Social Costs and Benefits of Recycling Coal Fired Electric Power Plant FGD By-Products

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Summary

Flue gas desulfurization (FGD) by-products from coal-fired electric power generation are increasing due to Clean Air Act legislation in the U.S. requiring removal of sulfur from coal. The FGD by-products are one of many waste products or residuals of economic production and consumption activities that may impose social costs when entering a natural environment with limits to its assimilative or "sink" capacity. The options for dealing with this problem include reducing levels of throughput, converting the residuals to new products or recycling them as inputs, changing the wastes to a more benign form, altering the time and place of residuals discharge and changing the assimilative capacity of the environment. This paper is part of a larger multidisciplinary research effort on FGD Recycling at The Ohio State University (see Dick et al., 1991) and focuses on developing a correct method for assessing the social or complete costs and benefits. It is oriented primarily to non-economists. The three options for converting FGD by-products to new products or recycling them as inputs include FGD by-products as an agronomic lime substitute, as an amendment on active and abandoned stripmine spoil, and as an embankment stabilizer for highway construction.

Social cost benefit analysis is concerned with estimating full willingness to pay and willingness to accept measures of economic value regardless of whether or not those values are currently reflected in market prices. It

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recognizes that technological externalities or unpriced environmental services can result in large gaps between private and social costs and benefits. A rapidly growing methodological literature in environmental economics is drawn upon to demonstrate how several of these gaps can be given economic expression in the coal-fired electricity production case. Examples in the landfill disposal vs. recycling of FGD by-products include: (1) monitoring, testing and remediation costs of groundwater contamination, (2) reduced rerouting, highway repair and maintenance costs related to embankment stabilization from FGD by-products, and (3) property value impacts (hedonic pricing) and contingent evaluation of willingness to pay for changes in amenities from landfill and stripmine reclamation activities. Finally, a hedonic pricing model is developed to illustrate how one might estimate the benefits of using FGD by-products for stripmine reclamation.

Materials Balance

Flue gas desulfurization (FGD) by-products are one of the many residuals of production and consumption activities prevalent in a contemporary society. Specifically, FGD by-products result from the post-combustion "scrubbing" of flue gases in coal burning electric power plants by wet or dry lime processes. As the gross national product (GNP) or value of goods and services of a society grows so does the variety and volume of FGD and other residuals. In fact, it has been suggested that GNP might more appropriately refer to "gross national pollution." According to Boulding (1968), Georgesen-Roegen (1977) and others, the controversy over the foregoing residuals and the environment stems from the tendency to treat the environment as a free good or God given right rather than a source of raw materials and a waste disposal "sink" with limits. In the simplest materials balance model, Freeman et al. (1974) view the environment as a large shell surrounding the economic system. It has the same relationship to the economy as does a mother to an unborn child--it provides sustenance and carries away wastes.

Raw materials flow from the environment, are processed in the production sector (that is, converted into consumer goods), and then--at least in part--pass on to the household sector. The materials returning to the environment from the household sector are wastes or residuals. They are the unwanted by-products of the consumption activities of households. Similarly, not all of the material inputs that enter the production sector are embodied in the consumption goods flowing on to the household sector. These are the wastes or residuals from production. Thus, there is a flow of residuals from both the production and consumption sectors back to the environment.

If the environment's capacity to absorb or assimilate wastes or residuals were unlimited, there would be no pollution problem and waste management would be a non-issue. However, the assimilative capacity of the environment is limited and in the case of some residuals like mercury it has no assimilative capacity. One of the limits of the environment's capacity to assimilate is the conflict or competition with other environmental services such as human habitat, amenities and materials inputs to the economic system. Many of these environmental services provide significant economic benefits even though they may not be currently or directly priced in markets.

The materials balance model and the notion of a service producing environment provide critical insights for the proper management of wastes or residuals. Examples suggested by Freeman et al. (1973) include (1) identification of the full range of technical options, (2) recognition of the interdependency among the various kinds of residual flows, (3) illumination of the relationships among population growth, economic growth and pollution, and (4) emphasis in public environmental institutions on broad jurisdiction over air, water and land pollution and over major physical systems such as river basins.

With increasing evidence of wastes or residuals exceeding the assimilative capacity of various environmental "sinks", it is important to first identify the major technical alternatives for either reducing wastes or altering assimilative capacity. Examples include the following:

1. Reducing the rate of throughput of materials and energy by reducing production, increasing the efficiency of production, converting residuals to new products or recycling them as inputs, or by changing the composition of GNP to lower residual products. The three alternatives uses proposed for FGD by-products all involve recycling or conversion to new products.
2. Biologically, chemically or mechanically treating or changing the residual to a more benign form for discharge to the environment.
3. Altering the time and place of residuals discharge.
4. Man-made investments to increase the residual assimilative capacity of the environment such as dams to store water for dispensing heavy waste loads and paddle wheels to augment the natural supplies of dissolved oxygen.

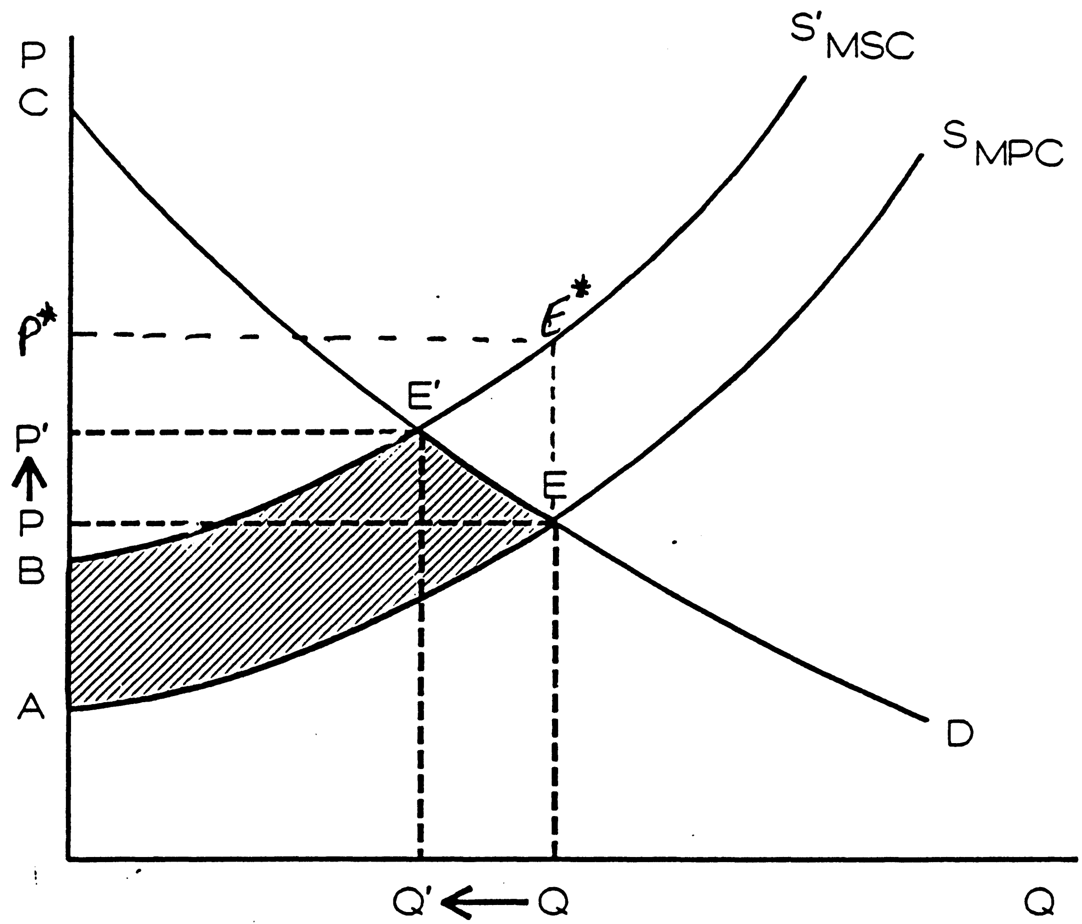
Social Costs and Benefits

Social costs and benefits or gains and losses from an economic perspective refer to the aggregation of individual producer and consumer measures of full willingness to accept or pay compensation. Individual preferences count in the determination of social benefits and costs and are weighted by income or more narrowly market by power. Since most policy changes involve economic gainers and losers, economists have developed the concept of potential Pareto improvement (PPI) to add up gains and losses to get net benefits. Simply stated, the concept holds that any policy change is a PPI or an increase in economic efficiency if at least one individual is better off after all losers are compensated to their original or before the policy change income positions. The compensation need not actually occur but must be possible (Dasgupta and Pearce, 1978).

These measures of social costs and benefits are not fully reflected in current market prices (thus the "social" terminology) such as the price of electricity resulting from the coal-fired power generation for several reasons. First, because there are consumers willing to pay more and producers willing to sell for less than prevailing market or regulated prices, they receive what economists call consumer and producer surpluses. Secondly, technological externalities in coal-fired electric power generation exist to the extent that external to the production and consumption of the resulting electricity, individuals experience uncompensated real economic losses or gains. Examples include water pollution or adjacent property value losses from strip mining of coal or air pollution and lake acidification from the combustion of coal to produce electricity. Finally, there may be willingness to pay to keep future economic options such as sport and commercial fishing open or for existence value of plant or animal species threatened by water or air pollution which are not reflected in the market price of electricity.

Figure 1 illustrates both the concepts of economic surplus and technological externalities. For example, at market price P consumer surplus is equal to area PEC and producer surplus is equal to area PEA. One might think of P as the market price for a kilowatt of electricity based on the intersec-

FIGURE 1
ACID RAIN AS AN EXTERNALITY



Technological Externality Defined (Dasgupta & Pearce 1978)

1. Necessary Condition
   Physical interdependence of production and/or utility functions
2. Sufficient Condition
   Not fully priced or compensated

S = marginal private (power plant) cost function

S' = marginal social (air shed) cost function

tion of marginal private cost (from the power plants perspective or accounting stance) of coal-fired production with demand.

The fact that some aquatic and forestry economic losses appear to be related to the sulfur emissions from coal burning electric power plants, the fact that strip mining of coal can lead to water contamination and lower surrounding property values and the possible global warming implications of CO_2 emissions from coal combustion for electric power all suggest the presence of uncompensated technological externalities. Stated another way, output Q exceeds the assimilative capacity of the environment. These external or social costs are internalized into the cost of producing coal-fired electricity in S′ or the marginal social cost function and P′ represents the price per kilowatt that would prevail if these external costs were included. The shaded area BE′EA represents the net loss in producer and consumer surpluses from the presence of these uncompensated externalities.

The foregoing is a static analysis and does not show the adjustments that might occur over time due to, for example, a tax on or a subsidy for electricity equal to the distance between P and P′. The willingness to pay to keep future options open or for existence value of species is also not shown in Figure 1. However, if a proposed stripmine site impacts an endangered species for which considerable WTP exists, it could result in the development of a higher cost alternative site which in turn would further increase the MSC function in Figure 1.

A rapidly growing empirical economic literature (see, for example, Hufschmidt et al., 1983 and Pearce and Turner, 1990) has evolved from the foregoing conceptual concerns which has the following major subsets relevant to the coal fired electricity production case:

1. Market values in related external markets such as agricultural or forest crops damaged from air pollution or reduced maintenance and private re-routing costs from highway embankment stabilization, replacement costs such as electricity generation from biomass or natural gas, and restoration or clean-up costs such as the liming of acidified lakes to return pH to normal levels or monitoring and treatment costs of contaminated groundwater. For example, analysis by Hitzhusen and Nyamaah (1984) of private re-routing costs from the closure or weight limit posting of bridges in rural Ohio found very large private savings relative to public repair costs. This would suggest the possibility of relatively large economic benefits from the stabilization of highway embankments from FGD by-products. As a second example, Sweden is spending several million dollars per year on a very modest program to apply lime to a few of many acidified lakes. This is an attempt to reintroduce fish and other aquatic life lost from coal burning induced acid rain which the Swedes claim comes primarily from their European neighbors to the south, an example of a transnational externality.
2. Surrogate market measures such as willingness to incur travel costs to use or avoid a particular natural resource or environmental service, impacts (hedonic) on property values from the decrease or increase in the quality of a particular environmental service such as a stripmine reduction of a landscapes utility, and wage differentials reflecting desirable or undesirable environmental attributes of a particular location impacted by water, air or sight pollution. For example, a travel cost analysis was done by Mullen

and Menz (1985) on the economic effect of acidification damage in the Adirondack fishery to fisherman from New York State. The lost willingness to pay as expressed by the willingness of New York fishermen to travel to Adirondack lakes and make expenditures to fish exceeded $1 million per year in 1976 values.

3. Direct surveys of WTP and WTA for gain or loss of goods and services such as loss of visibility from air pollution or loss of sport fishing from an acid rain impacted lake. Originally called hypothetical evaluation, this methodology now goes under the rubric of contingent valuation and includes much concern for various forms of strategic behavior of respondents. Bidding and trade-off games are used to elicit the responses on WTA and WTP. For example, Brookshire *et al*. (1976) used pictures of three alternative levels of visibility related to smokestacks and emissions from a proposed coal fired power plant in Lake Powell, Arizona. To elicit WTP measures from respondents for these aesthetic damages or losses, an entrance fee to Lake Powell was used as the instrument to collect bids. The estimated aggregate bids ranged from $400,000 to $700,000 per year, not a trivial sum.

Hedonic Pricing Illustration

One beneficial reuse or recycling option for FGD by-products is as a reclamation material for abandoned coal stripmines. While federal regulations in the U.S. require current mining activity to restore the mining area to its original environmental state, the legislation does not require abandoned stripmines to be reclaimed. If there are no substitute reclamation materials for the FGD by-products or no plan to reclaim the area, FGD-based reclamation will increase the income stream of the reclaimed land. In addition, it may increase surrounding property and land values and increase the life of existing landfills by diverting the FGD waste from landfills to reclamation of abandoned stripmines.

Hedonic pricing attempts to infer or derive a value for the pleasure lost or gained from environmental changes. The approach involves an attempt econometrically to capture differential prices for property (e.g., land and housing) which can be attributed to variations in one or more environmental characteristics. The hedonic pricing model for land and housing values assumes a well-functioning housing/land market in equilibrium with the major environmental costs and benefits accruing to owners of land and housing. It also assumes that buyers can perceive environmental impacts (e.g., stripmine reclamation) on land and housing values. The basic model can be stated as follows:

$$S_i = f(P_i, N_i, Q_i)$$

where

S_i = Sale price of property unit i

P_i = Characteristics of property unit i

N_i = Characteristics of neighborhood for property unit i

Q_i = Environmental quality characteristic for property unit i.

The foregoing hedonic implicit price function model is sufficient for estimating the land and/or housing price impacts of marginal changes in Q_i. However, for non-marginal changes in Q_i more complex procedures are required to "net out" an entire demand function from supply side factors. Figure 2 presents a schematic of the foregoing simple hedonic model showing housing, land use, community and environmental variables and data sources for applying

FIGURE 2

A Schematic of the Hedonic Model

Purchase Price of Home or Property
Dependent Variable

Characteristics

Housing	Land Use	Community	Environmental

Examples of Independent Variable Characteristics

* house size * No. of bdrms * No. of baths * Air condit. * Fireplace * Patio	* homesite * tillable * pasture * wasteland * woodland * R.O.W.	* quality of schools * population density * % of unemployment	* area of reclamation * distance from mining * type of mining damage

Data Sources

Real Estate Records	Real Estate Records	County Census	Ohio Dept. Natural Resources

Estimated Model

$$Y_i = \beta_o + \beta_i \text{ housing} + \beta_j \text{ landuse} + \beta_k \text{ community} + \beta_l \text{ environ} + u_i$$

the model to the estimation of property value benefits from FGD based stripmine reclamation. Remaining conceptual and empirical issues include identifying correct time lags in realization of benefits, estimating the increased landfill capacity from diversion of FGD, and any potential impacts of FGD chemical properties.

Earlier hedonic analysis by Havlicek et al. (1985) of adjacent residential property value impacts of a sanitary landfill in Fort Wayne, Indiana found significant statistical coefficients on both distance of the property from the landfill and the location (in absolute degrees) of the property away from being downwind (prevailing) from the landfill. Specifically, residential property values increased an average of $1.92 per foot of additional distance from the landfill and an average of $32.96 for each additional degree away from being directly in line and downwind from prevailing winds and the landfill.

Research by Ibrahim et al. (1982) using 1976 cross-sectional data studied the relationship between surface coal mining and reclamation activity, and property values in seven Ohio counties. Mining activity was found to have a positive relationship with residential property values and a negative relationship with agricultural and commercial property values. The opposite relationship is observed with surface mine reclamation. One explanation for the unexpected results on residential property is that surface mining reduces and reclamation increases supply of residential property sufficiently to impact price. Surface mine reclamation enforcement has also gotten more strict since 1976 which suggests the need to update this earlier analysis.

To the extent that stripmine reclamation reduces soil erosion from the mine site, related downstream sediment impacts may also decrease. Hedonic pricing was used by Hitzhusen et al. (1992) to estimate the downstream sediment impacts on residential property owners at four Ohio state park lakes. The statistical results are presented in Appendix A and show that the set of varibles measuring housing, community and environmental characteristics explain from 67 to 75 percent of the variation in prices of lakeside residential properties. For each foot of lake depth lost to sedimentation, the average lakeside property price decrease was $1,875.

The statistical estimation of the model in Figure 2 is underway but not complete. However, the earlier empirical results, preliminary hedonic results, and increasing public concern for environmental impacts of surface mining and coal combustion suggest that these externality values (as well as the earlier discussed existence values) will not be trivial and may be increasing over time. Economically efficient public policy requires that these "social" values be estimated and incorporated into the decision-making process. One need not necessarily appeal to non-economic motives or values to be more sustainable or environmentally correct in the analysis of FGD by-products or other issues.

Appendix A: The Hedonic Pricing Model

The Hedonic Pricing Model which was estimated in an earlier study by Hitzhusen et al. (1992) will be used to determine the gains to lakeside property owners from dredging. The hypothesis of the study was that a change in the quality of water by dredging would cause an increase in the value of the lakeside property. The Hedonic model used was based on property value estimates taken from the county auditors office records from the year 1990. The equation used in the Hitzhusen et al. study was expressed as follows.

VALPi = f (Size, Dwell, Room, AC, GR, DSTL, Age, PCom, DCty, AVDep, STPS)

where,
VALPi= the total value of property i, 1980
SIZE= the size of the lot, measured in acres
DWELL= the size of the dwelling, measured in square feet
ROOM= the number of rooms in the house
AC= a zero-one variable representing the existence (1) or the non-existence (0) of air- conditioning
GR= a zero-one variable representing the existence (1) or non-existence (0) of a garage
DSTL= the distance from the property to the lake's edge, measured in feet
Age= the number of years since the house was built
PCom= the population of the lakeside community
DCty= the distance from the property to the nearest city (population of greater than 5000), measured in miles
AVDep= the average depth of the lake, measured in feet
STPS= the estimated net accumulation of lake sediment per surface area per year, measured in tons
The marginal effects of hedonic pricing variables are given in Table 6.

The property value loss was calculated through use of the following equation:

VALTi= (coef. of ADEP * (SEDINT/SURFi) * MEANi) / SEDINT
i=1,..,4
where,

VALTi= the value loss of one unit of property per ton of sediment deposition, measured in dollars
SEDINi= the estimated accumulation of sediment per year, measured in tons

SURFi= the surface area of the lake, measured in square feet
MEANi= the mean value of property of the eight lakes

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