THE VALUATION OF ENVIRONMENTAL EXTERNALITIES IN ENERGY CONSERVATION PLANNING

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The determination of the full societal costs of energy usage must incorporate estimates of the environmental effects, or externalities, of energy production and delivery. An externality is any cost or benefit that is not reflected in the price paid by a utility or its customers for energy produced or consumed. The potential variety and scope of externality analyses are discussed.

Four methods of externality valuation are briefly discussed to highlight the uses, strengths and pitfalls of each method. The use of pollutants' relative potency, polling of experts, direct estimation of costs, and implied valuation, are compared. The authors' preferred method of valuation for near-term energy supply decisions, implied valuation, is discussed in detail.

The distinguishing feature of the implied valuation technique is its use of the cost of control, rather than the direct cost of emissions. Only the most expensive required control measure is relevant to valuation of the external effects. The difficulties in applying implied valuation, such as the definition of the margin, the multiple effects of pollutants and the imperfect nature of the regulatory system, are also considered.

The effect of environmental externalities on the benefits of conservation are summarized.

INTRODUCTION

The construction and operation of energy supply facilities result in negative effects on human health and the environment through intermediate effects on air, water and terrestrial systems. These environmental externalities can be valued and added to the direct internal costs of supply, to produce the full societal benefit of energy conservation.

The externalities discussed in this paper are relevant to determining the social cost effectiveness of conservation and fuel switching programs.

DEFINITION OF ENVIRONMENTAL EXTERNALITIES

The term "externality" can refer to any cost or benefit that is not reflected in the price paid by a utility or its customers for energy-related goods or services. Only environmental externalities are considered in this paper, although other important economic and social externalities also exist. Examples of environmental externalities include the health and environmental damages caused by the emission of air pollutants, and impacts on aquatic ecosystems from the water consumption of a power plant cooling system.

An exhaustive list of environmental externalities from energy production and consumption would include all disturbances to air, water and terrestrial systems. Some of those effects are well-understood, predictable effects, such as the amount of land required by a facility. Other effects are strongly supported by empirical evidence, such as ambient pollution effects on human health. Some represent risks, which may be well understood, both as to probability and effect, or may be highly uncertain. For example, the designers of a dam may know that there is a one-in-a-million chance of the dam's failing and killing 2,000 people. Similarly, the number of people who will be killed in grade-crossing accidents involving coal trains is unknown, but the probability distribution may be highly predictable. Still other consequences are not fully understood in a technical sense, such as the effect of trace gas emissions on global warming and the effect of global warming on human and ecological systems. Finally the net effects may be difficult to determine: the construction of a water reservoir may provide recreational benefits and habitat for waterfowl, but destroy other recreational opportunities, flood wetlands and disrupt the habitat of other ecosystems.

The complexity and results of an analysis of externalities are influenced by geographic scope. Some analyses of externalities are specifically designed to evaluate only those effects that occur in a specific service area or state. This type of limitation can simplify the assessment process, by excluding some impacts, or complicate the process, by requiring the identification of the location of each externality.[1] Some results of energy production have varying effects by location. For example, particulate emissions will be more important if they affect areas with important scenic benefits or with high populations.

VALUATION METHODS

In general, four basic approaches have been used in estimating values for environmental externalities:

- Estimating the relative physical, chemical, or toxicological potency of various pollutants;
- Polling of experts or other people;
- Direct estimation of the environmental effects of a pollutant, and the valuation of each of those effects; and
- Determination of the implied societal value of reduction of the pollutant, from the maximum cost society has committed (or appears about to commit) to pay for reductions of this pollutant.

The first approach, relative potency, works quite well for estimating the relative importance, or value, of the major energy-related greenhouse gases (CO_2, methane, N_2O and CO). The relative values of the greenhouse gases can be related to the value of CO_2, by correcting for the shorter lives and lower molecular weights of the other greenhouse gases, and properly discounting the effects of the gases over time. Lashof and Ahuja (1990) estimate that the instantaneous global warming potentials (GWP) of the greenhouse gases relative to CO_2 are: 10 for CH_4, 180 for N_2O, and 2.2 for CO.[2] Chernick and Caverhill (1990a) discount the cost of future global warming mitigation at 6% real and use Lashof and Ahuja's results to estimate the relative *value* of reducing emissions of the greenhouse gases as: 76 for CH_4; 320 for N_2O; and 6 for CO.

Relative potency might also be used for estimating the relative importance of other externalities. Data in Hendrey (1986) implies that the acid rain damages caused by NO_x are 83% those of SO_2, per pound of emissions (Chernick and Caverhill, 1989). Hohmeyer (1988) cites work by Grupp (1986), which finds that the toxicity of SO_2, particulates, and VOCs are equal per pound of emissions, and that NO_x is 25% more toxic per pound. Grupp's estimates appear to refer only to acute human toxicity, although Hohmeyer applies them for all purposes. While relative potency provides probably our best estimates of the relative value of reducing greenhouse gas emissions, it may be inferior to the more direct estimation techniques, described below, for the other major air pollutants.

The second approach, polling, can be employed in valuation if the polling instrument is designed

1 *For example, if oil spills were to be included in the analysis only if they occurred in New England waters, it would be necessary to determine the port through which marginal supplies of oil were imported.*

2 *That is, CH_4 is ten times as potent as CO_2 on a weight basis.*

carefully, and the poll respondents are experts in the field in question and are informed of the intended use of the poll results. For example, it may be useful to poll epidemiologists on the coefficients of the dose-response functions relating human illness and death to pollution levels.

However, the results of a polling effort can be useless for valuing externalities, or worse, misleading. A good polling effort must: (1) poll a representative sample of experts in the field of interest, and publish the names and credentials of the respondents for public review; (2) provide a clear statement of the question to be answered in the poll, and the intended use of the answer; and (3) make the polling instrument and the respondents' answers available for public review. If the polled respondents are not experts in the field in which they are responding, or the results of the poll are used in a computation other than that intended by the respondent, then the results will be useless for valuation. If the question posed is vague, then the respondents' answers may not be interpreted in the way they were intended. If the credentials of the respondents and their answers are not available for public review, it is difficult to rely on the integrity of the results for decision making. Polling may be useful to answer some specific questions relevant for externalities valuation, but its usefulness is critically dependent on the quality of the polling instrument and credentials of the respondents.

NEES (1989) used polling to develop a worksheet for including externalities in its supply planning process, and the results from this first effort are critiqued in Shimshak, et al. (1990) and Chernick and Caverhill (1990a). The main problems with NEES's polling effort were: (1) the polling instrument asked for the relative importance of externalities, without specifying whether the weights were to be stated in terms of damage for each pound of emissions, of the total damages from a typical new plant, of the total global damages from all current (or future) emissions, or of the regulatory difficulty for new plants; (2) the qualifications of the respondents for this exercise are not obvious; (3) the respondents replied to the poll on the condition of anonymity and the results of the poll are not available for review; (4) and there is no clear derivation of NEES's relative weights from the limited polling results reported. Clearly, polling must be better focussed than this initial effort, if it is to be useful.

The relative potency and polling approaches estimate the relative value of various externalities. The relative values can then be translated into costs by estimating the cost of one of the externalities, and relating the other externalities to it.

The third approach, direct estimation of costs, estimates the costs of externalities from first principles. The effects on human beings and their environment are estimated, a value is assigned to each effect, and the values of the effects are summed to generate a cost incurred due to the externality. Effects typically valued in these studies include degraded health or premature death, reduced wildlife, degraded or destroyed ecosystems, damage to buildings, and reduced visibility. The direct estimation of externalities is in its infancy and is fraught with complexity and uncertainty. Estimating effects requires knowledge of how emissions are transported through the atmosphere (or other systems), the chemical changes that occur before the pollutants reach ground level, and the dose-response relationships between the pollutants and humans, plants, wildlife, materials and visibility effects. The effects must be separated from background effects and attributed to specific pollutants, a difficult task. Direct estimation provides some useful information about the magnitude of direct costs, and may eventually be the preferable method of externalities valuation. For a more detailed discussion of direct estimation of externalities see Pace (1990) or Chernick and Caverhill (1989).

The fourth approach, implied valuation, relies on the costs of required or anticipated regulations or control measures to estimate a societal value of reducing residual emissions or another externality. For instance, the new Clean Air Bill, once adopted, gives us specific information about what society is willing to pay, on a national basis, to reduce SO_2, NO_x, VOCs and toxic air emissions. This method is also referred to as shadow pricing, revealed preference and marginal cost of abatement, and has been used by several analysts to estimate the societal value of reducing residual emissions, including Chernick and Caverhill (1989, 1990), Shimshak et al.

(1990), Shilberg et al. (1989), NYSEO (1989) and NYPSC staff (Putta 1990). SCAQMD (1990) also suggests valuing NO_x emissions reductions from the costs of control of stationary sources. The implied-valuation method is discussed in more detail below.

The direct-estimation and implied-valuation approaches estimate the societal value of reducing a unit of each externality. Typically, values are expressed in such terms as $/pound emitted, or $/unit of the externality. The combined value of all of the externalities of a power source (expressed in $/kWh, for example) is then the sum across externalities of the following product:

Amount of each pollutant emitted (in units such as pounds/kWh)	X	Unit value of that pollutant (in this case, $/pound)

Implied valuation has proven to be the most tractable of the four methods for estimating externality values for important air emissions of energy production such as SO_2, NO_x and VOCs, and is also useful for estimating values of a variety of other externalities, including oil spills and water use. It is more difficult to apply to valuation of emissions of the greenhouse gases, which are currently not regulated. The next section discusses important issues relating to the basis and use of the implied valuation method. For simplicity, the discussion will focus on externalities measured in pounds.

ISSUES IN IMPLIED VALUATION

Implied value of reducing emissions. Deriving externality values from the cost of pollution control is sometimes described as if the resulting values were proxies for the direct costs of emissions. In fact, the implied valuation technique uses the costs of control to provide direct information on the societal value of reducing emissions at the margin, under either of two theoretical approaches.

First, the cost of the required controls serves as an estimate of the price that society is willing to pay to reduce the pollutant.[3] This is the rationale behind the "implied valuation" or "revealed preference" approach to the use of control costs for valuing externalities. For instance, if society is willing to pay as much as $2/lb for current or planned emissions control, then avoiding a pound of emissions should also be worth $2/lb.

Second, the costs of required controls may directly establish the social benefits of reducing emissions, to the extent that they define the direct pollution-control costs that can be avoided by an exogenous reduction in emissions. For instance, if the objective of a particular regulation is to maintain a given level of ambient air quality, the construction of a less polluting plant, or the reduction in output requirements due to conservation, will allow regulators to avoid the most expensive control measures that would otherwise have been required.

Only the marginal cost of control matters. From the "implied preference" perspective, the fact that many required controls are inexpensive, or even that some inexpensive controls have not yet been required,[4] is irrelevant to the determination of the highest price society is willing to pay to reduce emissions at the margin. From the avoided-control-cost perspective, the appropriate estimate of the social cost of control is the highest-cost control that will be required if emissions are not reduced in another way, since conservation will allow that most expensive measure to be avoided.

Defining the Margin. Determining the marginal unit of externality control is difficult for at least three reasons. First, legislative and regulatory requirements for the control of externalities often seem mutually inconsistent, with some required measures having much higher costs than much less expensive measures that are not required. Second, the margin is often in flux. Third, the complexity of pollution control complicates the computation of the cost of controlling an environmental externality.

The first difficulty, apparent inconsistencies in regulatory behavior, will generally produce underestimates of externality costs. Controls are often not

3 *For a more detailed discussion see Chernick and Caverhill (1989) and Schilberg, et al., (1989).*

4 *For an explanation of why some inexpensive measures might not have been required, see Chernick and Caverhill (1989, pp. 40-41).*

required on all sources of an externality, for any of several reasons. Legislation and/or regulation may attempt to protect vulnerable (or powerful) economic interests or sectors, and thus may exempt such groups as small businesses, marginal industries, and households from controls imposed on other generators of the same externalities. Similar exemptions may be granted to sectors that are perceived to be contributing in other ways to the solution of the same or related problems. Exceptions are especially likely to be granted if those contributions are viewed as burdensome.[5]

The cost of administration may also restrict the application of controls on externalities. Some producers of externalities, especially those that are small and dispersed, may be very difficult and expensive to police. Regulators may also find their scarce resources are more efficiently used on new proposed sources (where the applicant must receive the regulator's active approval to proceed) than on existing sources (where the regulator may need to expend significant effort to force a change in the status quo).

The second problem, that of a potentially changing margin, is particularly clear in the present case of acid rain. Acid rain has been a heated issue for at least a decade, and at the present time, national legislation addressing acid rain seems very likely to be enacted by the end of the year. This legislation will redefine the margin and clearly establish prices that the nation is willing to pay for reduced emissions.

The third problem, the complexity of externalities, encompasses several aspects. Some control measures, such as catalytic convertors on automobiles, reduce the emission level of multiple pollutants. Catalytic convertors reduce emissions of carbon monoxide, nitrogen oxides, and reactive hydrocarbons. In such cases, it is sometimes difficult to determine which pollutants have motivated the imposition of the controls, and to apportion the cost of the controls among pollutants.

Multiple effects of externalities. A single pollutant may have several ultimate effects, each imposing its own costs on society. As a result, the same pollutant may be regulated under several different rules. For example, nitrogen oxides are regulated as a respiratory pollutant and as a precursor to smog, and the pending acid rain legislation will regulate nitrogen oxides as a precursor to acid rain. In addition, recent evidence indicates that nitrogen oxides promote cancer and may contribute to the release of methane from soils, which would make nitrogen oxides a candidate for regulation as a greenhouse precursor.[6] These multiple effects may confuse the valuation of the externalities, due to the need to distinguish between additive and cumulative controls.

Imperfections in the Regulatory System. The decisions of the legislative and regulatory system provide us with useful information, including some sense as to how social and political structures (sometimes at local, state, federal, and international levels) have valued the externalities in which we are interested. However, we must recall that these structures are imperfect. We should not delude ourselves into believing that required levels of pollution controls, for example, represent revealed truth regarding the social valuation of pollution.

Environmental regulation, like any other kind of regulation, occurs in a political context, as the balancing process of many complex interests. For the most part, society does not collectively pay the cost of reducing externalities; individual persons and corporations pay different shares of the costs, and receive different shares of the benefits. The distribution of the costs and benefits across interest groups and constituencies may have a greater effect on the eventual level of regulation than does the aggregate social value. Regulation may be too weak (in which

5 *For example, the Bush-Dingell Clean Air Act amendments would defer application of the Air Toxics provisions to electric utilities, even though arsenic emitted by a power plant is as dangerous as arsenic emitted by a smelter. The apparent rationale for the exemption is that the utilities will be responsible for most of the acid rain reduction, and in some cases for much of the local air quality improvements, mandated in other sections of the same bill, and that equity requires that utilities be temporarily exempted from the burdens of complying with the air toxics provisions.*

6 *Science News, September 30, 1989, p. 213.*

case the true value of the externality may be much higher than the value implied by regulatory standards), too strong (in which case reductions of the externality through choice of energy technology may still save society the costs of the controls, so the implied value may be a correct valuation), or a mixture of the two.

Even if legislators and regulators strove solely to identify and serve the social good, no one is omniscient. Given the multitude of interests and valuations, the choice made by the regulators may not match a reasonably defined social value.

In practice, neither the regulatory agencies nor the courts are normally given the responsibility of determining the public interest and pursuing it without restraint. Legislatures enact laws, and regulators and courts put them into effect. The regulatory and legal interpretation of the statute may not always be what the legislature expected or intended.[7]

Although rapidly changing regulations inevitably create some uncertainty, most of these issues are quite tractable. With a proper conceptual framework, and due diligence, the implied valuation technique can produce highly relevant and useful estimates of the social value of reducing externalities. One of the most desirable features from the perspective of the analyst and decision-maker is that the toughest social choices, assigning dollar values to human life and health, to wildlife, to natural ecosystems, to historical monuments and to visibility, are made by the legislators and by environmental regulators, rather than by utilities and their rate-regulating agencies.

CONCLUSION

The value of reducing externalities is greater than zero and can be estimated using at least one of four techniques. Implied valuation suggests that the societal value of reducing externalities is significant. The New York Public Service Commission is adding 1.4 cents/kWh for externalities to the avoided costs used in evaluating energy conservation. This represents approximately 25% of the New York direct avoided cost. The underlying New York analysis suggests that higher externality values are justified.

In addition, Chernick and Caverhill (1990b) estimate that new power plants' externality costs, based on the implied valuation method, range from about 13% of the internal cost for a gas combined cycle using the best available control technology, to almost 90% for a coal-fired boiler just meeting the NSPS. For existing units, the environmental costs range from 47% of the avoidable costs (excluding initial capital costs) for a gas-fired combined cycle unit, to as high as 300% for a 1.2% sulfur coal-fired boiler with particulate control (Chernick and Caverhill 1990b). The externality unit values adopted by the California Energy Commission are higher than those estimated by Chernick and Caverhill.

In summary, environmental benefits represent major increments to the total benefits of energy conservation and of switching loads from electricity to direct fossil combustion. The increased benefits will identify as cost effective, additional conservation of electricity and fossil fuels, and additional fuel switching.

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7 Indeed, in some cases, such as the National Environmental Protection Act that established the requirement of Environmental Impact Statements for major federal actions, it is clear that the legislature as a whole did not know how its language would be interpreted, and various legislators held very different views of just what the law would require.

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