Environmental Externalities From Energy Sources: A Review in the Context of Global Climate Change

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Environmental (or externality) costs, which result from the harmful impacts on the environment of energy production and use, were given considerable emphasis by a number of State Legislatures in the United States several years ago. Electricity costs were affected. Then, for various reasons, the effort to relate environmental and electricity costs moderated. But the concept now motivates the energy industry toward much of the recent growing international attention to the emerging risk of global climate change. This article provides the readers an opportunity to revisit these issues to become aware of what may, in the near future, influence their strategic energy and environmental plans.

WHAT ARE EXTERNALITIES AND EXTERNALITY COSTS?

Externalities are defined as benefits—or costs—generated as a by-product of economic activity, that do not accrue to the parties involved in the activity. Environmental externalities are benefits and costs that manifest themselves through changes in the physical/biological environment. Electric power plants that burn fossil fuels emit several pollutants linked to environmental problems of acid rain, urban smog and, possibly, of global climate change. Damages caused by those emissions are viewed by many economists as environmental externalities resulting from an inefficient market, in which electricity rates do not reflect, and ratepayers do not directly pay, the social costs associated with negative impacts on the physical/biological environment.

The simplest approach to address these environmental impacts is to characterize and describe qualitatively the environmental resource options. A somewhat more complicated approach is to rank and weigh air, water, and land impacts of individual options. Finally, one could quantify and *monetize* (assign a dollar value to) the externalities associated with resource options.

The costs or economic value of the environmental impact or harm are referred to as *environmental costs* or *externality costs*. To the extent that the energy industry does not pay these externality costs and consumers do not pay the full cost of energy they consume, energy resources are not allocated efficiently. Estimates of externality costs require quantification of emissions (e.g., tons of sulfur dioxide per ton of coal) and monetization of these emissions (e.g., dollars of environmental damage per pound of carbon dioxide). These externality costs are generally expressed in "per ton emissions" or "per kilowatt-hour of electricity." These monetary values are incorporated in the economic analysis of resource options from the societal perspective, such as by electric utilities and state regulatory agencies (public service commissions) in the United States.

The theory and application of externality costs covers all types of environmental impacts on land, water, and air, as well as those originating from all anthropogenic sources, ranging from power generation to cattle dung production to rice cultivation. They are manifested in a variety of ways, such as acid rain and urban smog. The following discussion is limited to air emissions occurring from energy sources, primarily electricity generation processes, that may lead to global climate change.

GLOBAL CLIMATE CHANGE

Greenhouse gases (GHGs) are necessary for life on earth because they keep ambient temperatures well above what they would otherwise be. Many scientists believe that anthropogenic additions to the earth's natural complement of GHGs are augmenting this greenhouse effect and thus raising global temperatures. The principle GHGs are carbon dioxide (CO_2), water vapor, methane, nitrous oxides, and chlorofluorocarbons. Of the fossil fuels, coal has the highest carbon content. Oil and natural gas have approximately 80 and 60 percent, respectively, of the carbon content of coal on an energy-equivalency basis.

Although CO_2 is not a regulated pollutant in most countries, the reduction of GHG gases in general, including those of CO_2, is the focus of several international efforts.

APPROACHES FOR VALUATION OF EXTERNALITIES

There are several methods used to monetize environmental externalities. Each technique has its pros and cons; thus there remains a large amount of uncertainty and disagreement among economists and policy makers regarding values that are determined and used for planning practices and policy development purposes. Externality costs are estimated using the following common approaches:

- Damage Cost Approach
- Control or Mitigation Cost Approach
- Revealed Preferences Approach

Damage Cost Approach

Damage costing determines environmental externality costs by monetizing the effect of their impacts (or re-mediating their impacts). This would include impacts on (1) human health (e.g., increase in cancer and infant mortality rates or decrease in life expectancy), (2) infrastructure (e.g., metal oxidation and limestone dissolution), (3) agriculture (e.g., soil chemistry changes, changing precipitation patterns, temperatures, length of seasons, storm severity, or incidence of ultra-violet light), as well as (4) bio-diversity (loss of animal species, deforestation, etc.).

It is very difficult to accurately monetize the cost of the impact (such as, the value of human life lost as a result of environmental impact). This approach is not only complex but fraught with uncertainty. It is also very difficult to determine the boundaries of any impacts. In short, the uncertainty, the lack of accurate data, the response to the perturbation (which may include non-linear responses as well as feedback effects), and other factors could confound the damage cost estimation method.

Control Cost Approach

The *control cost,* or *mitigation,* approach determines an externality cost by using the cost of reducing or preventing the emissions as proxy for damage costs. Usually, the cost of the most stringent emissions control technique is used. For example, How much does it cost to reduce emissions of sulfur dioxide by use of flue-gas desulfurization techniques or emissions of CO_2 through reforestation mechanisms? As can be expected, this results in a range of externality cost estimates, but the range is tighter than that found through the damage cost approach.

The implicit assumption in control costing is that society controls pollution until the benefits of additional controls will be outweighed by costs. However, there is no direct relationship between the control cost estimates and the real environmental externality costs.

In the context of electric utilities, when the control cost approach is applied (e.g., by state utility commissions in the US), the rationale is that it is appropriate to promote investments in those control measures that will reduce the emissions. For instance, in the early 1990s New York and California used control cost method to develop externality costs (for use during integrated resource planning in the electricity sector).

Revealed Preferences Method

Externality costs developed using the *revealed preferences* method (or *shadow pricing* approach) are based on the value that the public places on specific environmental impacts. For example, in the case of SO_2 (an important acid rain precursor), the highest (or marginal) cost reduction strategy in response to new legislation is taken as the (marginal) value that society places on reducing SO_2 emissions. Of course, this means externality costs are determined, largely, by those who develop environmental legislation. One can argue that legislators are not fully aware of the reduction costs when legislation is being developed.

DISCOUNTING EXTERNALITY COSTS

An important issue, which has significant impact on the externality cost, is the applied discount rate. Many externalities have impacts, particularly in case of greenhouse gases, over long periods of time. For instance, the atmospheric life of CO_2 is between 200 and 500 years. In these cases, the choice of discount rate (which, in general financial analysis and practice, is applied to value costs and benefits occurring at a future point in time) has significant impact on the externality cost. A positive discount rate would imply that costs occurring far into the future are of no concern to us, even if they are substantial. Environmental economists argue against this inter-generational bias in terms of handling externality costs.

SPATIAL VARIATION OF EXTERNALITY COSTS

The environment can absorb a certain level of pollution without damage. This threshold, below which control is not warranted, may be uniform throughout the country or may vary from region to region, depending on the pollutant and the environmental concern in question. Uniformly mixed pollutants have the same effect on the environment regardless of their geographic point of origin or impact.

For example, emissions of CO_2 from anywhere in the country or the world have uniform impacts on climate change. The effects of non-uniformly mixed pollutants, such as acid rain or urban smog causing pollutants, are very sensitive to conditions around the point of impact. This spatial variation of impacts of externalities on the environment causes bias in the valuation and uncertainty in the range of externality costs. Some of the variations in estimates are shown in Appendix.

ESTIMATES OF EXTERNALITY COSTS

In a recent study that reviews and compares valuation of externality resulting from electricity generation, the following damage cost-based estimates are provided for assessing the impact on global climate arising from coal use under various discount rates:

Discount rate	Externality Cost Estimate (cents/kWh)
0%	1.3 - 2.2
3%	0.19 - 0.3
10%	0.05-0.08

However, each of the studies reviewed concludes that it is not possible to use an impact pathway approach to provide reliable estimates of damages, and they assign a very low level of confidence to these estimates. Several researchers use this rule of thumb: each \$1 of damage estimated or assumed to result per ton of CO_2 translates roughly to 0.1 cent per kWh.

Some selected estimates for CO_2 and other GHGs, from specific studies are provided in the Appendix.[1] For each type of emission, the costs are indicated from the lowest to the highest estimate found in the literature that was reviewed. The variation is not only in terms of geographic locations, but even for the same location the estimates vary by the method applied to estimate the externality values or by the group that did the study. In addition, there are differences in terms of when the costs were estimated.

The availability of wide range of estimates makes the inclusion of costs into planning and policy development practices often controversial and debatable. Table 1 shows the externality costs of major air pollutants associated with coal plants that are actually used in practice by the regulatory agencies and electric utilities in different states in the US, when comparing coal plants with other electricity generation resource options. Their application is carried out generally in terms of externality "adders" (where the $/kWh term is added to the regular "private" cost of coal-fired electricity) in models for long-term resource planning and selection. None of the States have, however, mandated their use for electricity dispatch decisions on an operational basis.

CONCLUDING REMARKS

Environmental externalities, particularly those associated with fossil-fired electricity generation, entails serious risks like global climate change, acid rain and smog formation. Costs related to these negative impacts should be taken into account when making decision for resource choice in the electricity market.

However, reliable estimates of externalities are difficult to establish, because valuing externalities is apparently an inexact science. Estimates of externality costs vary widely as shown in this article. Each technique to monetize externalities has its pros and cons; thus there remains a large amount of uncertainty and disagreement among economists and policy makers regarding values that are determined and used for planning practices and policy development purposes.

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[1]The date when the cost estimate was developed is also provided. Adjusting the costs to current values just by adjusting for inflation, would be too simplistic. This is because both the values placed on the environment (as represented by our environmental legislation) and the changes in the cost of control will not necessarily track inflation. In fact, the cost of technical control measure should decline through normal technical advancements.

Table 1:
Externality Costs Used for Analyzing Electricity Generation Sources

	SO_2		NO_x		CO_2	
	$/kg	$/kWh	$/kg	$/kWh	$/kg	$/kWh
Massachusetts	1.65	0.0046	7.15	0.0201	0.024	0.0244
New York	0.92	0.0025	2.02	0.0055	0.001	0.0010
Nevada	1.72	0.0014	7.48	0.0165	0.024	0.0244
Minnesota	0.30	0.0005	1.64	0.0048	0.013	0.0136
Wisconsin	NA	NA	NA	NA	0.015	0.0150
Bonneville Power	1.65	0.0016	0.93	0.0024	NA	NA
Pacific Gas & Elec	4.47	0.0244	7.81	0.0213	0.029	0.0267

Also, many environmental externality estimates are very site-specific. Nevertheless, ignoring externality costs for resource choice could result in inefficient decision making and a multitude of potential environmental risks, including global climate change. Therefore potential benefits of their inclusion in strategic energy planning practices, at the minimum in terms of ball-park estimates, is extremely important.

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APPENDIX

Environmental Externality Cost Estimates of Global Climate Change-Causing GHG Emissions.

I. Carbon Dioxide

Estimate	*$ basis*	*method*	*location*	*source*
$1.2/ton	1989	legislation	New York state	NYSEO, 1989
$7/ton	1989	legislation	California	Putta, 1989
$9/ton	1992	legislation	California	EIA, 1995
$9.8/ton	1992	legislation	Minnesota	EIA, 1995
$14/ton	1990	control[1]	US	Calwell 1990
$14.2/ton	1990	control	New York state	PACE 1990
$15/ton	1992	legislation[4]	Wisconsin	PSCW, 1992
$22/ton	1988	control[1]	US	Chernick & Caverhill, 1988
$24/ton	1992	legislation	Massachusetts	EIA, 1995
$24/ton	1992	legislation	Nevada	EIA, 1995
$25/ton	1992	legislation	Oregon	EIA, 1995
$75-150/ton[2]	1993	control[3]	US	Haraden, 1993

Notes:
(1) CO_2 uptake through reforestation
(2) per ton carbon
(3) CO_2 removal at coal gasification power plants
(4) based on control

II. Methane

Estimate	*$ basis*	*method*	*location*	*source*
$0.11/lb	1989	based on CO_2[1]	US	Tellus, 1990
$0.35/lb	1988	control	US	Chernick & Caverhill, 1988
$0.75/lb	1992	legislation[2]	Wisconsin	PSCW, 1992

Notes:
(1) As the global warming potential (GWP) is estimated to be 10 times that of CO_2, its externality cost is 10 times that of CO_2.
(2) based on control

III. NOx (also leads to Acid Rain)

Estimate	$ basis	method	location	source
$0.425/lb	1992	legislation	Minnesota	EIA, 1995
$0.6/lb	1989	control	New York state	Putta 1989
$0.86/lb	1990	control	New York state	PACE, 1990
$1.50/lb	1988	control	Massachusetts	Chernick & Caverhill, 1988
$1.75/lb	1992	legislation	Oregon	EIA, 1995
$3.50/lb	1989	perceived	NE US	Tellus, 1990
$3.6/lb	1992	legislation	Massachusetts	EIA, 1995
$3.92/lb	1992	legislation	Nevada	EIA, 1995
$4.45/lb	1989	legislation	California	SCAG 1989
$8.15/lb	1989	control	California	Therkelsen 1989
$1.31/lb	1989	perceived	S California	Tellus, 1990

IV. N_2O (also causes Low-level Ozone)

Estimate	$ basis	method	location	source
$1.35/lb	1992	legislation[2]	Wisconsin	PSCW, 1992
$1.98/lb	1989	based on CO2[1]	US	Tellus, 1990

Notes:
(1) As the GWP is 180 times that of CO_2, its externality cost is estimated at 180 times that of CO_2.
(2) based on control

V. SO_2 (also causes Acid Rain and Smog)

Estimate	*$ basis*	*method*	*location*	*source*
$0.075/lb	1992	legislation	Minnesota	EIA, 1995
$0.27/lb	1989	control	New York state	Putta 1989
$0.72/lb	1992	legislation	New York state	EIA, 1995
$0.75/lb	1989	perceived	US	Tellus, 1990
$0.85/lb	1992	legislation	Massachusetts	EIA, 1995
$0.86/lb	1992	legislation	Nevada	EIA, 1995
$0.88/lb	1988	perceived	Massachusetts	Chernick & Caverhill, 1988
$2.13/lb	1990	control	New York state	PACE, 1990
$2.24/lb	1992	legislation	California	EIA, 1995
$8.68/lb	1989	legislation	California	SCAG 1989
$37.50/lb	1989	perceived	S. California	Tellus, 1990

VI. CO (also causes Smog)

Estimate	*$ basis*	*method*	*location*	*source*
$0.043/lb	1989	control[1]	US	Tellus, 1990
$0.375/lb	1989	perceived	S. California	Chernick & Caverhill, 1988
$0.43/lb	1989	perceived	S. California	Tellus, 1990
$0.9/lb	1989	control[1]	Rhode Island	Tellus, 1990

Note:
(1)As the GWP is 2.2 times that of CO_2, its externality cost is estimated to be 2.2 times that of CO_2.