies has attempted to address the issue of comprehensive economic effects or social costs associated with emissions. Cost related figures, instead, have focused primarily on abatement costs.

VI. SUMMARY AND CONCLUSIONS

Historically, the market price of conventional energy has not fully accounted for all the resultant external costs imposed on society. However, the attention paid to externalities, or social costs, is now growing rapidly. There are multiple influences behind this increasing concern including: economic growth and a concomitant expansion in electricity demand and its environmental impacts; a greater scientific understanding of external impacts; and improved methods of estimating the actual costs of impacts. The emergence of institutional mechanisms such as least cost planning and competitive bidding are also influencing this shift in priorities. Coinciding with these factors is a much broader range of technological choices available (at varying costs) to mitigate many externalities.

The first step in valuing social costs, or "internalizing" them into the decision process, is to identify and quantify their impacts; the next step is to develop values for these impacts. Attempting to fully describe the entire range of effects in the electric and gas power processes is difficult in itself. Placing a value on each individual effect is considerably more difficult, particularly because social costs fall outside the normal market pricing system; there is often little real market-cost information available to use as guidance.

In the process of accounting for social costs, there are specific considerations that need to be addressed. Deciding which impacts and costs to consider is most difficult. The breadth and depth of the categories selected for evaluation and the way in which they are defined have a tremendous impact on the outcome of any evaluation of social costs. Accurately attributing costs to their sources is not yet a finely developed science, and this may influence which parameters are selected. The specific definitions or assumptions made introduce significant complexity into the calculation of social costs, and will determine the rate at which social costs are traded off against others and will thus affect which impacts are mitigated. Despite these inherent difficulties, several techniques are being used to quantify and value social costs.

The primary purpose of this effort has been to review the concept of social costs and identify the procedural and methodological approaches to the problem of quantifying and pricing externalities. The various methodologies fell into four broad categories ranging from assessments based principally on value judgements of environmental and social impacts to attempts at full quantification and valuation of social costs. The methodologies are described in considerable detail in Chapter III. The pros and cons of different methods were described as well as their potential implications for the utility industry and PG&E.

In Chapter IV, a number of approaches were discussed that could be used to translate these values into an environmental attribute that can be employed in the utility competitive bidding process. Three efforts to account for social costs, either under way or under consideration by various utilities and/or regulatory bodies, were reviewed. Ultimately, the selection of a particular methodology to account for social costs may not be as important as the care taken in defining a final implementation methodology. As demonstrated by a recent study, the choice of a particular bidding framework has significant influence over final technology choices.

In light of our investigation, we believe that valuing the externalities associated with energy production will ultimately require the resolution of much larger conceptual issues. These include societal definitions of the total value of electric power, the capability and capacity of utilities to conduct research into external costs to society and implement the actions implied by such research, as well as existence and strength of regulatory mandates that will largely dictate which methodologies are implemented.

In addition, five studies were examined in detail to begin the process of developing a range of estimates for social costs by various categories of emissions and power sources. Major conclusions are summarized below, with further explanation following:

- Regulatory direction and/or intervention may limit PG&E's choice of a methodology and its implementation, and will certainly impact the relevance of PG&E's involvement in social cost analysis. Many of the key variables affecting the choice of a methodology are simply beyond PG&E's purview.
- Because regulatory uncertainties exist, PG&E should structure its methodology in a manner that is designed to influence the larger policy context in which social cost valuations must be considered. PG&E may wish to devise an approach to social costing that can be presented as an alternative or as a point of departure for other levels of policy making that may supersede PG&E.
- Based on our analysis of the strengths and weaknesses of the various methodologies, and the current uncertainties with regard to utilities' role in implementing social costs analyses, we recommend the development of a hybrid ranking and weighting approach (similar to the Temple Barker Sloane approach) at this time. This approach is relatively inexpensive, can incorporate and help rationalize existing data on social costs, and if properly implemented, can provide both reasonable estimates of social costs as well as help develop a policy consensus on the implications of externalities for energy production.
- Once PG&E has implemented a social costing methodology, they may elect to determine how different methods of accounting for externalities could affect future resource decisions. Once an approach to valuing social costs is implemented, it is important to see if the results imply significant changes, or if they will have relatively little impact on resource acquisition decisions.
- The changing regulatory environment, and specifically the growth of independent power producers that must be considered in competitive bidding systems, has heightened the importance of factors such as operational characteristics, viability, diversity, and flexibility at the same time that pressures are increasing to consider social costs.

Discussion of Conclusions

1. **Regulatory direction and/or intervention may limit PG&E's choice of a methodology and its implementation, and will certainly impact the relevance of PG&E's involvement in social cost analysis. Many of the key variables affecting the choice of a methodology are simply beyond PG&E's purview. Further regulatory direction may be required before PG&E can decide on the choice of a methodology and its implementation or whether PG&E should even become involved in social cost analysis. Three conceptual boundary issues -- Capacity, Mandate, and Total Cost -- define the context for social costing and require resolution. These are depicted in Exhibit 15 and are more fully discussed below.**

a. Capacity/Capability:

The choice of a particular methodology may depend on the ability of the individual utilities and/or regulatory bodies to effectively implement it. As we have pointed out, accounting for externalities can be a confusing, complex, and costly task. The decision to implement a methodology that entails major effort and expense has to be tempered by the realization that the individual utility will not be able to implement the results on its own. An individual utility may also lack the perspective or the resources to conduct an analysis at the appropriate level for implementation. The social costs of PG&E's power generation are only a small subset of all the external costs of energy use in California. And all of California's energy use accounts for only a fraction of the U.S. energy/environmental situation. Actions by governmental bodies at the international, national, and state levels could quickly render efforts by PG&E moot, and this possibility should figure into PG&E's strategy and methodology selection.

With regard to global issues in particular, the Department of Energy, Environmental Protection Agency, and the Department of the Interior are obvious federal agencies to conduct the necessary research. Academic institutions in each state could provide considerable expertise. For example, in California, some of the most recent work on quantifying externalities was performed by the California State University Fullerton Foundation for the South Coast Air Quality Management District. These external actors should be considered both as possible contributors in a PG&E effort and as potential source of intervention that PG&E should consider.

b. Mandate

The existence and strength of a mandate will largely dictate which methodologies are implemented. Any reasonable mandate must take into account the full ramifications of the requirements it sets, the jurisdictional authority that backs it up, and its political and methodological sustainability.

Exhibit 15

Three Intrinsic Boundary Issues

Some analysts believe that a national least-cost energy plan and process is necessary. It could be modeled after the Pacific Northwest Electric Power Planning Act under which Bonneville operates. This act is a forerunner of most of the state least-cost planning efforts under way. If state least-cost planning processes are expanded to assure that energy resources having the lowest social costs would be the first to developed, then legislative bodies may require utilities to perform full costing along the lines of that conducted in the Pacific Northwest.

The outcome of this situation depends on regulators both at the federal level (Federal Energy Regulatory Commission) and the state level and their commitment to include environmental costs in energy prices.

It is not clear whether it is the responsibility of utilities to act, or if state regulators should act before federal regulators such as EPA, FERC, etc. The site-specific nature of many externalities (and, for example, the concurrent growth in stature of air quality management districts) means that new mandates taking unprecedented forms may arise from new sources.

c. Total Costs:

Total costs include the value of social costs in addition to the traditional components of costs. The value of social costs is a function of the frame of reference -- society, individuals, companies -- for determining costs, and thus varies with the frame of reference selected by the analyst. This is one of the most complex and vexing factors in valuing social costs because the proper frame of reference is influenced by law, conflicting economic theory, and by public perceptions of equity. With heightened public awareness of the social costs of energy production, this problem of valuation has complicated the regulatory environment, because the public interest is now defined as much more than least energy cost.

The question is a matter of whose perspective on costs prevails: shareholders, utility customers, auto manufacturers, drivers, Californians, Americans? Although economists have devised constructs for valuing social costs, the underlying assumption that an economic value can be placed on life or on nature are not acceptable to many people who view these as moral issues beyond the purview of economics. Social cost valuation methodologies are also disputed by critics who point out that there simply isn't a known, direct, quantifiable cause and effect relationship between, for instance, emissions and human health. The argument is simply that there is not enough scientific certainty about causes and effects to determine the social costs of incremental changes in energy production and emissions, and incorporating invalid estimates of the social costs would distort the market as much or more than ignoring social costs. The point is, there are valid and strongly held objections to the fundamental assumptions behind the methodologies used to value social costs.

Thus, the best that can be done in valuing the social cost component of total cost is to explicitly state the perspective on social costs assumed in the valuation and proceed from that point. This doesn't resolve the conflict over whose measurement of value should

prevail, or whether social costs can be valued at all, but it can at least make the debate clearer.

How much is the total cost of power changed by accounting for externalities, and how are the values estimated for externalities distorted by the choice of methodology? There is a tremendous range in estimates of social costs. Although much of the variation is the product of uncertainty in the measurements, it is also a reflection of different perspectives on valuing social costs. This issue of changing social cost values as a function of perspective also applies to the larger question of how broadly social costs should be considered. For instance, if it is more cost-effective to reduce pollution from the transportation sector, shouldn't that be part of a social costing methodology for emissions that attempts to adopt a societal perspective? NO_x emitted from the tailpipe of a car is as potentially damaging as NO_x emitted from a utility boiler.

An internal document from the PG&E Electric Resource Planning Group in San Francisco, which advocates a Cost of Abatement approach to dealing with social costs, argues that with regard to NO_x emissions it may be least costly to reduce emissions in other sectors first:

"The cost of the cheapest abatement method not yet implemented by regulators should set a ceiling on the monetized value. If regulators have not implemented controls on forced air furnaces that would reduce NO_x emissions for \$1/pound of NO_x/year, there is no justification for assuming a higher value for reducing emissions from powerplants . . .

. . . the principle of monetizing pollutant emissions based on the cost of abatement measures not yet implemented may be very useful to PG&E. With regard to global warming, for example, it seems reasonable to assume that higher gas mileage standards for cars would reduce CO₂ emissions at lower cost to society than increasing efficiency of powerplants. If so, then PG&E can argue that PG&E will reduce CO₂ emissions after regulators have implemented all cheaper methods to reduce CO₂ emissions."

The reason the methodology for determining total cost is so important is the fact that a change in energy costs to reflect social costs will impact the market for energy by changing its price. In turn, price impacts demand and supply, and thus the general equilibrium of the economy. The distribution of wealth, income, productive resources, etc., will readjust to any new equilibrium, sometimes in unforeseen ways. These broader market implications of methodologies for determining social costs must be considered in any approach to valuing social costs and incorporating them into the market price of energy.

Yet regardless of fairness, regulatory approaches for accounting for externalities through utilities may be perceived as more expedient than reducing pollutants through the most dispersed transportation sector. Thus, utilities may be forced to bear a heavy burden for externalities if regulators are not shown the value of other options. These three intrinsic boundary issues, depicted in Exhibit 16, exist independently of the methodological and

Exhibit 16

Analysis, Implementation and Boundary Issues

implementation concerns raised in this report. Without achieving a dynamic balance between these issues, efforts to account for social costs will likely lead to an impasse.

2. Despite these regulatory uncertainties, PG&E may need to determine, or run the risk of having it determined for them, what it wants to provide in terms of accounting for externalities. It would be prudent to devise a methodology and be a leader in the field.

If the proper choice of methodologies can provide a correct evaluation of new risks, and shareholder interests can be protected, are there valid reasons for not moving towards a more accurate evaluation of the true costs of power?

Valid reasons might include PG&E's legitimate concern on the risk of bypass -- that they will be required to supply cleaner and therefore more expensive power -- and will be put at a disadvantage to their competitors such as cogenerators or municipals. An internal PG&E memorandum states:

"No matter how an environmental attribute is implemented, PG&E will pay a premium for new, cleaner resources. The results will be higher rates, which raise concerns about municipalization and bypass. Municipalities that, in effect, use an environmental attribute of zero will provide dirtier, but cheaper, power than PG&E can. Customers who do not want to pay the premium for clean power from PG&E may be able to bypass PG&E's electric service with packaged cogeneration units, diesel powered water pumps or other means."

In examining externalities from a state or even global perspective, other serious questions arise. For instance, approaches that result in the avoidance of combustion of high-sulfur coal or oil may miss the target (wholly or partially) if these fuels are simply shifted to other areas. A California report (ER-90) similarly states:

"If we adopt a social value for CO₂ emissions for electricity and if this value results in higher costs of electricity to consumers, this may have perverse effects. For example, higher rates might cause large customers to switch to self-generation fired by the cheapest possible fuel (probably gas) or might lead customers to choose to locate their new facilities in another state which produces electricity without CO₂ guidelines."

The source and degree of mandate, and the determination of cost, come head to head here. The threat of this bypass risk has the effect of shrinking the environmental attribute because no individual utility wishes to accommodate this risk while others are free to avoid it.

These conflicts typically require redress at the regulatory level. However, jurisdiction boundaries may be a problem here. As the Resource Group at PG&E has pointed out:

"The Joint Committee on Energy Regulation and the Environment may be

a good forum for presenting PG&E's views. The Committee is well situated, unlike the CEC or CPUC, to address the unintended consequences of a high environmental attribute through, for example, expansion of the CEC's justification to include very small projects or non-thermal producers."

Such inconsistencies in jurisdiction, if they are not resolved, could destroy efforts to include externalities or reduce their effectiveness.

3. Based on our analysis and the strengths and weaknesses of the various methodologies, and the current uncertainties with regard to any mandate being required for utilities to perform social costs analysis, we make the following observations/recommendations:

Each of the four categories reviewed can provide a good approach to accounting for social costs. The selection of each has tradeoffs in the degree of relative accuracy by the relative cost and complexity of the method. It was found that the last 3 categories of approaches are especially useful. The first category is basically a data collection phase, while the latter builds on this information and provides a useful analytical framework for decisionmaking.

With lack of guidance and current lack of consensus on regulatory issues, PG&E may not want to become involved in extensive data collection, since full costing techniques are expensive. It is not clear whether it is the responsibility of PG&E to undertake such a rigorous approach. This is essentially a mandate issue, and perhaps it may be necessary to have this function performed by other jurisdictional entities such as the California Public Service Commission, California Energy Commission, California Air Resources Board, etc, to determine whether current control standards are adequate or whether society is paying more than it should in terms of adverse societal impacts.

It may also be difficult to accurately pursue stringent full costing approaches in the near term. According to BPA's project manager who has conducted extensive research on social costs, it is clear that much more research is required in the full costing area. In this investigation, the observation was made that in some cases, data on the impacts of externalities derived from full costing approaches indicated lower social costs than costs derived from control cost approaches. That current control standards effectively overestimate social costs runs contrary to our expectations. This could mean that current measurement techniques are underestimating impacts. For example, although the BPA approach is one of the more rigorous, their data did not address impacts from acid rain or global warming, ozone depletion, etc.)

a. A hybrid ranking and weighting approach may be the best solution as this time.

It is recommended that some version of a ranking and weighting system be used that already exists, with efforts being made to refine them for PG&E's application. Temple Barker Sloane's (TBS) effort appears to be a very good start in this direction.

4. As realized by PG&E and pointed out in this study, considering social costs so explicitly can have a real impact on future energy resource allocation. Thus, PG&E may want to determine how different methods of accounting for externalities could affect their future resource decisions.

Since whatever public mandate for action emerges will be the key influence on how PG&E actually implements a social costing methodology for making resource decisions, it is important to blend both a strong foundation of data and a process that acquaints decision makers with the complexity of the issues.

An important conclusion emerging from this review of methodologies is that there is no definitive approach to dealing with the social costs of energy production. None of the methodologies has such a compelling rationale or is so based on irrefutable facts that it can escape serious and valid criticism. Because social costs are based on complex physical and social interactions -- economic, biological, aesthetic, chemical -- any attempt to value them is fraught with uncertainty. Therefore value judgments enter into even the most rigorous methodological approaches.

As an example, BPA made one of the most rigorous attempts at full social costing, with a significant amount of research and analysis invested in quantifying biological and other effects in terms of their economic consequences. But the analysis is still fraught with value judgments because of the approximations and assumptions that were required to simplify the complex situation being modelled. At best BPA was able to come up with a very broad range of what social costs might be, and even then the assumptions used to derive those values are open to dispute. As a result, attempts at full quantification and valuation of the measurable physical and social effects of energy generation are mainly of value as input to decision making -- as raw material for forming value judgments.

Realizing the limitations on quantitative analysis, the most valid approach to the problem of valuing the social costs of energy production is to concede that definitive values simply cannot be developed. Instead we recommend developing an approach to the problem that brings the value judgments and uncertainties inherent in quantifying social costs into the open, and then uses the information and analytical frameworks that are available to produce the best, most informed consensus on the value of social costs possible. Thus we are advocating a hybrid approach that combines the consensus-building techniques and expert polling of the Temple, Barker, Sloane methodology with the cost analysis framework and use of scientific data typified by the BPA analysis. The desired end-product is a structured consensus on the sources of social costs, their most important manifestations, and the uncertainties and caveats surrounding the data that is available. Based on this understanding of the issues, an informed estimate of the value of social costs from energy production technologies could be developed.

The most important element of this hybrid approach is constructing a framework that presents the available information to the experts involved in the polling process, allows them to debate and question the data and its assumptions, then focuses their expertise on developing a consensus on the parameters that determine social costs before they actually move to assigning values. The main shortcoming we see in the Temple, Barker Sloane

methodology and other approaches that rely directly on human judgment is the potential for the process to lose its definition. It is as important to know and understand the reasoning behind a given consensus as it is to reach the consensus. To base resource acquisition decisions on the results of a methodology like Temple, Barker, Sloane's, the user of the results must be assured that the judgments inherent in the process are truly informed, and are truly the product of a logical train of thought and analysis.

Especially with polling and ranking, there is a potential for bias and for loss of validity if the questioning and polling is not tightly focused. As an example, high rankings for high-profile issues may reflect their visibility more than their significance to social costs, undermining the validity of the poll results. Similarly, it is easy to undervalue issues like indoor air quality simply because they have a low profile. Bias can enter the results as a function of the backgrounds of the experts involved in the polling. A group of climatologists may have very different views on the major contributors to the social cost of energy than biologists. Where there are gaps in the information or expertise being provided by the participants in this type of methodology, the methodology itself should be designed to identify and redress the problems. The validity of this type of approach can also be improved by seeking operational measures of the valuation of social costs that parallel the measures used in full social costing approaches. For instance, building toward a valuation of the social costs of an emission source through first examining estimates of the number of people affected, the severity of effects, possible dispersions, etc., renders a more rational judgment of the final social cost value than jumping directly to an estimate of the full social cost.

Thus a hybrid approach that blends data, structured analysis, and informed human judgment can, if properly structured, make the most of the information that does exist, while at the same time acknowledging the limitations of our current understanding of social costs. It also has the benefit of furthering expert consensus on the subject, which can influence the public and decision makers who ultimately form the mandate for action.

5. The changing regulatory environment, and specifically the growth of independent power producers that must be considered in competitive bidding systems, has heightened the importance of factors such as operational characteristics, viability, diversity, and flexibility at the same time that pressures are increasing to consider social costs.

Social costs are only one of many factors that influence the optimal resource mix for a utility. Incorporating social costs into bidding and other resource acquisition processes will be a major challenge because it will be reconciling social costs within an already large and complex decision framework. Exhibit 17 describes some of the attributes that are considered in acquiring generation resources. These attributes, although they are in many cases as hard to value as social costs, are used to determine the optimal mix of resources for a utility to acquire. They are already highly interdependent and difficult to balance. Incorporating environmental impacts into the decision framework will tend to further expand the range of technologies that must be considered in determining an optimal resource mix. Many of the technologies with the most promising environmental profiles

Exhibit 17

The Impact of Valuing Social Costs on the Range and Complexity of Technology Choices

have operating characteristics, financial structures, etc., that are very different from the current mix of technologies. Thus, introducing social costs in to the decision framework also imply a reconsideration of the values of other decision criteria, and the balance between them.

BIBLIOGRAPHY

1989 ASES Roundtable on Societal Costs of Energy. Comp. by Michael Niklas. Boulder: 1989.

1989 ASES roundtable on Societal Costs of Energy. Arlington: March 9, 1989.

ARB Fact Sheet 38. Table A: Ambient Air Quality Standards.

Black, Pam. "Rising Tension Over High-tension Lines." *Business Week*. (October 30, 1989).

Bonneville Power Administration. *Issue Backgrounder: Counting the Costs - How BPA Performs Environmental-Cost Analysis*. June 1985.

Bonneville Power Administration. *Methods for Valuation of Environmental Costs and Benefits of Hydroelectric Facilities*. Final Draft. Portland: Bonneville Power Administration, June 5, 1984.

California Air Resource Board. *California Air Pollution Control Laws*. Sacramento: California Air Resource Board, 1989.

California Energy Commission. *California's Energy Outlook. 1987 Biennial Report*. Sacramento: California Energy Commission, 1987.

California. Testimony Before the Public Utilities Commission of the State of California. Application 82-04-044, et al. Prepared Testimony of Edward Douglas Mitchell.

California. Decision Before the Public Utilities Commission of the State of California. Decision 88-09-26. *Final Decision, Compliance Phase: General Resource Planning Issues, Performance Features ("Adders"); Availability of Standard Offer 2*. September 14, 1988.

California. Order Instituting Investigation. July 6, 1989.

California. Decision Before the Public Utilities Commission of the State of California. Decision 87-05-060. *Interim Opinion. Compliance Phase, Final Standard Offer 4: Bidding Protocol, Derivation of Prices from Avoidable Resource, and Associated Issues*. May 29, 1987.

California. Decision Before the Public Utilities Commission of the State of California. Decision 86-07-004. *Final Opinion in Phase II: Development of Final Long-run Standard Offers*. July 2, 1986.

Center for Clean Air Policy (An Efficient Approach to Reducing Acid Rain: The Environmental Benefits of Energy Conservation)

Crane, Cynthia M. *Externalities and Intangibles: Air Quality Benefits*. Pacific Gas and

Electric Company. August 1985.

Dasovich, Jeffrey. *Analysis of the Greenhouse Effect and Policy Considerations for the California Public Utility Commission*. San Francisco: California Public Utilities Commission, May 1989.

DeAngelis, Michael and Rashkin, Samuel. *The Social Benefits and Costs of Electricity Generation and End-Use Technologies*. California Energy Commission. 1989.

Dudek, Daniel J. *Offsetting New CO₂ Emissions*. New York: Environmental Defense Fund, September, 1988.

ECO Northwest, Ltd.; Shapiro and Associates, Inc.; and Seton, Johnson, and Odell, Inc. *Estimating Environmental Costs and Benefits for Five Generating Resources*. Prepared for Bonneville Power Administration under a Multiple-Award Contract Agreement with the U.S. Department of Energy (Contract DE-AC79-83BP11551). March 1986.

ECO Northwest. *Economic Analysis of the Environmental Effects of the Coal-Fired Electric Generator at Boardman, Oregon*. Final Report. December 29, 1983.

Electric Resources Planning Department. *Multi-Attribute Bidding Framework*. PG&E. August 10, 1989.

Eyer, James M. *Technology Information Module Content and Procedure Manual*. PG&E Advanced Energy Systems. August 1989.

Flavin, Christopher. *Slowing Global Warming: A Worldwide Strategy*. Worldwatch Institute. October 1989.

Fritsche, U. et al. *Environmental Analysis of Energy Systems: The Total-Emission-Model for Integrated Systems*. Germany: ÖKO-Institut, September 1989.

Gilbert, Richard J. and David M. Newbery. *Regulation Games*. Berkeley: University of California, Berkeley, June 16, 1988.

Goldman, Charles et al. *Least-Cost-Utility Planning in the Utility Sector: Progress and Challenges*. Applied Science Division, Lawrence Berkeley Laboratory, Berkeley, California. Energy Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee. LBL-27130; ORNL/CON-284. May 1989.

Gregory, Robin. et al. *Review of Uncertainty and Risk in BPA-sponsored Analyses of Energy Resources - Final Report*. Oregon: Decision Research, November 18, 1987.

Griggs, John Wyeth. "Industry?" *Energy Law Journal* (1988): 415-458.

Gross, George. *A Multi-attribute Bidding System for California Electric Utilities*. San Francisco: PG&E, January 1989.

Hall, Jane V. et al. *Economic Assessment of the Health Benefits from Improvements in Air Quality in the South Coast Air Basin*. Fullerton: California State University Fullerton Foundation, June 1989.

Heede, Richard H. et al. *The Hidden Costs of Energy: How Taxpayers Subsidize Energy Development*. The Center for Renewable Resources. Washington, D.C.: October 1985.

Heede, Richard, H. "Hiding the True Costs of Energy Sources." *Wall Street Journal*. September 17, 1985.

Hohmeyer, Olav H. "Macroeconomic View of Renewable Energy Sources." *Sunworld*. International Solar Energy Society, Volume 13, Number 2, 1989.

Hohmeyer, O. H. *Social Costs of Energy Generation - How Does Wind Compare?* Germany: Fraunhofer-Institute for Systems and Innovation Research, 1989.

Hohmeyer, Olaf. *Social Costs of Energy Consumption - External Effects of Electricity Generation in the Federal Republic of Germany*. A report prepared under contract for the Commission of the European Communities. Springer-Verlag. Heidelberg, Germany: 1988.

Integrating Environmental Externalities Into Resource Planning at New England Electric. Temple, Barker & Sloane, Inc.

Kahn, E.P. et al. *Evaluation Methods in Competitive Bidding*. Applied Science Division. Lawrence Berkeley Laboratory. University of California. Prepared for the U.S. Department of Energy under Contract Number DE-AC03-76SF00098. June 1989.

Kleinman, Michael T. et al. *Effects on Human Health of Pollutants in the South Coast Air Basin*. Fullerton: California State University Fullerton Foundation, June 1989.

Leopold, Luna B. et al. *A Procedure for Evaluating Environmental Impact*. Washington, D.C.: U.S. Department of the Interior, 1971.

Lincoln, Susan. "NEES Will Spend \$65 Million a Year on Conservation." *The Energy Daily* (November 7, 1989): 4.

Linder, Kenneth P. et al. *Potential Impacts of Climate Change on Electric Utilities*. Washington, D.C.: ICF Incorporated, December 1987.

MacKenzie, James J. and Mohamed T. El-Ashrey *ILL Winds: Airborne Pollution's Toll on Trees and Crops*. World Resources Institute. September 1988.

MacKenzie, Douglas. *Defining and Quantifying Externalities for the Evaluation of Demand-Side Programs*. Temple, Barker & Sloane, Inc. October 25, 1989.

Mansfield, Edwin. Microeconomics: Theory and Applications. Fourth Edition. W.W. Norton and Company, Inc. Toronto, Canada: 1982.

Massachusetts Photovoltaic Center. *An Overview of the External Issues of Electric Power Production*. November 1988.

Massachusetts Photovoltaic Center. *An Overview of the External Issues of Electric Power Production*. Massachusetts: Massachusetts Photovoltaic Center, November 1988.

Meade, William R. *In the Public Interest*. Council for Renewable Energy Education. July 20, 1988.

Meyer, P. et al. *Calculation of Environmental Costs and Benefits Associated With Hydropower Development in the Pacific Northwest*. Portland: Bonneville Power Administration, April 1986.

Mitchell, E. D. *Cogeneration Design Considering Optimum Use of Surplus Power*. San Diego: San Diego Gas and Electric Company, 1989.

New York State Energy Office. *Environmental Externality Issue Report*. Division of Policy analysis and Planning. New York State Energy Office. February 24, 1989.

New England Energy Policy Council. *Power To Spare: A Plan for Increasing New England's Competitiveness Through Energy Efficiency*. New England Energy Policy Council. July 1987.

New York. Case 88-E-241. Proceeding on Motion of the Commission as to the Guidelines for Bidding to Meet Future Electric Capacity Needs of Orange & Rockland Utilities, Inc. March 24, 1989.

North Carolina Utility Commission. *Testimony and Exhibits of Michael Niklas Before the North Carolina Utility Commission on Least-Cost Integrated Resource Planning*. Filed October 6, 1989.

OECD. *Understanding Pollution Abatement Cost Estimates*. OECD. March 1986.

OECD. *Energy and Clean Air: Costs of Reducing Emissions. Summary and Analysis*. Paris: OECD, 1987.

ÖKO-Institut. *Compilation of Climate-Related Emissions Data for Energy Systems in the FRG*. Final Report, Draft Version. Translated from German. June 1989.

ÖKO-Institute, Gemis model on Environmental Analysis of Energy Systems: The Total-Emission-Model for Integrated Systems, Federal Republic of Germany: September 1989.

Oregon. Order before the Public Utility Commission of Oregon. Order No. 89-507. *In the Matter of the Investigation into Least-Cost Planning for Resource Acquisitions by Energy Utilities in Oregon*. April 20, 1989.

Organization for Economic Cooperation and Development. *Environmental Effects of Electricity Generation*. Paris: Organization for Economic Cooperation and Development, 1985.

Ottinger, Richard L. et al. *Least-Cost Utility Planning and Demand-Side Management: A Bibliography*. New York: Pace University, Fall 1988.

Page, Talbot. *Conservation and Economic Efficiency: An Approach to Materials Policy*. Published for Resources for the Future by The Johns Hopkins University Press. Baltimore and London: 1977.

Peavy, Howard S. et al. *Environmental Engineering*. New York: McGraw Hill Publishing Company, 1985.

PG&E. Request for Proposal. No. 218.89. Special Cost of Energy Generation.

Sabonis-Chafee, Terry. *Projecting U.S. Military Power: Extent, Cost, and Alternatives in the Gulf*. Rocky Mountain Institute. Old Snowpass, Colorado: October, 1987.

Sebold, Frederick D. et al. *A Methodology for Integrating Air Quality Impacts Into Energy Resource Planning*. Developed under contract to the California Energy Commission (CEC) by Regional Economic Research, Inc. San Diego, California: 1989.

Shuman, Michael and Ralph Cavanagh. *A Model Electric Power and Conservation Plan for the Pacific Northwest: Environmental Costs*.

South Coast Air Quality Management District: *Air Quality Management Plan*. Final. South Coast Air Quality Management District. March 1989.

State of New York Public Service Commission. *Proceeding on Motion of the Commission (Established in Opinion 88-15) as to the Guidelines for Bidding to Meet Future Electric Capacity Needs of Oragne and Rockland, Inc.* At a session of the Public Service Commission held in the City of New York on March 22, 1989.

Susan Babb. Bibliography of Nuclear Costing. Draft. August 9, 1989.

Technical Support Division. *The Effects of Oxides of Nitrogen on California Air Quality*. Sacramento: State of California, March 1986.

Therkelsen, Robert L. *Valuing Emission Reductions for Electricity Report 90*. State of California Energy Resources Conservation and Development Commission. November 21, 1989.

Trexler, Mark C. et al. *Forestry as a Response to Global Warming: An Analysis of the Guatemala Agroforestry and Carbon Sequestration Project*. Washington, D.C.: World Resources Institute, June 1989.

U.S. Department of Commerce, Bureau of Economic Analysis. "Real Pollution Abatement & Control Spending Declined Slightly in 1987." *News*. Washington, D.C.: Gary Rutledge, June 21, 1989.

U.S. Congress. Senate. Committee on Energy and Natural Resources. *Hearing on PURPA and the National Energy Policy Act of 1989 (S.324)*. 101st Cong. 2d sess., 1989.

Vine, Ed. *Evaluating Energy and Non-Energy Impacts of Energy Conservation Programs: A Supply Curve Framework of Analysis*. California Institute for Energy Efficiency, Program on Energy Efficiency and Air Quality, Review Draft, September 18, 1989.

APPENDIX A

ASSESSMENT OPTIONS

ASSESSMENT OPTION I - DESCRIPTION AND CHARACTERIZATION OF IMPACTS

Environmental Effects of Electricity Generation, OECD, 1985.

This report describes the range and types of environmental impacts associated with electricity generation from various primary energy sources in qualitative and quantitative (but not price) terms.

A model for *Assessing Air Pollutants Emissions for Electricity Generation from Fossil Fuels* is included in the report. Emission estimates are derived from national emissions standards for electric generating technologies. Estimates apply to the generation stage only.

Author conclusions :

The demand for electricity as an energy source makes it important to have methods for abstracting the assessment of environmental impacts in order to provide information and insight to policy makers.

They indicate that the calculations of emission trends based on new source standards may not be sufficient if emissions of SO_x and NO_x are to be stabilized and reduced, and that it may be necessary to set a future date by which existing installations must also meet the new source standards.

Reviewer Summary :

A compact and powerful source of information on issues and impacts. It raises more questions than it answers and makes general recommendations for environmental strategies; i.e., increased efficiency, substitution of cleaner technologies for older, less efficient ones, increased waste heat utilization, and increased pursuit of renewable energy technologies. While their model for assessing air pollutants has some usefulness for modeling emissions resulting from future national energy mixes, it does not seem applicable at the state regulatory level.

Energy System Emissions and Material Requirements and Environmental Emissions from Energy Technology Systems: The Total Fuel Cycle, prepared by Meridian Corporation for the Department of Energy

This report attempts to quantify and compare emissions from various power generating technologies. A life-cycle approach was used to evaluate emissions from all aspects of energy production, from resource extraction through construction, operation and decommissioning. Fourteen electric generating technologies and 30 substances including carbon dioxide, nitrogen oxide, sulfur dioxide, and particulates were examined. The study then attempted to determine the extent to which renewable energy technologies could contribute to electricity supply while reducing CO₂ emissions.

Author conclusions :

When compared on the basis of emissions and material inputs used versus power output over the life of an energy facility, the environmental advantage of a material-intensive technology like photovoltaics is greater compared to a fuel-intensive system such as coal.

Reviewer summary :

As a basis to judge the relative impact of various resource options, specifically over the entire fuel cycle, such an approach can document certain resource parameters and provide the basis for relative ranking of technologies for a limited set of characteristics. Expansion of the parameters investigated tends to dilute the applicability of the approach, although certain relative measures may survive.

Its main limitation for PG&E is that it provides no quantification or judgment as to the impact of emissions -- it is purely descriptive and provides no means for assessing the relative importance of relative emissions.

Environmental Analysis of Energy Systems : the Total-Emission-Model for Integrated Systems, OKO Institute for Applied Ecology (West Germany)

This project is a compilation of standardized energy and emissions-related data for fuel cycles of various energy systems which provide space heating and electricity. The objective was to provide a computerized data base to provide a method for comparative assessment of energy systems, based on one unit of delivered energy, and to develop options for integrating non-comparative and qualitative impacts of energy systems into the decision-making process.

Quantitative data includes both standard cases (relating to environmental regulations currently in force in W. Germany) and best available control technology cases (referring to the cleanest available viable technologies) were developed for comparative purposes. Data that they considered qualitative but not necessarily quantifiable (safety issues, long term ecological effects, land use effects, etc.) were included in a grid matrix.

The system is organized to account for upstream, or fuel-cycle effects, and attempts to disaggregate local and global impacts. Attempts are also made to derive net impacts attributable to electricity in the cogeneration process.

Author Conclusions :

They stress that this model is descriptive rather than prescriptive, and is not meant to free decision makers from their responsibilities to value environmental effects, but is to enhance available information and present it in a form that can give support to the decision process.

Reviewer Summary :

While the actual computer program was not available for review, the documentation indicated a good potential to model emissions and changes in emissions for different fuel and technology scenarios. The approach is one of very few that consider emissions from the relatively large space heating sector.

Their organization of qualitative aspects seems to be more for raising issues than for prescribing responses.

ASSESSMENT OPTION II - RANKING AND WEIGHTING

The Social Benefits and Costs of Electricity Generation and End-Use Technologies, California Energy Commission, September, 1989. Michael DeAngelis and Samuel Rashkin, California Energy Office.

The authors explain the need for improved energy planning methods to consider the social benefits and costs of electricity generation technologies, they describe a simplified and qualitative method for determining these costs, and provide a sample use of the analytical method.

The methodology developed takes advantage of early land use planning and environmental impact analysis methods. They pursue an exhaustive list of societal costs, including the usual private costs (capital, operation, and fuel) as well as government subsidies, environmental impacts, and issues of economic development and system reliability/security.

Weighting criteria are presented that distinguish between the more subjective evaluation of the overall *importance* of an impact classification, and the separate, more objective determination of *magnitude* (relative level or degree) of a resource's impact within that category. Determinations for these weightings are developed through a combination of detailed analysis, survey techniques, and best estimates.

A framework for their analysis methodology, the resulting Cost Matrix that results, and a sample analysis are presented in the attached exhibit. This generic analysis of impacts (performed with the weighting factor left undefined at "1") ranks technologies in this order:

Electrical Generation Technology	Degree of Impact

Fuel Cells (natural gas)	highest cost
Oil combustion	*
Nuclear Fission	*
Coal	*
Ocean Thermal Conversion	*
Photovoltaics	*
Municipal Solid Waste	*
Cogeneration	*
Geothermal	*
Solar Thermal Electric	*
Natural Gas Combustion	*
Hydroelectric	*
Biomass	*
Wind	*
End Use (Conservation/Solar)	lowest cost

ENVIRONMENTAL ISSUES

	COAL	OIL	NATURAL GAS	NUCLEAR	HYDRO	CONSERVATION	SOLAR
1) Acid Rain							
2) Global Warming - CO2							
3) Air Pollution							
4) Water Pollution							
5) Toxic/Non-Radioactive Waste							
6) Radioactive Waste							
7) Electric and Magnetic Fields							
8) Noise Pollution							
9) Accidents							
10) Work/Home Environments							
11) Resource Depletion							
12) Land Use							
ECONOMIC ISSUES							
13) Employment							
14) Tourism							
15) Insurance Costs							
16) Safety/Security Costs							
17) Transportation Costs							
NATIONAL SECURITY							
18) Military							
19) Strategic Reserves							
SUBSIDY ISSUES							
20) Lost Tax Revenue							
21) R & D Funding to Specific Industries							
22) Agency Funding that Benefit Specific Industries							
23) Loans and Loan Guarantees							
24) Uranium Enrichment							
25) Approval Process Time and Expenses							
26) Price-Anderson Act (Nuclear Accident)							
OTHER							
27)							
28)							
29)							
30)							
31)							

PRIORITY RANKING

ISSUE/CONCERN

% OF TOTAL

% THAT LIST IN TOP 10

1	GLOBAL WARMING CO2
2	AIR POLLUTION
3	ACID RAIN
4	RADIOACTIVE WASTE
5	RESOURCE DEPLETION
6	WATER POLLUTION
7	R&D FUNDING TO SPECIFIC INDUSTRIES
8	SAFETY/SECURITY COSTS
9	LAND USE
10	MILITARY
11	TOXIC/NON-RADIOACTIVE WASTE
12	LOST TAX REVENUE
13	ACCIDENTS
14	PRICE-ANDERSON ACT
15	URANIUM ENRICHMENT
16	AGENCY FUNDING
	MISC.

23.8
13.0
12.7
9.2
6.0
5.0
4.3
4.0
3.6
3.5
2.9
2.4
2.2
1.9
1.5
.4
3.6
100.0

100
68
68
59
32
32
37
32
32
21
16
16
16
26
16
16

PRIORITY RANKING: Highest priority = 1, lowest priority listed = 16 (Priority ranking was established by assigning 10 points to each respondent's highest concern, nine to the second highest, etc. Up to ten issues were ranked by each. Those issues which were noted by only one individual were listed under MISC.)

% OF TOTAL: Using the priority point allocation system above, this percentage indicates the fraction of total possible points received by a particular issue. For example, global warming received 23.8% of all possible points.

% THAT LIST IN TOP 10: Indicates the percentage of all respondents who listed issue within their top-ten concerns.

		COAL	OIL	NATURAL GAS	NUCLEAR	HYDRO	UNDEVELOPED	OTHER
ENVIRONMENTAL ISSUES								
1) Acid Rain	A&B	2.0 - 2.0	2.5 - 7.5					
2) Global Warming - CO2			2.5 - 7.5					
3) Air Pollution	C	11.8 - 58.9						
4) Water Pollution								
5) Toxic/Non-Radioactive Waste								
6) Radioactive Waste				0	4.3 - 31.2			
7) Electric and Magnetic Fields								
8) Noise Pollution								
9) Acid Deposition								
10) Work/Home Environments								
11) Resource Depletion								
12) Land Use								
ECONOMIC ISSUES								
13) Employment								
14) Tourism								
15) Insurance Costs								
16) Safety/Security Costs								
17) Transportation Costs								
NATIONAL SECURITY								
18) Military	E	40.0 - 54.0						
19) Strategic Reserves								
SUBSIDY ISSUES								
20) Lost Tax Revenues	F	29.8 - 34.9	8.2 - 9.4	5.4 - 6.4	104.0 - 104.0	204.3 - 204.3	2 - 2	13 - 14
21) R & D Funding to Specific Industries		29.8 - 34.9	8.2 - 9.4	5.4 - 6.4	104.0 - 104.0	204.3 - 204.3	2 - 2	2
22) Agency Funding that Benefit Specific Industries		29.8 - 34.9	8.2 - 9.4	5.4 - 6.4	104.0 - 104.0	204.3 - 204.3	2 - 2	2
23) Loans and Loan Guarantees		5.4 - 6.4	5.4 - 6.4	5.4 - 6.4	5.4 - 6.4	5.4 - 6.4	5.4 - 6.4	5.4 - 6.4
24) Uranium Enrichment								
25) Approval Process Time and Expenses								
26) Price-Anderson Act (Nuclear Accident)								
OTHER								
27)								
28)								
29)								
30)								
31)								

ISSUE	\$ BILLION
A. CORROSION	2.0 - 2.0
B. CROP LOSSES	2.5 - 7.5
C. HEALTH IMPACTS	11.8 - 58.9
D. RADIOACTIVE WASTE	
DECOMMISSIONING	2.9 - 22.6
WASTE DISPOSAL	1.4 - 8.6
	4.3 - 31.2
E. MILITARY	40.0 - 54.0
F. SUBSIDIES	
LOST TAX REVENUES	29.8 - 34.9
R&D + AGENCY FUNDING	8.2 - 9.4
LOANS & LOAN GUARANTEES	5.4 - 6.4
TOTAL SOCIETAL COSTS IDENTIFIED =	104.0 204.3

Issue A - Corrosion

Information Source:

1) On Site, "Innovations in Construction," Volume 1, Number 2, 1988. The January 1982 edition of Material Performance indicated the damage due to corrosion (caused primarily to coal) of metal buildings and structures has been estimated at \$2 billion per year.

Assumption: Damage due to corrosion is estimated to be \$2 billion/year.

Issue B - Crop Losses Due to Global Warming, Acid Rain, & other Air Pollution

Information Source:

1) Dr. Walter Heck, USDA, NC State University, 1989. Estimated (b/c) that \$1 to \$5 billion in crop losses occur each year in the US.

2) Dr. Peter Robinson, UNC-CH, 1989. Estimated (b/c) minimum of \$1 billion in agricultural losses each year.

3) Dr. A. H. Teramura, Univ. of Maryland, Botany Dept., 1989. Estimated (c) \$1 to \$2 billion in soybean crop losses each year.

4) "An Overview of the External Issues of Electric Power Production," Mass. Photovoltaic Center.

In "Our Common Future," World Commission on Environment and Development, Oxford University Press, 1987, it was concluded that acid rain and other air pollutants were reducing wheat and rice crops by as much as 30%.

5) The Environmental Protection Agency last year reported that ozone pollution was reducing crop yields by 12% (\$2.5 to \$3.0 billion per year). This report was recently updated, through work by the Boyce Thompson Institute for Plant Research at Cornell University. The revised estimate was that crop losses could be as high as 30% (or \$6.25 to \$7.5 billion per year).

6) The Office of Technology Assessment estimates the cost of controlling emissions from all coal plants to range between \$4 to \$6 billion per year causing utility rates, across the country, to increase between 4% and 15%.

7) Gary Lovett (with NY Botanical Garden) stated in Newsweek, 8/29/88, that ozone pollution was causing \$1 to \$5 billion per year in losses to soybeans, corn, peanuts, and cotton.

8) "Coal Technologies for a New Age," EPRI Journal, Jan/Feb 1988. "Across-the-board scrubber retrofits would cost the utilities and their customers as much as \$12 billion per year over the life of the plant."

Assumption: Crop losses are between \$2.5 and \$7.5 billion per year.

Issue C - Health Impacts

Information Sources:

1) Shephard Buchanan, Bonneville Power Administration, estimates (b) that 90% to 95% of local economic damage attributable to fossil fuels is associated with health risks. Even with low sulfur coal and remote siting, the levelized environmental costs associated with health risks would range between \$.002 and \$.01/KWH.

2) "Energy Facts 1987," Energy Information Administration, lists coal consumption in the US for 1987 at 20.1 quads.

Assumption: The health costs associated with utilizing 20.1 quads of coal per year (health costs, assuming all low sulfur and remote siting) are between \$11.78 and \$58.89 billion per year.

Issue D, Part 1 - Cost of Decommissioning Nuclear Plants

Information Sources:

1) "An Overview of the External Issues of Electric Power Production," Mass. Photovoltaic Center.

The Nuclear Regulatory Commission estimates that about 70 plants will be decommissioned in the next twenty years.

A 1984 Battelle Memorial Institute study estimates the average cost of decommissioning an average nuclear plant at \$133 million (Smith, R.I., Et. Al., "Updated Costs for Decommissioning Nuclear Power Facilities," EPRI, May 1985)

By 1985 only \$600 million had been collected, nationwide, to offset the costs of decommissioning plants.

The World Watch Institute study, "Decommissioning: Nuclear Power's Missing Link," 1986 estimates that decommissioning costs add 5% to 25% to the cost of generating nuclear power.

2) "Energy Facts, 1987," Energy Information Administration, lists the amount of nuclear power generation for 1987 at 4.9 quads and the average cost of the power at 6.3 cents/kwh.

3) "Decommissioning Nuclear Power Plants," EPRI Journal, July/August 1985, suggests costs of decommissioning as high as \$195 million (1984 \$) and NRC had proposed \$100 million per plant be set aside.

Assumption: A 5% to 25% increase on 4.9 quads at 6.3 cents per kwh would produce an addition cost of \$4.52 billion to \$22.61 billion per year. If you assume the costs at the \$195 million amount and a 50% capacity factor, cost would be \$.001/kwh (40 year life) to \$.002/kwh (20 year life), without inflation. At \$.002/kwh, additional amount for 4.9 quads, would be \$2.88 billion.

Issue D, Radioactive Waste Disposal
Information Sources:

1) "An Overview of the External Issues of Electric Power Production," Mass. Photovoltaics Center

The World Watch Institute study, entitled "Decommissioning: Nuclear Power's Missing Link," 1986, estimates disposal costs in a range between \$.001 to \$.006 per kwh.

Assumption: For 4.9 quads costs would range between \$1.44 billion and \$8.61 billion per year.

Issue E - National Security, Military Costs

Information Sources:

1) "Projecting US Military Power: Extent, Cost and Alternatives in the Gulf," Terry Sabonis-Chafee, Rocky Mountain Institute, 1987. The military expenditures by the US, in the Persian Gulf, in order to protect the oil industry, is estimated to be between \$40 and \$54 billion per year.

2) Quote in Newsweek, by retired Secretary of Navy, John Lehman. He estimates amount spent in Persian Gulf to be \$40 billion per year.

3) Howard Moreland, Coalition for a New Foreign Policy, 1985, estimates amount to be \$54 billion per year.

Assumption: US Military spending to protect Persian Gulf oil is between \$40 and \$54 billion per year.

Issue F - Subsidies

Information Sources:

1) "The Hidden Costs of Energy," Center for Renewable Resources, 1984, Richard Heede, Richard Morgan, Scott Ridley. (amounts listed below in billions)

SUBSIDY	COAL	OIL	GAS	NUCLEAR	HYDRO	CONSERV	SOLAR
Lost Tax	1.915	7.310	4.292	9.954	.667	.280	1.406
Revenues	3.158*	.240*	.599*				
R&D and	1.484	1.271	.319	2.284	1.076	.510	.290
Agency Fund.	.167*	.013*	.031*				
Loans and	.012	-	-	3.320	.605	.074	-
Guarantees	1.126*	.086*	.213*				
Total	7.862	8.920	5.454	16.164	2.348	.864	1.696

2) "Energy Facts, 1987," Energy Information Administration. The following indicates the breakdown of electrical generation utilizing fossil fuels:

Coal	1,464 Billion kwh's	79%
Petroleum	118 Billion kwh's	6%
Natural Gas	273 Billion kwh's	15%
Total	1,855 Billion kwh's	100%

3) • indicates subsidies to the various fossil fuels, utilizing the percentages listed in above in (2) and applying them to the "Fossil Electric" category in the "Hidden Costs of Energy" report.

SUBSIDY	COAL 79%	OIL 6%	GAS 15%	TOTAL
Lost Tax Revenues	3.158	.240	.599	3.997
R&D and Agency Fund.	.167	.013	.031	.211
Loans and Guarantees	1.126	.086	.213	1.425

4) Richard Heede, Rocky Mountain Institute. Suggests that 1984 estimates, in "The Hidden Cost of Energy" study, should be updated and would probably be 18% higher (44 to 52 billion).

5) The Residential tax credits for solar installations has been eliminated, decreasing amount by \$.33 billion. To convert into 1988 dollars = $(1.406 - .33) \times 1.18 = 1.270$ Billion

Assumptions: Use 1984 numbers as bottom of range and 18% increase to reflect top range.

SUBSIDY	COAL	OIL	GAS	NUCLEAR	HYDRO	CONSERV	SOLAR
Lost Tax Revenues	5.986	8.909	5.771	11.746	.787	.330	1.270
R&D and Agency Fund.	1.948	1.515	.413	3.410	1.270	.602	.342
Loans and Guarantees	1.343	.101	.251	3.918	.714	.087	.000
Total	9.277	10.525	6.435	19.074	2.771	1.019	1.612

Author conclusions :

The authors deliberately pursue a more qualitative approach because of the importance they perceive in establishing broad boundary limits rather than specific cost assumptions. While they recommend a more exhaustive costing effort in the future, they believe that their method is valuable in that it educates the user in the broad range of societal cost components and requires him/her to think about the relative importance of individual impacts.

Conventional technologies have significantly higher societal costs than renewable energy technologies. Results indicate the need for "leveling the playing field" between fossil fuel and renewable energy technologies by comprehensively accounting for societal costs.

Reviewer Summary :

This approach is valuable in that it includes many impacts that more quantitative approaches would ignore. It also treats technologies and emissions generically, so that the results are more easily applied in a broad policy setting. It escapes the limitations of more quantitative, site specific approaches.

The greatest weakness is the subjective nature of the valuations. However, by documenting the issues considered and the logic and reasoning behind their valuations, the authors go further than others in documenting their rationale, and allow useful critique and dialogue.

Integrating Environmental Externalities into Resource Planning at New England Electric, Temple, Barker & Sloane, Inc.

In Massachusetts Department of Public Utilities 86-36-F, the state's electric utilities were charged with considering environmental effects in their resource planning process. During the summer of 1989, various Massachusetts utilities, regulators, and environmental interests met in a collaborative series of meetings to review environmental effects of power production and attempt to agree on approaches to the problem. The environmental groups preferred full costing methods, while utilities embraced ranking and weighting methods.

New England Electric hired Temple, Barker and Sloane, Inc. to develop a methodology for incorporating these effects into the resource planning process and the development of NEESPLAN II: 1990.

TBS compared a wide range of qualitative and quantitative approaches, and arrived at a hybrid approach; for this reason it was not discussed in the previous section. The TBS approach borrows much of the ranking and weighting methodology used in Orange and Rockland, but rather than using "cost of control" as a proxy for environmental impacts, they generated environmental categorizations and weights through Delphi survey techniques and from existing materials. A limited number of surveys (11) were completed by environmental professionals at both the primary level (where respondents weighed individual environmental effects) and the secondary level (where they assessed the total environmental score).

TBS and NEES determined some ground rules that are of interest:

- * externalities are best characterized as "issues"; i.e. global warming or acid rain rather than specific emissions
- * externalities should be considered from society's, not the utility's, point of view
- * only environmental externalities occurring in the operating stage would be considered initially
- * movement toward full costing was a desirable long-term goal

The worksheet that resulted from their work is included .

Each environmental issue set was composed of one or more sub-issues, and received a weighting within the total environmental block. The relative weighting of issues was determined by compiling information from studies and reports, Delphi polling of experts, and the use of weights determined in previous methodologies.

The factors contributing to scores for individual issues were compiled depending on the characteristics that best described their impact :

Regulatory :

If the factor could be described by legislated limits (such as NSPS),

ISSUES AND CONTRIBUTING FACTORS

Environmental Concern Weight	Issue	Contributing Factor Weight	Factor	(Least) -----> Impact -----> (Most)					Impact	Score
				0	1	2	3	4		
9%	Global Warming	100%	Carbon Dioxide (lb/kWh)	0	0.63	1.25	1.88	2.5		
14%	Acid Rain	50%	Sulfur Dioxide (lb/mmBtu)	0	0.3	0.6	0.9	1.2		
		50%	Nitrogen Oxides (lb/mmBtu)	0	0.15	0.3	0.45	0.6		
7%	Land Use	*	Amount (acres)	0	2000	4000	* multiply "amount" score by "character" score to calculate impact			
			Character	industrial	res/com/farm	pristine				
14%	Solid Waste	100%	Overall Assessment (lb/kWh)	0	0.05	0.1	0.15	0.2		
			Adjustment							
16%	Water Use/Quality	20%	Amount (gallons/MWh)	0	150	300	450	600		
		40%	Attributes of Input Water	no water used	minor loss of recreational area	minor loss of habitat	major loss of recreational area	major loss of habitat		
		30%	Thermal Attributes of Receiving Water	no change		receiving water with minor thermal change		receiving water with major thermal change		
		10%	Chemical Attributes of Receiving Water	no change		receiving water with minor chemical change		receiving water with major chemical change		
16%	Emissions to Air	25%	Air Toxics (fuel type)	no fuel		natural gas		coal or oil		
		25%	Particulates (lb/mmBtu)	0	0.0075	0.015	0.0225	0.03		
		25%	Sulfur Dioxide (lb/mmBtu)	0	0.3	0.6	0.9	1.2		
		25%	Nitrogen Oxides (lb/mmBtu)	0	0.15	0.3	0.45	0.6		
2%	Aesthetics	40%	Visual Effects	not visible or obstructive	seasonally visible	visible from major roads	visible from recreation areas	visible from sensitive areas		
		40%	Noise	no noise	below nighttime ambient	below daytime, above nighttime	above daytime ambient	meets property line limit		
		20%	Signal Interference (households affected)	0	10	20	30	40		
2%	Indoor Air Quality	10%	Creation	reduces production		no effect		increases production		
		90%	Retention (air changes)	increases number		no effect		reduces number		
4%	Fuel Issues	100%	Overall Assessment	no fuel		natural gas		coal/oil		
16%	Ozone	45%	VOCs (lb/mmBtu)	0	0.0015	0.003	0.0045	0.006		
		45%	Nitrogen Oxides (lb/mmBtu)	0	0.15	0.3	0.45	0.6		
		10%	CFCs	no release				CFCs released		

Figure 1: Externalities Worksheet

then the scoring scale related to the degree that a resource met that limit. For instance, the highest emission level of any realistic Massachusetts power source option determined the upper limit of the global warming category, and received a "4," whereas a source with no emissions would receive "0."

Range of options : this normalizes impacts in the range relevant to utilities; i.e., actual weight of emissions per kWh.

Root cause : this scale is an attempt to simplify effects by reducing them to their root cause, and is used primarily for assessing fuel issues.

Adjustment : this method allows subjective adjustments to account for mitigating effects.

Grading : this approach allows a subjective "minor - to - major" assessment comprised of broad issues (such a water/air use) that are made up of a large number of dissimilar elements.

State of the Art : This method recognizes that the lack of information on certain issues (they cite indoor air quality) precludes precision, but subjective evaluation is a reasonable proxy.

Reference to Others' Work : This method is essentially the borrowing of other work pertaining to ranking of impacts. For instance, in the case of aesthetics, they borrowed the ratings filed by Orange and Rockland in New York.

Author conclusions :

TBS adopted this method because they believed that full costing was not yet possible. They found that while sources used to develop factor weights were not necessarily consistent in their implied or stated weights, they did exhibit consistency in the relative weighting of environmental issues.

Reviewer Summary :

The TBS methodology is a highly developed ranking and weighting scheme, and attempts to integrate a number of approaches to evaluating disparate environmental characteristics in order to minimize subjectivity. Its one page evaluation sheet provides a simple but succinct evaluation of a resource option.

While the methodology purports to borrow some of the strengths of the Orange and Rockland approach, it does not, however, actually consider impact factors on any kind of price or cost-related basis, and is consequently much more arbitrary. The methodology depends on a limited number of expert opinions, and the results are relatively subjective. Available information on the method does not specify the size of the environmental block, nor how it is considered in overall bid evaluation.

ASSESSMENT OPTION III - COST OF CONTROL or ABATEMENT

Energy and Cleaner Air: Costs of Reducing Emissions, OECD, Paris, 1987

This report presents a summary and analysis of a symposium titled "ENCLAIR '86: Energy and Cleaner Air: Costs of Reducing Emissions." The report examines the issue of emission reduction costs and attempt to relate reductions in air pollutant emissions to their related costs. They review technological methods of reducing air pollution, explore methodological issues in quantifying the cost of emission reductions, and touch upon some policy considerations.

The aim of the paper is to further international exchange of information on the costs of techniques to reduce emissions of major air pollutants; from both mobile and stationary sources and fuel processing/storage/transportation.

Data are summarized from principal studies reporting costs of post-combustion emission control methods. Costs include only direct monetary costs to achieve emission reductions. They cite the fact that reliable information on costs is often unavailable and uncertain, and is reported in a number of ways.

They state that the most useful measures of cost include normalization of some relevant measure. These include capital costs, which are normalized in terms of size or capacity, while annualized costs are normalized in terms of useful output. "Cost-effectiveness" is obtained by dividing annual net pollution control cost by the magnitude of emission reduction of a given pollutant. However, they cite that cost-effectiveness can be misused or wrongly interpreted: cost effectiveness of control for SO_2 depends on the initial sulphur content of fuel, and on the percentage reduction achieved. They also cite uncertainty in reported costs stemming from a failure to report underlying assumptions in sufficient detail. They also caution no single measure of cost is "best," and state that in some cases reporting costs by more than one measure can reveal economic implications better than single indicators.

In comparing two options, they stress the importance of standardizing scales for comparison. For instance, when comparing technology options for their cost per ton of abatement, total reductions in emissions may be quite different. They demonstrate by comparing the cost per ton of abating emissions of a flue gas desulphurization plant removing 90% of SO_2 in a power plant burning 3% sulphur, to a comparable plant burning 1% sulphur coal. While the overall reductions will be higher for the high sulphur coal plant, and the cost per ton abated will be less, the total emissions and the cost per kWh of power will be higher.

The most relevant comparison is the overall cost of an advance system compared to a conventional system meeting comparative pollutant requirements,

and this is a difficult standard to attain. They describe some difficulties in comparing technologies, particularly as emerging technologies alter old baseline measurements and as measurement categories undergo a certain amount of flux. For instance, some technological changes affect fuel economy or other design parameters that are hard to cost out, or treat pollutant removal as an integral part of the process, making the allocation of overall costs to emission reduction somewhat problematic and not as meaningful for comparative purposes.

They describe four methodological issues:

1. producer vs. consumer price
2. hardware vs. life-cycle costs
3. allocation of cost to emission control systems
4. definition of the baseline from which changes are measured

Methodologically, they offer probabilistic analysis as a way of quantifying uncertainty in cost estimates of control, and state that it may be especially useful in comparing current technology with advanced processes under development. Techniques such as probabilistic analysis to quantify uncertainty in cost and emission reduction estimates, may be particularly useful in comparing known commercial technologies with advanced processes still under development. They stress that these analytical techniques should be used in combination with other information related to policy making, including secondary economic impacts and political constraints.

They describe how for comparable fuels and removal efficiencies, the cost-effectiveness of pollutant removal on small industrial systems is several times higher than for utility systems because of economies of scale. However, while it may be more cost effective on a per-ton basis to pursue reduction through smaller plants, this overlooks the aggregate emissions that could be avoided in other sectors. They also report the need for financing strategies to help small- and medium-size industrial facilities in evaluating and installing emission reduction systems. Cross-sector considerations are also important; they cited cost comparisons in Greece where the decision to require catalytic converters for autos was instrumental in defining cost effectiveness for removing pollutants from industrial and utility sources.

They demonstrate that innovations and simplification of conventional wet flue gas desulphurization (FGD) are resulting in substantial cost savings relative to first generation systems in Europe reaching 40% cost reduction in both capital and annual costs. A number of advanced processes under development for the combined removal of SO_2 and NO_x that offer the prospect of cost savings on the order of 15% to 30% compared to conventional systems employing separate processes. They stress that technological solutions need an opportunity to be explored in the marketplace, and caution against methodological approaches that prematurely preclude pursuit of such solutions.

They also point out that solid waste disposal costs are becoming more of a concern, at least in Europe, creating serious cost implications for some dry SO_2 systems such as furnace sorbent injection and lime spray dryer systems.

As additional quantities of waste materials are injected into the marketplace, it can be seen that technological solutions create some of their own cost constraints that must be assessed for their future impact on that technology's viability.

Author conclusions :

Dramatic technological opportunities exist for air pollution reductions. There is a growing consensus on the cost of emissions reduction from stationary sources; further efforts are needed to improve the degree of consensus and narrow the range of cost estimates for specific technologies, particularly mobile source controls and fuel desulphurization. Presentation of cost estimates must be accompanied by adequate supporting data and description of assumptions used to make them comparable with other estimates and useful to policy makers. They also cite the need for a more comprehensive approach to evaluating pollution costs in order to avoid shifting problems from one medium to another, ie., air to water or land.

They acknowledge that there may well be much lower cost methods of reducing pollutants through efficiency and conservation programs, but that this was not within the scope of their study.

Reviewer Summary :

This analysis provides useful information on the number, type, and characteristics of technologies that must be characterized in terms of their impacts on social costs. It is more useful as a source of data for technology characteristics than for assessing social costs. The control estimates provided could be used as a baseline of information for a ranking/comparison methodology.

Environmental Externality Issue Report (Preliminary Draft), Division of Policy Analysis and Planning, New York State Energy Office, February 24, 1989.

In this report, the New York State Energy Office (NYSEO) investigates a number of approaches to calculating the value of environmental impacts and incorporating that information into energy planning.

They cite the large variations in emission impacts from different technologies, even after they meet existing or proposed standards. Electric generation contributes 2/3 of SO₂, 1/5 of NO_x, and 1/4 of the CO₂ in New York, and they state that potential exists for significant reduction.

They then examine the cost of SO₂, NO_x, and CO₂ emission reductions for a generic 200 MW coal-fired power plant, meeting New Source Performance Standards using Advanced Control Technologies (ACT) and Mixed Control Technologies (MCT). They believe that the abatement costs associated with a given emission are a useful proxy for the external costs of the emission, and conclude that environmental externalities should be awarded 20-30% of the total bid score.

Integration of these figures into the bidding process can be accomplished in three ways : (1) through legislation/regulation, (2) through emission fees equal to the abatement costs, or, (3) through abatement costs considered in the bidding process. They state that the second approach is viable, but concentrate their efforts on presenting three formulas for developing the third option :

The physical ratio method determines a numerical point score based on the ratio of pollutants emitted to the amount of pollutants emitted by the utility's preferred resource option.

The cost/savings ratio method evaluates the dollar costs or savings associated with more or less stringent emission constraints towards attaining a predetermined level of emissions. It derives a point score from the amount of emissions as compared to the preferred resource option.

The cost/savings price method is similar, but incorporates an emission adder into the bid price. Since the environmental externalities that are internalized in the bid price, there is no longer a need to reserve a portion of the environmental block for those effects. If all environmental effects are internalized through the adder, then conceptually there is no longer an environmental block, and only a price block (and presumably a block of non-price factors to be considered as well).

Author conclusions :

While they say that New Source Performance Standards (NSPS) standards do not adequately address potential damages from NO_x or CO₂, they imply that

freezing emissions at current levels is reasonable and sufficient abatement. They acknowledge that it is difficult to properly account for CO₂ as abatement technology is in its infancy, and that costs for reforestation are unclear.

Reviewer Summary :

This is an interesting approach because of its ease of use and the fact that it is fairly easy to explain. It is a comparative abatement cost approach to valuing emission costs in that all the value ranking is in relation to an externally chosen point of reference, the preferred resource option. In effect the choice of a preferred resource option sets up a kind of emission vs. control cost tolerance level. By awarding points or price adjustments based on how much higher or lower either emissions or emission control costs are in comparison to the preferred option, the system creates an incentive to improve on its environmental performance. However, it also puts limits on how much of a cost advantage a technology can gain by placing upper and lower boundaries on the point values based in the lowest emission possible from a technology (zero) and the highest allowance or likely levels (such as NSPS standards). Therefore, the points themselves are only scalars of the abatement impacts, not of differential social costs. The actual decision on social cost values is obscured in the weighting given to environmental points in the cost savings ratio and physical ratio methods, or to the price boundaries set in the cost (savings) price method. The approach is a useful means of adapting decisions to a workable bidding system, but it does not relieve the necessity of valuing environmental cost and benefits.

Case 88-E-241 - Proceedings on Motion of the Commission as to the Guidelines for Bidding to Meet Future Electricity Capacity Needs of Orange and Rockland Utilities.

Generically referred to as the Orange and Rockland case, this paper is actually a State of New York Public Service Commission review of a representative utility bid program.

In June 1988, The New York State Public Service Commission (NYSPSC) requested (in Opinion 88-15) that the state's electric utilities file Draft Environmental Impact Statements (DGEIS) in order to assess the potential environmental impact of utility bidding procedures. On January 9, 1989, the Orange and Rockland utility was the first New York utility to file their DGEIS, and as a result, became a test bed for methodologies including environmental effects in the electrical bid process.

The document describes an evolutionary process. Orange and Rockland had originally proposed a 10% environmental block for bid evaluation. The State Energy Office, in their comments, stated their belief that environmental effects comprised 20-30% of avoided costs, and that bid scoring should reserve that amount for environmental effects. They estimated that air emissions alone were in excess of 8-24% of avoided cost, and recommended reserving 40-80% of the environmental block for NO_x, SO₂, and CO₂ emissions.

The issues then faced by NYSPSC staff included determining the appropriate weight to assign to environmental effects, and within this environmental block, the most appropriate methods for apportioning weights among individual environmental factors.

Both NYSPSC and the New York State Energy Office (NYSEO) assumed that new projects would comply with Federal New Source Performance Standards. For most air impacts, abatement costs for meeting NSPS standards were thus used as a proxy for the value of environmental damages. Other costs were developed using estimates from other sources. These costs were used as guidelines to confirm the size of the components of the environmental block, modifying what had originated as a more subjective ranking and weighting scheme. Their figures are as follows :

<u>Effect</u>	<u>Cost per kWh (Proxy)</u>
Sulphur Oxides	.25
Nitrogen Oxides	.55
Carbon Dioxide	.10
<u>Particulates</u>	<u>.005</u>
Total Air Emissions	.905
Water Discharges	.10
<u>Land Use Impacts</u>	<u>.40</u>
Total cost	1.405 cents/kWh

By assuming that winning bids would come in at no more than the company's avoided cost of 6.42 cents per kWh, environmental externalities were calculated to be about 24% of average cost. This price factor was then reinterpreted into a point factor that could be integrated into Orange and Rockland's existing point system. The final NYSPSC recommendation was for an environmental block sized at 24% of the price score (not the total score) where the price score comprised 47% of the total score.

Author conclusions :

The NYSPSC acknowledges that their conclusions do not form a complete methodology, and that additional efforts are necessary to ensure consistency in applying the methodology across different utilities. The NYSPSC also agreed that it was not in the state's best interests to assume the full cost of its CO₂ emissions until it received some assurances that other states would follow suit. They also expressed concern that premature use of very high estimates would offer a disproportionate advantage to gas-fired over coal generation. They did, however, recommend that New York utilities initially take small, unilateral steps as preparation for the imposition of more stringent requirements at a later date.

Reviewer Summary :

The strength of the New York-Orange and Rockland methodology is that it eliminates the problem of comparing price and point factors by essentially reducing them both to one price factor (even though they are later reconverted to points). Also, the size of the environmental block that should be considered in a bidding process is automatically defined by the components of the price factors themselves, and different resource options can be compared on a consistent basis. Thus, all factors that can be reduced to price are included in a price block where they may be compared consistently with the price factors of competing resources. Non-price factors (such as dispatchability, fuel diversity, risk, etc.) are considered in a separate block.

However, the major shortcoming is one of subjectivity. The use of abatement costs as a proxy for environmental costs is wholly dependent on the level of environmental control that is considered "sufficient," whether it be legislated emission limits or an academic best guess. While such a methodology could very quickly accommodate a new set of emission requirements, its focus is on targets rather than actual costing information.

ASSESSMENT OPTION IV FULL COSTING OF EXTERNALITIES

Social Costs of Energy Consumption - Externalities of Electricity Generation in the Federal Republic of Germany, Olav Hohmeyer, 1988.

Hohmeyer's intention is to show when market allocation mechanisms do not work, suboptimal allocation of resources leads to considerable losses to society. Since the general pricing mechanism does not work adequately in the case of competing electricity generating technologies, Hohmeyer believes that the government must step in and internalize the social costs of economic processes. Theoretically, this should be done by leveling a tax against all electricity generation processes causing social costs to offset the amount of costs passed onto society; or by paying subsidies for renewable energy systems to the extent of the social costs avoided through their operation. He stresses that required taxes and subsidies are not an intervention against markets but an incentive to perform better.

Two major types of external costs for the effects of energy systems are monetarized: 1) environmental and 2) economic. The latter category includes employment effects of energy technologies, depletion of nonrenewable resources, and public expenditures in the electricity sector. Employment effects of an energy system, in addition to inducing higher private income, may lead to the relief of government and public agencies by resolving issues of unemployment and social security payments. External economic effects may also result from the fact that depletable natural resources are not priced according to their long-term scarcity but only according to extraction costs (including transportation and profits) for the part of these resources currently being exploited. Furthermore, government payments for the promotion of research and development, market introduction or sales in connection with the use of different energy systems or energy sources are considered external costs. Hohmeyer states that this analysis must consider both the positive economic effects of the new renewable energy technologies (PV and wind) and the lost economic effects of the replaced "standard" energy technologies resulting from their production, installation, and operation. (See Hohmeyer's Figure 3.2 - Structure of the Net Effect Analysis.)

Major elements of Hohmeyer's methodology include:

Hohmeyer uses an input-output model to arrive at values for savings, imports, gross value added, employment effects, lowered bills for government and public agencies due to increased employment benefits, and to determine domestic external economic net effects, which are positive for wind and PV. Employment and other corresponding values for fossil and nuclear power generating technologies are not included by Hohmeyer in this section in his report.

Economic net-analysis includes positive and negative effects on the national economy, with changes in

imports included. The input-output tables are specially augmented for two renewable technologies: wind and PV.

Positive economic effects include investments in new energy technologies and related operation and maintenance that result in new economic activities. Their effects may be to increase income or reduce energy bills. If new energy technologies are not cost-effective, then the result is a negative income effect. In terms of lost economic benefits, if less investment occurs in standard energy equipment, this would be accounted for on the debit side.

Hohmeyer says that there have been relatively few studies on the economic, and more specifically, employment effects of the use of renewable energy technologies. However, all studies to date derive positive net employment effects for all renewable energy sources.

Depletion of nonrenewable resources :

The inevitable depletion of fossil fuels raises the question of whether the increasing long-term scarcity has been taken account in the market price of such goods in order to assure an optimum intertemporal allocation. In effect, Hohmeyer argues that the current use of fossil fuels has opportunity costs which are beyond present exploitation costs (opportunity costs for future generations). Hohmeyer examines several theories in this area and applies a methodology by R. Wagner which assumes that the long-term supply of energy services can best be guaranteed by applying a surcharge for the depleted part of the resource which is equal to the price of the next most cost-effective substitute technology. Such substitution technology for fossil fuels could include electricity produced by solar or wind or hydrogen.

Hohmeyer develops weighted scarcity surcharges for electricity-based fossil fuels as well as for electricity generated by nuclear power. For the calculation of the substitution price of electricity based on fossil fuels, the present market prices of electricity differentiated according to the fossil fuel used, it is necessary to determine the degree of resource depletion for each fossil fuel, the market prices for the fossil fuels used and the efficiency of the electric power station. He applies the same methodology to uranium-based nuclear electricity and

arrives at the scarcity/depletion surcharges shown in Table 3.17.

Both electricity derived from fossil fuels and nuclear have relatively high depletion surcharges in Hohmeyer's analysis, which increase the values for the external costs of electricity generation. Depletion surcharges for fossil fuels in 1985 amounts to about 0.02 DM/kWh, which is roughly 10 percent of the actual generating costs. Monetary subsidies and other economic effects seem to play a relatively minor role for fossil fuels. Other major areas of external costs which play a role in electricity based on fossil fuels are primarily environmental, with negative health effects playing a major role.

Nuclear power has a comparatively high depletion surcharge as well as a comparatively value for R&D expenditures. Other costs associated with its use include the possible damage resulting from major nuclear accidents.

Induced public expenditures as an element of social costs :

Hohmeyer states that induced public expenditure, public transfer and lost taxes need to be examined as an element of social costs to the extent that these costs appear as a reduction of public funds available for other purposes. Monetary values are given in Table 3.18, with the accompanying explanation below.

R&D transfers are the major sources of public financing for new energy systems. This is true for nuclear and renewable energy sources.

For renewable energy sources, he estimates the sum of grants necessary to bring the technologies to the state of maturity. For electricity generation from wind turbines as well as for photovoltaic generation, this sum is estimated to be in the range of 5 to 10 times the amount awarded up to 1984. The equivalent annual subsidy is then related to 8 percent of the technical potential at this higher level of technology, which is estimated to be 245 TerraWatt Hours for both wind and solar energy. Thus the R&D expenditures are related to 20 TWh of energy production which is about 5 percent of present annual electricity production.

Nuclear has the highest subsidy at .0235 DM/kWh. Wind is .0026-.0052 DM/kWh. Photovoltaics is .0052-0.0104 DM/kWh. Annual public expenditures are shown in Table

3.18.

He states that the mean figure on the positive externalities of wind energy of 0.09 DM/kWh, is in the range of 30% of the overall internal costs of electricity generation from wind energy today (0.25 DM/kWh).

Author conclusions :

Societal costs must be taken into account in deciding future energy options. If externalities were included in West Germany's coal and nuclear options, the cost of coal production would increase by 80% and nuclear power would increase 3 times its current price charged to consumers. He concludes that failure to include external costs in the marketplace puts renewable energy systems at a systematic disadvantage -- if the social costs had been included in the market prices of conventionally generated electricity, then the cost-effectiveness of wind energy would have been reached in 1984. If the social costs continue to be excluded, it may take until 1994 for cost-effectiveness to be demonstrated. Thus, by ignoring social costs, "The introduction of renewable energy technologies have been delayed by 7 to 15 years for wind and 4 to 10 years for photovoltaics." Hohmeyer's Tables 3.20, 3.21, and 3.22 are perhaps the most crucial in his analysis. Table 3.20 is a summary of the externalities of energy systems monetarized in his study. The major benefits considered by Hohmeyer in examining renewables includes the avoided external costs of present electricity generation from fossil and nuclear fuels as well as their positive net economic effects. He states that these numbers "...strongly indicate that the omission of these externalities is not simply a minor distortion, but in fact a massive distortion of the optimal allocation of resources."

Reviewer Summary :

While Hohmeyer attempts to cost out perhaps the broadest range of externalities, his proposed system of taxes or credits is not well developed. As such, it does not offer sufficient guidance on integrating full costing into a competitive bidding methodology.

He does succeed, in bringing up a number of boundary issues, and is specific about which issues are currently too complex to be considered; i.e., the full costs of global warming.

One of the most salient aspects of Hohmeyer's approach is his description of the ultimate effect of external impacts in terms of the delay they impose on the development of many of the renewable energy technologies that could mitigate many external costs of fossil fuels.

Table 3.20: Summary of the external effects of energy systems monetarized in this study

External Effects discussed	Electrical output in 10(8) kWh/a used for standardization (2°)	Estimated annual external effects in million DM82/a (1°)	Estimated external costs per kWh electricity supplied (2°) DM82/kWh (el)
1. Environmental effects			
1.1 Electricity from fossil fired power station	245 800		
1.1.1 Flora		1690 - 2550	0.0089 - 0.0104
1.1.2 Fauna		30	0.0001
1.1.3 Mankind		450 - 11300	0.0018 - 0.0460
1.1.4 Materials		620 - 1090	0.0025 - 0.0044
1.1.5 Climate		20 - 30	0.0001
Total	245 800	2810 - 14970	0.0114 - 0.0609
1.2 Nuclear power - Major nuclear accidents	15.10(6) - 15.10(7)	1.8 - 10(8)	0.012 - 0.12
1.3 Renewable energy sources			
1.3.1 Photovoltaics	20 000		
- Occupation of land		87.8	0.00438
- Health effects due to the risk of accidents		0.7	0.00004
1.3.2 Wind energy	20 000		
- Noise		1.8	0.00009
2. Economic effects			
2.1 Wind energy (net effects)	20 000		
2.1.1 Gross value added		-160 - -767	-0.0080 - -0.0384
2.1.2 Savings		-73 - +481	-0.0037 - +0.0231
2.1.3 Employment		+315 - +494	+0.0053 - +0.0094
Total		+10 - +188	+0.0053 - +0.0094
2.2 Photovoltaics (net effects excl. 1982)	20 000		
2.2.1 Gross value added		-1648 - +1084	-0.0824 - +0.0532
2.2.2 Savings		-1183 - +1128	-0.0592 - +0.0564
2.2.3 Employment		+748 - +1448	+0.0374 - +0.0724
Total		+479 - +1329	+0.0240 - +0.0665
2.3 Depletion of nonrenewable resources (depletion surcharge 1985)			
2.3.1 Natural gas	34 300	1221	0.0357
2.3.2 Crude oil	7 900	408	0.0542
2.3.3 Hard coal (domestic)	104 800	3220	0.0307
2.3.4 Hard coal (imported)	12 800	427	0.0339
2.3.5 Lignite	81 900	352	0.0043
2.3.6 Average for 1984/85 electricity (total)	245 800	5628	0.0229
2.3.7 Nuclear energy	84 400	4188 - 5258	0.0591 - 0.0621
Average for 1984/85 total electricity	358 200	10810 - 10830	0.0298 - 0.0306
Dynamic depletion surcharge 1985-2080	358 200	10810 - 23940	0.0298 - 0.0672

External Effects discussed	Electrical output in 10(6) kWh/s used for standardization (2 ^o)	Estimated annual external effects in million DM\$2/a (1 ^o)	Estimated external costs per kWh electricity supplied (2 ^o) DM\$2/kWh(e)
2.4 Government subsidies			
2.4.1 Goods and services supplied			
publicity			
• Public disaster provisions (nuclear)	84 400	34.1	0.00043
• Public expenditure for environmental administration and control			
• emission monitoring	245 800	6.1	0.000025
• radioactivity monitoring	84 400	3.4	0.000043
• Cost of publicly provided infrastructure			
• Fossil fuels	245 800	156	0.00063
• Nuclear	84 400	53	0.00063
2.4.2 Monetary subsidies (direct)			
• Hard coal	245 800	563	0.00229
• Oil and gas	245 800	11	0.000045
• Nuclear energy	84 400	118	0.001374
• Accelerated depreciation	245 800	206	0.000834
2.4.3 Public R&D transfers			
• Renewable energy sources			
• wind energy	20 000	52 - 104	0.0026 - 0.0462
• photovoltaics	20 000	104 - 208	0.0052 - 0.0104
• Nuclear energy	84 400	1988	0.021531
• Fossil fuels			
• hard coal	245 800	96	0.000385
• oil and gas	245 800	0.4	0.000002
Total subsidies			
• Fossil fuels	245 800	1040	0.0042
• Nuclear	84 400	2170	0.026
• Renewable energy	40 000	196 - 312	0.0053 - 0.0078

1^o) All cost figures given in 1982 prices. Prices have been adjusted by the West German cost of living price index. In some cases the base year of figures derived from the literature had to be estimated.

2^o) Costs per kWh are based on the electricity production from the relevant fuels in 1984 not including own use and distribution losses (336 200 GWh(e)); total: 117 500 GWh hard coal, 81 900 GWh(e) lignite, 4680 GWh(e) other solid fuels, 7500 GWh(e) heavy fuel oil, 34 200 GWh(e) gas, 16 000 GWh(e) water, 84 400 GWh nuclear). Wind energy figures and photovoltaics are based on an assumed production of 20 000 GWh(e) each (maturity stage). Figures based on Arbeitsgemeinschaft Energiebilanzen (1983) and own calculations.

Own calculations and different sources, which are given in the text, mainly: Niehs (1986), Jochen (1984), Dingen (1984), Arbeitsgemeinschaft Energiebilanzen (1983).

West German cost of living price index used (1982 = 100) (Statistisches Bundesamt (1986), p. 310 and Wirtschaft und Statistik 3/1987 p. 183)

1975	73.75
1976	77.03
1977	78.73
1978	81.79
1979	84.82
1980	88.29
1981	94.91
1982	100.00
1983	103.21
1984	105.71
1985	108.04
1986	107.77

Table 3.21: Gross external effects of electricity generated on the basis of fossil fuels and nuclear energy, excluding some economic effects which are calculated only as net effects for renewable energy sources 1982 prices).

a) Gross external effects of electricity generated from fossil fuels (all figures are estimated minimal external costs)

1. Environmental effects	0.0114 - 0.0609	DM ₈₂ /kWhel
2. Depletion surcharge (1985)	0.0229	DM ₈₂ /kWhel
3. Goods and services publicly supplied	0.0007	DM ₈₂ /kWhel
4. Monetary subsidies (including accelerated depreciation)	0.0032	DM ₈₂ /kWhel
5. Public R&D transfers	0.0004	DM ₈₂ /kWhel

Total	0.0386 - 0.0681	DM ₈₂ /kWhel
-------	-----------------	-------------------------

b) Gross external effects of electricity generated in nuclear reactors, excluding breeder reactors (all figures are estimated minimal external costs)

1. Environmental effects (human health)	0.0120 - 0.1200	DM ₈₂ /kWhel
2. Depletion surcharge (1985)	0.0591 - 0.063	DM ₈₂ /kWhel
3. Goods and services publicly supplied	0.0011	DM ₈₂ /kWhel
4. Monetary subsidies	0.0014	DM ₈₂ /kWhel
5. Public R&D transfers	0.0235	DM ₈₂ /kWhel

Total	0.0971 - 0.2083	DM ₈₂ /kWhel
-------	-----------------	-------------------------

c) Average gross external costs of the electricity generated in the FRG in 1984

1. Costs due to electricity from fossil fuels (weighting factor 0.7444)	0.0287 - 0.0658	DM ₈₂ /kWhel
2. Costs due to electricity from nuclear energy (weighting factor 0.2556)	0.0248 - 0.0532	DM ₈₂ /kWhel

Total	0.0535 - 0.1188	DM ₈₂ /kWhel
-------	-----------------	-------------------------

Table 3.22: Estimated minimal net external effects of electricity generated on the basis of wind and solar (photovoltaic) energy (1982 prices)

a) Wind energy		
1. Environmental effects (noise)	- 0.0001	DM ₈₂ /kWhel
2. Public R&D transfers (estimate)	- 0.0026 - (-) 0.0052	DM ₈₂ /kWhel
3. Economic net effects	+ 0.0053 - (+) 0.0094	DM ₈₂ /kWhel
4. Avoided external cost of present electricity generation	+ 0.0535 - (+) 0.1188	DM ₈₂ /kWhel
<hr/>		
Total external benefits	+ 0.0561 - (+) 0.1229	DM ₈₂ /kWhel
rounded to three digits	+ 0.056 - (+) 0.123	DM ₈₂ /kWhel
mean	+ 0.089	DM ₈₂ /kWhel
b) Solar energy (photovoltaics)		
1. Environmental effects	- 0.0044	DM ₈₂ /kWhel
2. Public R&D transfers (estimate)	- 0.0052 - (-) 0.0104	DM ₈₂ /kWhel
3. Economic net effects (not including 1982 figures)	+ 0.0240 - (+) 0.0685	DM ₈₂ /kWhel
4. Avoided external cost of present electricity generation	+ 0.0535 - (+) 0.1188	DM ₈₂ /kWhel
<hr/>		
Total external benefits	+ 0.0679 - (+) 0.1705	DM ₈₂ /kWhel
rounded to three digits	+ 0.068 - (+) 0.171	DM ₈₂ /kWhel
mean	+ 0.119	DM ₈₂ /kWhel

Table 3.23: Gross external effects of electricity generated on the basis of fossil fuels and nuclear energy, excluding depletion surcharge

a) Gross external effects of electricity generated from fossil fuels (all figures are estimated minimal external costs)

1. Environmental effects	0.0114 - 0.0509	DM ₈₂ /kWhel
2. Goods and services publicly supplied	0.0007	DM ₈₂ /kWhel
3. Monetary subsidies (including accelerated depreciation)	0.0032	DM ₈₂ /kWhel
4. Public R&D transfers	0.0004	DM ₈₂ /kWhel

Total	0.0157 - 0.0652	DM ₈₂ /kWhel
-------	-----------------	-------------------------

b) Gross external effects of electricity generated in nuclear reactors, excluding breeder reactors (all figures are estimated minimal external costs)

1. Environmental effects (human health)	0.0120 - 0.1200	DM ₈₂ /kWhel
2. Goods and services publicly supplied	0.0011	DM ₈₂ /kWhel
3. Monetary subsidies	0.0014	DM ₈₂ /kWhel
4. Public R&D transfers	0.0235	DM ₈₂ /kWhel

Total	.038 - 0.146	DM ₈₂ /kWhel
-------	--------------	-------------------------

c) Average gross external costs of the electricity generated in the FRG in 1984

1. Costs due to electricity from fossil fuels (weighting factor 0.7444)	.0117 - .0485	DM ₈₂ /kWhel
2. Costs due to electricity from nuclear energy (weighting factor 0.2556)	.0097 - .0373	DM ₈₂ /kWhel

Total	.0214 - .0858	DM ₈₂ /kWhel
-------	---------------	-------------------------

Table 3.24: Estimated minimal net external effects of electricity generated on the basis of wind and solar (photovoltaic) energy (1982 prices) with revised avoided external costs

a) Wind energy			
1. Environmental effects (noise)	- 0.0001		DM ₈₂ /kWhel
2. Public R&D transfers (estimate)	- 0.0026 - (-) 0.0052		DM ₈₂ /kWhel
3. Economic net effects	+ 0.0053 - (+) 0.0094		DM ₈₂ /kWhel
4. Avoided external cost of present electricity generation	0.0214 -	0.0858	DM ₈₂ /kWhel
<hr/>			
Total external benefits	0.0347 -	0.0371	DM ₈₂ /kWhel
rounded to three digits	.035 -	.037	DM ₈₂ /kWhel
mean		.036	
b) Solar energy (photovoltaics)			
1. Environmental effects	- 0.0044		DM ₈₂ /kWhel
2. Public R&D transfers (estimate)	- 0.0052 - (-) 0.0104		DM ₈₂ /kWhel
3. Economic net effects (not including 1982 figures)	+ 0.0240 - (+) 0.0665		DM ₈₂ /kWhel
4. Avoided external cost of present electricity generation	0.0214 -	0.0858	DM ₈₂ /kWhel
<hr/>			
Total external benefits	0.0465 -	.0847	DM ₈₂ /kWhel
rounded to three digits	0.047 -	.085	DM ₈₂ /kWhel
mean		.066	

Social Cost Priority Matrix - American Solar Energy Society Roundtable 1989

This report attempts to characterize and quantify total societal costs of energy use, ASES sent out questionnaires to research organizations to evaluate the impact of societal costs of energy on a national scale. Sixteen issues were identified and ranked by priority. Global warming, air pollution, acid rain, radioactive waste and resource depletion developed as the top five issues. Their results are included as an exhibit. ASES also developed estimates on the societal costs associated with corrosion, crop losses, health impacts, radioactive waste, the military, and subsidies.

Every response to the questionnaire listed global warming as a top concern. Other concerns included the need for a national energy plan based on a least-cost approach; the need to quantify societal costs; to encourage least-cost planning among utility commissions; to develop pollution fees; to more strongly enforce existing pollution standards; the need to desubsidize some of the existing energy fuels, and emphasizing R&D as very important from the standpoint of quantifying these costs to help solutions evolve.

Author conclusions :

Total societal costs identified ranged from \$104 to 204.3 billion.

Reviewer Summary :

Total costs are not a very useful presentation unless they can be broken down to source, and are put in a form where they can be compared to conventional costs of energy production. Their matrix is a good visual aid but not a planning tool in itself.

Results are highly dependent on selection of those contacted for input.

***Testimony of Michael Nicklas before the North Carolina Utility Commission on
Least-Cost Integrated Resource Planning***

Much of the work behind this paper resulted directly or indirectly from Mr. Nicklas' work for the American Solar Energy Society, for which he organized the survey leading to the Societal Cost Matrix described earlier in "Option II".

Mr. Nicklas attempts to demonstrate that there are significant externalities associated with all our energy supply and demand side options, and that it is important for society to account for externalities in all options in order to more clearly understand the ramifications of various energy sources. He specifically summarizes costing information for energy sources as a method for determining the actual least-cost set for North Carolinians.

Nicklas narrows his focus to a limited set of societal costs, preferring to limit comments to impacts that are clearly quantifiable. He concentrates on coal-fired power generation in North Carolina, because of the apparent magnitude of coal use in that state. His parameters include :

- 1) Sulfur Dioxide : health impacts, visibility, and soiling
- 2) Particulates: mortality, loss of work, reduced activity,
incidence of chronic respiratory diseases, and
incidence of acute respiratory diseases
- 3) Crop Losses
- 4) Corrosion Losses

For the benefit of the North Carolina Utility Commission, he presents a rough costing of these impacts, using generic and specific data from a number of sources, and extrapolating results through back-of-the-envelope calculations. He finds that the total impact from coal in North Carolina ranges from \$1 billion to 3.3 billion. When societal costs are added to the cost of power generation of 3.5 cents, then true cost of power generation range between 6.1 to 11.8 cents per kWh.

Author conclusions :

Nicklas presents his case as one primarily of magnitude; that even rough measurements indicate a doubling or tripling of the "true" cost of coal power in the state.

Reviewer conclusions:

While Nicklas' conclusions are rough, site specific, and not accompanied by any particular application proposal, they grapple directly with a measurable set of impacts. A strong point that emerges is that shying away from cost calculations is not necessary as long as assumptions made are explicit.

Estimating Environmental Costs and Benefits for Five Generating Resources,
U.S. Department of Energy, Bonneville Power Administration, April 1986.

This paper attempts to estimate the economic values of the environmental costs and benefits of a set of proposed electricity-generating resources, including cogeneration from biomass, cogeneration from municipal solid waste, geothermal, solar, and wind.

The analysis focuses on net (or residual) environmental effects: those impacts of a project that remain after environmental controls and all likely mitigating measures have been implemented.

The method comprises six steps:

1. Characterize the generic resources: by type, size, and location.
2. Identify and describe the potential environmental effects associated with each phase of the fuel cycle of a generating resource: extraction, transportation, construction, operation, and decommissioning.
3. Determine which effects are significant enough to warrant a detailed economic analysis.
4. Describe and estimate the magnitude of the significant environmental effects, by estimating dispersion concentrations, population exposures, and estimating dose-response relationships.
5. Estimate the economic value of the physical effects.
6. Calculate the present value of the expected environmental effects for each generating resource.

The authors describe the potential environmental costs as being very large, (e.g., for biomass-fueled cogeneration there are 35 potential environmental effects and four stages in the fuel cycle -- yielding a total of 140 potential effects for that resource alone). They developed a screening system to determine those variables likely to have a significant impact on the total cost of the resource by assuming that the costs of the potential environmental effects would be completely incorporated into the electric bill and asked, "How big would those costs have to be annually to cause the cost of electricity to increase by one mill per kWh?" Seven types of resources survived the screening process: air quality, water quality, land productivity, solid waste, endangered species, aesthetic qualities and religious or cultural values.

Environmental effects that were found to be significant occurred during plant operation; none occurred during construction. Only municipal solid waste was found to have a significant impact on the levelized costs of air quality. External environmental costs were found to be only a small component

of capital and operating costs.

Costs were both annualized in dollars over the life of the proposed plant and levelized to a kWh basis using a 3% discount rate. The authors commented that expected values could vary widely depending on whether one assumed that existing standards were sufficient to protect from health effects. To illustrate the range of variation possible the study includes high, low, and expected values.

BPA also conducted comparable analyses of a generic coal plant, a gas turbine, and a nuclear plant, producing one of the few data sets that spans the range of generating technologies.

Author conclusions :

The authors made it clear that this was a preliminary best attempt to evaluate impacts. Their opinion was that more detailed, technically accurate analysis was possible, but that these were the most sound estimates that could be made based on currently available information.

They acknowledged that since they attributed all environmental externalities to electricity, that their approach overestimated environmental effects for the biomass cogeneration scenario, in that part of the effects should be attributed to steam production.

In their view, environmental costs are a relatively smaller component than capital and operating costs, and that more work needs to be done on estimating variances regarding capital/operating costs. Valuation of cultural/religious effects, considered relevant for the Pacific Northwest, proved too difficult to quantify.

Reviewer Summary :

This approach applied a site-specific, generic resource selection tool rather than prescribing a definitive method for comparing bid proposals. Its approach to valuing impacts is the most ambitious in terms of actually trying to trace emissions through their impacts and then assigning economic values. The approach itself is rigorous and very well documented, but it is very dependent on the assumptions made in the description of the dose-response relationships.

A Model Electric Power and Conservation Plan for the Pacific Northwest
(Appendix 2 - Environmental Costs), no date of publication (ca. 1980's)
Michael Shuman and Ralph Cavanaugh.

This report analyzes some of the more significant generic environmental impacts of five energy options: coal-fired generation, nuclear generation, wind power, solar water heating, and household weatherization. However, most of the author's attention is given over to coal and nuclear concerns in the published report.

Low discount rates are used: 1 percent for property damages and a zero discount rate for death or injury. They analyze earlier efforts to assign dollar values to a human life, and introduce some ground rules for using these values in evaluation.

Their results show that total environmental costs from coal-fired and nuclear power generation could run as high as 207 mills per kWh for coal and 302 mills per kWh for nuclear. These cost estimates are substantially larger than the zero to 1.2 mill per kWh environmental cost that was calculated for wind power and solar heating. The environmental costs of a properly designed residential weatherization program is essentially zero. They emphasize that these numbers are highly controversial because of enormous uncertainties and unknowns, but that the analysis is conservative, making assumptions least favorable to its case.

In a relatively informal set of calculations, they make an attempt to integrate the results of two studies on CO₂ and global warming to determine the costs on a per kWh basis. They assume a 4.6 meter rise in ocean level with an estimated property damage cost (1980) of \$5.1 trillion, or \$1.55 trillion if discounted over 120 years. Apportioning this to the coal burned in a low-energy growth scenario, they derive an implied cost of .4 mills per kWh.

Author conclusions :

The authors point out that preserving legitimate uncertainties is better than ignoring them: that "environmental analysis can easily be abused by opponents or proponents of a given technology if the many uncertainties in the analysis are collapsed into a single cost figure". Thus, they suggest monetarizing whenever possible, but stress the importance of cost ranges, ensuring that other, less definable concerns are not ignored in evaluation merely because they are not quantifiable.

A Methodology for Integrating Air Quality Impacts into Energy Resource Planning, Frederick D. Sebold and Mark A. Thayer of Regional Economic Research, Inc. (San Diego, California) undertaken for the California Energy Commission.

This paper by Sebold et al., which was prepared for the California Energy Commission, reviews the conceptual role of externalities in utility bidding systems and makes recommendations for valuating air quality impacts and integrating these values in bidding systems. The external cost per kW would then be added to the bid price of each technology/resource.

The paper begins by discussing the limitations of certain methodologies, including ranking/weighting systems or those that depend heavily on rules of thumb or quotas/points; most of these limitations have already been discussed in Option I and Option II.

Also included are two interesting observations on Option III approaches that focus on abatement costs:

- * That abatement levels set at, for instance, the national level, will result in accounting inaccuracies because of the different emissions and impacts in different air basins.
- * As the abatement cost for particular emissions varies widely even within air basins, it is not clear which abatement cost level should be chosen as the generic proxy. He cites the cost of NO_x control in California's South Coast Air Basin to range from \$8,800 per ton for petroleum refineries to \$42,600 per ton for electric utilities.

Sebold et al., suggest a methodology to approach the economic valuation of damage costs as follows:

1. They believe that a large body of literature already exists on dose-response relations and that the dollar value of physical impacts can be estimated from this information. They discuss the resource approach, contingent valuation (willingness to pay) and revealed preference methods.
2. They recommend the construction of reference values of external costs, e.g. the air quality impacts per unit, the physical dose-response functions, and the dollar values of key physical responses. Impacts are measured as the dollar value of a one-unit ton change in each emission in each air basin.
3. The next step is the integration of reference values into the bidding system:

- * Each technology/resource offered in the auction would be reviewed and a set of emission factors would be determined. These factors would indicate the level of emissions per ton for each of the subject emissions.
- * These values would be multiplied times the reference value (dollar values per ton) for each emission for the basins in question, to get an estimate of the external costs associated with the resource per ton.
- * An assumed capacity factor and resource lifetime would then be used to translate this value into the implied external cost per kW of capacity.
- * Finally, the external cost per kW would be added to the bid price of the resource in question.

Author conclusions :

They assert that the information exists, and that while assembling the information in useful form would be complex, it results in a practical yet rigorous methodology that they feel is superior to other methods.

Reviewer Summary :

Sebold and Thayer make the very important observation that environmental effects may be site-specific, making it difficult to evaluate them generically. That the economic value of an environmental effect may vary depending on where it originates has broad implications. For certain impacts in some areas -- those that have health or material damage implications, or occur in areas where the dose-response relationship is already high -- using a generic cost would underestimate the actual impact. Other impacts, such as CO₂, have no localized impacts in the short run, and generic worldwide costs may be the more effective proxy.

Such an approach would be costly and time-consuming, and would only be fairly applicable if it were performed consistently over a very large area. If only air impacts were to be considered, the proposed methodology could be workable. However, applying the method to a significantly broader set of concerns might make the process too onerous for practical application. Little guidance is suggested regarding the integration of results into the bidding process; however, since their methods would deliver strict price results, integration should not be very difficult.

APPENDIX B

SOCIAL COST ESTIMATES

ESTIMATES FOUND FROM AVAILABLE SOURCES ON SOCIAL COSTS FROM POLLUTANTS

INTRODUCTION

Five studies were examined to begin the process of developing ranges and categories for social costs by emissions category and power source. These include: Olav Hohmeyer's *The Social Costs of Energy Consumption*; Shuman and Cavanaugh's *A Model Plan for the Northwest*; three studies undertaken for the Bonneville Power Administration entitled 1) *Estimating Environmental Costs and Benefits for Five Generating Resources*, 2) *Generic Coal Study: Quantification and Valuation of Environmental Impacts*, and 3) *Environmental Cost and Benefits Case Study: Nuclear Power Plant -- Quantification and Economic Valuation of Selected Environmental Impacts/Effects*; Mike Nicklas's *Testimony and Exhibits Before the North Carolina Utility Commission on Least-Cost Integrated Resources Planning*; and values used by the New York Public Service Commission on environmental externalities in the bidding process.

Graphics were generated for each study that depicted their estimates of the social cost from pollutants, including: 1) the original data given by the author(s); 2) original units converted into 1989 dollars; and 3) 1989 dollars converted into 2002 dollars. (See *Social Cost Impact Estimates by Source and Generation Technology - Data Tables*). The U.S. All-Commodity Producer Price Index was used as a basis to convert costs into 1989 and 2002 dollars. The rate of change in the index from 1980 to the third quarter of 1989 was 24.69%. This value was used to inflate 1980 prices to 1989 values. The average annual rate of change during the 1980-1989 period was 2.82% (24.69% divided by 8 3/4 years). This value was used as a proxy for an annual inflation factor during the 1990-2002 period.

The exchange rate to convert 1982 deutsche marks to 1982 dollars was \$1.00 = 2.4266 DM.

Four of these charts were then consolidated to show the range of values given by the source of the data by generation technology in *Cost Impact Estimates by Source and Generation Technology - Summary Tables*. (The fifth chart showing values by the New York Public Service Commission took more of a control cost rather than a social cost approach and was not included in the compressed chart. In addition, estimates for social impacts from oil and gas-fired turbines were not included in this draft in the summary tables but disaggregated numbers are available in the data table for Bonneville Power Administration).

To the extent possible in this first draft, the reviewed author(s) values and assumptions are explained for each of the categories in the above charts which range from NO_x, SO_x, CO₂, Land, Water, Fuel Cycle Generation, and Total Social Costs by Technology in the supplemental section entitled *Assumptions and Footnotes By Report*.

Estimates on abatement costs for CO₂ through reforestation as well as various technology options for pollution control are presented in the charts on *Estimates of Cost of Abatement*.

**Social Cost Impact Estimates
By Source and Generation Technology**

Data Tables

Hohmeyer (DM/kWh, 1982)

	NO _x	SO _x	CO ₂	Land	Water	Fuel Cycle Generation	Total Social Cost
PV				.00438		.00004 (PV health)	.00442 PV environmental .0477-.085 PV total
Fossil Fuel	.0064-.0104 (flora) .0001 (fauna) .0018-.0460 (mankind) .0025-.0044 (materials)		.0001		(see fauna)		.0716 fossil environmental .0157-.01352 fossil total
Wind						.00009 (wind noise)	.00009 wind environmental .035-.037 wind total
Nuclear						.012-.120 (nuclear accidents)	.012-.120 nuclear environmental .038-.146 nuclear total

Hohmeyer (¢/kWh, 1982)

	NO _x	SO _x	CO ₂	Land	Water	Fuel Cycle Generation	Total Social Cost
PV				.1805		.0016 (PV health)	.1821 PV environmental 1.9369-3.5028 PV total
Fossil Fuel	.2637-.4286 (flora) .0041 (fauna) .0742-1.8957 (mankind) .103-.1813 (materials)		.0041		(see fauna)		2.9506 fossil environmental .647-5.572 fossil total
Wind						.0037 (wind noise)	.0037 wind environmental 1.4423-1.5248 wind total
Nuclear						.4945-4.9452 (nuclear accidents)	.4945-4.9452 nuclear environmental 1.566-6.0166 nuclear total

Hohmeyer (¢/kWh, 1989)

	NO _x	SO _x	CO ₂	Land	Water	Fuel Cycle Generation	Total Social Cost
PV				.2021		.0018 (PV health)	.204 PV envrionmental 2.1687-3.9221 PV total
Fossil Fuel	.2953-.4799 (flora) .0046 (fauna) .0831-2.1226 (mankind) .1154-.203 (materials)		.0046		(see fauna)		3.3084 fossil environmental .7244-6.2385 fossil total
Wind						.0042 (wind noise)	.0042 wind environmental 1.615-1.7073 wind total
Nuclear						.5537-5.5371 (nuclear accidents)	.5537-5.5371 nuclear environmental 1.7534-6.7368 nuclear total

Hohmeyer (¢/kWh, 2002)

	NO _x	SO _x	CO ₂	Land	Water	Fuel Cycle Generation	Total Social Cost
PV				.2901		.0026 (PV health)	.2928 PV environmental 3.1132-5.6303 PV total
Fossil Fuel	.4239-.6889 (flora) .0066 (fauna) .1192-3.047 (mankind) .1656-.2915 (materials)		.0066		(see fauna)		4.7493 fossil environmental 1.0399-8.9555 fossil total
Wind						.006 (wind noise)	.006 wind environmental 2.3184-2.4508 wind total
Nuclear						.7949-7.9487 (nuclear accidents)	.7949-7.9487 nuclear environmental 2.5171-9.6709 nuclear total

Shuman and Cavanaugh Estimates (mills/kWh, 1980)

	NO _x	SO ₂	CO ₂	Land	Water	Fuel Cycle Generation	Total Social Cost
Solar, Wind²				1		0-1.2 (Health)	0-1.2
Coal¹			0-123.6 (Health) 0-4 (Property Damage)			.1-81.2 (Health Effects) .2-1.6 (Health and Crops)	.3-207
	Radiation Effects			Land	Water	Fuel Cycle Generation	Total Social Cost
Nuclear³						.5-165.4 (RadonHealth Impacts, milling) 0-1.2 (Health Impacts Fuel Cycle) 0-21 (Property Damage, Proliferation) 0-112.6 (Proliferation Health) 0-6 (Property Damage Nuclear Accidents) 0-20.5 (Health Effects, Accidents)	.5-303

Shuman and Cavanaugh Estimates (¢/kWh 1980)

	NO _x	SO ₂	CO ₂	Land	Water	Fuel Cycle Generation	Total Social Cost
Solar, Wind²				1		0-.12 (Health)	0-.12
Coal¹			0-12.36 (Health) 0-.04 (Property Damage)			.01-8.12 (Health Effects) .02-.16 (Health and Crops)	.03-20.7
	Radiation Effects			Land	Water	Fuel Cycle Generation	Total Social Cost
Nuclear³						.05-16.54 (RadonHealth Impacts, milling) 0-.12 (Health Impacts Fuel Cycle) 0-.21 (Property Damage, Proliferation) 0-11.26 (Proliferation Health) 0-.06 (Property Damage Nuclear Accidents) 0-2.05 (Health Effects, Accidents)	.05-30.3

Shuman and Cavanaugh Estimates (¢/kWh 1989)

	NO _x	SO ₂	CO ₂	Land	Water	Fuel Cycle Generation	Total Social Cost
Solar, Wind²				1		0-.15 (Health)	0-.15
Coal¹			0-15.41 (Health) 0-.05 (Property Damage)			.01-10.125 (Health Effects) .02-.2 (Health and Crops)	.04-25.811
	Radiation Effects			Land	Water	Fuel Cycle Generation	Total Social Cost
Nuclear³						.062-20.6254 (RadonHealth Impacts, milling) 0-.15 (Health Impacts Fuel Cycle) 0-.262 (Property Damage, Proliferation) 0-14.04 (Proliferation Health) 0-.075 (Property Damage Nuclear Accidents) 0-2.556 (Health Effects, Accidents)	.06-37.781

Shuman and Cavanaugh Estimates (¢/kWh, 2002)

	NO _x	SO ₂	CO ₂	Land	Water	Fuel Cycle Generation	Total Social Cost
Solar, Wind²				¹		0-.215 (Health)	0-.215
Coal¹			0-22.124 (Health) 0-.072 (Property Damage)			.018-14.534 (Health Effects) .036-.286 (Health and Crops)	.054-37.052
	Radiation Effects			Land	Water	Fuel Cycle Generation	Total Social Cost
Nuclear³						.089-29.606 (RadonHealth Impacts, milling) 0-.215 (Health Impacts Fuel Cycle) 0-.376 (Property Damage, Proliferation) 0-20.115 (Proliferation Health) 0-.107 (Property Damage Nuclear Accidents) 0-3.669 (Health Effects, Accidents)	.089-54.235

Bonneville Power Administration Estimates (mills/kWh, 1986)

	Air Emissions	Land	Water	Total Fuel Cycle/Generation	Total Social Cost
Coal¹	.62, 9.23. (Human, mostly health) .01, .02 (Crops) .01, .13 (Materials) .01, .19 (Visibility)				.64, 9.56
Solar, Wind²	0			0	
MSW²	0, 103.482, 466.664 (Health) .309, 1.020, 2.008 (Materials Damage) 1.545, 6.951, 15.447 (Visibility)			-33.653, -50.976, -67.582 (waste reduction)	-31.8, 60.477, 416.567
Biomass Cogeneration²	0, 1.16, 6.04 (Health) -.11, .31, 4.90 (Visibility)			0	-.11, .31, 4.9
Geothermal²	0, 0.043, 0.188 (Health)				0, 0.043, 0.188
	Radiation Effects	Land	Water	Total Fuel Cycle/Generation	Total Social Cost
Nuclear³	.00837-.126 (Mortality Effects, using different measurements)			1.05, 4.24 (Based on different measurement approaches for construction /employment)	1.05837, 4.366

Bonneville Power Administration Estimates (mills/kWh, 1986)

	Air Emissions	Land	Water	Total Fuel Cycle/Generation	Total Social Cost
Combustion Turbine Gas⁴	.754 (Visibility, Health, Materials, Ecosystems and Crops in order of priority)			.018 (Accidents in extraction, transport) -.38 (Local Economic Benefits)	.772 (no local benefits) .392 (with local benefits)
Combustion Turbine Oil⁴	2.46 (Visibility, Health, Materials, Ecosystems and Crops in order of priority)			.040 (Accidents in extraction, transport) -.38 (Local Economic Benefits)	2.5 (no local benefits) 2.12 (with local benefits)

Bonneville Power Administration Estimates (¢/kWh, 1986)

	Air Emissions	Land	Water	Total Fuel Cycle/Generation	Total Social Cost
Coal¹	.062, 0.923 Human, mostly health) .001, .002 (Crops) .001, .013 (Materials) .001, .019 (Visibility)				.064, .956
Solar, Wind²	0			0	
MSW²	0, 10.3482, 46.6664 (Health) .0309, .1020, .2008 (Materials Damage) .1545, .6951, 1.5447 (Visibility)			-3.3653, -5.0976, -6.7582 (waste reduction)	-3.18, 6.0477, 41.6567
Biomass Cogeneration²	0, .116, .604 (Health) -.011, .031, .490 (Visibility)			0	-.011, .031, .49
Geothermal²	0, .0043, .0188 (Health)				0, .0043, .0188
	Radiation Effects	Land	Water	Total Fuel Cycle/Generation	Total Social Cost
Nuclear³	.000837-.0126 (Mortality Effects, using different measurements)			.105, .424 (Based on different measurement approaches for construction /employment)	.105837, .4366

Bonneville Power Administration Estimates (¢/kWh, 1986)

	Air Emissions	Land	Water	Total Fuel Cycle/Generation	Total Social Cost
Combustion Turbine Gas⁴	.0754 (Visibility, Health, Materials, Ecosystems and Crops in order of priority)			.0018 (Accidents in extraction, transport) -.038 (Local Economic Benefits)	.0772 (no local benefits) .039 (with local benefits)
Combustion Turbine Oil⁴	.246 (Visibility, Health, Materials, Ecosystems and Crops in order of priority)			.0040 (Accidents in extraction, transport) -.038 (Local Economic Benefits)	.25 (no local benefits) .212 (with local benefits)

Bonneville Power Administration Estimates (¢/kWh, 1989)

	Air Emissions	Land	Water	Total Fuel Cycle/Generation	Total Social Cost
Coal¹	.069, 1.031 (Human, mostly health) .001, .002 (Crops) .001, .015 (Materials) .001, .021 (Visibility)				.072, 1.07
Solar, Wind²	0			0	
MSW²	0, 11.564, 52.15 (Health) .035, .114, .224 (Materials Damage) .173, .777, 1.726 (Visibility)			-3.761, -5.697, -7.552 (waste reduction)	-3.554, 6.758, 46.551
Biomass Cogeneration²	0, .13, .675 (Health) -.012, .035, .548 (Visibility)			0	-.012, .035, .548
Geothermal²	0, .005, .021 (Health)				0, .005, .021
	Radiation Effects	Land	Water	Total Fuel Cycle/Generation	Total Social Cost
Nuclear³	.001-.014 (Mortality Effects, using different measurements)			.117, .474 (Based on different measurement approaches for construction /employment)	.118, .488

Bonneville Power Administration Estimates (¢/kWh, 1989)

	Air Emissions	Land	Water	Total Fuel Cycle/Generation	Total Social Cost
Combustion Turbine Gas⁴	.084 (Visibility, Health, Materials, Ecosystems and Crops in order of priority)			.002 (Accidents in extraction, transport) -.043 (Local Economic Benefits)	.086 (no local benefits) .044 (with local benefits)
Combustion Turbine Oil⁴	.275 (Visibility, Health, Materials, Ecosystems and Crops in order of priority)			.0044 (Accidents in extraction, transport) -.043 (Local Economic Benefits)	.28 (no local benefits) .237 (with local benefits)

Bonneville Power Administration Estimates (¢/kWh, 2002)

	Air Emissions	Land	Water	Total Fuel Cycle/Generation	Total Social Cost
Coal¹	.099, 1.481 (Human, mostly health) .002, .003 (Crops) .002, .021 (Materials) .002, .03 (Visibility)				.092, 1.37
Solar, Wind²	0			0	
MSW²	0, 16.601, 74.862 (Health) .05, .164, .322 (Materials Damage) .248, 1.115, 2.478 (Visibility)			-5.399, -8.178, -10.841 (waste reduction)	-5.101, 9.702, 66.825
Biomass Cogeneration²	0, .186, .969 (Health) -.018, .05, .786 (Visibility)			0	-.019, .05, .786
Geothermal²	0, .007, .03 (Health)				0, .007, .03
	Radiation Effects	Land	Water	Total Fuel Cycle/Generation	Total Social Cost
Nuclear³	.001-.02 (Mortality Effects, using different measurements)			.168, .68 (Based on different measurement approaches for construction /employment)	.17, .7

Bonneville Power Administration Estimates (¢/kWh, 2002)

	Air Emissions	Land	Water	Total Fuel Cycle/Generation	Total Social Cost
Combustion Turbine Gas⁴	.108 (Visibility, Health, Materials, Ecosystems and Crops in order of priority)			.003 (Accidents in extraction, transport) -.055 (Local Economic Benefits)	.111 (no local benefits) .056 (with local benefits)
Combustion Turbine Oil⁴	.353 (Visibility, Health, Materials, Ecosystems and Crops in order of priority)			.006 (Accidents in extraction, transport) -.055 (Local Economic Benefits)	.359 (no local benefits) .304 (with local benefits)

Nicklas Estimates (¢/kWh, 1989)

	NO_x	SO₂	CO₂	Land	Water	Fuel Cycle Generation	Total Social Cost
Coal		.36-.0054				0-.18 (Health) .024-.213 (Material Damage) 0-.0067 (Agricultural Losses) .002-.003 (Visibility) .0017-.0023 (Morbidity, Soiling)	2-8

NYPSC Estimates (¢/kWh, 1989)

	NO_x	SO₂	CO₂	Land	Water	Fuel Cycle Generation	Total Social Cost
Generic	.55	.25	.1	.04	.1	.1	.1405

Nicklas Estimates (¢/kWh, 2002)

	NO_x	SO₂	CO₂	Land	Water	Fuel Cycle Generation	Total Social Cost
Coal		.517-.008				0-.26 (Health) .034-.306 (Material Damage) 0-.01 (Agricultural Losses) .003-.004 (Visibility) .002-.003 (Morbidity, Soiling)	2.872-11.48

NYPSC Estimates (¢/kWh, 2002)

	NO_x	SO₂	CO₂	Land	Water	Fuel Cycle Generation	Total Social Cost
Generic	.79	.36	.14	.06	.14	.14	2.016

**Social Cost Impact Estimates
By Source and Generation Technology**

Summary Tables

**Health Impact Estimates, by Source and Generation Technology
(¢/kWh, 2002)**

	BPA	Hohmeyer	Shuman & Cavanaugh	Nicklas
Coal	.099,1.481	.1192-3.047	.018-36.873	0-.26
Nuclear	.001-.022	.0759-7.949	0-14.043	
Renewables				
Solar		.0026		
Wind				
Biomass	0, .186, .969			
MSW	0, 16.601, 74.862			
Geothermal	0, .007, .03			

**Material Impact Estimates, by Source and Generation Technology
(¢/kWh, 2002)**

	BPA	Hohmeyer	Shuman & Cavanaugh	Nicklas
Coal	.002, .021	.0103-.1854	0-.072	.034-.306
Nuclear			0-.107	
Renewables				
Solar			0-.215	
Wind			0-.215	
Biomass				
MSW	.05, .164, .322			
Geothermal				

**Crop Impact Estimates, by Source and Generation Technology
(¢/kWh, 2002)**

	BPA	Hohmeyer	Shuman & Cavanaugh	Nicklas
Coal	.002, .003	.2637-.4276	(see health effects)	0-.0067
Nuclear				
Renewables				
Solar				
Wind				
Biomass				
MSW				
Geothermal				

**Animal Impact Estimates, by Source and Generation Technology
(¢/kWh, 2002)**

	BPA	Hohmeyer	Shuman & Cavanaugh	Nicklas
Coal	(see crop values)	.0041		
Nuclear				
Renewables				
Solar				
Wind				
Biomass				
MSW				
Geothermal				

**Visibility Impact Estimates, by Source and Generation Technology
(¢/kWh, 2002)**

	BPA	Hohmeyer	Shuman & Cavanaugh	Nicklas
Coal	.002, .003			.002-.003
Nuclear				
Renewables				
Solar				
Wind				
Biomass	-.018, .05, .786			
MSW	.248, 1.115, 2.478			
Geothermal				

**Miscellaneous Impact Estimates, by Source and Generation Technology
(¢/kWh, 2002)**

	BPA	Hohmeyer	Shuman & Cavanaugh	Nicklas
Coal				.0017-.0023
Nuclear				
Renewables				
Solar		.2901 (land)		
Wind		.006 (noise)		
Biomass				
MSW	-33.653, -50.976, -67.582			
Geothermal				

Estimates of Cost of Abatement

Estimates of Cost of Abatement

Cost Abatement Strategy	Source of Estimate	Cost Estimate
A. Reforestation	IEP (cited in ER-90, p. 10)	CO2 at \$14.70/ton, derived from the cost of rural reforestation in N. California and Pacific Northwest. This would yield an extra cost for coal-fired generation of 2 cents/kWh and gas-fired at 1.2 cents/kWh.
	Akbari (ACEEE, and ER-90, p.10)	1.5-8 mils/kWh for coal, 1-5 mils/kWh for gas, .6-3 mils/kWh for new gas combined cycle. Values include planting trees to reduce cooling costs (70% carbon reduction) and to sequester CO2 (30% carbon reduction).
	New York SEO	.1 cent/kWh, used as social cost.
	Rosenfeld, et al (cited in Dudek, p.15)	\$1.49-\$7.43/metric ton of CO2 removed by planting trees to reduce air conditioning demand.
	Ranney (cited in Dudek, p.15)	\$5-\$10/metric ton of CO2 sequestered in managed plantations.
	Dudek, EDF p.10	.003-.008 cents/kWh continuing rental costs, \$.67-\$1.34/metric ton (1985 dollars). Scenario using tree planting alone to offset emissions from new power sources. According to NYSEO reviewing Dudek, they say 2.23 cents/kWh (levelized cost).
	Buchanan (unpublished)	4.8 mils/kWh, \$700/kW of installed coal capacity using Douglas fir.
	Trexler/AES	.04-.3 mils/kWh using Peacer Corps labor and concessionary food aid for plantation in developing countries. NYSEO says AES's project with unlevelized capital cost of approximately 1.3 cents/kWh. AES reforestation cost estimate does not include O&M costs.

Estimates of Cost of Abatement

Cost Abatement Strategy	Source of Estimate	Cost Estimate
B. Technology Options	New York State Energy Office	<p>Recognizing that emissions abatement costs can vary, NYSEO analyzes two control technology scenarios to define a range of costs.</p> <p>These are the Advanced Control Technologies (ACT) scenario and the Mixed Control Technologies scenario.</p> <p>Cost estimates for abating the CO₂, NO_x, and SO₂ emissions for an NSPS coal facility based on a 200 MW standardization are presented.</p> <p>ACT: Include Flue Gas Desulphurization (FGD); Selective Catalytic Reduction (SCR) for NO_x; and Scrubbing for CO₂.</p> <p>MCT: This scenario assumes a 50%/50% blend of low cost mitigation measures (i.e., switching to lower sulphur coal for SO₂; Low NO_x Burner (LNB) for NO_x; and Reforestation for CO₂ and the Advanced Control Technologies.</p> <p>The mitigation of SO₂, NO_x, and CO₂ emissions from an NSPS coal facility could cost between 2.7 cents/kWh (the MCT cost) and 6.0 cents/kWh (the ACT cost).</p> <p>The removal of SO₂ is estimated to cost between .04 cents/kWh and 42 cents/kWh. The removal of NO_x is estimated to cost between .06 and .98 cents/kWh. The removal of CO₂ is estimated to cost between 1.85 to 4.59 cents/kWh. (See attached table).</p>

Estimates of the Cost to Abate SO₂, NO_x and CO₂ Emissions from a Generic NSPS Coal Facility

Scenario/ Pollutant	[1] NSPS Plant's Emission (tons)	[2] Mitigation Measure	[3] Cost (¢/kwh)	[4] Emissions Removed from an Existing Facility (tons)	[5] Cost to Remove NSPS Emission (¢/kwh)
Advanced Control Technologies: 1/					
SO ₂	4,394	FGD	1.70	17,577	0.42 2/
NO _x	3,969	SCR	0.82	3,321	0.98
CO ₂	1,455,201	Scrubbing	5.54	1,757,710	4.59
TOTAL					5.99
Mixed Control Technologies: 3/					
SO ₂	4,394	FGD	1.70	17,577	0.21 4/
		Switch 1.7 to 1% Sulfur Coal	0.18	9,188	0.04
NO _x	3,969	SCR	0.82	3,321	0.49
		LNB	0.03	1,038	0.06
CO ₂	1,455,201	Reforestation	2.23	1,757,710	1.85
TOTAL					2.65

/1 The Advanced Control Technologies level assumes the use of control measures which are capable of mitigating a large amount of emissions at a relatively high dollar per ton of pollutant removed. These include Flue Gas Desulfurization (FGD) for SO₂; Selective Catalytic Reduction (SCR) for NO_x; and Scrubbing for CO₂.

/2 The cost to remove the NSPS facility's emissions for the ACT measures (5), is equal to the relative share of the total emissions removed from an existing facility ([1]/[4]), multiplied by the cost (3).

/3 The Mixed Control Technologies level assumes a 50%/50% blend of low cost mitigation measures (i.e., switching to lower sulfur coal for SO₂; Low NO_x Burner (LNB) for NO_x; and Reforestation for CO₂) and the Advanced Control Measures. The low cost mitigation measures generally remove small amounts of emissions at a significantly lower cost per ton relative to the Advanced Control Technologies.

/4 The cost to remove the NSPS facility's emissions for the MCT measures (5), is equal to 50% of the relative share of the total emissions removed from an existing facility ([1]/[4]) for an advanced control technology multiplied by the cost (3), plus 50% of the relative share of the total emissions removed from an existing facility for the low cost measure ([1]/[4]), multiplied by the cost (3), e.g. $((4394/17577) \times 50\%) \times 1.7 = 0.21$.

ESTIMATES OF COST ABATEMENT (Original, 1989, and 2002 values)

SOURCE	(OTHER)	1989	2002
A. Reforestation			
IEP		\$14.70/ton 2 ¢/kWh 1.2 ¢/kWh	\$21.10/ton 2.81 ¢/kWh 1.22/kWh
Akbari	1.5 mils/kWh 1-5 mils/kWh .6-3 mils/kWh	.15-.8 ¢/kWh .1-.5 ¢/kWh .06-.3 ¢/kWh	.22-1.15 ¢/kWh .14-.72 ¢/kWh .09-.43 ¢/kWh
NYSEO		.1 ¢/kWh	.14 ¢/kWh
Rosenfeld		\$1.49-7.43 metric ton	\$2.17-10.67/metric ton
Ranney		\$5-10/metric ton	\$7.18-14.36/metric ton
Dudek	.003-.008 ¢/kWh (1985) .67-1.34/metric tons (1985)	.00327-.01 ¢/kWh .73-1.46 ¢/kWh	.00469-.01 ¢/kWh 1.05-2.10 ¢/kWh
NYSEO/Dudek		2.23 ¢/kWh	3.20 ¢/kWh
Buchanan	4.8 mils	.48 ¢/kWh	.69 ¢/kWh
Trexler/AES	.04-.3 mils	\$700/kW .004-.03 ¢/kWh 1.3 ¢/kWh	\$1004.86/kWh .01-.04 ¢/kWh 1.87 ¢/kWh

SOURCE	(OTHER)	1989	2002
B. Technology Options			
MCT	(NYSEO)	2.7¢/kWh	3.88 ¢/kWh
ACT		6.0 ¢/kWh	8.61 ¢/kWh
MCT, removal of SO ₂		.04 ¢/kWh	.06 ¢/kWh
ACT, removal of SO ₂		.42 ¢/kWh	.6 ¢/kWh
MCT, removal of NO _x		.06 ¢/kWh	.09 ¢/kWh
ACT, removal of NO _x		.98 ¢/kWh	1.41 ¢/kWh
MCT, removal of CO ₂		1.85 ¢/kWh	2.66 ¢/kWh
ACT, removal of CO ₂		4.59 ¢/kWh	6.59 ¢/kWh

ASSUMPTIONS AND FOOTNOTES BY REPORT

HOHMEYER

(In 1982 Deutsche Marks/kWh)

.00004 (PV Health impacts - Fuel Cycle Generation) External costs due to accident risk of maintenance personnel of decentralized photovoltaic (PV) installations (quantified by Jochem et al. 1987) cited on p. 55 in Hohmeyer. .00007 DM/kWh but says .00004 on chart, p. 100.

.00438 (Land Value - PV) - Assumes that the external costs of land use not covered by real estate prices are in the order of magnitude of 10% of the real estate price. Hohmeyer states that this assumption probably leads to an overestimation of the external costs of such land use but it's consistent with his policy of making assumption to the disadvantage of renewable energy resources.

.0064 - .0104 (Flora - Fossil Fuel) Includes air pollution damages to forests and vegetation (says this minimum value doesn't include important damage to wild plants).

.0001 - (Fauna - Fossil Fuel) Hohmeyer says very few quantitative studies of topic. He interpolates value from Wicke study and compares result from an OECD study estimating production losses from Scandinavian surface waters due to SO₂ acidification. Numbers are recalculated for West Germany.

.0018 - .0460 (Mankind - Fossil Fuel) Says a very important role is played by air pollution and related respiratory diseases which lead to decreased availability of the production labor factor (morbidity) or to casualties of the production labor factor (mortality). Evaluation of costs is for health damages from air pollution. Does not include external costs resulting from soil pollution or direct external cost of water pollution.

Hohmeyer discusses deriving damage potential of different pollutants (includes SO_x, NO_x, CO, dust, and volatile organic compounds). The specific emissions are given in million tons per year and are multiples by toxicity factors calculated on the basis of German MAK values. These factors range from 1.0 for CO to factor 125 for NO_x. Thus, the relative weight of the different pollutants change considerably after multiplying the annual emissions by the toxicity factors. (Tables 3.3 and 3.4), pp. 32-33. This is somewhat confusing because in introduction, Hohmeyer said he quantified only for sulphur oxides.

.0025 - .0044 (Materials - Fossil Fuels) Based on a range of values for corrosive damage of air pollution to steel construction. Not clear what numbers actually used. Mention corrosion by air pollution of outdoor works of art which can hardly be evaluated in monetary terms according to Hohmeyer. Air pollution creates considerable additional costs for cleaning (e.g., cleaning of windows, clothes and entire buildings).

.00009 (Fuel Cycle - Noise- Wind) The costs of the noise disturbance are calculated as a

reduction in the rental values of the living quarters affected by the noise. A reduction in the rental value of about 3 % is assumed for a noise level of 30-35 decibels.

.00001 (Climate Change - Fossil Fuels) Hohmeyer bases this on rough estimates of the necessity of increasing the height of coastal defense works due to a rise of the mean sea level of up to 165 cm. (p. 39)

.012 - .12 (Nuclear Accidents) Hohmeyer does not take into account external costs associated with nuclear plant decommissioning (land), disposal of nuclear waste, or environmental damages cause by routine operation of nuclear power plants. He accounts only for production losses due to cancer deaths and illnesses. He states "Since the catastrophe of Chernobyl, it seems appropriate for a first analysis to quantify the probable effects of large meltdown accidents and to temporarily neglect the actual costs of the routine operation of nuclear power plants. This should lead to an underestimation of the total health effects of nuclear power plants by approximately 30 percent." p. 45.

He states estimates of health damages resulting from the Chernobyl accident will be used as a starting point for estimates in the order of magnitude of health damages due to nuclear accidents.

According to a Worldwatch Study, waste disposal costs range from .1 to .6 of a cent per kWh of nuclear electricity. Total decommissioning costs add 5% to 25% to the price of nuclear generated electricity.

The Total Social Cost column includes the total environmental costs as well as total social costs (without the depletion surcharge value).

SHUMAN AND CAVANAUGH

(In 1980 mills per kWh)

General Assumptions

Shuman and Cavanaugh state future environmental costs should be discounted, on the theory that society prefers a dollar of damage in the future to a dollar of damage today. He uses a 1 percent discount rate to reflect this time preference. However, for environmental damage that takes the form of human injury and premature human deaths, they use a discount rate of zero.

0-1.2 (Fuel Cycle - Environmental Impacts - Solar/Wind) Shuman and Cavanaugh state that most solar technologies have two common impacts. First they use large amounts of materials, the production of which presents both occupational and public hazards. Second, some solar technologies use large amounts of land -- uses that can adversely affect local ecosystems, climates and aesthetics. Their model plan does not assume any use of land-intensive solar (e.g., solar/thermal power plants).

Their discussion of the environmental impacts of materials used by renewables states that these facilities have no unusual pollutants or impacts arising from materials requirements that are not applicable to the coal/nuclear sectors. Says that wind and solar construction should create occupational hazards on par with or less than coal. Says air pollution emissions from renewables are typically less from the emissions from nonrenewables. He concludes that the health costs of nuclear (excluding accidents, radon emissions and proliferation) are probably a good proxy for the health costs of the renewables -- roughly \$0-10.7 million per gigawatt-year, or between 0 and 1.2 mills per kilowatt-hour. (pp. 46-51).

0-124 (Climate change - Health effects - Coal) Shuman and Cavanaugh examines the expected number of deaths from climate-induced famines worldwide and calculates emissions generated from coal as being responsible for 32 percent of deaths. They calculate a rate of loss of 361 deaths per gigawatt-year. Since a death is worth between \$300,000 and \$3,000,000, the total cost of this famine would be between \$108 million and \$1.08 billion per gigawatt-year, or between 12.8 and 123.6 mills per kilowatt-hour.

0-0.4 (Property Damage Due to Global Warming - Coal) Cited in the Shuman and Cavanaugh report is a study by Schneider and Chen that concludes a 4.6 meter ocean level rise would cause \$ 160 billion in damages to the U.S. in 1971 dollars and perhaps \$2.5 trillion in damages to the world. In 1980, the world damage would be roughly \$5.1 trillion, or 1.55 trillion if the damage is discounted over 120 years. Schuman and Cavanaugh say based on a low energy scenario growth, 32 percent of the \$1.55 trillion in damages -- about \$496 billion -- will be attributable to electricity production. "This amplifies an average rate of loss for coal-fired electricity production of about \$3.7 million per gigawatt-year, or 0.4 mills per kilowatt-hour."

0.1 - 81.2 (Fuel Cycle Health Effects - Coal) These numbers are based on finding of the British Health and Safety Executive concerning the risks of both conventional coal burning

and nuclear power. Immediate deaths or injuries are those caused by industrial accidents while latent deaths or injuries include those caused by cancer, pneumocomiosis (Black lung disease) and sulphur-related respiratory diseases.

The value of a worker's expected earnings represents between 10 and 100 percent of the value of a human life, and 20 extra years of income for a latent victim restore roughly 40 percent of the victim's lifetime income, latent deaths can be "priced" by shifting their Value of Life (VHL) rate uniformly downward by \$120,000. They develop cost ranges of \$24,000 to \$240,000 for an immediate occupational injury, and \$240,000 to \$2.4 million for an immediate occupational death. The total cost of these annual values of life and injury to the expected health impacts of coal plants is between \$922,780 and \$711,777,000 per gigawatt-year for coal (0.1-81.2 mills per kilowatt-hour).

0-1.2 (Fuel Cycle Health Impacts - Nuclear) The total costs based on above, of annual effects is between \$49,000 and \$10,723,000 per gigawatt-year for nuclear (0-1.2 mills per kilowatt-hour).

.2-1.6 (Fuel Cycle Pollution Damage to Property and Crops-Coal) Researchers have estimated that a new coal plant will cause between \$700,000 and \$7 million in property damage per gigawatt-year and between \$245,000 and \$2.5 million in crop damage per gigawatt-year (1976 dollars) p. 32. Together these damages imply costs per gigawatt-year of between \$1.36 million and \$13.6 million (1980 dollars), or 0.2 to 1.6 mills per kilowatt-hour -- bringing the total impacts of coal to 0.3 to 82.2 mills per kilowatt-hour.

0 (Property Damage-Nuclear) Shuman and Cavanaugh assumed that the normal operation of a nuclear plant causes no significant property damage. (p. 32)

.5-165.4 (Radon Release from Uranium Milling Tailings) Shuman and Cavanaugh state that some long-lived radionuclides may have enormous health consequences. Routine releases of gaseous carbon-14 from reactors and the escape of radon-222 from mill tailings piles could kill hundreds more people than all the other impacts of nuclear put together. The nuclear milling industry, for example, conceivably could kill 5.5 million people over the next 77,000 years. Ramsey and Russell estimates that the impacts arise at a rate of between 30,000 and 200,000 deaths per 2×10^{12} kilowatt-hours, or between 72 and 482 deaths per reactor-year. With a cost of human life between \$300,000 and \$3,000,000, their total cost of this health hazard is between \$21.6 million and \$1.45 billion per reactor-year, or between 2.5 and 165.4 mills per kilowatt-hour.

0-112.6 (Weapons Proliferation-Nuclear) While some analysts believe that nuclear power is unrelated to weapons proliferation, others, state Shuman and Cavanaugh, find the linkage direct and substantial. Some experts believe that nuclear power is the primary force behind horizontal weapons proliferation, increasing the chances of both regional and international nuclear war. These assumptions would raise the upper limit on proliferations costs to 5.1×10^7 due to nuclear power, or 50,000 to 100,000 deaths per quad. Numbers by Holdren are used that estimate 10,000 to 20,000 deaths per quad which translates into 165 to 329 deaths per gigawatt-year. At a unit value of between \$300,000 and \$3,000,000, these deaths will cost between \$49.5 million and \$987 million per gigawatt-year. Thus, these costs would fall between 0 and 112.6 mills per kilowatt-hour.

0-2.1 (Weapons Proliferation-Property Damage) A conservative value of property-related damages from a nuclear war between the United States and the Soviet Union is given-- "If nuclear power increases the likelihood of this catastrophe by even one percent between now and 2010, the rate of loss would be \$298 billion for 500 to 1,000 quads, or \$9 million to \$18 million per gigawatt-year. Since this damage conceivably could occur in a war tomorrow, discounting is not appropriate. Proliferation-related property damage might thus range between 0 and 2.1 mills per kilowatt-hour.

0-6 (Property Damage- Nuclear Accidents) Shuman and Cavanaugh say that for their purposes this number appear relatively insignificant. They mention the Rasmussen Report which estimated that the \$21.5 billion maximum credible accident might happen once over 200 million reactor years. If Shuman and Cavanaugh employ the uncertainty level of plus or minus a factor of 1000, this accident might occur between 2×10^7 and 2×10^{11} reactor-years. The upper limit on property damage would be \$108,000 per reactor year, or well under one mill per kilowatt-hour.

0 -12.3 ? (Health impacts from core melt accidents - nuclear) The so-called Rasmussen Report", the most comprehensive analysis of nuclear reactor safety ever performed, concluded that a "maximum credible loss of coolant accident" could have the following consequences: 3,300 early fatalities; 45,000 early illnesses; 45,000 long-term cancer fatalities; 240,000 to 480,000 thyroid nodules; 5000 genetic effects; and \$14 billion in property damages (or \$21.5 billion in 1980 dollars). The report, however, used "dose-effectiveness factors" at low radiation exposure levels instead of the more widely accepted linear hypothesis. Adjustment of the long-term effects of the maximum credible accident to the linear hypothesis produces 225,000 long-term cancer fatalities, 1,200,000 to 2,400,000 thyroid nodules, and 25,000 genetic effects. The Rasmussen Report also estimated that this accident might occur every 200 million reactor years.

Shuman and Cavanaugh develop numbers for the annual cost of reactor accident deaths ranging between \$72 and \$72 million per gigawatt-year, or between 0-8.2 mills per kilowatt-hour. They enlarge these error bounds by considering the two most costly accidents in the history of the U.S. nuclear industry -- Browns Ferry in 1975 and Three Mile Island in 1979 - which happened in ways that the Rasmussen Report did not anticipate (including fire damage and shutdown costs). Thus the annual cost of reactor accident injuries would range between \$108 and \$108 million, or between 0 and 12.3 mills per kilowatt-hour. p. 35.

BONNEVILLE POWER ADMINISTRATION (BPA)

(in 1986 Mills/kWh)

Coal - Health impacts from air emissions are 95% of the total value of the coal plant's emissions, followed by visibility, agricultural products (crops, livestock, timber), materials damage, and general ecosystem impacts.

Sulfate compounds formed as secondary emissions account for the majority of the health impacts, followed by SO_2 , which is a sulfate precursor. Ozone, which is mainly related to

NO_x emissions rank next in health effects, followed by particulate. The same rankings are effective for livestock losses. In timber and crop losses, ozone is the only contributing factor considered and accounts for all of these losses.

Nuclear - Radiation effects were calculated using two different approaches, one a human capital approach, the other a marginal value of safety approach. The marginal value of safety approach is based on occupational risk/compensation comparisons to arrive at a value for the marginal value of increased risk. The human capital approach measures the value of lost lives in terms of medical costs and lost income/productivity. the marginal value of safety approach is associated with the higher values in the radiation effects category. Radiation effects are a combination of air, water, and solid emissions causes, with airborne emissions the most significant.

The construction/employment impact categories are the result of analyses of the impacts or community services and infrastructure associated with plant employment and construction.

0, 103,482, 466.664 (MSW - Health) For an MSW facility the important contaminants are carbon monoxide and sulfur dioxide, which together account for 95% of the health effects.

.309, 1.020, 2.008 (MSW - Materials Damage) Material damages include sulfur and nitrogen oxide emissions as well as two acids -- sulphuric and hydrochloric.

1.545,6.951,15.447 (MSW - Visibility) Emissions of particulate and nitrogen oxides from MSW cogenerators, plus the emissions of sulfur dioxide from the MSW cogenerators, all contribute to visibility reduction.

-33.653, -50.976, -67.582 (MSW - Waste Reduction) The burning of solid waste reduces the volume of waste that must be disposed of in landfills by about 80%, saving society those costs. Those costs are indicated as a negative cost (benefit). The estimates of benefits vary only by a factor of two; the variance results form some uncertainty about the amount of waste reduction and the costs of landfilling at different locations in the Northwest. Summary Report, p. 4-5.

Biomass - Health Carbon monoxide accounts for two-third's of the health effects of biomass cogeneration. Includes ozone (O₃), Totally Suspended Particulate (TSP), and Polycyclic Organic Matter (POM).

Biomass- Visibility Emissions of particulate and nitrogen oxides from biomass and contribute to visibility reduction.

Geothermal - The health effects of geothermal facilities are small and result primarily from the emissions of hydrogen sulfides.

BONNEVILLE POWER ADMINISTRATION (BPA)
(in 1986 Mills/kWh)

Combustion Turbine Gas

.754 (Air Emissions - Visibility, Health, Materials, Ecosystems & Crops)

The model captures the effect of pollutants on plants, animals, materials, and people within 150 kilometers of the power plant. Beyond 150 km, acid rain and global warming are considered (but not in the model). The important emissions include carbon monoxide, carbon dioxide, nitrogen oxide and particulates. Visibility losses were computed using average ambient pollution concentrations and visibility impairment algorithms developed by EPA (1980). Separate impairment factors were computed for each pollutant type. Multiplying the visibility loss per person at several locations by the number of people at each location by .17 (the frequency of operation) yields the total annual person-kilometer losses from each pollutant.

To determine losses effecting human health, crops, materials, and the ecosystem, exposure information on Table III-3, p. III-12 was multiplied by the response coefficient in Table III-4, p. III-13. Results are found on Table III-5, p. III-15.

.018 (Total Fuel Cycle/Generation - Accidents in Extraction, Transport) Data was compiled on health impacts associated with natural gas extraction from the Office of Research and Development EPA (1979). Assumes 150 MW plant (Frederickson plant) is operated 1500 hours/year. Assuming the average worker has an additional 40 year life-expectancy, deaths during natural gas extraction result in the loss of 109 days/year. Total health losses are 208 days per year for natural-gas extraction. Natural gas transportation is not expected to generate significant environmental impacts. Morris (1980) has calculated expected accidents during fuel transport of coal. These numbers would not exceed those found at the oil and gas-fired Frederickson plant. 7×10^4 deaths from accidents and five days lost through injuries during fuel transport were computed. It was determined that 15 days would be lost which were evaluated at \$75/day, assuming three-fourths of costs are captured by wages, sick days etc. The additional cost of human-health impacts from transport accidents is \$281/year.

-.38 (Local Economic Benefits)

The Frederickson plant pays property tax (\$170,684 each year), the resulting net socioeconomic impacts could be beneficial. Assuming one-half of property tax pays for local services, the effect would be \$85,000 per year.

.772 (Total Social Costs - No Local Benefits)

Over 97% of this effect is from air pollution damages from burning gas at the plant. Remaining costs are from accidents associated with fuel extraction.

.392 (Total Social Cost - With Local Benefits)

The number adds in the local economic benefit (.772-.38=.392).

Combustion Turbine Oil

2.46 (Air Emissions - Visibility, Health, Materials, Ecosystems and Crops)

The same assumptions used for natural gas are used for oil, except that the oil evaluation includes sulfur dioxides.

.040 (Total Fuel Cycle/Generation - Accidents in Extraction, Transport)

See assumptions used for natural gas. Deaths during oil extraction result in the loss of 219 days of health per year. Total health losses are 462 days per year for oil extraction. A study performed by the Oceanographic Institute of Washington (1980) estimates damage/barrel of oil is \$133. On average Frederickson could account for 2.2 barrels of spilt oil/year. Total cost is \$290/year.

-.38 (Total Fuel Cycle/Generation - Local Economic Benefits)

See explanation for natural gas.

2.5 (Total Social Cost - No Local Benefit)

About 98% of this effect came from air pollutant damages from burning fuel at the plant.

2.12 (Total Social Cost - With Local Benefits)

See explanation for natural gas (2.53.8-2.12).

NICKLAS

(1989 dollars)

.36-.0054 Nicklas lists different values for total SO₂ impacts ranging from \$145,803,000 to \$216,535,000 (p. 11) and \$144,852,000 to \$207,739,000. These values were divided by 40 billion kWh's which is the approximate amount of power generated by coal in 1986 in North Carolina.

0 -.18 SO₂ health impacts include mortality, loss of work, reduced activity, incidences of chronic respiratory diseases, incidences of acute respiratory diseases (p. 12)

.024 - .213 Material damages include corrosion to metal buildings and structures. Does not include air pollution damages to many other materials such as exterior paints, stone, masonry, concrete, textiles, leather, and paper.

0 - .0067 Includes sulfur oxides' damages on soybeans, wheat, and oats and expands this to include tobacco, corn, peanuts, and cotton.

.002 - .003 Visibility. No explanation of numbers.

.0017- .0023 Morbidity and Soiling. No explanation of numbers or category.