Marginal Damage Estimates for Air Pollutants

Source: *Federal Purchasing Categories Ranked by Upstream Environmental Burden: An Input/Output Screening Analysis of Federal Purchasing* (Sylvatica, North Berwick, ME; October 1998). Analysis performed under contract to the Office of Pollution Prevention and Toxics, U.S. EPA

Numerous studies have been done to estimate the "external" costs to members of society caused by air pollution . Many of these have been conducted with the objective of estimated appropriate values for "externality adders" to inform decision making about which sources of electricity have the lowest total social cost [e.g., OTA 194, Bertraw et al. 1994]. The externality adders, expressed in units such as dollars per ton of pollutant emitted, are intended to reflect the costs of the pollution borne by members of society which are not reflected in the market pricing of the activity (in this case, the total private cost of electricity generation).

Estimates of the external costs of pollution have been developed in two general ways: the damage value method and the control cost method [Wang and Santini, 1995]. The damage value method attempts to model the chain of consequences from emissions to damages, including translating emissions into altered concentrations, estimating exposure of humans and other objects to these concentrations, estimating the health and physical outcomes from these exposures, and conducting economic valuation of the outcomes. The control cost method is based on the assumption that ideal emission or air quality standards have been established, in that the marginal damage of additional pollution is equal to the marginal cost of controlling pollution [Wang and Santini 1995]. In the present analysis, we emphasize the use of estimates from the damage value method.

For the purposes of our analysis we would ideally like to identify and use a value for each air pollutant which represents its estimated marginal external damage cost per unit emission. Three factors confound our ability to simply identify such values. First, published estimates are based on varying analysis methods and assumptions, even within the the damage value method family [OTA 1994]. For example, [Rabl et al. 1996] reviewed estimates of CO_2 damage estimates, and found that differing assumptions about the effects of lower soil moisture on agriculture leading to famine and mortality among the poorer nations' population can lead to a factor of 100 difference among estimated CO_2 damages per ton.

The paper by Wang and Santini [1995] demonstrates how damage estimation versus control cost estimation methods can lead to results which differ by a factor of 100 or greater in some instances. Their review also finds that within the damage estimation method, estimates from different studies for different regions can range over factors of 50 or more for a given pollutant.

They go on to develop a regression model which attempts to determine and account for the influence of regional factors upon the divergence among these published estimates. They find population density and ambient air quality to be two significant independent variables. However, according to their final models, which were selected from among various functional forms on the basis of explanatory power, variation in these parameters alone appears to account for a small portion of the total variance in published estimates of pollutant specific damage coefficients (See Table 3-1). Their model estimates that differences in ambient concentrations and population densities among 9 major US metropolitan regions may account for differences in estimated damages per ton emitted of less than a factor of 3 for Nox, VOCs, Sox, and within a factor of 4 for Particulates.

Their results are corroborated by another study which assessed the influence of power plant location on estimated damages of air pollution [Curtis and Rabl, 1996) found that moving a pollution source from the most rural to urban representative areas within France lead to changes in estimated external damage costs of within a factor of 3.

Finally, some studies have attempted to gauge the relative influence of variability and parameter uncertainty upon the spread in their results. [Rabl et al. 1996] estimated uncertainties for a given site at generally an order of magnitude for damages of particulates, SOx, and Nox. An assessment of the costs and benefits of the Clean Air Act Amendments by the US EPA cited uncertainties in physical effects estimation and economic valuation as the two largest; the effect of these uncertainties on estimates of the value of air quality improvements for particular health effects endpoints lead to differences between the 5th and 95th percentiles of generally a factor of 10 or less. An integrated assessment which compared the relative influence of uncertainties in estimating the benefits of reducing Nox and Sox emissions [Bloyd et al. 1996] found that uncertainties in the value of a statistical life and uncertainties in concentration-response functions (physical effects estimation) had comparable influence; the range of values cited from the literature for the VSL was a factor of 5 - $1.6 million to $8.5 million.

Finally, in a study which did not include economic valuation of damages, [Hertwich et al. 1998] compared the uncertainties affecting estimates of the relative influence of toxic releases upon human health. They found that for most chemicals, the uncertainty in what is known about the chemical properties (their environmental fate and toxicity) contributes more variance in results than does the variability in exposure factors and landscape parameters.

Taken together, the above review of studies suggests the following observations and tentative conclusions:

- Differences in methodology, assumptions, and approach appear to lead to the largest differences among estimates. For example, assumptions about famine mortality can lead to a two order of magnitude difference (factor of 100) for climate change. Even for the criteria air pollutants whose effects are considered much better understood, variations in published estimates can approach a factor of 100 (See Table 3.1).
- Uncertainties in dose-response functions (physical effects calculations) and in economic valuation have repeatedly been shown to be more important than uncertainties which arise due to regional variation in ambient concentrations or population densities.
- Uncertainties in dose-physical effect modeling and economic valuation may be on the order of factors of 3 to perhaps 10;
- Site-dependent variability in externality costs for a given pollutant due to differences in ambient concentrations and density of exposed population appear to be a factor of 3 or less.

Note that we generally do *not* find in the published estimated ranges adequate information to assess the variability in *relative* costs per ton, across pollutants. That is, in the present paper we wish to apply marginal externality values to weight and sum the emissions of different pollutants, in order to rank the US sector in terms of overall environmental burdens. We can create a high-value scenario and a low-value scenario (as did Leach et al, for example), but this approach assumes that the high-end values for each pollutant go together, and likewise for the low-end values for the pollutants.

The only exception is the paper by Wang and Santini, which provide separate sets of values for different US metropolitan areas. However, as we have seen, regional variability appears to be a rather small contributor to the overall uncertainty in externality values.

Some uncertain parameters - notably the value of a statistical life - as well as some regionally variable parameters - notably population densities - will lead to covariation in the estimated externality values among the pollutants. But we should not assume that this is the case for *all* factors which contribute to the wide variation in estimated values. This issue merits further research.

For the present analysis, we follow the example of [Leach et al, 1997], adopting high and low range sets of externality values which are somewhat narrower than the extremes evident in the published literature. The intent is to reflect the strong variability among estimates without adoption the extreme outliers as our scenario values. We adopt low end values which are roughly mid-way between centrally-tending values and the low-end extremes; and we adopt high-end values which are roughly midway between centrally-tending values and the high-end extremes.

Two papers summarized ranges of values for each criteria air pollutant: [Leach et al. 1997 (which adopted data from [Hormandinger 1995]), and [Wang and Santini 1995). The minimum and maximum values for each pollutant from each review are summarized in Table 3-1, after conversion to 1996 US dollars per short ton. (Leach et al. provided results in terms of 1996 British pounds sterling. The monthly exchange rate during 1996 ranged from 1.52 to 1.66 US dollars per pound; we used 1.60. We used the historical gross domestic product implicit price deflator of 1.2176 to convert Wang and Santini's values from 1989 dollars to 1996 [SLFRB 1998]) Leach et al's values for both high and low extremes are lower than those of Wang and Santini for PM10 (particulates), and higher than those of Wang and Santini for all other pollutants.

We first calculate the average of these two reviews' high-end extremes, and do the same for the two reviews' low-end extremes. The paper by Wang and Santini also developed regression models which estimate regression values as a function of regional population and ambient air quality. They used this model to estimate values for 9 major metropolitan regions of the US. The values, shown in Table 3-1, essentially reflect the estimated sensitivity of an otherwise averaged value (across the studies they surveyed) to these regionally variable parameters. As a low-end value for our study, we take the average of the regression-based low-end value and the mean of the two reviews' low-end extremes. We do the same to develop high-end values for our study. All of these results are summarized in Table 3-1. Our final externality values are rounded to the nearest $100/ton, to help avoid an appearance of false precision.

Table 3-1: Damage values for air pollutants from various sources, 1996 $/ton

	Nox			VOCs			CO			PM10			SO2		
	hi	low	hi/ low	hi	low	hi/ low	hi	low	hi/ low	hi	low	hi /low	hi	low	hi/ low
W&S 95 literature	17635	256	68.9	8415	110	76.5	4	0	-	57982	671	86.4	9041	341	26.5
Leach 97	33378	1450	23.0	23219	290	80.1	5805	1450	4.0	21768	290	75.1	24670	1450	17.0

literature															
literature min & max	33378	256	130.4	23219	110	211.1	5805	0	-	57982	290	199.9	24670	341	72.3
lit mean	25507	853	29.9	15817	200	79.1	2905	725	4.0	39875	480.5	83.0	16856	895.5	18.8
W&S 95 model	8389	3458	2.4	4310	1644	2.6	-	-	-	13199	3604	3.7	4383	2691	1.6
Mean of model & lit. rounded to 100	16900	2200	7.7	10100	900	11.2	2900	700	4.1	26500	2000	13.3	10600	1800	5.9

Sources for table: W&S 95: Wang, Q.W. and D.J. Santini, 1995. "Monetary Values of Air Pollutant Emissions in Various US Regions." *Transportation Research Record #1475.* Washington, DC: National Academy Press. Values from Wang and Santini's Table 1, converted from 1989 dollars.

Leach 97: Leach, M.A. Bauen, and N. Lucas, 1997. "A systems approach to materials flow in sustainable cities: A case study of paper." *J. Env Plan Mgt, 40 (6)*: 705-723, which adapted data from a literature review by Hormandinger, G (1995): Fuel cells in transportation, unpublished MSc thesis (University of London, Imperial College of Science, Technology and Medicine, Centre for Environmental Technology). Values adopted from Leach et al.'s Figure 4, and converted from 1996 British pounds.

Wang and Santini did not develop a regression model for CO, as they were focusing on electric power plants and contended that CO's reactivity made CO emissions from such point sources unlikely to lead to human exposures. For this pollutant, we adopt the mean and max values which are each half of those reported by Leach et al., since both the high and low values, which essentially leads to taking min and max values which are half of those reported by Leach et al., since both the high and low values cited by Wang and Santini are essentially zero.

Wang and Santini did not review estimates for damage costs of CO2. For this principal greenhouse gas we calculate the difference between the low and high-end extremes reported by Leach et al. We then adopt a low range value which is Leach's low-end plus 20% of this difference, and a high range value which is Leach's high-end minus 20% of the difference. These results are summarized in Table 3-2.

Table 3-2: Damage values for carbon dioxide emissions, 1996 $/ton, [Leach et al. 1997]

Minimum published value	1.5
Maximum published value	51
Difference	49.5
Minimum +20% of difference	12
Maximum -20% of difference	41

Source for table: Leach 97: Leach, M.A. Bauen, and N. Lucas, 1997. "A systems approach to materials flow in sustainable cities: A case study of paper." *J. Env Plan Mgt, 40 (6)*: 705-723, which adapted data from a literature review by Hormandinger, G (1995): Fuel cells in

Technology and Medicine, Centre for Environmental Technology). Values adopted from Leach et al.'s Figure 4, and converted from 1996 British pounds.

Obviously, the low and high end estimates which we have adopted for all pollutants based on these reviews do not have a formal statistical or confidence interpretation. As mentioned above, the intent in selecting them was to reflect the strong variability among estimates without adopting the extreme outliers as our scenario values. Thus, our low-end values are roughly mid-way between centrally-tending values and published low-end extremes; and our high-end values are roughly mid-way between centrally-tending values and published high-end extremes.

Back to top

Return to the most frequently asked questions about The Top 20

Return to The Top 20 Priorities

Pollution Prevention Home | OPPT Home

EPA Home | Privacy and Security Notice | Contact Us

Last updated on Friday, June 9th, 2006
URL: http://www.epa.gov/oppt/epp/pubs/guidance/top20faqexterchart.htm