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Agency

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EPA

Quantifying Environmental Impacts

Analytic Center

QUANTIFYING ENVIRONMENTAL IMPACTS

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May 1981

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EXECUTIVE SUMMARY

The Pacific Northwest Electric Power Planning and Conservation Act outlines general procedures for power planning and for selecting specific power generation and conservation sources. The procedures are to include a methodology for determining the most cost-effective means of generating power, giving precedence to conservation and renewable resources over conventional thermal sources (coal and nuclear). Quantifiable environmental impacts are to be included in the methodology. The Bonneville Power Administration (BPA) is charged with developing the cost-effectiveness methodology for interim use until the Northwest Power Council (established by the Act) can modify it, or develop its own.

The problems inherent in developing such a methodology can be divided into three categories:

1. How can environmental impacts be measured (physically)?
2. Can dollar values be placed on environmental impacts?
3. Can the decision-making process be structured to avoid comparisons of projects having unlike impacts?

Our review of the literature on environmental impact quantification first focused on physical measurement of impacts. There is a significant lack of research on the cause and effect relationships between changes in pollutant levels and alterations in the physical and human environment; the mixing, diffusion, and transport of pollutants is not well understood. As a result, only crude estimates of magnitude can be made for most categories of impacts.

Knowledge of the physical and cultural setting in the project area, as well as ambient air and water conditions, is virtually mandatory to obtain any meaningful estimates. Similar projects can have widely divergent impacts in different areas. However, site-specific information can be expensive to collect, and is often unavailable.

Even where impacts can be measured, we lack agreement on the dollar values of specific types of impacts. Valuing human lives, pain and suffering, and aesthetics, for example, have been frequently researched. However, no consensus has developed for these and many other values. In addition, many valuation techniques have serious weaknesses involving double counting, equity considerations, and the needs of future generations.

It is not impossible to quantify environmental impacts. We can often determine the amount of natural vegetation/wildlife habitat that will be cleared or inundated by a project, as well as other resulting land use changes. Fish loss can be calculated, and several widely-accepted methods of projecting recreation benefits are available. However, reliably quantifiable impacts represent only a small portion of expected impacts. A methodology that quantifies them and ignores the rest may not be accurate in determining the most cost-effective projects.

The following guidelines for quantifying environmental impacts are suggested:

1. Values should only be calculated for impact categories that can be measured in absolute terms.

2. All assumptions and techniques should be clearly stated.

3. Sensitivity analysis should be performed on all major assumptions

4. All values should be presented as a range, representing a high and low estimate.

5. Up-to-date site-specific information should be used whenever possible.

Impact mitigation costs provide valuable information for the quantification process. Although just one element of environmental costs and benefits, mitigation costs tend to be among the most readily calculated, and should be determined at the time project construction costs are calculated. They can then be included in total "system costs," required by the Act to be used in cost-effectiveness assessments.

While it may not be possible to enumerate or value all impacts, techniques have been developed that use expert judgment to determine relative impacts of alternative projects. These techniques frequently utilize scoring systems to rate the magnitude of a project's positive and negative environmental consequences. These values are often weighted (using experts' opinions of importance), and in some cases are displayed on a matrix. In this manner, a greater variety of impacts can be considered than by using traditional quantification systems. However, the results cannot be added to financial costs to derive total system costs; they would require a subjective analysis.

Quantification is most difficult when we must compare very unlike alternatives. The impacts of a hydro facility are quite different from those of a solid waste-fueled thermal plant: How do we compare a loss of fish with decreased visibility? The problem would be alleviated if we could place a dollar value on all impacts, but this is simply not realistic. We can significantly reduce the problem, however, by properly structuring the decision-making process, as shown in the suggestions made below.

The first step should be a determination of power need. By using a detailed end-use forecast to determine the amount and quality of energy required in each sector and subsector, the most effective distribution of conservation measures and direct-application renewables (first priorities under the Act) can be determined. Remaining deficits broken into energy and capacity requirements, within certain timeframes, can provide categories for distinguishing alternative renewable baseload and capacity resources whose availability and power factors best match the deficits. The same procedure would apply to cogeneration and high-efficiency technologies (third priority). Any remaining deficits would involve an examination of alternative thermal resources.

At each stage, the environmental evaluation process would be applied to determine the most environmentally preferable alternatives within each priority class. Alternatives not meeting certain minimum financial, technological, and environmental criteria would be gradually eliminated. Detailed information gathering and subsequent application of an evaluation methodology would thus be applied to a more manageable set of feasible alternatives that were similar in power characteristics and availability, and had the same priority under the Act. Such a process would help minimize the number of comparisons between dissimilar technologies.

In summary, a sound methodology should have the following basic characteristics:

1. Environmental costs and benefits that are directly measurable, and that can accurately be expressed in dollar values, should be calculated. Such costs constitute a legitimate component of total system costs that can be computed with relative ease.

2. To account for those impacts that cannot be expressed in dollars, the project evaluation process should be structured to minimize comparisons among unlike projects. This can be achieved by grouping feasible alternatives first by priority under the Act and second by power characteristics and availability, by examining similar alternatives collectively, and by using an end-use analysis forecast.

3. An evaluation methodology should be applied to each group of similar projects. This process should be applied successively to each priority group to identify acceptable alternatives that best match the nature and timing of remaining resource deficits over the planning period. The methodology should employ an interdisciplinary team of recognized experts as well as citizen involvement.

I. INTRODUCTION

Consider two power projects--one a coal fired thermal plant, the other a dam on a river. Both produce electricity. In addition, the coal plant emits sulfur dioxide and particulates, affecting the health, cleaning bills, and visibility of nearby residents. The dam, on the other hand, alters the ecology of a river, eliminating free-flowing stretches and salmon-rearing habitat, creating a barrier to fish migration, and causing unusual fluctuations in downstream water levels.

The Pacific Northwest needs electricity, and needs to obtain it at the least cost to consumers and to the environment. Which project should we choose?

This is the type of decision facing the Northwest Regional Power Council and the Bonneville Power Administration in the years ahead. As part of the Pacific Northwest Electric Power Planning and Conservation Act, Congress has required that a methodology be developed for determining the cost-effectiveness of proposed energy conservation and power generation projects. As part of this methodology, the Act requires that "a methodology for determining quantifiable environmental costs and benefits" related to conservation measures and resource projects be developed. These costs are to be considered as part of the "system costs" of the projects. BPA staff are presently developing an interim methodology for integrating environmental impacts into their cost-effectiveness methodology; the Regional Council will have to adopt some methodology as part of its Plan.

EPA wishes to bring its experience in dealing with environmental decision-making to bear on this difficult task. Environmental impacts must be given due consideration during Northwest power planning, a process made simpler if decision-making is structured so as to ease the task of making comparative judgments among unlike projects.

This report assesses various techniques used to quantify environmental costs and benefits (both physical measurement and dollar values). Its purpose is to aid BPA and the Regional Council in their methodology development.

To understand the structure of this report, let us return to the coal plant/hydroelectric dam example. In order to choose between these projects, we need to know the following:

1. The direct costs of each project (these will be estimated by BPA as part of its cost-effectiveness analysis).

2. The environmental impacts of each project--how many tons of sulfur dioxide emitted, how many tons of particulates, how many fish killed during migration, how much fish habitat destroyed, how much visibility degradation occurs.

3. The value of those impacts--how much it is worth to prevent a given amount of sulfur dioxide emissions, or to protect a given number of fish, or to preserve visibility.

4. How to compare cost differences (from item (1)) with differences in environmental impacts (items (2) and (3)).

The first of these issues is not directly the concern of this report.

The second is covered in Chapter II, "Problems Encountered in Quantifying Environmental Impacts." These are generic practical and conceptual problems typically encountered in both measuring and valuing impacts. The problems described include the shortage or nonexistance of pollutant/impact data, limitations of models, expense of site-specific information, double counting, and equity considerations.

Next, Chapter III, "Specific Quantification Techniques," discusses specific techniques used to measure and assign dollar values to the different categories of environmental costs and benefits. The problems here include difficulties in attributing cause and effect (e.g., how much does a given amount of sulfur dioxide affect human health), and difficulties in valuing ultimate effects (how much should we pay in order to reduce illness caused by air pollution).

Chapter IV, "Mitigation Costs," investigates using the cost of mitigating specific impacts to gauge the values of those impacts to society. The results of this technique are useful indicators of the ease of correcting environmental problems caused by a project.

Chapter V, "Environmental Values and the Power Planning Process," surveys alternatives to placing dollar values on impacts. Matrix techniques, and other environmental assessment systems, have been employed in recent years to summarize impacts and provide a framework for analyzing (often dissimilar) alternative projects.

It is crucial that a methodology be developed that portrays environmental impacts as accurately as possible, and allows careful comparison of impacts of different projects. However, it is unrealistic to assume that all environmental impacts can be precisely quantified; subjectivity will inevitably play a major role. The value placed on impacts can vary by several orders of magnitude, depending on the assumptions and methodology employed. One must consequently proceed with great caution when simultaneously considering environmental and financial costs, taking care to communicate the uncertainties and specific assumptions to both decision-makers and the public.

II. PROBLEMS ENCOUNTERED IN QUANTIFYING ENVIRONMENTAL IMPACTS

This chapter discusses several generic difficulties encountered in the quantification of impacts. Some of these problems develop when we attempt to measure the magnitude of the impacts, while others crop up as we try to place a dollar value on these same impacts. It is critical to understand and disclose the problems inherent in whatever methodology is ultimately chosen, so that the decision-making process will be better served. After discussion of these generic problems, we will turn in Chapter III to a review of specific techniques.

Measuring Environmental Impacts and Their Health Effects

The measurement of environmental impacts conceals substantial uncertainty. One source of uncertainty is the lack of reliable data on the exact magnitude of impact caused by specific pollutants. This data is ordinarily lacking on a national scale, and especially lacking on a site-specific basis. Empirical impact data would normally be very expensive to generate for each small proposed energy project. Therefore, much extrapolation and subjectivity are a necessary part of most impact calculations. This fact must be made clear to the user of such information.

A second source of uncertainty is the scarcity of scientific knowledge and theory necessary for predictions of increased pollution effects, particularly health effects. A 1980 U. S. Senate report on Benefits of Environmental, Health, and Safety Regulation lists five issues to weigh in predicting the effects of exposure to hazards:

1. Cause-and effect is hard to demonstrate. Because of time lag between exposure and effect, the existence of intervening factors, and imperfect data, the relationships between the exposure of a hazard and its effects are difficult to ascertain.

2. Epidemiological data is scarce or nonexistant. Multiple exposure to hazards makes it difficult to pinpoint effects of individual hazards.

3. Availability of models for environmental pollutant diffusion and transport is very limited for most areas. Often, little is known about the way a substance moves through the environment or how it interacts with other compounds.

4. Dose-response relationships are uncertain in the low exposure ranges likely to be encountered. Frequently, data on dose and responses are available for only very high exposure levels, and conjectural extrapolation techniques are necessary.

5. Inferring human health effects from animal test data is very imprecise. Much of the scientific dose-response research has been performed with animals, and translating that data to human terms can be very speculative.

A third source of uncertainty is change over time. In order to make any predictions, impacts must usually be assumed consistent over time. This implies the following assumptions:

1. Technological advances will not alter the magnitude of pollution coming from a plant, nor will they alter the cost of resultant damage to society. This is an important frailty when we are comparing the impacts of completely different types of facilities, or where impact costs relative to financial costs associated with diverse projects vary markedly from each other.

2. There will be no new regulations controlling stationary source pollution, and existing regulations will not be modified substantially.

3. Enforcement of permit levels and standards will be the same for a small number of large conventional thermal plants as it would be for a large number of renewable resource projects. Given recent staff cutbacks and potentially long-term budget difficulties in at least some northwestern states, this point is debatable.

Valuing Impacts

Lack of information

Placing dollar values on impacts can be somewhat more troublesome than simply measuring them. It is virtually impossible to price all external impacts of a power plant, since we do not know, or understand, the true extent of these unpaid costs. Moreover, the pollution level/impact relationships that we understand best indicate that the use of simple formulas to place dollar values on pollutant levels can be very misleading. Impacts are not necessarily linear, nor will a given amount of added pollution have the same effect in all areas. Some site-specific information will be necessary at least to determine the relative magnitude of impacts of different projects, even if the values are only very rough estimates.

A frequent difficulty encountered in pricing impacts is that the values chosen normally reflect personal biases and perceptions of the analyst, rather than those of the public or decision-makers. A preferable approach would employ more widely accepted values, such as market prices. No market exists, however, for impacts affecting "public goods" (goods enjoyed in common), such as visibility and natural habitat. Most studies seemingly understate the value of these impacts, or neglect it entirely. This is a result of the near impossibility of accounting for all impacts. For example, how do we determine the value of preserving a habitat to the millions of people who will never even be near it, but who still attach some personal value to its preservation? These types of costs are normally omitted.

Survey techniques

Several related approaches have been used to infer the value of improving an environmental condition, or the cost incurred from degrading it. The "willingness-to-pay" method is perhaps the most widely used. This approach deduces market values from individuals' actual or predicted reactions to environmental modifications. The procedures most commonly used to derive these values include travel costs, property values, and personal interviews. These techniques all have the disadvantage of requiring a significant amount of site-specific information in order to provide reasonable estimates. For example, the U.S. Congress has accepted travel costs as a partial measure of the value of water resources recreational facilities. This assumes the amount of money people are willing to spend in getting to a particular area, and the user fees they pay upon arrival, are an indication of that resource's value as a recreation site. However, estimating future demand for a proposed site, giving consideration to population growth, intervening opportunities, and many other local characteristics, can prove quite costly when assessing a number of projects.

Personal interviews have also been frequently used by analysts as a means of obtaining values for environmental/psychological impacts that have few relevant market transactions. People are asked how much they feel a particular environmental condition is worth, or how much they would be willing to pay to avoid environmental damage (and perhaps the concurrent personal distress or injury). This enables analysts to derive estimates of the value of aesthetics, wilderness, even life itself. However, responses to interviews can often be considered unreliable. For instance, it is difficult for people to accurately perceive a hypothetical situation dealing with air pollution. What would a 10% increase in particulates and sulfur dioxide in the air be like? Or more specifically, how might people perceive a three mile reduction in their visibility under certain atmospheric conditions? People may give extremely high or low values to an impact in the hopes of affecting the outcome of the survey. People also tend to value consequences of a hypothetical situation significantly less than they do those of an actual circumstance. These items add a significant degree of uncertainty to the results of the surveys.

In addition, it has been shown that various survey techniques can be used to generate completely different values for the same type of impact. The value of a life (very frequently studied) has been given values between $20,000 and $6 million by various analysts.

Persons attempting to value environmental impacts for a particular project are prone to latching onto willingness-to-pay values generated for other projects located in completely unrelated areas. These values can be misleading, since site-specific information is normally required for these values to have any real significance. Knowledge of local ambient air and water conditions, physical setting, number of people to be affected, etc., are all critical in determining the magnitude of impacts of a project.

In the event no other information is available, at least willingness-to-pay values provide something. However, extreme caution must be exercised in their use and interpretation.

Double counting

Market value estimations are often flawed by double counting. As an example, the value of health impacts are often calculated using total health expenditures in an area and combining that with an estimate of the increase (or decrease) in illness that is expected to result from a particular pollution-related action. Then, property value differentials are employed to determine what people are willing to pay for aesthetic qualities. Property values in parts of a community with clean air are compared to those with relatively dirtier air (other differential factors affecting values are normally subtracted out). However, people's perception of health problems associated with poor air quality may affect property values. Therefore, health impacts may be counted twice, an important weakness.

Equity

The distribution of financial and environmental costs and benefits of electric power facility development is a key factor that can probably be determined in only a very superficial manner for purposes of the Regional Act. Important considerations include the financial cost to persons paying for facility construction, the unequal burden imposed on persons according to their financial situation, and the distribution of construction benefits. However, BPA's system of spreading the costs of a facility among all purchasers of BPA power simplifies the problem by mandating that every BPA power user will pay for the construction of the most cost-effective facilities. Since everyone must pay whether they personally will use the power from the proposed project or not, financial equity can be best served by choosing the least cost power. This assumes that there are no hidden financial costs associated with the environmental impacts of that power.

Even though every user of BPA power helps pay for a particular facility, not all persons are exposed to the same beneficial or negative environmental impacts, even in a very localized situation. Impacts are rarely felt uniformly across areas or income groups. Equity considerations only magnify the difficulty of placing dollar values on environmental impacts. However, they should be given some weight in the decision-making process, at least in cases where a particular group will be forced to incur an inordinate proportion of the impact.

A related equity problem stems from discounting. In virtually all long-term projects, costs and benefits are discounted to a present worth value. This enables us to compare project costs occurring at one time with benefits that (normally) occur at another. Since most projects are deemed to have a useful life of 50 years or less, and since discounting virtually negates the value of any cost or benefit occurring more than 50 years in the future, almost all cost-benefit and cost-effectiveness analyses are performed for a 50 year period or less. We virtually ignore the concerns of future generations in these analyses. This may be a critical problem when we are analyzing the use of a nonrenewable resource (such as coal). Regardless of the benefits that resource may have for future generations, they are ignored in the decision-making process as structured by these analyses.

Summary

The above discussion briefly outlines some of the more important basic problems encountered in attempting to quantify environmental impacts. The next section of this paper deals with methods of measuring various categories of impacts and with valuing them.

We have seen that each of the following elements of environmental impact estimation processes leads to uncertainty regarding the final value assigned to those impacts:

- Numerical values mask uncertainty
- Only a few data points are used to extrapolate trends
- Cause-and-effect is hard to demonstrate
- Epidemiological data is scarce or nonexistent
- Models for environmental pollutant diffusion and transport are limited
- Many dose-response uncertainties exist
- Inter-species extrapolation adds ambiguity
- Significant changes from the status quo (e.g. technological advances, modifications of regulations, change in enforcement patterns or effectiveness) can invalidate estimates
- Lack of market values eliminates benchmarks
- Uncertainties and biases in interviews hinder use of "willingness-to-pay"
- Site-specific information is expensive
- Certain impacts are susceptible to double counting
- Equity is often not considered
- Discounting ignores concerns of future generations

It is therefore important that the following guidelines be considered in developing and applying an impact costing methodology:

1. Values should only be calculated for impact categories which can be measured in absolute terms. (eg. a 10% increase in particulate, or 500 acres of wetlands destroyed).

2. All assumptions and techniques should be clearly stated. Since some subjectivity will inevitably be required, it is important that decision-makers are made aware of exactly where this has occurred.

3. Sensitivity analysis should be performed on all major assumptions. This includes varying the population projections, boundaries of impact area, values assigned to types of impacts, and discount rates.

4. All values should be presented as a range, representing a high and low estimate. This helps make users aware of the uncertainties involved in impact estimating, and provides a display of the effect environmental considerations can have on cost-effectiveness.

5. Up-to-date site-specific information should be used whenever possible. The validity of using national average data can, in some circumstances, be almost nil.

III. SPECIFIC QUANTIFICATION TECHNIQUES

When comparing the financial costs of various proposed energy projects, we are able to break down and analyze all the individual aspects of the project and then place a fairly reliable dollar estimate on them. We can then sum the individual costs using an accepted discount rate, and derive one value which represents the total financial cost of each respective project. This value is then readily comparable to that derived for other projects, or the base alternative.

Unfortunately, measuring individual environmental impacts and then synthesizing them into a single value with enough reliability for comparison purposes, is a much more elusive goal. The measurement of environmental impacts is largely a very recent pursuit of researchers, and no methodologies enjoy complete acceptance. In those cases where several impacts can be measured, there is seldom enough comparability in the units used to enable their addition to a single number that would be a measure of overall impact. As a result, there has been increasing pressure to translate these units into dollar terms, which can then be summed. This transition is a very difficult process, and the results are not usually very satisfactory.

The first portion of this chapter briefly outlines some of the methodologies commonly used to measure environmental impacts. This is followed by a discussion of techniques used to put a dollar value on these impacts. This is not meant to be an exhaustive literature review, but rather is designed to give the reader an idea of the methodologies in general use, and their principal constraints.

Chapter IV describes an alternate method of obtaining at least a partial value of impacts through an assessment of mitigation costs. Other analytical techniques, such as matrixes and ranking/rating evaluation methods, are discussed in Chapter V. All of these techniques deserve critical review for possible use in BPA's cost effectiveness methodology.

Techniques for Measuring Impacts

Most pollution impact measuring efforts have been designed to determine the health benefits of particular regulations. The results have been used to help justify air pollution regulations from a cost/benefit standpoint. A methodology used to measure the benefits of a nationwide 50% reduction in specific pollutant levels, however, is not particularly appropriate for use in determining the costs of a 2 ton/day point source emission of that pollutant. Some researchers have extrapolated national data to local situations, but the assumptions of impact uniformity and linearity of the pollutant level/impact relationships, lead to questionable results. The need for site-specific data is extremely important, though it can be costly.

Health

An increase in health costs is generally believed to be the most significant financial impact caused by air pollution. Work performed on this topic has formed the cornerstone of environmental impact quantification efforts. It therefore will receive greater coverage in this paper than that given to other impact categories.

A substantial amount of research on the health effects of air pollution has been recently undertaken, but is far from complete; the results cannot be considered conclusive. Sulfur dioxide in the air, especially in combination with particulates, causes significant respiratory problems in humans. Coal-fired electric power plants emit large amounts of these pollutants, and disperse them over a wide area. Other pollutants, with perhaps less understood impacts, are also present in thermal plant emissions.

Research has concentrated on the derivation of mathematical relationships between air pollution and health impacts. The goal has been the development of dose-response functions, which can estimate illnesses and premature deaths resulting from exposure to a particular pollution level. Nonparametrics, cross tabulation, and regression analysis have each been used to some degree to derive dose-response functions. Regression analysis has received the most attention in the literature.

Regression has been used to correlate the morbidity and mortality rates in different localities with their pollution levels. Other factors, such as income levels, manufacturing employment, and climate, have been entered into the equations to better isolate pollution related impacts. The resulting formulas have been used to estimate costs of air pollution increases and benefits of decreases on both national and site-specific levels.

Lave and Seskin use this technique in Air Pollution and Human Health. They gathered data from over 100 urban areas on sulfate and particulate levels, as well as on death rates related to various diseases. They also entered variables dealing with population density, age distribution, racial characteristics, income levels, occupation mix, climate, and housing. Using the variables on population density, age, race, income, and two pollution measures, they were able to account for 83% of the variation in death rates in the cities tested. Further refinement led to an estimate of early deaths related to pollution. Lave and Seskin stated that a 50% reduction in sulfates and particulates would lower death rates by 4.7% - 6.3%. Further studies provided projections for declines in cardiovascular and respiratory diseases, and cancer.

There are a number of difficulties in applying the data to a specific project. When local data are absent, national relationships between pollution levels and health are sometimes assumed to be uniform and linear. For example, if national data show a 50% decrease in pollution yields a 4.7% decrease in morbidity and mortality, then the same is assumed true locally. And it is assumed that a 50% increase would produce a 4.7% increase in those factors, or a 10% increase would create a 0.9% rise in them. These assumptions may be invalid because of variation in:

- local climate and topography,
- population density and demographic characteristics,
- interaction with other pollutants in the area, and
- the variation of pollutant levels over time.

At best, extrapolation of national averages to local situations can provide only very gross estimates of the health impacts of a particular project.

To circumvent this problem, site-specific data can be used (sometimes in conjunction with national average figures) to make presumably more precise estimates of impacts. However, it would be difficult for BPA to do this to any significant degree. The cost of obtaining a sufficient amount of reliable information on the impacted population of each proposed project could prove to be quite high.

Health impacts of waterborne pollutants from electric power plants can also be a problem. NPDES permits and concurrent effluent monitoring help to limit these impacts. However, runoff from coal and residue storage can still be serious, and accurately estimating the magnitude of these potential problems is very difficult.

In addition, there are health impacts and accidents associated specifically with the mining and transport of coal, as well as with coal-fired plant operations. The Bureau of Labor Statistics, other Federal agencies, and private organizations, regularly update figures on the number of deaths, accidents, and illness rates in surface and underground mines. Some agencies also keep track of injuries and deaths occurring in the shipment of coal and in plant operations. Various researchers have used this information to derive estimates of the annual deaths and illnesses expected to result from the construction and operation of a 1000 Mw coal-fired power plant (for example, see <u>Unpaid Costs of Electrical Energy</u>, by William Ramsay, and <u>Energy and the Environment: Cost-Benefit Analysis</u>). Illnesses are generally listed as man-days lost.

Similarly, in the case of nuclear plants, accidents and fatalities have been documented on uranium mining, transport, and plant operations. Again, researchers have calculated the average man-days lost due to injuries, and the average number of deaths resulting from the construction and operation of a nuclear power plant. The commensurate data for most renewable resources-related power facilities does not exist to the degree it does for coal and nuclear power.

In summary, given a reasonable amount of site-specific information, estimates of pollution-related health impacts can be made for some thermal power projects. Similarly, accidents from mining, transportation, and plant operations can be estimated for certain types of operations. The estimates would not be complete, but could certainly be used for project comparison purposes.

<u>Materials damage and soiling</u>

Pollution causes soiling as well as actual physical damage to certain materials and structures. Costs result from more frequent painting of buildings, cleaning of clothes, and shortened life of metals and fibers. Controlled experiments (exposing painted surfaces and various materials to both polluted and unpolluted air, while limiting all other external factors) are virtually nonexistent. Laboratory studies show that certain airborne pollutants (including particulates) increase material deterioration rates. The usefulness of these findings is limited by three factors. First, peak pollution levels were frequently more important than average levels. Second, local conditions (climate, exposure) were critical deterioration rate determinants. Third, a broad range of possible pollutant combinations can affect an area; there is no current way of lab-testing the myriad conceivable combinations.

Even if information on materials damage relationships were available we would still be left with the task of estimating the quantity of various materials in the area. For these reasons, very few attempts have been made to estimate materials damage and soiling due to pollution in a specific area. Rather, researchers have normally skipped this step and, through a series of sweeping assumptions, have attempted to directly estimate the dollar cost of the damages. A few of the methods will be discussed in the costing section of this chapter.

Crop and natural vegetation loss

Air pollution damages crops and natural vegetation. Field studies have observed air pollution effects on crops over time. However, these studies are necessarily subjective. The investigators must appraise both the cause and extent of damage. Drought, disease, pests, and environmental factors occurring the previous year may all affect the healthiness of a crop, and can often have the same impact as recent air pollution. Economic factors resulting in new crops or planting locations may make impact estimates even more complex. In any case, substantial local crop-specific data for ambient conditions are needed to provide meaningful estimates of potential losses from energy projects.

One methodology used to make estimates of local crop losses due to air pollution, and which minimizes field work, was developed by SRI (An Estimate of the Nonhealth Benefits of Meeting the Secondary National Ambient Air Quality Standards). A county's ambient and potential pollution levels are rated on a scale (based on sulfur dioxide amounts). Damage indices (previously developed) are then applied to the total acreage of each crop in the county, yielding an estimate of incremental total crop damage. Several users of the technique have acknowledged that it provides only a "best guess," and that no real accuracy should be assumed in the results. As with most other air pollution-related impacts, probably the best which can be obtained is some method which would display the relative impacts of one alternative versus another.

Very little completed research is useful in determining natural vegetation losses caused by air pollution. A few site-specific cases of extreme degradation are exceptions. It is doubtful if the site-specific studies would be useful in projecting the impacts of most energy-related projects. Instead, analyzing the value (in commercial and/or social terms) of potential habitat loss has been the more common approach. This is described below in the fish and wildlife section.

Inundation of areas upstream of a hydroelectric facility destroys vegetation, in some cases forests or cropland. Likewise, the construction of thermal plants and the transmission lines associated with energy generation will normally result in vegetation loss. Compared to other types of impacts, these losses can relatively easily be measured using site plans, aerial photographs, and/or field surveys. The categories of vegetation/agricultural land loss can be determined, and their acreage estimated with reasonable accuracy.

Aesthetics/visibility

Visibility impairment caused by airborne pollutants from a thermal power station can be measured to some degree. Certain site-specific information (including topographic, meteorological factors, and ambient air conditions), can be considered in concert with emission projections for the proposed facility to estimate air quality degradation. There are models currently used for this purpose, but they have not been created for all areas in the Pacific Northwest. This is important, as a general model cannot be applied to all areas with equal reliability. In addition, with sufficient project-specific engineering and hydrologic information, estimates of water turbidity and thermal pollution can be made.

Not all aesthetic qualities can be measured. The visual impact of the plant itself, as well as associated mines, transmission lines, and odor problems, do not lend themselves to ready measurement. Depending on the type and proposed location of the facility, these impacts can be very significant.

Recreation/fish and wildlife

The methodologies used in measuring recreation benefits resulting from water-related projects are somewhat more widely developed and tested than those used for most other benefits. The Water Resources Council (WRC) has specified methodologies that can be used for such estimations. While these regulations are designed for large Federal projects, and would not be enforced on most small-scale hydro facilities, the methodologies are certainly worth considering.

Since most of these methodologies are geared to the calculation of a dollar value of projected recreation uses, they will be discussed in the costing portion of this chapter. Basically, they utilize survey techniques, gravity models, and other methods to determine the potential demand for the recreation opportunities to be created by the facility. For example, we can estimate the annual recreational user-days by using some of these methodologies.

Fish and wildlife impacts (gains or losses) overlap to some degree with recreation measures. Since, in some cases, the methodology employed to estimate recreation values can consider fish and wildlife as well, care must be exercised to avoid double counting. As with recreation, many of the methodologies used attempt to directly derive a dollar value. However, field techniques for estimating the annual number of fish and wildlife lost are also available. A better measure of fish and wildlife impacts is the loss of habitat productivity. While substantial site-specific information is necessary, studies of terrestrial and aquatic habitat carrying capacities can be used to derive estimates of this loss. The Habitat Evaluation Procedure developed by the U.S. Fish and Wildlife Service is one example. It can be used to convert habitat values into standard Habitat Units. The total Habitat Unit gains or losses for each project can then be compared, even if the projects involve radically different habitat types. The major advantage of this technique is its ability to eliminate biases toward game species (common to most other techniques), and treat the ecosystem as a whole.

Techniques for Valuing Impacts

At this point it would be ideal if we could develop a simple, low-cost methodology for placing a reliable dollar value on the projected environmental impacts of a project. This value could then be added to the financial costs of the project, and the total costs of all alternatives directly compared for relative acceptability. However, no such methodology exists. While it is not possible to derive a meaningful value (one having reasonably tight confidence limits) on all impacts, techniques are available for making gross estimates of many values. Some impacts can be valued with a much higher degree of reliability than others. Some of the more commonly employed techniques are discussed below.

Health

Deriving dollar values to represent human life and health is quite difficult, and inevitably controversial. Three methods have primarily been used to estimate such values, including foregone earnings, willingness-to-pay, and (what Lave and Seskin termed) implicit valuations based on private and public decisions. None of these methods enjoys overriding acceptance.

The foregone earnings approach assumes that a person's worth to society is most accurately measured by the wages he receives. Therefore, society's loss of an individual through his early death can be measured by the wages he would have earned had he lived until retirement. Likewise, loss through illness can be measured by lost wages and medical costs. Of course, this method does not consider the will to live and enjoy life, the value of pain and suffering, and the value of an individual to family and friends. It is implicitly assumed that people who are not working for wages (such as retirees and housewives) have no value. Foregone earning studies normally reveal a median value of life of approximately $250,000. Not surprisingly, this is significantly lower than the value derived by using other methods.

The second method determines what people are willing to pay for better health and a longer life expectancy. People are asked what they would pay to reduce their chance of dying from a particular disease this year. Widely divergent responses frequently result, with many people unable to provide any information at all.

A widely used approach today includes an analysis of the decisions which individuals and public agencies have made pertaining to the risk of death and injury. One method used has been to determine the risk of death or injury associated with a variety of jobs, then compare it to the salary paid for these jobs. The amount of money people are willing to accept for an incremental increase in risk is then determined. Extrapolation produces the value they are implicitly placing on their lives. This procedure requires several gross assumptions. First, it assumes that people accurately perceive the relative risk associated with their job. Second, they have virtually complete freedom to change jobs on the basis of that risk perception. Lastly, it assumes the value of an increment of risk is linear at all points on the scale. Despite the questionability of these assumptions, the resulting values have recently gained significant acceptance. The value of life determined in different studies using this methodology has varied from about $200,000 to $5,500,000 in 1978 dollars.

In a 1980 paper ("The Value of Life: What Difference Does it Make?"), Graham and Vaupel assessed 57 Federal policies and regulations to determine their cost per life saved (perhaps the Federal Government has some intrinsic value it places on human life). The cost per life saved, however, varied from $0 to $169,200,000, with very little grouping around any particular figure. Saving lives, however, is not the sole purpose of most of the 57 regulations assessed in the study.

In light of the uncertainty and extreme ranges in values produced by the above methodologies, it is not surprising that there is little agreement on the value of life. The problem is most acute among decision-makers, who occasionally have to publically defend the use of a value. The most commonly used values of life in current research lie between $500,000 and $1,000,000. It may not be possible to obtain agreement on the use of such a narrow range for a particular project. The public may not even approve of such values being used. (Only three of the 57 regulations assessed by Graham and Vaupel had values falling into this range.)

Assigning values to illness is perhaps a less sensitive issue than valuing a life, but has not proven to be much easier. Illness data is far less complete, and is of significantly lower quality, than that on deaths. As with the value of life, values assigned to illness can only be assumed to be crude estimates.

Researchers have generally taken two approaches to valuing illness. Many have attempted to determine the per case or per day medical costs associated with contracting a particular disease. To account for lost productivity a dollar value per day of work lost is generally added. These figures are derived from doctor, hospital, and other medical care costs, and average wage figures. This method is dependent upon having reliable data on the relationship between air pollutants and the aggravation of particular diseases. While regression analyses have been employed to prove such a relationship exists, the results have been far from conclusive. Most researchers are convinced of a significant relationship, but no clear, irrefutable associations have yet been shown. Therefore, this uncertainty must be added to the uncertainty in costs associated with specific illnesses.

The second approach begins by determining the overall relationship between illness (not specific diseases) and pollution, generally using regression techniques. Next, average figures for medical costs associated with pollution-aggravated diseases and productivity loss are calculated. The illness-related costs of air pollution are determined. As an example, in 1979 Freeman (The Benefits of Air and Water Pollution Control: A Review and Synthesis of Recent Estimates) determined that a 20% reduction in air pollution nationally could lower the annual number of restricted activity days associated with acute illness by 29 million. He valued a restricted day at between $85 and $105, including medical and productivity costs, to derive a national savings estimate of $2.48 to $3.06 billion.

Freeman went on to calculate the annual benefits of national air pollution control to be somewhere between $4.6 billion and $51.2 billion (1978 dollars). Table III-1 shows a breakdown of these figures. The order of magnitude range of values attests to the uncertainty of current estimates. This situation is further aggravated when we apply the above described methodologies to local area calculations.

To further illustrate the problems with using different methodologies and assumptions, the American Lung Association (The Health Costs of Air Pollution) summarized three studies on the health costs of coal-fueled power plants. One study concluded that a 600 megawatt (Mw) plant in New York would add $38.3 million to the nation's health costs, while one in West Virginia would add $12.9 million. A second study estimated that a 1000 Mw coal-fired plant created $20,000 in health costs, while the third study concluded that all currently proposed coal-fired plants in Utah would result in the annual addition of $5,700 in health costs. Even though the same project was not used in each example, there is no question that different assumptions can yield completely different results.

Almost any case on the health costs of air pollution can be built or destroyed simply by the methodology and assumptions employed. This is a critical point when assessing the results of such studies. The relative impacts of one project versus another may be somewhat reliably discerned from the data (if common methodologies and assumptions are used), but absolute values can only be educated guesses.

To summarize, substantial methodological, empirical, and philosophical difficulties exist on this subject. Some of these problems may be alleviated through more extensive studies on the relationships between pollutant levels and mortality and morbidity. Analytic techniques for calculating and projecting costs related to pollution should also become increasingly sophisticated with time. However, philosophical dilemmas (such as placing a value on human life and the virtual impossibility of placing a value on matters like pain and suffering) will continue to hinder the development of realistic dollar values that can be agreed upon by analysts, decision makers, and the public.

TABLE III-1

Air Pollution Control Benefits Being Enjoyed in 1978
(In Billions of 1978 Dollars

Category	Realized Benefits: Range	Realized Benefits: Most Reasonable Point Estimate
1. Health		
A. Stationary Source		
Mortality	$2.8 - 27.8	$13.9
Morbidity	.29 - 11.5	2.9
Total	$3.1 - 39.3	$16.8
B. Mobile Source	$ 0 - .4	.2
Total Health	$3.1 - 39.7	$17.0
2. Soiling and Cleaning	$ .5 - 5.0	$ 2.0
3. Vegetation		
A. Stationary Source	0	0
B. Mobile Source	$ .2 - 2.4	$ .7
Total Vegetation	$ .2 - 2.4	$ .7
4. Materials		
A. Stationary Source	$ .4 - 1.1	$ .7
B. Mobile Source	.1 - .3	.2
Total	$ .5 - 1.4	$ .9
5. Property Values		
A. Stationary Source	$ .9 - 6.9	$ 2.3
B. Mobile	.2 - 2.0	.4
Total	$1.1 - 8.9	$ 2.7
GRAND TOTAL*	$4.6 - 51.2	$21.4

* Because of overlap, only 30 percent of property value benefits are added to other categories.

Source: Freeman, A.M., III. "Benefits of Air and Water Pollution Control: A Review and Synthesis of Recent Estimates." Prepared for the Council on Environmental Quality, December 1979.

Materials damage and soiling

To evaluate the magnitude of pollution-related cleaning costs, the usual procedure has been to compare cleaning costs in a city (or portion thereof) having a particular pollution level with those in another city or area having a different level. Multiple regression techniques are often used to sort out various physical and socioeconomic factors which can affect the results.

The research has generally been site-specific, concentrating on results found in a handful of locations. Once a number or formula is generated from these studies, other analysts have been quick to latch onto it and apply it across the entire nation. Given the assumptions necessary in this process, a wide range should be attached to the projected values.

As an example, one study (described by Freeman) compared cleaning frequencies for households in Steubenville, Ohio and Uniontown, Pennsylvania, having average annual suspended particulate levels of 235 and 115 micrograms/cubic meter, respectively. Households in the more polluted town were found to spend an average of $84 per capita (in 1966) more in annual cleaning costs than these in the less polluted location. This number, derived for specific pollution levels in cities with individual physical and socioeconomic circumstances, has been widely applied by other analysts (with minimal justification). The more detailed multiple regression studies have generally estimated national level savings in cleaning costs to be realized through attainment of pollution standards. Most attempts at Standard Metropolitan Statistical Area (SMSA) level estimates have merely been disaggregates of national estimates.

Materials damage presents bigger problems of cost identification than cleaning. Some studies have shown a relationship between pollutant levels and physical damage. This still leaves the task of estimating the quantities of materials at risk and their absolute exposure levels. By employing some rather sweeping assumptions, a few local and national level estimates of pollution damages have actually been derived. Freeman lists annual material damages from air pollution nationally at between $2.7 and $7.2 billion (1978 dollars). A separate study (described by Ramsay in Unpaid Costs of Electrical Energy) concluded that a 1,000 Mw coal-fired power plant causes annual property damage of between $700,000 and $7,000,000 (presumably 1976 dollars). However, site-specific factors are critical in determining impacts for a particular plant. The cost of obtaining this data for many potential projects would likely be very high.

Crop and natural vegetation loss

If the physical damage to crops and trees can be measured, it is also possible to derive a dollar value for those losses. Normally, the market value of the lost production of both crops and trees are used. For crops, both revenue and production cost changes should actually be considered; farmers may react to pollution by changing production techniques and/or crops. Natural vegetation is much more difficult to value since most species have no market values. The vegetation's role in supporting wildlife and providing aesthetic qualities is one method of obtaining such values. The most common techniques are discussed under "Recreation/fish and wildlife." Also, consideration must be given to foregone land use opportunities at the power source material site (forest, mine, stream, etc.), at the plant site itself, and along the transmission corridors. For example, if it is reasonable to believe that potential farmland will be destroyed by the project, this lost production should be evaluated.

Aesthetics/visibility

Air pollution can impair visibility and cause odor problems, and thereby create an amenity loss. This, in turn, may lower property values and reduce business (notably in recreation areas). Property value studies have been rather numerous. There are many factors, however, which affect property values besides air pollution. These include socioeconomic characteristics of the neighborhood, and proximity to schools and shopping.

Not all air pollution related effects on property values can rightfully be attributed to aesthetics. Some of the effect is presumably attributable to perceived health impacts, which are valued separately. In any case, many studies have correlated air pollution increases with decreases in property values. These studies developed average dollar reduction figures for a given increase in particulates, sulfates, and/or oxidants, and normally relate to specific cities.

A second way to value aesthetic impacts is by asking people what they would be willing to pay not to suffer a specific reduction in air quality. This may be used with both residents and recreationists in the case of potential visibility impairment from proposed power plants. Survey and bidding games techniques can be used to obtain these estimates. The controls placed on the interviews, the elimination of bias, and the standardization of results have all presented problems in obtaining valid responses. Difficulties in accurately perceiving potential degradation also affects the outcome of these studies.

Similar techniques can estimate the recreation-oriented business which is (or will be) lost due to visibility impairment. This impairment might include the sheer presence of an energy facility within a recreation area.

However, the generation of this type of information for a multitude of projects in different locations can be very costly. It is possible to use average figures to estimate relative, though not absolute, visibility impairment costs. For instance, figures have been developed on the specific cost/man-kilometer of impairment. The value is taken times the average number of residents and visitors to have their visibility reduced (on a daily or annual basis) by pollution from a specific facility. That number is then taken times the average number of kilometers of visibility reduction in the impacted area. Again, this method is probably only useful for comparative purposes.

Willingness-to-pay surveys are also frequently used to assess aesthetic damage from water pollution. Personal interviews are conducted to determine what residents and recreationists are willing to pay not to have the water degraded by a certain amount. These interviews are subject to bias, perception difficulties, and a recognized disparity between what people state they would pay and what they actually pay, given the opportunity. This methodology does not measure the value placed on the impact by people who will never see it, but who nonetheless place a value on it.

The impact of water pollution on the property values of nearby residents are another measure of the impact's cost. Again, perception, double-counting, and difficulties in subtracting out extraneous factors represent drawbacks.

Treatment costs

Waterborne pollutants, especially suspended solids and substances which affect odor and taste, must normally be removed if they enter a production facility or municipal treatment plant. If such pollutants from a proposed project are deemed significant, the added cost of removing them at downstream facilities can be calculated by determining the project-added pollutants per unit of water reaching the treatment facilities, and the added cost of their removal. This would be appropriate for only a very few projects.

Recreation/fish and wildlife

The Water Resources Council (WRC) has mandated the use of specific methodologies in calculating recreation benefits of certain water resources projects. These methodologies may have application to some hydro projects in the Northwest. The WRC regulations require site-specific data for each project. If no recreation use-estimating models are available for the region, WRC requires that the Travel Cost Method (TCM), Contingent Valuation Method (CVM), or Unit Day Value Method (UDV) be used (unless another can be adequately justified). These methodologies are very briefly described below.

1. TCM - Uses travel behavior of users and travel costs to develop willingness-to-pay functions. Demand curve for recreation sites developed based on cost and distance. Can determine recreationists' willingness-to-pay for new facility.

2. CVM - Survey of households made to determine willingness-to-pay for various proposed recreation opportunities. Can be site-specific, or used to develop regional model.

3. UDV - Uses expert opinion to determine willingness-to-pay values. Unit Day Values have been derived for specific sites, and the nation, and are applied to estimated use figures.

WRC regulations are quite detailed on choosing and performing the appropriate methodology. Nonetheless, there are significant difficulties involved. For example, in time of rapidly rising travel costs, it is important to use very recent data on costs and recreation patterns. Likewise, projections of future costs and accompanying changes in recreation use, are critical in estimating the magnitude of future benefits. Another complicating factor is the determination of all potential intervening opportunities available to recreationists that will effectively lower the recreation potential of a site. This is especially important where site-specific data is limited, and a regional gravity model (or similar procedure) is used to estimate demand.

Other techniques have been derived, including the application of regression techniques to determine recreation potential for given areas. Various modifications of willingness-to-pay formulations have also been developed. As with the WRC methodologies and gravity models, these techniques have inherent method and data limitations. Regardless, calculations of recreation benefits have been frequently used as major justifications for water impoundment projects. It is doubtful, however, if many large hydro projects with significant recreation benefits will be proposed to BPA over the next several years.

Values for fish and wildlife impacts (gains or losses) overlap to some degree with recreation values. Since the methodology employed to estimate recreation values can additionally consider fish and wildlife, care must be exercised to avoid double counting. In fact, some of the methodologies available to determine these impacts are similar to those discussed for recreation.

For example, the Modified Unit Day Value Method (MUDVM) measures the willingness-to-pay to obtain, or keep, a given level of wildlife availability (from a recreation standpoint). The willingness-to-pay figures are developed from all costs directly incurred by the hunter/fisherman (including entry and use fees), and are taken times an estimate of the total number of use-days to be gained or lost by a proposed action. Like most other methodologies summarized in this paper, this technique can become extremely complex, depending on the need and resources of the user. Information on habitat suitability, sustainable use, and projected use changes, can all come into play.

There are a number of other ways of obtaining the same information. Questionnaires have been used to determine what people would be willing to pay to have more hunting and fishing opportunities, or conversely, what they would pay to keep a particular site in its present condition for such activites. The value of fish and wildlife for aesthetic purposes has been similarly calculated. For commercial fishing, the current dockside value of fish can be determined, and an estimate made of the increase or decrease in the fish population expected to result from a particular project. The total value of fish gain or loss is then estimated.

Can Dollar Values be Used to Measure Impacts?

Obviously, numerous techniques have been employed in the derivation of dollar values for environmental impacts. The foregoing analysis by no means covers all of these methodologies, but includes those which are most commonly used. The accompanying chart summarizes the general impact categories and the most frequently used costing techniques.

It is obvious that there are many shortcomings in the techniques currently used to measure and value environmental impacts. These shortcomings include:

- controversy over the value of life and health,
- impossibility of quantifying pain and suffering,
- lack of scientific research associating degree of pollution with magnitude of impacts,
- unknown effects of mixing pollutants from several sources,
- uncertainties associated with data extrapolation,
- requirements of certain impacts to use subjective willingness-to-pay surveys,
- lack of commonality in results using different techniques to estimate the same impact,
- difficulty of eliminating double counting,
- uncertainties of delineating impacted area and estimating exposed population,
- problems with using discount rates,
- difficulty in convincing public of the logic used in cost estimation, and
- uncertainty over future technological advances in pollution control, mine safety, and other areas.

A large number of assumptions must therefore be made in costing environmental impacts; so many, in fact, that the results have little accuracy. Generally, when we are projecting the physical, social, or economic impacts of certain actions, we can not be certain of their accuracy. However, we normally feel that the projections provide at minimum an "order of magnitude" value (accurate within a factor of 10) that will be useful for planning purposes. This is not necessarily the case with most of the environmental costing methodologies currently available.

Varying just one or two assumptions, while still maintaining the same degree of logic, can easily account for a two- or threefold (or more) change in the estimates. Likewise, some assumptions are almost completely subjective, and will vary tremendously from one researcher to another. Different methodologies often force a completely unrelated set

MOST FREQUENTLY USED COSTING TECHNIQUES

Impact	Foregone Earnings	Willingness-to-Pay	Implicit Valuations	Market Value/Costs	Multiple Regress.	Travel Costs/Fees	Foregone Opps.	Prop. Values
Illness/ Accidents	X	X	X	X				
Death	X	X	X					
Materials Damage					X			
Soiling				X	X			
Crop Loss				X			X	
Natural Veg. Loss		X		X			X	
Aesthetics		X						X
Recreation		X			X	X		
Fish and Wildlife		X		X		X		
Treatment Costs				X				

of largely unresearched assumptions to be made. As a result, by varying assumptions and methodologies within what appear to be logical bounds, one can easily derive cost estimates of a project which will vary by one, two, even three orders of magnitude.

This must be kept in mind whenever making these cost estimates, or when using them in a decision-making capacity. Researchers can always derive a methodology which will provide very specific estimates (or ranges). However, these figures should never be accepted on faith. To better understand the limitations of the projections, the user or reviewer should carefully assess the techniques and assumptions which were employed.

Placing a dollar value on environmental impacts is not without some merit. The methodologies briefly discussed in this paper, and the hundreds of variations which have been derived by academia, private organizations, and government agencies, do serve a purpose. Increasing pressure is being placed on government agencies to determine the most cost-effective course of action in given circumstances, and environmental impacts are destined to be part of those considerations. While environmental costing techniques still suffer from severe data constraints, they do provide a means for obtaining estimates of sorts. The use of these methodologies will help isolate areas in which pollution/effect research is most critically needed, and will publicize the need for such research.

Another use is in the determination of the relative impacts of alternative projects. However, reasonably reliable results can probably be obtained only when considering identical categories of impacts. For instance, sulphur dioxide-related impacts of one project can perhaps be estimated and compared to the sulphur dioxide impacts of another, but those results cannot reliably be compared to the waterborne thermal pollution of a separate alternative. In other words, the dollar values themselves are not likely very reliable, but they can be used to display relative degrees of impact where impact categories and pollutant types are held constant. This can also be important in determining the levels at which regulatory standards should be set. Even though the dollar values may not be accurate, the relative change in the value of expected impacts with each increment of protection can disclose the most cost-effective level at which to establish a standard.

As should be evident, a principal complicating factor in environmental cost estimates is the bilevel nature of the assumptions. Not only must a series of assumptions and estimates be made to measure the impacts (number of illnesses, extent of visibility degradation, number of fish lost, etc.), but an entirely different set of equally variable assumptions must then be made to value these impacts. With most other project evaluation efforts (e.g., construction material and labor, and social-economic impacts) we can use past experience and proven techniques to obtain reasonable estimates of the physical magnitudes and costs involved. Very little of the corresponding effort of measuring or valuing environmental impacts can be based on experience or time-proven techniques. Being forced to make gross assumptions on both levels, we greatly compound uncertainties, normally well beyond those associated with other project cost components.

Some of this uncertainty can be diminished by quantifying impacts in terms of physical magnitude only. Then, decision-makers would assume the responsibility of weighing the diverse impacts of various alternatives. The uncertainties associated with particular impacts can thus be more easily considered. Remember, all dollar values are treated as having equal validity when they are added together in a standard cost-benefit procedure. The use of ranges can only temper this problem a little, as decision-makers almost always tend to key on a "most likely" or average value.

IV. MITIGATION COSTS

So far we have addressed only the costs associated with environmental impacts. The conclusion we draw from reviewing the major techniques available today for valuing impacts is that none can be applied successfully in all situations. Only estimable damages or improvements to marketable goods offers a sound basis for cost development, although various methods for valuing recreational opportunities have been in use for some time.

In this chapter we examine the costs of impact mitigation. Although just one component of total system environmental costs and benefits, per section 3(4)(B) of the Act, these costs are among the least difficult to quantify. Mitigation*, in its most general sense, refers to measures implemented as part of a program or project which are designed to prevent impacts, reduce them to socially acceptable levels, or compensate for impacts if they cannot be avoided or reduced to acceptable levels.

Too often the costs of required mitigation measures are determined late in the stages of project planning, after the cost-effectiveness determination has been made. And in some very unfortunate instances, proper mitigation was not a part of the project planning process, resulting in the application of very costly measures after project completion. Had these measures (e.g., proper siting and noise controls for a combustion turbine; fish passages for several dams) been a part of the original project, mitigation costs would have been significantly lower. These costs must be developed early in the project planning stages and incorporated into the system costs prior to any determination of a project's cost-effectiveness.

Below is a summary of the types of mitigation that we feel, at a minimum, must be considered for each type of resource. The list is by no means exhaustive. Every project has its own quirks and particular problems which require special attention. Many of these require special studies and innovative solutions. However, it is essential that the costs of such special studies, designs, and all other information gathering, planning, and implementation costs are estimated and included in total system costs to give a realistic view of "cost-effectiveness."

* The CEQ NEPA regulations (40 CFR 1508.20) define "mitigation" to include:

(a) Avoiding the impact altogether by not taking a certain action or parts of an action.
(b) Minimizing impacts by limiting the degree or magnitude of the action and its implementation.
(c) Rectifying the impact by repairing, rehabilitating, or restoring the affected environment.
(d) Reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action.
(e) Compensating for the impact by replacing or providing substitute resources or environments.

Weatherization Programs - Maintaining indoor air quality (source identification and control, or air-to-air heat exchangers if necessary).

Hydroelectric Projects - fishery mitigation (ladders or other passage facilities, hatcheries, spawning channels, dissolved gas supersaturation control, temperature control, and adequate flows); wildlife habitat mitigation and/or compensation; population relocation; work force housing and services; archaeological preservation and/or salvage.

Biomass Projects - emission controls; waste water disposal and monitoring; solid waste (ash) disposal; soil conservation measures (for plantations or slash recovery).

Municipal Solid Waste - emission controls; waste water disposal and monitoring; residual waste disposal.

Geothermal Power Generation - emission controls; effluent disposal and monitoring; ground water monitoring; noise abatement; wildlife and fishery protection; work force housing and services; archaeological preservation and/or salvage; seismic monitoring.

Geothermal Low-Temperature Applications - effluent disposal and monitoring; possibly groundwater monitoring.

Wind Power - low-frequency noise control.

Central Station Solar (thermal) - waste water disposal and monitoring; wildlife habitat mitigation; archaeological preservation and/or salvage.

Central Station Solar (photovoltaic) - wildlife habitat mitigation; archaeological preservation and/or salvage.

Cogeneration - emission controls; noise abatement (for combustion turbine); waste water disposal and monitoring (for boiler).

Combustion Turbine - emission controls; noise abatement (particularly low frequency).

Coal-Fired Thermal - emission controls and monitoring; waste water disposal and monitoring (possibly groundwater); stored coal runoff control; solid waste disposal (scrubber sludge and fly ash); wildlife habitat mitigation; work force housing and services; archaeological preservation and/or salvage.

Nuclear Power - emission controls and monitoring (radiation); spent fuel processing, storage, and ultimate disposal; waste water disposal and monitoring (e.g., thermal pollution); groundwater monitoring; emergency contingency planning; work force housing and services; wildlife habitat mitigation; archaeological preservation and/or salvage.

The above list relates to general types of mitigation costs incurred by the more common energy resources and technologies available today. It does not include "end of cycle" costs, or decommissioning costs, which can be quite substantial, particularly for nuclear plants. The Act expressly states, however, that end of cycle costs shall be included in total system costs. Thus we have not discussed them as a component of environmental costs, although many might view them as such.

Developing reliable estimates for mitigation costs is often a stumbling block in project planning of any type. Perhaps the major reason is reluctance on the part of project sponsors to commit to any specific mitigation measure or strategy early in the planning stages. Too often mitigation measures are tacked on as conditions of approval of the various permits required, or as a forced component of an agency's Record of Decision. We hope this situation will not occur during implementation of the Regional Act. The Act clearly mandates inclusion of quantifiable environmental costs and benefits in total system costs, such that they become a component of the cost-effectiveness determination. This means that mitigation costs must be developed up front, prior to the determination.

Although the experience with mitigation costs is less extensive than with project construction costs, estimates are available. Emission controls, surface and groundwater monitoring, habitat management, erosion control, waste disposal, etc., do not rely on unproven technologies, although clearly the state-of-the-art is advancing rapidly on nearly all of these fronts. Estimates can be developed by qualified professionals, and will improve with the quality of information available. Unlike health cost studies (whose results are not directly transferrable to dissimilar areas), many energy projects employ similar technologies in dissimilar areas. Thus emission control costs may be comparable, as would waste disposal, monitoring, and work force housing costs, etc. The major advantage of estimating mitigation costs as opposed to estimating health costs is that they rely on physically measurable quantities instead of such intangibles as the value of pain and suffering, or life itself.

V. ENVIRONMENTAL VALUES AND THE POWER PLANNING PROCESS

In this chapter we take a step beyond the quantification of environmental costs and benefits to look briefly at how environmental values, particularly those that cannot be quantified, can best be factored into the decision process. Subsequent submissions to BPA and the Regional Power Council will elaborate further on this. At this time, however, we feel it is important to present a brief discussion of the importance of giving due consideration to nonquantifiable values.

Alternative Evaluation Systems

As evidenced by this paper, we do not believe that all adverse and beneficial impacts can be reduced to a common denominator and expressed in dollars and cents. Where marketable goods or opportunities are involved, such as fish or kayak trips, one can make some headway. Mitigation costs that represent the value of preventing, reducing, or compensating for impacts can also be tallied and expressed as a component of system costs. But to rely solely on measurable environmental impacts in the cost-effectiveness determination could seriously malign the true, if immeasurable, value of preserving environmental quality.

There are other ways of evaluating projects from an environmental perspective in addition to adding up quantifiable environmental costs and benefits. Most of these methods rely on expert judgment to value impact categories. Some methods applicable to the power planning process are briefly summarized below. A more complete discussion and critique of these methods can be found in Evaluation in Environmental Planning by Donald M. McAllister.

Goals-Achievement Matrix

This evaluation method, conceived by Morris Hill, is based upon a series of goals. Each goal is weighted; project impacts are scored according to their ability to promote or detract from achieving each particular goal. Value weights for each goal are set to reflect their relative importance to the affected population. In addition, impacts are classified according to the various community or user groups affected, which are also assigned weights. The weights are multiplied by the impacts to derive a total score of goals-achievement for each alternative.

Although this system can incorporate intangible values, it has two major weaknesses. First, the goals established may not include certain impact categories, particularly if new information on impacts appears after the goal statements are established. Thus the system, if used, should remain flexible enough to incorporate new goal statements. A second weakness might stem from the difficulties of weighting various consumer groups. No procedures for determining weights is included in the method. It would be very difficult to arrive at a public consensus on such weights, without charges of discrimination. The major advantage of Goals-Achievement Matrix is the emphasis on popular goals and issues which, in the power planning process, could incorporate economic, reliability, operational, and environmental criteria.

Energy Analysis

The concept behind this method is similar to cost-benefit analysis, except energy is substituted for dollars. In this system, energy is viewed as a more accurate measure of intrinsic value than money since energy is the most fundamental limiting factor on all human action. Using this method, the "cost" of land disturbance would be expressed as reduced plant production (e.g., in kilocalories). The "cost" of materials would be measured by the kilocalories of fuel required to produce them. However, this system cannot distinguish between biomass and beauty or endangered species and weeds. It is best applied to analyzing alternative processes, such as steel refining, to determine the most energy efficient alternative.

Land-Suitability Analysis

This approach, upon which a number of techniques are based, focuses on the intrinsic ability of landscapes to accommodate a particular type of development, e.g., an energy facility. By relying on expert judgment to rank suitability, ratings are assigned to subclasses of each land characteristic and aggregated for each alternative site. This produces a grand index of land suitability for the particular type of facility. The approach is used in a number of forms, but is basically limited in application to evaluating alternative sites rather than alternative projects.

Environmental Evaluation System

This method was developed for the Bureau of Reclamation (now Water and Power Resources Service) by Battelle Laboratories in Ohio to assist in evaluating water resource projects. It is designed to be comprehensive from an environmental, but not economic perspective. It is systematic, providing replicable answers, and relies on an interdisciplinary team of experts. Impact categories are established for use in all applications, and scientific procedures are used where possible to estimate impacts. Environmental impacts are divided into four broad categories: ecology, environmental pollution, aesthetics, and human interest. The four categories are broken down into 78 parameters. Impacts related to the "with project" and "without project" conditions are then quantified. In the second step, impact measures are transformed by "value functions" into a value from 0 to 1, where 1 indicates "very good quality." The last step is to multiply each environmental quality score by the value weight of the corresponding parameter ("parameter importance units").

The "value functions", developed by the interdisciplinary research team, rely where possible on scientific information. However, they incorporate a fair amount of value judgment, according to McAllister. Also, the process is geared to water resource projects, so the "value functions" may not be applicable to other types of projects. The "parameter importance units" are developed using the Delphi approach. This system employs independent, but iterative, judgments of relative values and is commonly used in expert judgment situations where weighting values must be assigned.

The Environmental Evaluation System seems to offer promise as an evaluation tool, although clearly it would have to be adapted to evaluating projects other than water resource developments. Also, while cost-benefit analysis has difficulty with nonmonetary values, this system does not consider economic costs and benefits. Developing reliable "value functions" could be a lengthy and controversial process.

Judgmental Impact Matrix

This system was developed at Northwestern University to assist the Army Corps of Engineers assess alternative wastewater management systems. It is particularly useful for screening a large number of alternatives with many diverse impacts. It employs expert judgment to estimate impacts and to assign value weights.

Rather than look at each alternative's impact on a particular element of the environment, the impact of each discernible aspect of an alternative is determined on a relative scale for all relevant, weighted parameters. The result is many bits of information that are aggregated by a specified computational procedure. A panel of experts use a variant of the Delphi procedure to determine the relevant environmental and societal elements to estimate impact magnitudes and to assign value weights. Although complex, the method is comprehensive. Results, however, are sometimes difficult to explain due to the mathematics involved. The model also assumes additivity and linearity of impacts.

These examples of evaluation techniques are presented simply to demonstrate the issues to be faced in developing any methodology for decision-making that attempts to be holistic while considering all relevant details. Although the methods presented are just a few of the many that have been developed by planners, government agencies, and private institutions, they have three basic features in common. First, they examine an array of alternatives systematically. Second, they incorporate a system of weighted values. Third, they rely on an interdisciplinary team of experts for determining impacts and valuing them.

By examining alternatives collectively and systematically, all alternatives should receive fair and equal treatment. By using weighted values, the results reflect a view of the most important decision criteria. And finally, by relying on an interdisciplinary team of experts the results should be as scientifically accurate and unbiased as possible.

The major weakness of all of these methods, however, is a failure to involve the public in determining value weights or perceived impacts. Although public involvement can complicate a decision process, citizens can be most helpful in determining the importance and magnitude of those impacts that are most difficult to scientifically quantify, such as visual impacts, land use changes, or lifestyle impacts. A secondary benefit of citizen input is greater public confidence in the decision. These advantages should outweigh any problems of increased complexity.

Structuring the Decision-Making Process

Any methodology has the greatest difficulty when used to compare very unlike alternatives. This problem cannot be eliminated entirely from a decision process that must examine a wide variety of energy resources for such a large region. However, the problem could be significantly scaled down by properly structuring the decision.

The first step in the regional power planning process is a determination of need. By using a detailed end-use forecast to determine the amount and quality of energy required throughout the planning period by each sector and subsector, the most effective distribution of conservation measures and direct-application renewables (first priorities under the Act), can be determined. Remaining deficits broken into energy and capacity requirements, within certain timeframes, can provide categories for distinguishing alternative renewable baseload and capacity resources whose availability and power factors best match the deficits. For instance, the availability of wind power, which can be developed within a relatively short time frame, coincides roughly with winter peaks caused by stormy weather. Geothermal power, however, is a baseload resource available year-round that may take five years or more to develop. After selecting all cost-effective renewables, the same procedure would apply to cogeneration and high-efficiency technologies, the third priority under the Act. Finally, any remaining deficits would involve an examination of alternative thermal resources.

At each stage, the environmental evaluation process would be applied to determine the most environmentally preferable alternatives within each priority class. A screening process at each stage should gradually eliminate alternatives not meeting certain minimum criteria (e.g., more than avoided cost; impact endangered species or anadromous fish; unproven technology). This would narrow the number of alternatives within each priority and deficit category. Thus detailed information gathering and subsequent application of an evaluation methodology would be applied to a more manageable set of feasible alternatives that were similar in power characteristics and availability, and had the same priority under the Act. Such a process would tend to minimize the number of comparisons between dissimilar technologies.

Conclusions

Accounting for environmental costs and benefits in the regional power planning process can best be achieved through a combination of approaches.

First, environmental costs and benefits that are directly measurable, and that can accurately be expressed in dollar values, should be calculated. These include impacts to marketable goods and services and impact mitigation costs. Such costs constitute a legitimate component of total system costs that can be computed with relative ease.

Second, to account for those impacts that cannot be expressed in dollars, the project evaluation process should be structured to minimize comparisons among unlike projects. This can be achieved by adhering to the following principles:

- Similar alternatives should be examined collectively, in one procedure, rather than judged independently of one another.

- Feasible alternatives should be grouped first by priority under the Act and secondly by power characteristics and availability.

- An end-use analysis forecast should be used to facilitate matching resource power characteristics with the nature of power deficits.

Third, an evaluation methodology should be applied to each group of similar projects, i.e., those with the same priority under the Act, similar power characteristics (e.g., energy, capacity, intermittent), and similar availability (e.g., within five years, five to ten years, etc.). The evaluation process should be applied successively to each priority group to identify acceptable alternatives that best match the nature and timing of remaining resource deficits over the planning period. The methodology should have the following characteristics:

- An interdisciplinary team of recognized experts should determine impacts and evaluate them.

- Citizen involvement should be used to help determine impacts and assign value weights to different evaluation criteria.

Finally, the entire process should be fully documented and subject to public scrutiny.

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