Chapter 3

Transported Air Pollutants: The Risks of Damage and the Risks of Control

Contents

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As discussed previously, the risks of transported air pollutants are amenable only to qualitative descriptions. Certain aspects can be described numerically—for example, the numbers of lakes and streams currently altered by acid deposition, or people exposed to health risks from airborne sulfates and other small particles. Wherever possible, this report also presents numerical estimates of the risks to a region's resources, industry, jobs, and consumer pocketbooks, However, the substantial uncertainties associated with available data and theory mean that these numerical descriptions should be viewed as qualitative estimates, rather than exact, quantitative answers. One should not be misled by the apparent precision of the numbers. The information presented is intended to convey approximate outcomes—in some cases with unknown margins of error— and broad regional patterns.

This chapter summarizes the OTA estimates of risk to the Eastern United States as a whole. OTA-sponsored or in-house work provides the basis for most of these estimates. Chapter 5 will examine who bears these risks, by State and by economic sector. These chapters use the somewhat artificial dichotomy of *mandating further emissions reductions vs. maintaining the status quo* as a framework for describing potential consequences. Chapters 6 and 7 of this report present congressional options, including interim decisions, in greater detail.

NO CONGRESSIONAL ACTION

Resources at Risk

Two factors determine the potential for resource damage from transported air pollutants: 1) the *amount* of pollution to which the resource is exposed, and 2) the *sensitivity* of resources to acid deposition and ozone. Resource sensitivity varies from resource to resource— and among the specific plants, animals, soils, and materials within each resource category. Some resources are *directly affected* by the pollution received. For example, crops are affected by exposure to ozone, and some building materials are affected by acid-producing substances deposited on their surfaces.

For other resources, sensitivity also depends on characteristics of the local environment. For example, lakes and streams are affected primarily by the amount of acid-producing substances that eventually travels through the watersheds to lakes and streams, as well as by the acid deposition that falls directly onto the surface of the water. The acid-neutralizing capabilities of the soil and bedrock in the surrounding watershed help determine the susceptibility of water bodies to acid deposition. Acid deposition may affect forests through subtle soil chemical changes—here again, the sensitivity of the forest resource could largely depend on soil characteristics.

Aquatic Ecosystems

More is known about how acid deposition affects aquatic ecosystems—and the current extent of these effects—than for any other resource. Substantial evidence indicates that acid deposition alters water chemistry in sensitive lakes and streams. Most vulnerable are small lakes and streams in watersheds that have little capability to neutralize acid, due either to the chemical composition and/or thinness of the soils, or to terrain that is so steep or rocky

[1]This section is based primarily on material from: The Institute of Ecology, "Regional Assessment of Aquatic Resources at Risk From Acid Deposition, contractor report submitted to the Office of Technology Assessment, 1982.

Photo credit: Lars Overrein

Highly acidified waters, and water chemistry changes caused by acidity, may prevent fish from developing. In the experiment illustrated above. Brown trout eggs were placed simultaneously in waters of differing acidity. The embryos shown at left failed to develop in acidic water (pH 4.6). The fry at right were raised in less acid water (pH 5.5) and appear normal

that rainfall runs over it before acid can be neutralized.

Fish are sensitive both to the acidity of water, and to toxic metals-primarily aluminum-that are released from the watershed under acid conditions. When waters become more acid than pH 5, many fish species are eliminated and major changes in lake ecosystem processes frequently occur. High acidity, toxic concentrations of metals such as aluminum, or some combination of the two appear to cause these changes.

Based on the predominant soil and geological characteristics in each county, OTA classifies about 25 percent of the land area of the Eastern 31-State region as "sensitive, i.e. , allowing the transport of acidity through a watershed to lakes and streams. Within these identified sensitive regions are approximately 17,000 lakes and 112,000 miles of streams —these figures provide an upper bound of the aquatic resources at risk. Only a portion of the total number of lakes and streams in the sensitive regions should currently be considered vulnerable to acid inputs. Small lakes and stream segments are, in general, most susceptible to change. While some areas have geologic characteristics that make them sensitive to acidification, they may not receive enough acid deposition to alter the water quality of lakes and streams. In addition, local variations in geology, soil conditions, and topography affect the land's ability to prevent acidification of water bodies.

OTA used available water quality data from about 800 lakes and 400 streams throughout eight States in the Eastern half of the United States to estimate the number of lakes and streams currently vulnerable to acid deposition. OTA estimates that about 9,500 lakes and 60,000 miles of streams currently have limited acid neutralizing capabilities such that, given sufficient acid deposition, they might acidify—a "best guess' encompassing about half the upper-bound estimate presented earlier.

OTA also used available water quality data, correcting for a percentage of lakes and streams that may be naturally acidic, to estimate that about

3,000 lakes and 23,000 miles of streams have already become acidified, or have so little acid-neutralizing capability left that they are extremely vulnerable to further acid deposition. This corresponds to about 20 percent of the lakes and streams found in identified sensitive areas.

Of the approximately 50,000 lakes in Eastern Canada, the Ontario Ministry of the Environment estimates that about 20 percent, or 10,000, are currently acid-altered. *

Scientists cannot yet estimate how many more lakes and streams could become acidified if current levels of acid deposition continue into the future. Two cumulative processes are important: 1) the potential loss of the soil's ability to neutralize acid inputs, and 2) for lakes, the accumulation of acidifying substances over years to decades, until lake waters come into equilibrium with the level of deposition received from the watershed. The latter process delays lake response to acid deposition, with greater time delays in larger lakes and lakes with slow rates of water replacement.

Many smaller acid-altered lakes and streams in the Northeast are probably in equilibrium with present deposition levels. By assuming that continued acid deposition will not further degrade the soil's neutralizing capability-the ' 'best-case' situation—one can estimate improvements in water quality that reduced levels of acid deposition might produce. OTA used a simple, theoretical model to project how future *changes* in acid deposition levels might change the numbers of acid-altered lakes and streams in the Eastern United States. If sulfate deposition were decreased by 20 percent, OTA estimates that 10 to 25 percent of these water bodies might show improvement. If sulfate deposition were reduced by 30 percent, about 15 to 40 percent might show improvement. If sulfate deposition were increased by 10 percent, OTA estimates that acid-alteration of lakes and streams might intensify by about 5 to 15 percent.

Again, these are best-case estimates, assuming that the effects of acid deposition are *not* cumulative. However, in those areas that are not in equilibrium with above-normal deposition levels, some lakes and streams might still continue to acidify slowly despite the reduction levels discussed above. Such effects might be most pronounced in the Southeast and upper Midwest.

● LI.S. -Canada Memorandum of Intent on Transboundary Air Pollution, Impact Assessment, Work Group 1, February 1983.

Terrestrial Ecosystems

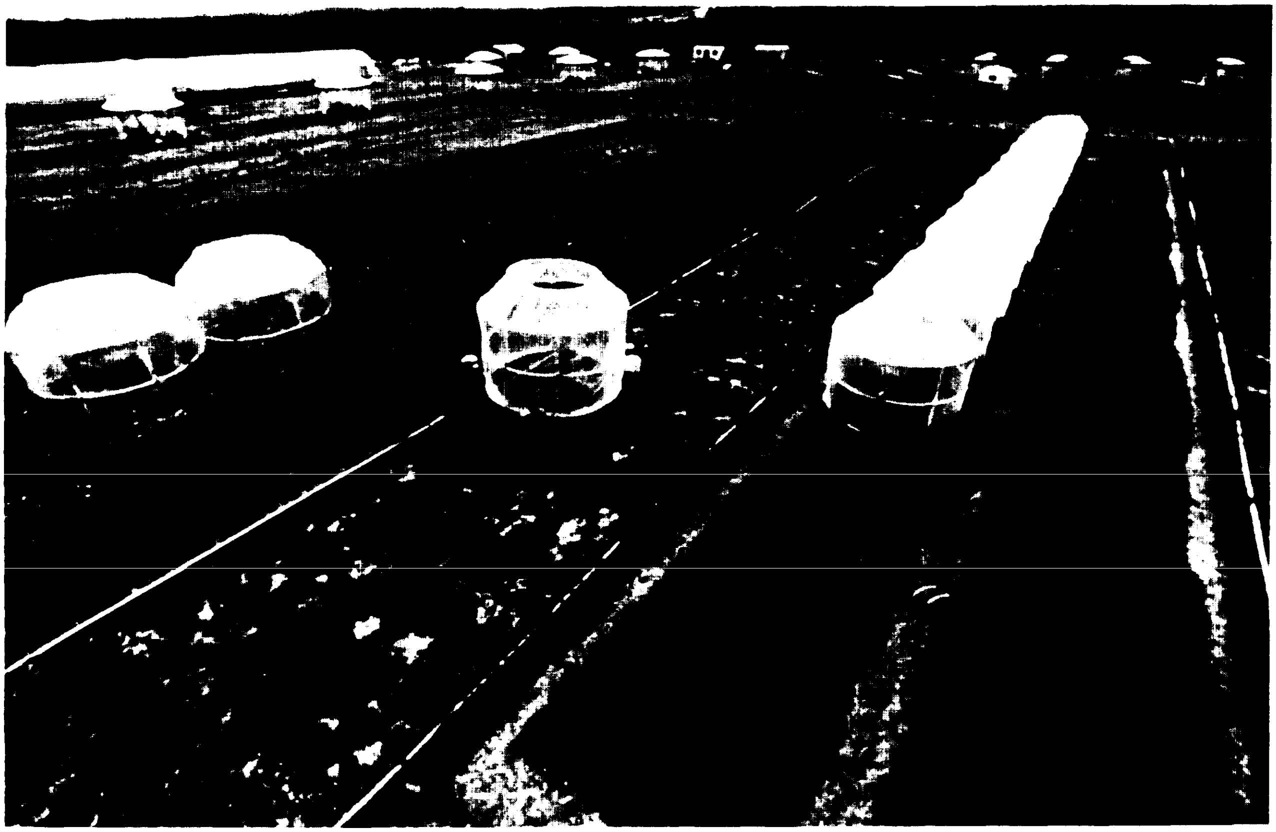
A variety of transported air pollutants affects both croplands and forested ecosystems. Ozone, a gaseous pollutant toxic to plants, may account for up to 90 percent of air pollution-related damage to crops. How much crop damage is due to transported rather than locally produced ozone is uncertain. Observed effects include both damage to the quality of crops (e. g., leaf spotting) and reductions in crop yield.

Damage to crops from acid deposition under *natural* conditions has not yet been observed, although experiments using simulated acid rain have shown reduced yields and altered crop quality. Since the chemistry of agricultural soils is already highly controlled with fertilizers and other chemicals, the primary effects of acid deposition would likely be on the above-ground portions of plants. The role of pollutant ***mixes*** may also be significant, since acid deposition seldom occurs in the absence of other pollutants. In some cases, it appears that the presence of sulfur or nitrogen oxides in the atmosphere makes crops more susceptible to ozone damage.

To assess the risks to crops from transported air pollutants, OTA has estimated the benefits that might result from reducing *ozone* concentrations to natural "background' levels. Similar estimates of the effects of acid deposition on crops, or of the effects of pollutant mixes, are not yet possible.

Data from field experiments were used to estimate ozone effects on crop productivity for peanuts (a sensitive crop), soybeans (sensitive/intermediate), wheat (intermediate), and corn (tolerant). These "dose-response' relationships were then combined with 1978 ozone monitoring data and 1978 agricultural statistics. Results suggest that if ozone con-

[2]This section is based primarily on material from: Oak Ridge National Laboratory, Environmental Sciences Division,' 'An Analysis of Potential Agriculture and Forest Impacts of Long-Range Transport Air Pollutants, contractor report submitted to the Office of Technology Assessment, 1982.



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centrations had been reduced to natural, background levels in 1978, corn yields would have increased by 2 percent, wheat by 5 percent, soybeans by 13 percent, and peanuts by 24 percent. As measured by 1978 crop prices, ozone caused about a 6- to 7-percent loss of agricultural productivity, of which almost two-thirds stemmed from soybean losses.

In forest ecosystems, transported pollutants may directly damage trees, as well as affect the soils in which trees grow. Because trees are long-lived species, they are vulnerable to long-term chronic effects. Scientists have documented ozone damage to the foliage of many tree species, but the concentrations of ozone necessary to cause damage is not well known. About one-quarter to one-third of the forested land area in the Eastern United States is exposed to ozone concentrations about twice the natural background levels.

Concern over the effects of acid deposition and ozone on forests stems from observed productivity declines and tree death in areas with elevated pollution levels. Pests or disease—common causes of forest declines—do not appear to be responsible for damage in such areas as the Adirondack Mountains in New York, the White Mountains in Vermont, the Pine Barrens in New Jersey, the Shenandoah Mountains in Virginia, the Smoky Mountains in Tennessee, and forested areas of West Germany. Acid deposition, ozone, heavy-metal deposition, severe winters, drought, or a combination of these are possible causes under investigation. Acid deposition might be a factor either by affecting trees directly or by altering the soils on which trees grow.

Acid deposition can remove essential nutrients such as calcium and magnesium ***directly*** from tree foliage. If the rate of nutrient loss is greater than can be replaced through the roots, nutrient defi-

Photo credit: Arthur Johnson

Dead and dying red spruce at Camel's Hump in the Green Mountains of Vermont. Tree death and growth decline of red spruce in Northeastern forests have led some researchers to speculate about potential links between forest damage and acid deposition. Scientific investigations cannot yet confirm or rule out acid deposition as a contributor to the observed damages

ciency will result. Scientists do not know which tree species are most susceptible to foliar nutrient loss, or the level of acid deposition at which such loss becomes harmful.

Forest soils may be altered by acid deposition with either beneficial or harmful results. The nitrates and sulfates from acid deposition can supply essential plant nutrients. In many areas, nitrogen in the soil is in short supply; on these soils nitrates in acid rain might improve forest productivity. Sulfur-deficient soils, however, are quite rare.

Nonacidic or weakly acidic soils typically contain such large quantities of neutralizing substances (e. g., calcium) that harmful changes to these soils seem unlikely. Of greatest concern are forest ecosystems with naturally acidic soils. The major soil-mediated risks from acid deposition include:

1. mobilization of metals such as aluminum that are toxic to plants in sufficient quantity, and
2. the potential stripping of calcium, magnesium, and other nutrients essential for plant growth from the soil.

Naturally acidic soils occur fairly extensively, being the predominant soil type in about half the counties east of the Rocky Mountains covered by forest or rangeland. In about one-third of these acidic soils, the strong, freely moving acids from acid deposition can release aluminum and other toxic metals from the soil. However, whether toxic metals are released in sufficient quantities to affect forest productivity is unknown. The remaining two-thirds of Eastern acidic soils are underlain with surface layers that can trap sulfate, possibly preventing the release of aluminum in these areas.

Acid deposition can remove essential nutrients such as calcium and magnesium from the soil, but the ***rate*** of removal-and the importance relative to other factors—is difficult to determine. Moderately acid soils are thought to lose nutrients at a faster rate than more acid soils, but the more acid soils typically have less nutrients. On nutrient-poor acid soils, especially those where sulfate can travel freely through the soil, further nutrient loss—even at a slow rate—from the soil, forest canopy, and decomposing plant material might be significant. About 15 to 20 percent of the Eastern counties meet these criteria, but whether nutrient loss is significant enough to affect near-term forest productivity is unknown.

Though relatively rare in the Eastern United States, some moderately acid soils might further acidify from nutrient loss over decades of exposure to acid deposition. About 1 to 5 percent of the Eastern counties (depending on the soil criteria used) are dominated by soils of this type.

Data and knowledge limitations prevent **a** more detailed description of the risks of transported air pollutants to forests than given above. Of concern are forested lands exposed to: 1) high ozone concentrations, 2) high levels of acid deposition, or 3) underlain with soils that maybe sensitive to acid deposition.

Other Resources

Air pollution damages a broad range of materials-including building stone, rubber, zinc, steel, and paint. Ozone is the pollutant that most affects rubber, while many other materials are chiefly affected by sulfur oxides. Humidity plays a key role in materials damage—dry-deposited sulfur dioxide and sulfate that dissolve on moist surfaces (forming concentrated sulfuric acid) may cause greater damage than relatively less acidic rain. Since air pollution is only one of many environmental factors (e. g., temperature fluctuations, sunlight, salt, micro-organisms) that cause materials damage, it is difficult to determine what proportion of damage it accounts for. Moreover, it is difficult to determine the proportion of materials damage caused by transported pollutants as opposed to local pollution sources.

Analyses of the monetary costs of materials damage frequently make assumptions about the quantity of sensitive materials exposed to elevated pollution levels and the effects of damage on replacement or repair rates. A recent EPA-funded study employed an alternative approach, using data on expenditures in 24 metropolitan areas and 6 manufacturing sectors to estimate the extra materials-related costs attributable to sulfur pollution.[3] It concluded that reducing sulfur dioxide emissions in urban areas to meet concentrations about 25 to 30 percent below the national primary standard would create benefits of approximately $300 million annually for about one-half the households and about 5 to 10 percent of the producing sector in the United States. These results cannot be extrapolated to provide estimates of benefits to the Nation overall, as the lack of necessary data precludes analyzing the rest of the economy in this manner.

Photo credit: Ted Spiegel

Statues in a Kentucky cemetery illustrate one of the difficulties in assessing pollution-related damages to materials. Acidic pollutants and natural weathering have helped erode both the covered and uncovered marble statues shown above. However, rainfall also washes away some of the dry-deposited pollutants from the uncovered statue at right

Yet another resource at risk from transported air pollutants is visibility.[4] Visibility levels depend on a number of factors, including humidity, manmade pollutant emissions, and such other factors as fog, dust, sea spray, volcanic emissions, and forest fires.

Pollutants impair visibility by scattering and absorbing light. Concentrations of fine particles-primarily sulfates and nitrates—can sufficiently inter-

[3] E. H. Manuel, Jr., et al., "Benefits Analysis of Alternative Secondary National Ambient Air Quality Standards for Sulfur Dioxide and Total Suspended Particulate, Mathtech, Inc., report submitted to the U.S. EnvironmentaJ Protection Agency, OAQPS, 1982.

[4] This subsection is based primarily on: B. L. Niemann, "Review of the Long-Range Transport of Sulfate Contribution to Regional Visibility Impairment, contractor report submitted to the Office of Technolog, Assessment, 1983.

fere with the transmission of light to reduce visibility levels significantly. Elevated levels of these and other particles in the atmosphere periodically create regional haze conditions, reducing contrast, distorting nearby objects and causing distant ones to disappear, discoloring the atmosphere, and decreasing the number of stars visible in the night sky. Examination of airport data, pollution measurements, and satellite photography also indicates that regional-scale hazy air masses move across large geographic areas, and cause significant visibility reduction in areas with little or no air pollutant emissions. Episodic haze conditions during summer currently make it the worst season for visibility.

Sulfate concentrations correlate well with visibility impairment over large regions of the United States; in the East, sulfate appears to be the single most important contributor to visibility degradation. Recent studies suggest that sulfates account for 70 percent of visibility impairment during the summer, and 50 percent annually, in the Eastern United States. Nitrates rarely contribute substantially to visibility degradation in the East. However, in the Western United States, windblown dust and nitrogen oxides can also reduce visibility significantly.

Photo credit: John Skelly

View of the Peaks of Otter in the Shenandoah National Park under different visibility conditions. The picture at top was taken on a relatively pollution-free day; the picture on the bottom shows the same scene when a regional-scale hazy air mass obscures the view

Risks of Health Effects[5]

Extremely small particles, including airborne sulfates, are the component of transported air pollutants of greatest concern for human health. These small particles can travel long distances through the atmosphere and penetrate deeply into the lung if inhaled. Statistical (cross-sectional) studies of death rates throughout the United States have found some correlation between elevated mortality levels and elevated ambient sulfate levels. Whether sulfate is actually linked to premature mortality, or merely indicates other harmful agents (e. g., other particulate) associated with sulfates, is unknown.

To estimate damages caused by transported air pollution quantitatively, OTA used sulfate concentrations as an index of this “sulfate/particulate mix. The analysis projected a *range* of mortality estimates for a given population exposure level, in order to incorporate disagreements within the scientific community over the significance of sulfates to human health. While some researchers conclude there is a negligible effect, others have found a significant association, ranging up to 5 percent of the deaths per year in the United States and Canada attributed to current airborne sulfate/particulate pollution. Though further research and data are needed to resolve this controversy, this pollutant mix could be responsible for about 50,000 premature deaths per year (about 2 percent of annual mortality), particularly among people with preexisting respiratory or cardiac problems. If pollutant emissions remained the same through the year 2000, increases in population might cause slightly higher numbers of premature deaths; a 30-percent decrease in emission levels by 2000 might reduce the percentage of deaths annually attributable to air pollution to 1.6 percent (40,000 persons). In each of these cases, ranges of mortality are estimated to extend from zero deaths to about three times the number reported above.

[5]This section is based primarily on: Brookhaven National Laboratory, Biomedical and Environmental Assessment Division, “Long-Range Transport Air Pollution Health Effects, contractor report submitted to the Office of Technology Assessment, 1982.

Researchers have not found consistent associations between health effects and outdoor concentrations of nitrogen oxides. High localized concentrations of nitrogen dioxide are considered greater cause for concern than ambient levels of transformed and transported nitrogen oxide pollutants. However, quantitative estimates of health-related damages due to nitrogen oxides, or of the populations at risk from these pollutants, cannot yet be developed.

Acidified waters can dissolve such metals as aluminum, copper, lead, and mercury, and release such toxic substances as asbestos, from pipes and conduits in drinking water distribution systems as well as from soils and rocks in watersheds. Water samples from some areas receiving high levels of acid deposition show elevated metal concentrations, raising concern about a possible connection between acid deposition and degradation of drinking water quality. Drinking water samples in the Adirondacks have shown lead concentrations of up to 100 times health-based water quality standards. Mercury concentrations above public health standards have been found in fish from acidified lakes in Minnesota, Wisconsin, and New York. Elevated levels of aluminum and copper, two metals not considered toxic to the general public, have also been found both in Adirondack well water and in surface water samples throughout New England. Acidified municipal water supplies can be monitored and corrected quite easily. However, acidified well water in rural areas is more difficult to detect and mitigate. Potential health effects due to acidification of these water supplies and subsequent leaching of toxic substances remain of concern.

Potential for the Courts or EPA To Rule in the Absence of Congressional Direction[6]

The existing Clean Air Act does not directly address long-range pollution transport; however, provisions added to the Act during a previous reauthorization (1977) require States and EPA to ensure that stationary sources of pollution in any given State do not prevent attainment of air quality standards in another State. These provisions are worded very generally; the act contains no procedures or guidelines for determining how interstate pollution effects are to be measured, or what levels of interstate transport are impermissible.

A number of States have sought to use these interstate pollution provisions as a vehicle for compelling other States to curb emissions of transported pollutants. These States have challenged EPA-approved pollution control plans in court, and have petitioned EPA to require reductions in cumulative emissions from upwind States in order to abate present levels of interstate pollution. EPA has made no determinations on petitions requesting relief from long-range pollution effects; however, in legal proceedings the Agency has taken the position that no reliable analytic tools are currently available to assess long-range pollution transport. Affected parties are likely to challenge any future EPA determination on these petitions in court; thus, in the absence of further congressional action, the judicial branch could ultimately be required to arbitrate the long-range transport controversy.

Risk of Strained International Relations[7]

Present Federal policies on transported pollutants have also strained relations between the United States and Canada. Bilateral efforts are proceeding under a Memorandum of Intent (MOI) to develop an accord on the acid deposition issue. However, the Canadian Government has not been pleased by the progress of these negotiations. A dissatisfied Canada could choose to link the acid rain issue to other important areas of bilateral concern. The Clean Air Act currently provides Canada no explicit means of legal recourse for abating long-range transported air pollution from the United States. However, the previous administration took actions under the international provision of the Clean Air Act that may have created a legal obligation for this country to reduce emissions.

[6]This section is based primarily on material from: ' 'Avenues for Controlling Interstate Pollution Under the Current Clean Air Act, the Office of Technology Assessment staff paper, 1982.

[7]This section is based primarily on material from: Environmental Law Institute, "Long-Range Air Pollution Across National Boundaries: Recourses in Law and Policy, contractor report submitted to the Office of Technology Assessment, 1981.

IF FURTHER EMISSIONS REDUCTIONS ARE MANDATED

Of the major transported pollutants, congressional attention has focused on controlling acid deposition. Acid deposition results from both sulfur and nitrogen oxides; however, in the Eastern United States, sulfur oxides currently contribute about twice as much acidity as nitrogen oxides. Several bills proposed during the 97th and 98th Congresses would mandate reducing sulfur dioxide emissions by about one-third to one-half either throughout the continental United States or in the 31 States bordering and east of the Mississippi River.

Of the 26 to 27 million tons of sulfur dioxide emitted in the United States during 1980, about 22 million tons were emitted in the Eastern 31 States. Electric utilities emitted about 70 to 75 percent of the total eastern, approximately 16 million tons. Non-utility combustion (primarily industrial boilers) accounted for about 10 to 15 percent of the total, with the remainder coming from industrial processes and other sources. Each of three States—Ohio, Pennsylvania, and Indiana—emitted in excess of 2 million tons of sulfur dioxide per year, totaling 30 percent of the region's emissions. Six additional States—Illinois, Missouri, Kentucky, Florida, West Virginia, and Tennessee—emitted in excess of 1 million tons each, together producing an additional 30 percent of the 3 1-State total.

Most current legislative proposals would place the greatest burden of emissions reductions on the utility sector and the Midwestern States. The costs likely to result from a control program include:

1. increased electricity costs to consumers,
2. loss of coal production and subsequent unemployment in regions where high-sulfur coal is mined, and
3. financial strain to certain vulnerable utilities and industrial corporations.

The *risk* imposed by a control program is that some of these costs might be unnecessary. A control program designed 10 years hence might achieve the same level of protection at lower cost than one designed today; similarly, the level of required protection might be more accurately identified. This section first presents the potential costs of control, and then discusses the risk that the control program might not be as efficient or cost effective as desired.

Utility Control Costs

Both the total tonnage of sulfur dioxide to be eliminated, and control costs per ton, determine the cost of controlling utility sulfur dioxide emissions. Costs rise as greater removal is sought, both because more emissions are being controlled and because the cost of eliminating each additional ton of sulfur dioxide increases. OTA estimates the costs of reducing sulfur dioxide emissions in the 31 Eastern States, in 1982 dollars, to be about:

- $0.5 to $1 billion/year to eliminate about 4 to 5 million tons/year
- $1 to $2 billion/year to eliminate about 6 to 7 million tons/year
- $2 to $2.5 billion/year to eliminate about 8 million tons/year
- $2.5 to $3.5 billion/year to eliminate about 9 million tons/year
- $3 to $4 billion/year to eliminate about 10 million tons/year
- $4 to $5 billion/year to eliminate about 11 million tons/year

The estimates above are based on the costs of controlling utility emissions, and do not include costs to offset any ***future emissions increases*** from utilities and industry. These costs can also be presented as percent increases in average residential rates for electricity, on both a regional and State basis. For example, a 50-percent reduction in utility sulfur dioxide emissions (8 million tons per year, about 35 percent below total regional emissions) would increase ***average*** residential rates by about 2 to 3 percent. Rate increases would vary by State, of course—consumers in some States would pay no increases, while others would pay over twice the regional average. For specific utilities, costs may be somewhat higher—several utilities have asserted that their residential rates might increase by 25 percent or more.[8]

These cost estimates are for control strategies that limit ***rates*** of emissions—sulfur dioxide emitted per quantity of fuel burned—similar to provisions in several bills proposed during the 97th and 98th Congresses. The range of cost estimates for each reduction level presented above reflects alternative methods of allocating emissions reductions within a State. In addition, the estimates assume that each utility chooses the most cost-effective method applicable to plant conditions. This results in a mix of scrubber use and fuel switching throughout the region.

The cost of removing a ton of sulfur dioxide is generally lower when a plant's emission rate is high. Consequently, total regional control costs are lower when emissions cutbacks are allocated to States on the basis of their emissions rates than when equal percentage reductions are required for all States. As discussed in chapters 6 and 7, this method of allocating reductions concentrates a higher proportion of reductions on Midwestern States whose utilities burn high-sulfur coal. However, many areas that currently have lower sulfur dioxide emissions rates already pay higher electricity costs than prevail in the Midwest.

Effects on the U.S. Coal Market

Switching from high- to low-sulfur coal is one of the major available options for achieving substantial emissions reductions. Consequently, mandating further emissions reductions creates the risk of significant coal-market disruptions by increasing the demand for low-sulfur coals at the expense of high-sulfur coals. Risks of production and employment losses occur almost exclusively in the Eastern United States, where coal reserves are primarily of high-sulfur content. The Western coal-producing States, and parts of Kentucky and West Virginia, contain low-sulfur coal reserves and might therefore benefit from acid deposition controls. For the nation as a whole, regulations designed to control acid deposition would probably not affect total coal production.

The extent to which utility and industrial users would shift to low-sulfur coal depends on the relative cost advantage of fuel switching as opposed to removing sulfur dioxide by technological means (e.g., scrubbers). Each method has clear advantages for some situations, but for many plants, the cost difference is modest enough to make predictions of future preferences highly uncertain. The following projections of future coal production and employment shifts are based on current costs, and might change significantly if new control technologies become available or coal prices change.

OTA estimated the extent to which coal production and employment would be affected by an emissions reduction program of 10 million tons or more that neither mandates nor provides financial incentives for using particular control technologies. Under such a program, 1990 levels of production in the high-sulfur coal areas of the Midwest (Illinois, Indiana, and western Kentucky) and Northern Appalachia (Pennsylvania, Ohio, and northern West Virginia) might decline to about 10 to 20 percent below 1979 levels. Estimates of production declines are averaged over these regions, and thus may be greater or less in some States and counties than others.

For the low-sulfur coal areas of Central Appalachia (eastern Kentucky, southern West Virginia, Tennessee, and Virginia) and the Western United States, acid rain control measures are projected to expand coal production beyond currently projected 1990 levels. This effect is more pronounced in Central Appalachia than in the West, due to its proximity to Eastern markets.

In general, ***employment*** changes would follow changes in production. A 10-million-ton emissions cutback is projected to reduce employment in ***high-sulfur coal-producing areas*** by between 20,000 and 30,000 jobs from projected 1990 levels. About 15,000 to 22,000 additional jobs would open up in Eastern low-sulfur coal-producing areas, and an additional 5,000 to 7,000 jobs in the West. The risk of unemployment is most severe in Illinois, Ohio, northern West Virginia, and western Kentucky—for these areas, coal-mining employment is projected to decline more than 10 percent below current levels.

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8 'A Report on the Results From the Edison Electric Institute Study of the Impact of the Senate Committee on Environment and Public Works Bill on Acid Rain Legislation (S. 768), " National Economic Research Associates, Inc., report submitted to Edison Electric Institute, 1983.

Photo credit: Douglas Yarrow

Last shift comes out at Eccles #5 before the 1977 contract strike

These employment shifts would cause proportional changes in direct miner income. At the national level, benefits to low-sulfur regions are projected to balance out losses to high-sulfur regions. This level of aggregation, however, obscures the regional distribution of coal-related economic costs. Direct income effects for a 10-million-ton emissions reduction are estimated below:

- Northern Appalachia: $250 to $350 million per year *loss;*
- Central Appalachia: $400 to $550 million per year gain;
- Midwest: $250 to $400 million per year loss;
- West: $100 to $200 million per year *gain.*

The total economic impacts of coal-market shifts—reflecting, in addition, indirect employment and income effects on other economic activities—may be two to three times greater.

Effects on Utility and Industrial Financial Health

While the costs of further controlling utility sulfur emissions are ultimately passed on to electricity consumers, they can strain the resources of financially troubled utilities that must initially pay them. Additionally, reducing industrial process and boiler emissions imposes the risk of rendering sulfur dioxide-emitting industries in controlled regions less competitive than their less or uncontrolled counterparts in other geographic areas.

On the basis of average 1980 utility bond ratings and stock indicators, utility sectors in eight States appeared to be relatively vulnerable to the additional capital requirements that could result from further sulfur dioxide control: Arkansas, Connecticut, Florida, Maine, Michigan, Pennsylvania, Vermont, and Virginia. * If cutbacks are allocated on the basis of emissions rates, three of these States—Pennsylvania, Florida, and Michigan—are likely to be required to reduce emissions significantly. Greatest reductions would be required in Pennsylvania, where present State regulatory policies also cause substantial delays before utilities can pass increased fuel costs and/or construction costs on to consumers.

Several other States have regulatory policies considered unfavorable to utility pollution control expenditures, although their utilities showed better average financial health in 1980. The regulatory policies set by public utility commissions in each State can significantly affect the financial burden of raising additional capital to further control sulfur dioxide emissions. Such policies vary substantially from State to State. Moreover, these policies are subject to change, and might themselves be affected by the passage of new pollution control legislation.

Major increases in electricity costs due to increased controls might also hurt utilities by reducing demand for electricity. However, OTA-projected increases in average electricity rates resulting from stricter sulfur dioxide emissions controls are not high enough to affect demand for electrical power appreciably.

OTA also identified industries in which electricity is a major component of production costs. For about 15 industries, concentrated primarily in the areas of primary metals, chemicals and allied products, and stone, clay, and glass products, electricity costs exceed 10 percent of the value added* by the manufacturer—nearly four times the national average. Electricity costs are equal to about 40 percent or more of the value added in industries that produce electrometallurgical products, primary zinc, primary aluminum, alkali- and chlorine-based chemicals, and industrial gases—these five industries alone use about 16 percent of the electricity consumed by industry in this country. Within these energy-intensive industries, manufacturers served by utilities with high control costs might be rendered less competitive than those in regions that are either uncontrolled or incur lower control costs.

Preliminary analyses of industrial process emissions also suggest some potential for economic dislocation in the iron and steel and cement industries if their emissions were to be strictly controlled. Stricter sulfur dioxide emissions controls, if imposed in the Southwestern United States, could also create hardships for the region's currently depressed copper smelting industry.

‘Individual utilities in relatively weak financial conditions were also found in Massachusetts, Indiana, Ohio, Georgia, New Jersey, and West Virginia.

•' 'Value added" is the difference between the selling price of the product and the cost of energy and materials to manufacture it.

RISK THAT CONTROL MAY NOT BE AS EFFECTIVE OR EFFICIENT AS DESIRED

Proposals for controlling sulfur dioxide emissions aim to reduce sulfur deposition—a major contribution to acidification—in areas sensitive to its effects. However, as discussed previously, incomplete understanding of pollutant transport and transformation creates the risk that any control strategy designed at this time: 1) will not reduce deposition to the extent, and in the specific locations, desired; and 2) may not be as cost-effective as possible.

This section reviews estimates of the reduction in acid deposition needed to minimize further damage to sensitive resources—and the likelihood of reaching these "deposition targets" under alternative control strategies. In addition, the section discusses the potential for designing a more cost-effective strategy to reduce acid deposition by controlling nonsulfur pollutants in addition to sulfur dioxide.

Effectiveness of Emissions Reductions for Achieving Desired Deposition Reductions

While any major reduction in acid deposition levels would likely benefit some sensitive resources, scientists have attempted to define ' 'target' deposition levels—the maximum level of deposition for avoiding further damage to all but the most sensitive resources. * Target deposition values have been presented in reports by the National Academy of Sciences (NAS), the Impact Assessment Work Group established by the United States-Canada Memorandum of Intent on Transboundary Air Pollution, * * a working group at the 1982 Stockholm Conference on the Acidification of the Environment, and others. These have been expressed as levels of acidity, levels of sulfate in rainfall, or total deposited sulfur.

OTA estimated the reductions in ' 'wet sulfur deposition' —the sulfur deposited in rain and snow—necessary to reach these target deposition levels. As outlined in chapter 5 and appendix C, the estimates range from eliminating about 50 to 80 percent of deposition in those areas receiving highest levels, to eliminating about 20 to 50 percent of deposition over large regions of Eastern North America identified as having sensitive aquatic resources.

Several bills introduced during the 97th and 98th Congresses proposed cutting sulfur dioxide emissions back by about 8 to 10 million tons per year—about a 35 to 45 percent reduction in Eastern U.S. emissions. Using two different types of computer models, OTA estimated the sulfur deposition reductions that might result if these legislative proposals were enacted. The more optimistic model estimate suggests that both wet and dry sulfur deposition would be reduced by as much as 45 to 60 percent in the areas of greatest deposition. Both wet and dry sulfur deposition would be reduced by about 30 to 50 percent annually over large regions of Eastern North America. The second model projection—based on conditions that prevail during extreme pollution episodes—suggests that emissions reductions of 35 to 45 percent would comparably reduce ***dry*** sulfur deposition. However, the model predicts that wet sulfur deposition would respond less directly, decreasing by about 25 to 35 percent in areas of greatest deposition, and by 20 to 30 percent over much of Eastern North America, during high pollution episodes. [8]

These estimates provide a plausible range of deposition reductions that might result from reducing emissions by 35 to 45 percent. The reductions in total sulfur deposition estimated above are difficult to compare to target deposition levels, because these targets have been expressed in a variety of ways. However, the following preliminary conclusions can be drawn, subject to a large degree of uncertainty: In areas of greatest deposition, for example, western Pennsylvania, reducing Eastern United States sulfur dioxide emissions by 8 to 10 million tons per year might not be sufficient to bring deposition levels within the targeted maximum for protecting all but the most sensitive resources. In areas receiving less deposition, such as northern New England, the southern Appalachians, and the upper Midwest, sulfur dioxide emissions reductions of this magnitude are likely to achieve the target deposition levels.

Efficiency Concerns

Because large-scale cutbacks in sulfur dioxide emissions will cost billions of dollars annually, some have suggested that even if the deposition reduction goals could be achieved now, a more cost-effective program might be designed when atmospheric processes are better understood, Such concerns raise the following questions:

1, Can specific sources or source areas affecting sensitive resource areas be identified for emissions control?

● Maximum deposition targets are based on protecting aquatic resources, as too little is known about the sensitivity of other resources to allow similar levels of protection to be defined. In addition, most targets are based on amounts of wet deposition, since current data are insufficient for considering dry deposition.

•● Only the Canadian members of the Work Group recommended a target deposition value.

'A recent NRC study for the National Academy of Sciences used slightly modified model assumptions to reexamine the OTA analysis. The NRC committee concluded that reductions in wet sulfur deposition would more closely approximate the reductions in sulfur dioxide emissions than OTA had estimated. *Acid Deposition: Atmospheric Processes in Eastern North America*, Committee on Atmospheric Transport and Chemical Transformation in Acid Deposition, National Research Council, National Academy Press, Washington, DC., 1983.

2. Can cutbacks in other acidifying pollutants, such as nitrogen oxides, eliminate acid deposition for lower cost?
3. Can sulfur deposition be controlled more cost effectively by controlling co-pollutants such as reactive hydrocarbons concurrently with sulfur dioxide emissions?

Atmospheric transport models for linking source regions and receptor regions have been available for several years, but their accuracy is subject to debate, Current understanding suggests that, given the widespread distribution of sensitive resources, a program to bring deposition within the previously mentioned target rates in all sensitive areas would have to encompass most of the Eastern United States. Within some bounds, emissions reductions from one area can be substituted for reductions from another without jeopardizing the desired pattern of deposition, but the goal of minimizing total costs is likely to conflict with cost distribution goals. The dual problems of defining the value of one resource area relative to others, and equitably distributing costs, are difficult political questions that could not be solved through more accurate modeling capabilities.

Controlling nitrogen oxides may be less expensive for some sources than controlling sulfur oxides, but whether it is as efficient for preventing resource damage is subject to question. Currently, twice as much rainfall acidity comes from sulfur oxides as from nitrogen oxides. In addition, plants often take up nitrogen oxides as nutrients, further increasing the proportion of lake and stream acidity produced by sulfur oxides. Though future research may reveal that intermittent events—such as spring snow melts containing high levels of both deposited nitrogen oxides and sulfur oxides—are responsible for the greatest share of damage, current understanding suggests that sulfur oxides are the first choice for control.

Future research may reveal more cost-effective opportunities for reducing sulfur deposition by controlling co-pollutants concurrently with sulfur dioxide emissions. Preliminary modeling results indicate that the ratio of reactive hydrocarbons to nitrogen oxides is an important determinant of the atmospheric transformation of sulfur oxides. Though broad regional sulfur oxide deposition overall might remain relatively constant, reducing emissions of these co-pollutants along with sulfur dioxide might achieve more desirable patterns of deposition than would result from reducing sulfur dioxide emissions alone.