ACID RAIN: SCENARIO FOR SOLUTION

by

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ABSTRACT

Acid rain is a problem that has received much attention over the past several years, but it has remained unsolved. This paper presents an explanation of this complex environmental dilemma. It does not present a solution, but rather it suggests a scenario under which an efficient and effective solution should become a reality.

Most scientists now agree that acid rain is responsible for certain environmental damage across North America and Europe. However, devising and implementing a solution to this problem has proven to be close to impossible. Proposed remedies have not been able to placate both of the diametrically opposed sides on this issue, the environmentalists and the utility and business interests. Congressional discussion on acid rain has consistently broken down into a regional political battle and the executive branch has done little to address this issue.

This paper concludes that there are four events that must occur before the acid rain dilemma can be resolved: those involved in the acid rain issue must refrain from focusing solely on cost-benefit tools for analysis; the general public must become vocal on this issue; the environmentalists and the utility and business interests must soften their stands and work towards a compromise solution; and finally, an equitable method of distributing the costs of acid rain reduction must be determined.

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INTRODUCTION

"Acid rain"--a simple term that represents a vastly complex environmental dilemma. For almost two decades the environmental community, the utility industry and the government have battled over this issue, but the damage continues. This turmoil has cost millions of dollars and produced hundreds of conflicting reports, but little progress has been made to date. The solution to this crisis has so far eluded the participants.

In this paper I will attempt to explain the acid rain issue by describing the phenomenon itself, outlining the elements of proposed solutions, and discussing the positions of the combatants. Finally, I will conclude the paper by suggesting a scenario under which the "best possible" solution could become a reality.

SECTION 1--THE ENVIRONMENT

Although it is popularly known as acid rain, rain is not the only culprit. This phenomenon is more accurately described as acid deposition, as it includes acid snow, acid sleet, acid fog, acid mist, acid dew and "dry" deposits of acid particles, aerosols, and gases.[1]

The problem of acid deposition, as most experts agree, begins with the worldwide burning of coal, oil and natural gas. Despite general adherence to existing environmental controls, the smokestacks of electrical generating plants, industrial boilers, and smelters release 50 to 60 million tons of sulfur dioxide and nitrogen oxides annually, the chief precursors of acid rain. Nitrogen oxides are also emitted by the exhaust pipes of motor vehicles and slowly escape from chemical fertilizers.[2] It is true that natural sources such as volcanoes and mud flats can contribute to the formation of acid rain by generating sulfur dioxide, but their involvement is minimal.[3] Exhibit 1 displays a breakdown by percentage of the various sources of both sulfur dioxide and nitrogen oxides.

Other contaminants are also discharged by these activities. Acid deposition often contains other products of combustion, such as lead, zinc, mercury, copper, cadmium,

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[1]Robert H. Boyle, "An American Tragedy," Sports Illustrated, September 21, 1981, p. 70.

[2]Anne LaBastille, "Acid Rain: How Great a Menace?," National Geographic, November 1981, p. 657.

[3]Robert H. Boyle and R. Alexander Boyle, "Acid Rain," The Amicus Journal, Winter 1983, p. 22.

and nickel, among other poisonous heavy metals.[4] However, it is the oxides of sulfur and nitrogen which are the major ingredients in the formation of acid deposition.

Some of these pollutants hover above the city or industrial plant where they originated, however, most of the SO_2 and NO_x, reach higher altitudes, especially when vented upward by tall smokestacks. There they circulate with the air currents and weather systems.[5]

The sulfur dioxide and nitrogen oxides may travel over hundreds or even thousands of miles, across state and even national boundaries. En route, these pollutant molecules interact chemically with sunlight, moisture, oxidants, and catalysts to change into other compounds of sulfur and nitrogen. The longer the SO_2 and NO_x remain airborne, the greater the amount that undergoes this transformation. Eventually some of the compounds are captured within clouds or by moisture to form acid precipitation--which is actually a dilute solution of nitric and sulfuric acids.[6]

The remaining sulfur and nitrogen compounds descend to the earth as gases and dry particles. The first rainstorm or dewfall will transform them into droplets of acid.[7] Exactly where the deposition occurs depends both on the weather and the presence of other chemicals in the atmosphere that control the conversion of the pollutant particles into acidic compounds.[8] Exhibit 2 shows a map of the annual wet sulfate deposition for the eastern United States.

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[4]Boyle, p. 74.

[5]LaBastille, p. 657.

[6]Ibid.

[7]Ibid.

[8]Betsy Carpenter, "Yes, They Mind If We Smoke," U.S. News & World Report, July 25, 1988, p. 44.

Ironically, well-intended regulations unwittingly have been a major cause of this proliferation of acid deposition from its points of origin. In an attempt to improve the ambient air quality in the immediate vicinity of power plants and smelters, the governments of many industrialized nations, including the United States, ordered these operations to increase the height of their smokestacks. It was generally believed that building these tall stacks would bring about the mixing of the pollutant gases with large volumes of air which would dilute them to essentially harmless concentrations. Unfortunately, while ambient air quality standards in the areas of the plants improved greatly, the pollutants ultimately were distributed over a much larger geographic area as described above.[9]

For several years, many prominent scientists have debated the effects of acid rain on the environment. In the past the focus had mainly been a few fresh water ecosystems of the northeastern United States. However, in recent years the scientific community has paid increasingly more attention to the possible damage acid rain is inflicting upon aquatic ecosystems, forests, and buildings and monuments in many areas of North America and northern Europe. Currently, new charges that acid rain is endangering coastal waters and even human health have come to the forefront of the discussion.

The numbers are truly staggering where acid rain damage to fresh water ecosystems is concerned. In the U.S., one quarter of the Adirondack's lakes and ponds are too acidic to support fish, and half the streams of the mid-Atlantic coastal plain are threatened. In Canada, the Department of the Environment reports some 14,000 lakes are almost fishless, and an additional 150,000 are in peril. The news from Europe is not much cheerier, especially for countries downwind of major industrial cities. Half of

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[9]LaBastille, p. 662.

southern Norway's fish population has been wiped out, while in Sweden, fully 20% of its 85,000 lakes are damaged.[10]

In addition to these many areas which are already experiencing the detrimental effects of acid rain, there are even larger geographic regions which have been determined to be geologically vulnerable to this scourge. In the U.S., besides the well-known northeastern sector of the country, large acid-sensitive areas are now known to occur in Minnesota, Wisconsin, upper Michigan, several southeastern states and many of the mountainous areas of the West. It is estimated that half of the 700,000 lakes in the six eastern provinces of Canada are extremely acid-sensitive. Large acid-sensitive areas are known to exist in parts of the western provinces and the Yukon. (See Exhibit 3 for a complete map of the acid-sensitive areas of North America). In Europe, acid-sensitive regions of the Netherlands, Belgium, Denmark, Switzerland, Italy, West Germany, and Ireland have been added to the better known areas of Scandinavia and the United Kingdom. Vast tracts of geology in Asia, Africa, and South America are also acid-sensitive.[11]

Not all the fresh water ecosystems of the world are acid-sensitive. The effect of acid rain on a body of water depends on the nature of the rock and soils in the watershed. A watershed containing readily available calcium and magnesium or carbonates weathered from limestone can buffer acid in much the way a Maalox tablet will neutralize an upset stomach. Some parts of the planet, such as much of the western U.S. with its more alkaline soils, have great buffering capacities. However, there are other areas, such as the Adirondacks that have hard rock and/or infertile sandy

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[10]Carpenter, p. 44.

[11]D. W. Schindler, "Effects of Acid Rain on Freshwater Ecosystems," Science, January 8, 1988, p. 149.

soil, and these have minimal buffering capacity. Geologic anomalies can result in vast differences even within a small area. How much acid rain it takes to acidify a specific body of water depends on that body's acid-neutralizing capacity.[12]

The damage to the lakes and streams with minimal buffering capacity occurs as acid rain raises the acidity of these waters by depositing both sulfuric and nitric acids into them. Acidity is measured on a pH scale which runs from zero to 14. Seven is neutral: the numbers above increasingly alkaline, the numbers below increasingly acidic (see Exhibit 4). It is an exponential scale, so as pH drops, acidity rises exponentially, so that a liquid with a pH of 5 is ten times as acid as one with a pH of 6. Carbon dioxide in the atmosphere dissolves in pure water and produces a weak carbonic acid with a pH of 5.6; anything lower than this is considered acid rain.[13] The rains in many of these acid-sensitive areas routinely are measured in a pH range from 4.1 to 4.6--ten to thirty times as acid as uncontaminated rain (see Exhibit 5). Specific storms have dumped pH 2.7 rain--as acid as vinegar--on Pennsylvania and pH 1.5 rain--stronger than lemon juice--on West Virginia.[14]

The fish populations of these lakes cannot flourish and often are completely destroyed as acid rain increases the acidity of a body of water. At 6.5 pH level, brook, brown, and rainbow trout experience significant reductions in egg hatchability and growth. At 5.5, largemouth and smallmouth bass, walleyes and rainbow trout are completely eliminated and declines in other trout and salmon populations can be expected. Below 5, most fish are unable to survive. A low pH can cause female fish

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[12]Boyle, pp. 74-75.

[13]Eville Gorham, "What to Do About Acid Rain," Technology Review, October 1982, p. 60.

[14]LaBastille, p. 669.

to retain their eggs, but even if the eggs are laid, mortality rates can be high in acidified waters because fish are ultra-sensitive in the egg, larval, and fry stages.[15]

A reduced pH level is not the sole reason fish perish in water contaminated by acid rain. Low pH by itself interferes with the salt balance fresh-water species need to maintain in their body tissue and blood plasma. Apart from that, however, there is another factor at work: aluminum. Acid rain leaches aluminum (one of the most abundant metals in the earth's crust) from the surrounding soil and places it into circulation where it can be lethal to fish and other organisms at pH levels that are normally considered safe for the host fish themselves. Acidification also mobilizes mercury and cadmium, and fish that survive may become poisonous to predators (including humans), because of the accumulation of such heavy metals in the fish's tissue.[16]

In addition to the loss of its fish population, an acidified body of water also loses hundreds of other organisms, including certain types of algae, amphibians, crustacea, mollusks, and insects. For example, in a stream stone flies and mayflies generally disappear at pH 5. Many species of these two important insect orders are detritivores that feed not on the submerged vegetation, but on the dead leaves that have fallen, been blown or washed into the waters. The leaf fall in autumn is one of the largest transfers of energy on the planet and these insect detritivores are a vital link in the energy flow that travels from the sun, soil, and trees to stone flies and mayflies to trout and finally to fish-eating birds and mammals, including man.[17]

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[15]Boyle, p. 75.

[16]Ibid.

[17]Ibid.

Another longstanding charge against acid rain is that it is eating into metals, marble, limestone, and sandstone and thus accelerating the degradation of statues, buildings, bridges, and monuments around the globe. The list of the damaged includes many famous names: the caryatids of the Acropolis, Egypt's temples at Karnak, the Statue of Liberty, and the U.S. Capitol.[18] "The east side of the Capitol is white Lee marble from Lee, MA.," says Dr. Erhard Winkler of Notre Dame. "There are craters one-quarter inch or more in it. It looks like shrapnel has hit it." [19]

In recent years, many scientists have investigated the theory that acid rain may also be contributing to widespread forest decline in many areas of North America and Europe. Since 1980, these forests have suffered an alarming loss of vitality. For example, two-thirds of the trees in Germany's vast Black Forest exhibit a significant amount of damage. It has been logically determined that trees located on mountaintops are subject to pollutant deposits because they are frequently bathed in polluted cloud water. However, many of the damaged trees have been discovered at lower altitudes. Many scientists studying the problem have concluded that the sulfuric and nitric acids do not kill trees directly but rather weaken them to the point where they are no longer able to withstand the normal episodes of moderate drought or insects or diseases that they could otherwise easily resist.[20]

The scientific community has also been working on the effects of acid rain on agriculture. Experimental work with simulated acid rain has shown a number of harmful effects on crops, such as the leaching of nutrients from foliage and the

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[18]LaBastille, p. 675.

[19]Boyle, p. 79.

[20]Jon R. Luoma, "Acid Murder No Longer a Mystery," Audobon, November 1988, pp. 129-130.

inhibition of nitrogen fixation essential to photosynthesis.[21] In recent studies at North Carolina State University, corn plants exhibited significant damage after being subject to simulated "showers" of rain at acidity levels now commonly found outdoors.[22]

Currently, serious concern over the effects of acid rain have centered on two areas, coastal waters and human health. Long recognized as a major peril to freshwater ecosystems, acid rain is also seriously damaging the inhabitants of coastal waters, according to a report released in early 1988 by the Environmental Defense Fund (EDF). In seawater, most of the damage is done by nitrogen oxides. Acting as a nutrient, nitrogen promotes excessive algal growth, which blocks sunlight and depletes dissolved oxygen, thus suffocating other plants and animals. Known as eutrophication, this process has been on the upswing in both frequency and intensity on the Atlantic coast during the past few years.[23]

The EDF study was centered on the Chesapeake Bay, the nation's largest estuary and an important spawning ground for many species of economic importance. It has been known for years that these waters are suffering from nitrogen pollution. Until recently, it was assumed that most of the nitrogen was coming from sewage and agricultural runoff. However, based on data collected from state and federal agencies, EDF scientists estimated that nitrates from acid rain are responsible for one quarter of the nitrogen entering the bay and its contribution is growing. Similar situations are expected to be present along most of the Eastern seaboard.[24]

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[21]Boyle, p. 80.

[22]"Acid Rain on the North 40: Harmful, But Not Devastating," Business Week, October 26, 1987, p. 119.

[23]Laura Tangley, "Acid Rain Threatens Marine Life," Bioscience, September 1988, pp. 538-539.

[24]Ibid.

Likely the most frightening danger of acid rain is the threat it poses to human health. Sulfur dioxide, at sufficiently high levels, has long been considered a threat to public health--irritating the lungs, stressing the heart, and lowering the body's resistance to respiratory infections. Despite the implementation of corrective actions forced by the Clean Air Act, according to the American Lung Association, 115 million Americans continue to be exposed to air pollution levels exceeding federal health standards.[25] Also, 1987 estimates by the federal Office of Technology Assessment state that some 50,000 Americans may die prematurely each year from diseases (including lung cancer) caused or exacerbated by airborne sulfates.[26] Concerned scientists even point to past episodes of "killer fog". This phenomenon occurs when certain atmospheric changes form sort of a lid over an area which prevents the warm gases of pollution from escaping. These pollutants cannot rise out of the area and instead accumulate close to the ground. Although certainly a rare occurrence, in December 1952 such a fog settled over London, and the intensely polluted air caused the deaths of an estimated four thousand residents.[27]

There is also troubling speculation that acid rain is leaching toxic metals into drinking water. In the mid-1970s, the Quabbin Reservoir in central Massachusetts became so acidic that it dissolved water conduits and fixtures, producing unhealthy levels of lead in the drinking water.[28] Finally, in early 1988, two California researchers presented a report that stated that acid rain could be responsible for elevated death rates

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[25]Luoma, pp. 16-18.

[26]Robert Sullivan, "Playing Games With Acid Rain," Sports Illustrated, May 18, 1987, p. 10.

[27]Luoma, pp. 16-18.

[28]Frederic Golden, "Storm Over a Deadly Downpour," Time, December 6, 1982, pp. 84-85.

from cancer of the colon and other organs in the northeastern U.S. They said that sulfur dioxide absorbs ultraviolet light that normally would fuel the body's production of Vitamin D. Without Vitamin D, an individual cannot absorb enough calcium to protect tissues from becoming cancerous.[29]

The damaging effects inflicted by acid rain are not confined simply to the environment, they reach into the economic sector as well. Economically damaging effects vary: they can be short-term or long-term; reversible or irreversible. A partial list might include some crop damage, some decline in forest growth, fisheries losses, long-term decreases in property values on acidified lakes, effects on recreational industries in acid-sensitive areas and costs incurred by having to treat chemically altered groundwater. In terms of people and their livelihoods, acid rain will take business away from farmers, lumber companies, commercial fishermen and fishery owners, real estate agents, resort owners, and all of the enterprises that depend on the tourist industry.[30] In terms of the possible magnitude of this damage, consider for example the multibillion-dollar European forest industry which is currently faced with rapid forest decline. It provides jobs for some 1.4 million workers in the European Economic Community alone.[31] In addition to these financial losses in the private sector, governments around the globe have funneled billions of dollars towards acid rain research and related corrective actions.

Now that I have outlined all the damage that has so far been attributed to acid rain, there are a few questions that need to be addressed.

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[29]Larry Tye, "Acid Rain and Colon Cancer are Linked," The Boston Globe, February 10, 1988, p. 12.

[30]Boyle and Boyle, p. 31.

[31]Jon R. Luoma, "Forests are Dying but is Acid Rain Really to Blame," Audobon, March 1987, p. 44.

Is there conclusive scientific proof linking acid rain to all this devastation? The answer is yes, in many instances, particularly in the case of fresh water ecosystems. The debate over acid rain's guilt has centered on the fact that it is difficult to link acidity in precipitation to a specific smokestack. However, in 1986, the prestigious National Academy of Sciences issued a comprehensive report concluding that acid rain causes plenty of environmental problems. "The connection between acid rain and environmental damage is real," said James H. Gibson, chairman of the committee that issued the report.[32] It must be realized however, that no matter how strong the case against acid rain becomes there will always be some determined dissenters. "You're never going to prove anything to everybody, as we've seen with cigarettes and cancer," said Jack Calvert, a senior scientist at the National Center for Atmospheric Research. "You're never going to satisfy industries with an ax to grind."[33]

What is the outlook for the environment? It is true that certain abatement measures mandated by the Clean Air Act and additional emissions laws passed by individual states have slowed the increase of SO_2 emissions, but industry experts predict that the amount of coal burned in the U.S. will rise significantly (even double) by the year 2000. Also, the emission of nitrogen oxides is expected to rise by 40% over the next decade. (Both increases are attributable to an expanding economy and a growing population.) It is the SO emissions that attract the most attention, however, as they account for over two-thirds of the excess acidity in the damaging rains.[34]

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[32]Marjorie Sun, "Academy Study Dispels Doubt on Acid Rain," Science, March 28, 1986, p. 1500.

[33]"Polluted Air and Acid Rain: A Missing Link?," Newsweek, September 2, 1985, p. 25.

[34]Gorham, p. 68.

How much does acid rain need to be reduced to initiate the recovery of the affected areas? While the scientific community currently is seeking more information in order to make an accurate estimate, certain members speculate that sulfate deposition in sensitive areas needs to be cut to less than 50% of its current level in order to actually reverse the negative trend in these regions. Since most agree that sulfate deposition is roughly proportional to SO_2 emissions, an appropriate goal for the present is to decrease these emissions also by 50%.[35]

Unfortunately, even with such reductions, it is not clear that the sensitive areas will recover completely. For example, many scientists believe that lakes and streams can at least partially recover soon after acid input ceases, but it might be dozens or hundreds of years before the original pH values will be reached and even longer for the original ecosystem to re-establish itself.[36]

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[35]Gorham, p. 70.

[36]Jon R. Luoma, "Canada Tracks the Relentless Toll of Acid Rain," The New York Times, September 13, 1988, pp. C1, C11.

SECTION 2--ELEMENTS OF A SOLUTION

When scientists, lawmakers and others have discussed solving the acid rain problem, they have generally focused on controlling emissions from power-generating plants, as these utilities account for almost 75% of the SO_2 released into the atmosphere (Exhibit 1). Although it is viable to consider this single source for the problem, this does not make formulating a solution any less complex. There are numerous decisions that must be made in a variety of areas in formulating a solution to the acid rain crisis. To begin with, the level of sulfur dioxide reduction must be determined. The size of the geographic area to be addressed by any solution must also be defined. Next, the method of reduction, from new technologies to alternative energy sources, must be chosen. Finally, the policy measures utilized to implement any program, whether they be direct regulations or certain tools based in economic theory, must be determined. (Note that underlying all of these decisions is the most crucial question related to any program to control acid rain--who will pay for the reduction of acid rain? This question will be discussed in Sections 4 and 5.)

Two of the most pertinent issues associated with acid rain legislation are the level of sulfur dioxide and the size of what has been called in the literature, the Acid Rain Impact Region. These two issues can be addressed together by referring to legislation which has previously been entered into Congress. Within this area there have been three major types of SO_2 reduction bills: fixed reduction, specific area reduction, and maximum deposition.[37]

[37]Robert G. Schweiger and Thomas C. Elliot, ed., Acid Rain: Engineering Solutions, Regulatory Aspects, (New York: McGraw-Hill, 1985), p. II-2.

A fixed reduction type of bill delineates a specific annual tonnage reduction. Most bills proposed by Congress to date have been of this form and these have generally fallen in the range of 8 million to 12 million tons per year of SO_2 reduction. The baseline year used in most of these bills has been 1980. To put these tonnage reductions in proper perspective, it should be noted that the total utility sulfur dioxide emission in 1980 was approximately 16 million metric tons, while the total sulfur dioxide emission in the same year was approximately 24 million metric tons. The states affected are those in the northeastern, middle-Atlantic and midwestern regions of the country.[38]

The appeal of this type of bill is that it treats each state equally, as a formula is established in the legislation to calculate SO_2 reduction requirements and each state is treated identically by the formula. This is not to express that each state has the same percentage reduction requirements, however, since some states obviously have higher emissions that others. This type of bill may or may not be considered equitable, depending on the specific formula utilized to allocate the level of SO_2 reductions by state.[39]

It should be noted here that the marginal cost for compliance in terms of dollars per ton of SO_2 reduction becomes progressively steeper with the higher fixed reductions. Some analysts believe that it costs up to $400 per ton (1984 dollars) for SO_2 removal at the 5 million ton level. For a 10 million ton reduction, the marginal cost of reduction is $800 per ton, while the marginal cost of reduction is approximately $1200 per ton at the 12 million ton level.[40]

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[38]Schweiger and Elliot, p. II-2.

[39]Ibid., pp. II-2, 3.

[40]Ibid., p. II-3.

The specific area reduction approach to acid rain control targets SO_2 reduction for recognized sensitive receptor sites. The logic of this approach is that since the Adirondack region of New York is widely recognized as a sensitive receptor site and one which has received significant damage to date, legislation should concentrate on controlling sources which have a greater impact on that area. The appeal of this type of legislation is that the control costs can be greatly reduced over that of a fixed reduction type of control to achieve the same emission reduction in a certain area. It has been estimated that the control costs could be decreased from 75 to 90% to attain the same level of emission reduction in the Adirondacks as a fixed 12 million ton reduction bill.[41]

The weaknesses of this type of bill are that it requires the use of an atmospheric transport model to predict the effect of a specific emission source on a specific receptor site. This type of control would also require an assumption of linearity as well as representative meteorological data for the region in question.[42]

In the political arena, this approach may be less palatable than the fixed reduction approach since nearby states will obviously be targeted for more reduction than more distant states. This is in contrast to the equality characteristic of the fixed reduction form of legislation. This approach also has the appeal of a phased reduction initiative since the total reduction required would be substantially less than the 8 to 12 million ton reduction generally proposed in the fixed reduction bills.[43]

The maximum deposition type of legislation would require a specific target deposition rate, such as 30 kilograms of SO_2 per hectare per year, which would be determined by scientists to protect sensitive areas. Like the fixed reduction idea, the

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[41]Schweiger and Elliot, p. II-3.

[42]Ibid., II-3, 6.

[43]Ibid., p. II-6.

appeal of this bill would be that it could be applied uniformly to all states and as such, express a vision of fairness. It also has the positive attribute of significantly reducing the costs from the fixed reduction type of bill. Analysts predict that the cost to meet a target of 30 kg/ha/yr would be about 20% of the cost of a 12 million ton fixed reduction. The costs to meet a target of 20 kg/ha/yr would be approximately half the cost of a 12 million ton fixed reduction.[44]

The drawback of this type of legislation is that similar to the specific area reduction approach, it requires the utilization of atmospheric transport modeling, linearity assumptions, and representative meteorological data. Also, this plan would necessitate an absolute prediction of transport by a model, not just a relative prediction as in the specific area reduction idea.[45]

It is important to note here that two large computer atmospheric transport models of the type needed by both the specific area reduction and maximum deposition approaches are currently being tested. One of these was developed by the U.S. Environmental Protection Agency and the other by agencies of the Canadian and West German governments. However, the accuracy, and hence the usefulness of these models with respect to these two types of approaches has yet to be determined.[46]

In conclusion, the merits of both a specific area approach and a maximum deposition plan warrant further consideration. Each approach appears to offer substantial cost savings over a fixed reduction plan for equivalent benefits.[47]

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[44]Schweiger and Elliot, p. II-6.

[45]Ibid.

[46]Volker A. Mohnen, "The Challenge of Acid Rain," Scientific American, August 1988, pp. 35-36.

[47]Schweiger and Elliot, pp. II-6, 7.

A wide variety of methods have been suggested for the task of reducing the emission of SO_2 from coal-fired power plants. Most of the attention has been directed toward scrubbers and the newer clean-coal technologies. However, other methods have been considered, including the wide-scale burning of low-sulfur coal and alternative energy sources, such as nuclear, solar, hydro, and cheap Canadian power. An explanation of each method and their inherent strengths and weaknesses is outlined below.

Under the 1977 amendments to the Clean Air Act, scrubbers have been installed in 146 new electricity generating plants. These amendments required that newly constructed power plants meet federal air standards with the "best system of emission reduction available", which up until recently had been scrubbers.[48] In this process, technically known as flue-gas desulfurization, wet limestone is sprayed into the plant's hot exhaust gases, where it eliminates as much as 90% of the sulfur dioxide[49].

Among the problems associated with scrubbers is that they are expensive. They can account for up to one-third of the cost of building a new power plant. Also, they are inefficient, as their operation consumes 3% to 5% of the generating plant's energy. Finally, the process does not eliminate any of the NO_x emitted from the smokestack.[50]

The new clean-coal technologies developed jointly by the government and the coal and utility industries over the past few years offer a more comprehensive solution. In 1988, 16 companies received $537 million in grants from the Department of Energy and

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[48]Thomas Pawlick, A Killing Rain, (San Francisco: Sierra Club Books, 1984), p. 138.

[49]Mohnen, p. 36.

[50]Edward C. Bain, "Scrubber Scrapper," Fortune, April 14, 1986, pp. 63-64.

they contributed $810 million of their own in the search for better methods to reduce SO_2 emissions. The two most promising technologies that have been developed involve fluidized-bed combustion.[51]

In the system known as atmospheric fluidized-bed combustion, a turbulent bed of pulverized coal and limestone is suspended by an upward blast of air. The violent mixing of the coal and the air allows combustion to take place at a lower and more even temperature than it does in a conventional boiler, which reduces the formation of nitrogen oxides. Meanwhile the limestone reacts chemically with the coal to capture as much SO_2 as a scrubber would. The result, however, is a dry waste product that may have some use as a building material. In a related technology known as pressurized fluidized-bed combustion the coal is burned in compressed air, which improves the plant's efficiency as well.[52]

Fluidized-bed combustion is a concept that has been around for many years but was not seen as commercially viable by the utility industry until the 1970s when oil prices skyrocketed. Now with more research and refinement completed, this technology is being applied on a larger scale. For example, in 1986, at its Black Dog facility in Minnesota, Northern States Power opened a $52 million fluidized bed boiler. In Kentucky, the Tennessee Valley Authority is constructing a $205 million power plant which will utilized this technology.[53] American Electric Power, the huge utility holding company, is currently planning to modify a 330,000 kilowatt, conventional coal-fired power plant, using pressurized fluidized-bed combustion. AEP's chairman, W.S. White,

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[51]Jeremy Main and Richard I. Kirkland, Jr., "Here Comes the Big New Cleanup," Fortune, November 21, 1988, p. 110.

[52]Mohnen, pp. 36-37.

[53]Bain, p. 64.

Jr. believes that such clean-coal technology "has the potential for making the nation's coal supply usable in an environmentally safe manner."[54] Nearly all of the utilities doing this pioneering work have been aided by money from utility or coal industry associations, other private companies or the federal government. However, industry experts state that no further subsidy is needed for building conventional fluidized-bed plants.[55]

Retrofitting existing plants with scrubbers offers the quickest way to decrease power-plant emissions. Almost half of the coal-fired plants in the U.S. were constructed prior to 1975 and have no controls for sulfur and nitrogen pollutants. Heavily concentrated in the eastern half of the U.S. They account for most of the country's sulfur dioxide emission. Adding conventional scrubbers to the plants could cut total emissions of SO_2 from all power plants to less than half their present level, and the reduction could be accomplished in fifteen years. However, NO_x emissions would not be affected. Also, utilities object to the expense of installing and operating scrubber equipment and the loss of plant efficiency that would occur.[56]

Clean-coal technologies are an attractive alternative to the problem-plagued scrubber method. Experts agree that any effort to control acid rain must be focused on the aging power plants, many of which will soon be at the age of retirement or refurbishment. Replacing them with new conventional plants equipped with scrubbers would yield only modest reductions in emissions, and the cost of designing, constructing and getting regulatory approval for the new plants would be staggering.

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[54]"American Electric Says It Plans to Build a 'Clean Coal' Plant," The Wall Street Journal, May 20, 1988, p. 47.

[55]Bain, p. 64.

[56]Mohnen, p. 37.

As an alternative, most of the old plants could be "repowered": remodeled with a new combustion section incorporating one of the clean-coal technologies.[57]

A repowered plant could retain much of its existing handling equipment and most of its steam-cycle and electricity-generating machinery. As a result, the repowering of an existing plant would be quick and cheap compared with erecting a new one. This approach has a an additional bonus for the utility industry: the new hardware could be added to the plant in modules, which would enable utilities to adjust generating capacity to the demand for electricity. This strategy would make environmentalists smile also, as it promises ultimately the greatest emission reductions, cutting SO_2 by 80% and NO_x by 50%.[58]

Another approach to SO_2 emissions control is to switch from high-sulfur Eastern coal to low-sulfur Western varieties. This method has been utilized by several utilities to help them meet air quality standards. It is an attractive alternative for the utilities as it brings about the reduction of a significant amount of SO_2 while requiring minor expenditures and little modification to a plant. However, the seemingly high potential of this fuel switching is sharply limited by certain political and social realities. The first and most obvious of these is that any quick, wholesale change to Western coal would result in unemployment for thousands of Eastern miners and wreak economic and social havoc on communities throughout such high-sulfur-coal producing regions as Ohio, West Virginia, Pennsylvania and Kentucky.[59]

As for the use of other energy sources as a method to reduce SO_2 emissions, there are many individuals in both government and industry who believe that nuclear power

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[57]Mohnen, p. 38.

[58]Ibid.

[59]Pawlick, p. 137-138.

is a viable alternative to coal-fired electricity generation. This belief is attractive to utilities that have already sunk so many billions into nuclear plant construction that they are unable to turn back financially. However, both the economics of the marketplace and the mounting evidence of the adverse health effects of even low-level radiation are making it increasingly difficult to support the argument for nuclear power. Tales of disaster, financial and otherwise, from coast to coast, have plagued this energy source for a decade.[60] One needs to look no further than the local area and the tremendous turmoil which has occurred at both the Seabrook and Pilgrim nuclear power plants.

Other alternative power sources, such as solar and hydro power, are not potentially dangerous to the environment or very costly, but they also have not proven to be commercially viable on a large scale. Solar power has been shown to be a useful energy source only in certain regions of the country and even in these locales it does not replace the burning of coal to any significant degree. Hydro power is an old and reliable source of energy and there are presently many potential sites for small dams in this country. However, these dams cannot begin to produce energy on a scale similar to the conventional coal-fired power plants.[61]

Finally, some have suggested that the U.S. should increase the amount of electricity it currently imports from Canada. These imports have been utilized to help alleviate the energy shortages often encountered in this country, particularly in the Northeast. The Canadian power is currently plentiful and relatively inexpensive, but increasing the amount that this country imports is a temporary stopgap measure at best with respect to reducing SO_2 emissions. The energy may be available now, but industry experts predict that Canada will need increasing amounts of its domestically produced

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[60]Pawlick, p. 145.

[61]Ibid., p. 142.

power over the next decade. Also, Canada has its own severe acid rain crisis to address, and producing excess energy on a large scale to export to the U.S. would do nothing to ameliorate this problem.[62]

The emission limits of the Clean Air Act (1970) and current Environmental Protection Agency regulations are the chief policy measures presently addressing the acid rain problem. Five major regulatory provisions attempt to minimize atmospheric loading and long range transport of utility emissions: ambient air quality standard requirements restrict emissions from new and existing plants; new source performance standards require new coal-fired power plants to comply with limitations on allowable sulfur dioxide emissions; prevention of significant deterioration regulations require all new major utility plants to comply with the best available control technology to reduce emissions; nonattainment provisions limit new source construction; and restrictions of stack height credits eliminate the use of dispersion control techniques to regulate new emission sources.[63]

All of these regulations may be viewed as impressive on paper but their usefulness, in terms of reducing environmental damage caused by acid rain, has not been quite sufficient. Many experts on the acid rain issue are calling for more stringent regulations to be passed, they want to beef up the Clean Air Act and related EPA regulations.[64] However, others believe that this type of policy measure is not the answer. They prefer lawmakers look to economic theory instead to develop appropriate policy. These individuals, primarily economists, believe that economic theory can aid

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[62]Malcolm Gladwell, "Rain, Rain, Go Away," Saturday Night, April 1988, p. 54.

[63]13th Annual Report of Council on Environmental Quality, (Washington: United States Government Printing Office, 1982), p. 213.

[64]Carolyn Curtis, ed., Before the Rainbow: What We Know About Acid Rain, (Washington: Edison Electric Institute, 1980), pp. 79-80.

society in comprehending the various facets of the acid ran dilemma. It can furnish us with a conceptual structure necessary for devising effective and efficient policy approaches to such environmental problems as acid rain. In addition, economic theory can demonstrate the advantages and disadvantages of potential policy measures.[65] The application of economic theory to the acid rain problem follows.

Even with such a simple resource as air, it is often found that a system of individual ownership needs public regulation because of "externalities" such as the sulfur dioxide and nitrogen oxide emissions which can cause acid rain. One person's use of a natural resource can inflict damage on other people who have no way of securing compensation, and who may not even know they are being damaged. Society would like to insure that each resource is allocated to that use in which its net social value is highest. But if the full costs of some use of a resource do not fall upon the private owner or public-decision maker, but upon someone else, then the resource is unlikely to find its way into its socially best use.[66]

As it is well known, air has only a limited capacity to absorb wastes or to carry them away. A modern industrial economy, such as the United States', generates so much waste--in the form of toxic emissions--that its disposal taxes the capacity of the atmosphere and in the case of acid rain, the entire environment. In the present situation, the assimilative capacity of air has become a scarce resource, but it is provided free of charge as common to any one with some waste to dispose of. It is easy to see that, under these circumstances, the scarce resource will be overused. The

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[65]Allen V. Kneese, Economics and the Environment, (New York: Penguin Books, 1977), p. 17.

[66]Robert M. Solow, "The Economist's Approach to Pollution and Its Control," in Why Do We Still Have An Ecological Crisis?, Terry Armstrong, ed., (New Jersey: Prentice-Hall, 1972), p. 48.

normal system of incentives is biased. This scarce resource does not carry a price tag to reflect its scarcity. If high-sulfur coal is cheaper to produce than low-sulfur coal, it will be burned and the SO_2 wastes will be dumped into the air. Society pays a price in terms of damage to bodies of water, to wildlife, to buildings and monuments, to human health, and also to the economy. However, that cost is not normally attached to the burning of high-sulfur coal, thus it does not become part of the private costs and does not influence private decisions.[67]

One important effect of externalities is to warp the allocation of productive resources. Because an electricity-generating utility, for example, can get by without cleaning up its emissions, its costs of production are artificially understated. Since in a competitive economy prices tend to reflect production costs, the utility's prices may also be understated. If so, the result is greater demand for electricity than if prices reflected the full costs of electricity generation--both the costs borne internally by the utility and those borne externally by the individual and industries which are affected by the emissions, through acid rain. At the same time, some of the industries affected by the utility's emissions--farming, perhaps--may have higher costs and prices, tending to depress demand. Society thus gets relatively too much electricity and too little farm produce, and consumers of farm produce in effect subsidize consumers of electricity. In some degree, then, resources are allocated with less than maximum efficiency and equity.[68]

Economists realize that the implications of externalities can be traced further. Externalities have secondary effects on the system of resource allocation. If electric

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[67]Solow, p. 49.

[68]Sanford Rose, "The Economics of Environmental Quality," in Environment, ed., Fortune, (New York: Harper & Row, 1970), p. 66.

power is too inexpensive to the customer, because he is not charged with its full social costs, other commodities that are produced with the aid of large amounts of electricity will also be cheap, and they will be overproduced. Other industries will be more likely to utilize techniques of production that use more electric power than they would if the price of electricity were higher. The rest of society will find itself subsidizing those individuals (if they are an identifiable group) who consume a large amount of electricity or numerous goods made with large amounts of electricity.[69]

Economic theory suggests that changes in the economic incentive structure must play a large role in the successful management of acid rain. More specifically it reveals strong evidence that a plan of charging a fee for or taxing dangerous emissions, if properly implemented, would have advantages in efficiency and effectiveness over the efforts to do the entire job with direct regulation which has characterized past policy in this country. Quite simple charge systems can be designed to induce responses which will cause environmental standards to be met at a lower cost than even a successfully implemented program of conventional regulations. Experience in the U.S. and elsewhere advocates that enforcement of regulation-type controls presents great difficulties and is often unsuccessful in gaining its objectives.[70]

One conceivable way (which has been preferred by the government up to this point) to reduce an environmental problem, such as acid rain, consists of prohibitions or agreements which are referred to as regulations. The imposition of regulations means that the socio-economic costs represented by the damages to the environment are not allowed to exceed certain limits, which are determined from case to case. These rules can often be unspecific so that the producer in question can attempt to discover how to

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[69]Rose, p. 67.

[70]Kneese, p. 253.

limit the damage. But the rules often give instructions on how the delineations should occur.[71]

One result of this approach is that producers' costs are raised. They may be forced to invest, for example, in emission control devices or they may shift to more expensive production or distribution methods. In both cases the environment is improved not only directly (through a reduction in acid rain), but also indirectly. The price increases which producers can be presumed to follow with are likely to reduce demand and therefore lead to a shift downward to a production level that still damages the environment, though to a smaller degree than the previous level of production.[72]

Unfortunately for society, the negative aspects of the regulations approach are numerous. A characteristic of all such regulations in the market system is that they are rather inflexible and therefore not very well suited for reducing the damages to an optimum level from a general resource allocation point of view. In addition, there is no incentive among producers to find new production methods and product designs which could be more beneficial to the environment than necessitated by the regulation. This incentive to innovate further would be limited to firms offering various abatement and purification equipment and alternative processing techniques. The incentive for the other producers can be assumed to be directed at just minimizing the extra costs brought about by the regulation. Even this limited incentive would disappear if the authorities choose to subsidize away the marginal cost increases resulting from the changes brought about by the regulations.[73]

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[71]Erik Dahmen, "Environmental Control and Economic Systems," in The Economics of Environment, Peter Bohm and Allen V. Kneese, ed., (London: The MacMillan Press Ltd., 1971), p. 49.

[72]Ibid., p. 50.

[73]Ibid, p. 51.

Another acute deficiency with employing regulations to control acid rain lies with the enforcement of these regulations. The simplest way to deal with such a pollution problem is to set minimum quality standards for air and enforce them on each polluter. But this ignores the fact that some sources of pollution are more readily remedied that others. If two firms producing different commodities both contaminate the same airspace to the same extent, it may seem natural to require each of them to reduce its contamination by, for example, 50%. If that were done, it would be almost certain that the incremental cost of a small further reduction would be different for the two firms since they use different production techniques. But then it would be better if one of the firms--the one with the smaller incremental cost--were required to pollute still a little less, and the other permitted to pollute a little more. The total amount of pollution would be the same, but the total cost of attaining the 50% reduction would be smaller. Since it is the total amount of pollution that matters, the cheaper possibilities of reduction should be exploited first.[74] (It should be noted here that by setting different standards for plants of varying vintages and fuel types, the Clean Air Act and its amendments make some attempt to recognize technological differences across polluters. These standards, however, do not guarantee that the total cost of achieving a given level of air quality or a given level of emissions is minimized.)[75]

This could be accomplished if, instead of the direct imposition of regulations, the two firms were charged or taxed an amount proportional to their emission of pollutants. The height of the tax could be varied until the desired total reduction in pollution occurred; the factories themselves would see to it that it occurred in the most

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[74]Solow, p. 51.

[75]Frank M. Gollop and Mark J. Roberts, "Cost-Minimizing Regulation of Sulfur Emissions: Regional Gains in Electric Power," The Review of Economics and Statistics, February 1985, p. 82.

inexpensive way possible. It is perfectly true that this way of accomplishing a reduction in emissions affects the distribution of income; the cost of preserving the environment is borne in a particular way. But that is true of any method, including simple regulations. The redistribution is only more visible in the case of a tax or emission charge. The tax also provides some revenue which can be utilized either to further improve the environment or to assist genuine hardship cases or to achieve socially desirable ends of any kind.[76]

This approach of charging a fee has been the one most apparent to economists when dealing with environmental problems. This method would not set any strict limitations for the damages inflicted on the environment. Instead, a bill would be presented to a utility. Its amount would be reduced or increased proportional to the reduction or increase in environmental damage. This can be assumed to help reduce the damages to an optimum level from a general resource allocation point of view in a more effective way than the regulation approach. The fact that a stronger incentive to bring down the damage would be given is of particular importance. Even if the initial effect in the form of, for example, investment in emission-control equipment or other technical solutions might not be the same in the tax method as in the regulation method (i.e. in the case of small fees), there is a great probability that the effect in terms of environmental improvement over a period of time would be greater. Above all it could be hoped that technological progress in the field of environmental control would receive a powerful and continuing stimulus.[77]

Economizing on information is another reason for favoring taxes or emissions charges over direct regulation. The construction of a sound schedule of taxes or fees

[76]Solow, p. 52.

[77]Dahmen, p. 52.

also requires information, but rather less information, especially once it has been implemented. Also, the process of collection itself produces new information that can be used to improve the schedule in use.[78]

Finally, financial incentives are usually easier to administer than direct regulations. They preserve decentralized decision-making, and as such they induce everyone directly concerned to seek out trade-offs, substitutions and improved techniques that could not be known to any central office, such as the federal government.[79]

It would be relevant to mention here that most economists hold the general principle that taxes or emission charges are more effective that subsidies. It is probably an unpopular principle as nobody likes a tax, but there is always at least on person who likes a subsidy. A tax is levied against the amount of pollution actually discharged, an observable quantity. A correct subsidy depends on how much pollution has been reduced from what it would have been in the absence of the subsidy, a hypothetical quantity. If one subsidizes actual waste treatment, this may lead to the perverse result that techniques may be adopted that lead to the production of waste on a n unnecessarily large scale, simply to collect the subsidy for treating it. Also, subsidies will lead to higher net profits in pollution-intensive industries, and perhaps attract a socially undesirable expansion of those industries.[80]

Most economists have long proposed that a system of charging a fee or tax be implemented in place of the current plan of direct regulations in an effort to combat acid rain. However, in recent years, markets in pollution rights, in which polluters buy and sell the right to emit a unit of pollution, have received increasing attention from

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[78]Solow, p. 53.

[79]Ibid.

[80]Dahmen, p. 53.

many economists as a workable and less costly alternative. Individuals supporting this view point out that although tax schemes involve lower information requirements than direct regulation, the need for information when administering such plans is still substantial. Also, these economists refer to the limited use of a fee system to date, because of uncertainty about both the appropriate level of tax and the final level of emissions.[81]

A system of marketable pollution rights or emission permits requires that a regulatory body determine the desired level of total regional emissions. Emission permits, equaling in number the desired total level of emissions, would be created and then distributed. Firms would be allowed to trade permits. Polluters with high marginal abatement costs would buy the right to pollute from those whose marginal costs are lower. Regulators would need to know nothing about the polluters' marginal cost of abatement functions. In equilibrium, the marginal cost of pollution removal would balance across firms and would equal the price of a pollution permit. A competitive equilibrium in this market minimizes the total cost of abatement for the given level of emissions.[82]

Although in theory this appears to be a promising development, the proponents of such a market in pollution rights face a nontrivial list of unanswered questions. These include the specific form of the property right itself, the distribution method for the property rights, the determination of the optimal size of trading areas, the number of rights to be issued, and the possibility that competitive markets would be difficult to sustain.[83]

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[81]Gollop and Roberts, p. 86.

[82]Ibid., p. 87.

[83]Ibid, p. 89.

SECTION 3--GOVERNMENT

Although it is clear to almost all of those involved in the acid rain debate that the U.S. government must play a large role in controlling the emission of the chief precursors of acid rain, up until now, the government has been unable to undertake this responsibility with any degree of effectiveness. From the view of environmentalists, for the entire eight years it was in power, the Reagan Administration performed dismally on the acid rain issue. In Congress, proposed acid rain legislation has continually met with powerful opposition as the issue has become a regional battle between representatives of the Northeastern states and those of the Midwestern-coal-producing areas. However, while the United States, the world's leading polluter, continues to wrestle with the acid rain issue, many other countries, including Canada and West Germany have devised explicit acid rain strategies and taken concrete action to reduce the dangerous smokestack emissions.

To quote the Boston Globe, "The Reagan administration's record on acid rain has been one of calculated delay and cynical promise."[84] On the issue of acid rain, as on most other environmental issues, former President Reagan demonstrated his unique brand of genial ignorance.[85] Throughout his tenure, Mr. Reagan claimed there was not enough scientific evidence to support enactment of legislation that would reduce emissions of SO_2 and NO_x from coal-burning powerplants. Further, regardless of evidence, the Administration also opposed such legislation on the grounds that it constitutes to much government control of private industry. Finally, Mr. Reagan viewed this type of legislation as too expensive for the results it is intended to

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[84]April 4, 1988, p. 18.

[85]David Seideman, "The Acid Test," The New Republic, March 3, 1986, p. 11.

achieve.[86] In 1983, then-Budget Director David Stockman argued triumphantly that an acid-rain clean-up would cost $6000 per pound of fish saved.[87]

Former president Reagan's posture of delay on acid rain in the face of repeated calls for activism caused innumerable difficulties for his administration. For example, just before Mr. Reagan's March 1987 press conference, the staff of the Environmental Protection Agency released a report predicting still more acid-based mortality for fish in the Northeast. As a result, the ensuing press conference feature a few distasteful questions concerning acid rain. A couple of days later a review at the EPA led to a major retreat on the original findings. The revised perspective was that a number of Northeastern lakes adversely affected by acid rain might be as few as ze

Another instance which brought controversy to the Reagan adn on's position on acid rain, occurred in September 1987 when the National Acid Precipitation Assessment Program finally released a long-awaited "interim report." The NAPAP, set up late in the Carter Administration to coordinate federal acid rain research, had already been blasted by the General Accounting Office for foot-dragging. When the interim assessment was finally released (two years late), it sparked an explosion of scientific protest.[89]

There were few complaints about the three main volumes of the report. But the slim fourth volume, the executive summary, was at the center of the controversy.

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[86]Philip Shabecoff, "State Acid Rain Accord Puts New Pressure on Washington," The New York Times, June 12, 1988, p. 4.

[87]Larry Martz, "Deaver Takes the Offensive," Newsweek, May 26, 1986, p. 16.

[88]Daniel Seligman, "April Fooling," Fortune, May 11, 1987, p. 153.

[89]Luoma, "Acid Murder...," pp. 133-134.

J. Lawrence Kulp, then the NAPAP director appointed by Ronald Reagan, had authored much of the fourth volume himself.[90]

Critics were especially disturbed that the summary's count of acidified lakes included only those so acid that adult fish could not survive. The report downplayed the more numerous acidified waters where amphibian and insect life are harmed, fish reproduction is destroyed, and ecosystem food chains are disrupted. In addition, some critics were outraged that the summary stated as fact an unproven chemical "steady state" theory favored by Kulp, that bodies of water in the Northeast would not become more acidic.[91]

Several prominent figures in the acid rain debate, including some scientists whose work had contributed to it, spoke out vociferously against the NAPAP interim report. Canada's Environment Minister Tom McMillan claimed the report was "voodoo science," deliberately designed to prove that the situation is not serious enough to warrant immediate action.[92] Richard Ayres, attorney for the Natural Resources Defense Council, took a somewhat different view, claiming that the summary purports to reflect science, but is in essence "nothing more than political propaganda for the Reagan Administration's position on acid rain." The report, he believes, provides conclusive evidence that NAPAP was nothing more than "an Administration device to stall the enactment of acid rain control legislation".[93]

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[90]Luoma, "Acid Murder...," p. 134.

[91]Ibid.

[92]"U.S. is Denounced on Acid Rain Study," The New York Times, January 9, 1988 p. 7.

[93]Conrad B. MacKerron, "The Controversy Over Acid Rain Grows," Chemical Week, October 14, 1987, p. 25.

This swirling controversy soon brought about Kulp's resignation as director of NAPAP. The new director, James R. Mahoney pledged to prepare a new executive summary which would be "more representative of all the data available." The massive final assessment is due from NAPAP in 1990.[94]

The Reagan Administration's footdragging on the acid rain issue also caused a continuous rift in U.S.-Canada relations. Acid rain has been blamed for widespread damage to lakes and forests in eastern Canada over the past several years. The Canadian government has undertaken a comprehensive program of reduction, but their success is limited by the fact that 50% of the acid rain that falls on this area is caused by emissions produced in the U.S. During his tenure, Ronald Reagan continually refused to cooperate with Canadian officials anxious to resolve this difficult matter.[95]

Canadian officials thought they had convinced the U.S. to take action in 1978, when the two countries signed an agreement with then President Jimmy Carter. However, the Reagan administration largely ignored that commitment for the next eight years.[96] In four annual summits, Canadian Prime Minister Brian Mulroney confronted President Reagan about the acid rain dilemma, and each time Mr. Reagan stated that he would "reflect upon" or "consider" the matter.[97] The results were not concrete actions, instead the president sponsored a $.5 billion program to develop cleaner ways of burning coal in the future. Canadian officials were incensed as they saw this as a smokescreen rather than as a genuine attempt to deal with the problem. Canadian Environment Minister Thomas McMillan stated that the president's response "is not so

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[94]Luoma, "Acid Murder...," p. 134.

[95]Carpenter, pp. 43-44.

[96]Tye, p. 22.

[97]"Promises, Promises on Acid Rain," The New York Times, April 30, 1988, p. 30.

much science but politics"--a method by which the U.S. government can act without offending opponents of further controls.[98] In a speech in New York City last spring, Prime Minister Mulroney, who has been under substantial domestic pressure to extract a commitment from the U.S., acknowledged that he must wait for Mr. Reagan's successor to see any results on the acid rain front.[99]

Other than the clean-coal technology program previously mentioned, the Reagan Administration begrudgingly took some small additional steps towards controlling acid rain in recent years. For example, last fall, the U.S. joined 4 other industrialized nations in signing an international protocol to freeze the rate of NO_x emissions. Under the agreement, beginning at the end of 1994 the participating nations will limit nitrogen oxide to levels not to exceed those prevailing in 1987.[100]

This move was labeled as a major policy reversal for the Administration, but environmentalists were not overly encouraged. To begin with, this treaty is unlikely to have an immediate practical effect, as the EPA expects NO_x emissions to fall steadily until the early 1990s because of previous pollution control efforts. Also, the U.S. did not join with a group of twelve Western European nations that agreed at the same series of meetings to go beyond the freeze and roll back emissions of NO_x by 30% over the next ten years. Finally, the Reagan Administration had previously declined to join an earlier protocol to reduce emissions of sulfur dioxide, contending that this country had already cut such pollution substantially.[101]

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[98]Ian Austen, "A Tough Debate on Acid Rain," MacLean's, March 24, 1986, p. 16.

[99]"Strains on a Friendship," Time, April 11, 1988, p. 29.

[100]Philip Shabecoff, "U.S. Agrees to Limit Pollutant Linked to Acid Rain," The New York Times, November 2, 1988, p. A24.

[101]Ibid.

While proponents of acid rain reduction were continually frustrated during the Reagan years, there may be a ray of hope if George Bush lives up to his early promises on this issue. The new president, in his budget address to Congress in early February, made a special pitch for fighting acid rain. In addition to continue funding the clean-coal technology program, Mr. Bush stated that he would propose legislation for new federal emission reductions, saying "the time for study alone has passed, and the time for action is now." In addition, in a meeting in Ottawa with Prime Minister Mulroney, Mr. Bush promised that there would be speedy U.S. action on curbing border-crossing emissions that cause acid rain.[102]

There have been many proposals pertaining to the reduction of acid rain set forth over the past several years in the legislative branch of the U.S. government. Those that have concerned research on cleaner ways to burn coal have fared relatively well. Those that have dealt with specific reductions and concrete actions have been defeated one after another in Congress, as the battle over acid rain has seen the lines drawn on a regional basis.

New England legislators, such as Senator George Mitchell of Maine, whose states have experienced first-hand the damage acid rain can cause, have pushed emission control since 1981. However, Midwestern lawmakers, such as former Senate Majority Leader Robert Byrd of West Virginia, have blocked these attempts at reform. West Virginia, like other states in the region, not only has large coal-fired power plants that would require significant improvements under most reduction proposals (and thus raise electricity rates for consumers), but also a high-sulfur coal industry that would be hurt if power plants switch to cleaner fuels to meet any new emission standards. A

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[102]Tom Raum, "Bush Vows Speedy Action on Acid Rain," Journal Inquirer, February 11, 1989, p. 3.

powerful ally of Senator Byrd's in the fight against acid rain legislation has been Representative John Dingell of Michigan, the chairman of the House Energy and Commerce Committee. Mr. Dingell has fought such legislation because most of these bills have included tougher regulations on exhaust emissions, which would impose new costs on Michigan's auto industry.[103]

One of the most widely supported pieces of acid rain legislation dates back to 1984. This bill, co-authored by Representative Gerry Sikorski (D-Minnesota) and Representative Henry Waxman (D-California), was seen by many as one of the most politically realistic and well-balanced plans to control acid rain in the U.S. It for called cutting total annual emissions of SO_2 by 10 million tons and of NOx by 4 million tons.[104]

The reduction was to be accomplished by requiring the 50 largest pollution emitters burning medium- or high-sulfur coal, most of which are located in the Midwest, to install scrubbers by 1990, thus resulting in a 7 million ton reduction in SO_2. Also, the 48 continental states would have been required between them to achieve a 3-million-ton reduction in SO_2 from other emission sources utilizing any means available, including fuel switching and installing scrubbers. The NO_x reduction was to occur by a tightening of limits on emissions for newly constructed power plants, as well as for light- and heavy-duty trucks manufactured after 1986.[105]

Requiring the top 50 emitters to utilize scrubbers would have allowed these plants to continue burning high-sulfur eastern coal, thus preserving the jobs of thousands of coal miners in those regions. The considerable expense to these utilities of installing

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[103]Shabecoff, "State Acid Rain...," June 12, 1988, p. 4.

[104]Pawlick, pp. 155-157.

[105]Ibid., p. 157.

scrubbers in their plants would have been partially offset by imposing a one-tenth of a cent-per-kilowatt surcharge on the generation of electricity throughout the country. This would have resulted in an increase of only an additional 50 cents per month on the average residential utility bill. Employing this method would have prevented utility ratepayers in the industrial states whose plants would be installing the scrubbers from bearing the full costs of the clean-up.[106]

One of the most promising proposals in more recent times emerged not from Washington, but from the governors of two states that have been on opposing sides in the acid rain debate, New York and Ohio. The plan is promising not as much for its contents, but rather for the fact that it was negotiated by Governor Mario Cuomo of New York, where acid rain originating in the Midwest has inflicted substantial damage, and Governor Richard Celeste of Ohio, one of the leading emitters of the pollutants that cause acid rain.[107]

The Cuomo-Celeste plan would reduce SO_2 emissions by 50% by the year 2003, a reduction of approximately 10 million tons. One half of the costs of the proposal, which are estimated to be $1.8 billion, would be paid by polluters (aided by federal subsidies), while the remaining half would be borne by the oil industry through a tax on imported oil.[108] While the proposal is less stringent than others that environmentalists have preferred and the use of an oil import tax is seen as controversial, many believe that this plan may represent a break in the deadlock over Congressional legislation on the acid rain issue.[109]

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[106]Pawlick, pp. 157-158.

[107]Shabecoff, "State Acid Rain...," p. 4.

[108]Carpenter, p. 45.

[109]Shabecoff, "State Acid Rain...," p. 4.

Recent Congressional action on this dispute once again centered on two major players, Senator Mitchell, long a supporter of acid rain reduction, and his chief rival, Senator Byrd, a constant guardian of the coal industry's interests. Last fall, the two clashed over a bill sponsored by Mr. Mitchell which was similar in content to the Cuomo-Celeste proposal except for requiring the polluting utilities to assume the entire cost of the clean-up. Utilizing the power of his position, Mr. Byrd forced Mr. Mitchell to weaken his original bill, in terms of the specific reductions, the time period in which these reductions were to be achieved, and the distribution of the costs of reduction.[110] Although this bill received the support of many members of both houses, it never reached the Senate floor and the House version was deadlocked by a tie in the House Energy and Commerce Committee (chaired by Rep. Dingell).[111]

There was good news recently for proponents of acid rain legislation as Sen. Mitchell replaced his long-time adversary, Sen. Byrd as Senate Majority leader. With such an ardent supporter of acid rain reduction in this powerful Congressional position, it appears that the U.S. may finally take some tangible steps to protect the environment. But this remains to be seen.

While the U.S. continues to debate over the acid rain issue, elsewhere in the world, in both North America and Europe, strict anti-pollution controls have been enacted. In 1985, Canada launched a major abatement program. The goal of the program, the result of an agreement between the federal government and the seven

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[110]Michael Kranish, "Maine Senator Backs Down on Acid Rain," The Boston Globe, September 29, 1988, p. 11.

[111]Paulette Thomas, "Maine Senate Sponsor of Clean-Air Bill Gives Up Hope of Passage This Session," The Wall Street Journal, October 5, 1988, p. A34.

provinces east of Saskatchewan, is to reduce total SO_2 emissions to 2.6 million tons by 1994. This would represent a 50% reduction of emissions from 1980 levels.[112]

The ten-year program contains specific emission reduction requirements for polluters, but permits major industrial emitters time to develop and test new technologies, and to install the necessary controls. This plan, once fully implemented, is expected to cost approximately $500 million (Canadian) annually over a 20-year period. These costs are primarily to be borne by the private sector and the provincial utilities.[113]

West Germany, like many of its European neighbors, has enacted a stringent clean-air code in response to the vast damage acid rain has inflicted on its environment. The code place strict limits on emissions from all new and existing power plants. These plants have from three to eight years to achieve compliance, using whatever means necessary, depending on the current level of emissions. Those plants with the highest emissions are given the least amount of time.[114]

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[112] Stopping Acid Rain, Government of Canada, 1986, pp. 2-3.

[113] Ibid.

[114] "Europe Enacts Acid-Rain Controls, U.S. funds R&D," Electrical World, February 1987, pp. 52-53.

SECTION 4--UTILITIES

It should come as no surprise to the reader that the electric power and other related industries are bitter enemies of the movement to reduce acid rain. These bodies have offered many arguments to support their position, including: there is not enough data, more study is needed; the situation is not critical as SO_2 has fallen and continues to decline due to corrective measures taken by the utilities; and, acid rain controls are too costly and the increased costs would have to be passed on to the utilities' residential and industrial customers. In recent years, these industries have spent millions of dollars on intense and well-organized lobbying efforts against the passage of acid legislation. However, as such legislation seems likely to become a reality in the near future, the utilities have been promoting alternatives to the changes the proposed bills dictate for their operations. Finally, some experts on the acid rain issue believe that these opponents of such legislation have been blinded by the associated compliance costs and continue to overlook the important benefits it holds for the U.S. economy.

Utility and other business interests have rallied around the "we need more study argument" since the fight for the Clean Air Act in 1970.[115] No matter what type of evidence is presented to them, they almost unilaterally refuse to acknowledge that their operations are causing significant damage to the environment. When confronted by proponents of acid rain reduction, the utilities point to the fact that SO_2 emissions in the U.S. have declined over one million tons between 1980 and 1985 even though the use of coal to generate electric power has risen significantly over the past decade. The utilities state that without any new legislation, emissions will continue to fall as modern

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[115]Gorham, p. 66.

plants come on line and old ones are scrapped.[116] Now it is true that SO_2 emissions did fall over that period and that newer plants emit less pollutants than the older ones; however, due to population increases and rising industrial activity, experts predict that SO_2 emissions will gradually increase over the next several years in the absence of remedial programs.[117]

The costs of any proposed acid rain legislation are usually the main focus of the utility industry's argument. It claims that most of the reduction programs set forth in Congress so far would result in annual costs between $5-$10 billion to be borne chiefly by the utilities. The utilities in turn would be forced to transfer these costs to their customers, both residential and industrial, in the form of higher, possibly significantly higher electricity rates.[118]

In terms of residential customers, utilities claim that their rates would increase 10-30% in some areas of the U.S. under most acid rain legislation. The largest impact would be felt in the Midwestern states, whose electric power plants produce the greatest proportion of SO_2 emissions in the country. This magnitude of increase would obviously cause great dissatisfaction among state utility commissions and ratepayers. Today, bitter rate hearings and legal battles are routinely waged over utility requests for rate increases in the range of 2 to 4%.[119] James Sullivan of the Alabama Public Service

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[116]Main and Kirkland, p. 106.

[117]James H. Easterly, "Acid Rain Legislation Could Drown U.S. Utilities," Modern Power Systems, November 1987, p. 23.

[118]"Industry Braces for Acid-Rain Battle," Electrical World, June 1986, pp. 18-19.

[119]"Acid-Rain-Control Picture Exposes Ruinous Costs," Electrical World, February 1987, p. 15.

Commission: "Let me assure you that residential customers consider any rate increase excessive unless there is adequate justification."[120]

The utility industry alleges that industrial customers would have to pay as much as 50% more for electricity under many of the proposed acid rain control remedies.[121] These increased expenses would add to the burden of many industrial plants already under severe financial stress due to imports and other market factors. Since electricity is a large component of industrial production costs (as much as 40% or more for larger users of electricity), acid rain legislation, in certain cases could weaken a company's competitive position or even endanger a plant's very existence. Those firms operating in very competitive environments which would be unable to pass on the additional costs to their customers would be particularly hard-pressed in the face of acid rain legislation.[122]

A study performed in 1985 by Temple, Barker & Sloane, Inc., for the Edison Electric Institute (an industry group) put forth the following examples of the damage acid rain legislation would inflict on certain industrial plants:

A) Acid rain legislation would bring about a $1 million increase in the annual production costs of Container General's glass food and beverage container manufacturing plant located in Mount Vernon, Ohio (annual production 110,000 tons). This would translate to a 3% rise in the cost of a ton of glass. This production cost increase would be difficult for the company to handle as it faces stiff competition from plastics and other glass manufacturers.

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[120]"Industry Braces for Acid-Rain Battle," p. 19.

[121]Main and Kirkland, p. 110.

[122]Lucien E. Smart, "Secondary Costs Effects of Acid Rain Legislation Noted," Public Utilities Fortnightly, May 16, 1985, pp. 4, 6.

B) Briggs and Stratton manufacturers small engines for lawn and garden equipment producers worldwide at six related plants in the Milwaukee area. In 1984, it put out 166 million pounds of engines and it employed almost nine thousand people (the largest private employer in the area). Its annual production costs would increase by over $650,000 through higher electricity prices. This would have a detrimental effect on its competitive position both nationally and internationally, as it faces vigorous competition from both domestic and Japanese companies.[123]

(It should be noted for comparison's sake that the government Office of Technology Assessment projects that much of the proposed acid rain control legislation would cost between $4 and $5 billion annually and electricity rates overall would likely be raised an average of 2 to 3%)[124]

In response to the push for acid rain legislation over the past several years, the utility industry and other business interests have waged a concerted lobbying effort through many groups in Washington against any such bills. Among the leading lobbying factions in this battle is Citizens for Sensible Control of Acid Rain, an organization formed, and cleverly named, by a number of electric utilities and coal producers in 1983. The American Electric Power Company, Southern Company, Union Electric Company, Consolidation Coal Company and several others have all contributed to this group.[125]

In 1986, this so-called citizens organization spent $3 million, the highest of any registered lobbying group in Washington. Most of this money went to public-relations

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[123]Smartt, p. 6.

[124]Alexandra Allen, "Blow Away the Foul-Air Lobby," The New York Times, June 11, 1988, p. 31.

[125]Ibid.

firms to generate "constituents" letters urging legislators to defeat bills on acid rain. These letters typically contain exaggerated estimates of the cost of acid rain control in terms of total costs and resulting increases in electric rates which bear no relation to projections by the Office of Technology Assessment. The recipient of the letter is strongly encouraged to sign and mail it to their Congressman "in the postage paid, pre-addressed envelope provided for your convenience."[126]

Another related multimillion dollar project, the Clean Air Working Group, is funded by major business interests, such as the United States Chamber of Commerce, the National Association of Manufacturers, the Chemical Manufacturers Association and individual companies including Shell and General Motors. Inconsistent with its name, the objective of this organization is to prevent clean air legislation, rather than to work for clean air.[127]

In addition to lobbying activities, this group is responsible for a national publicity campaign to promote their founders' opposition to proposed air pollution reduction laws. The campaign promises a "quiet death for businesses across the country" if clean air legislation becomes reality.[128]

As can be readily determined from the information presented above, the electric power industry does not want the government to impose new emission standards. However, as the likelihood of the passage of an acid rain bill increases steadily, the utilities have been promoting alternatives to the common remedies, the installation of scrubbers or the switch to low-sulfur coal, included in most of the proposed legislation. The utilities have been supporting the previously mentioned "clean-coal" technologies as

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[126]Allen, p. 31.

[127]Ibid.

[128]Ibid.

more efficient and cost-effective answers to emission reduction. However, these technologies are still in the research and testing stage and the utilities have been unable to predict when they will be available on a large-scale. "We're very suspicious that the promise of future technological improvements is being used as an excuse for not introducing technology that's already known," says Jan Beyea, senior staff scientist at the National Audobon Society.[129]

Critics of the stance that the utility industry and other business interests have taken on the acid rain issue point out that abatement legislation would have a significant positive impact on the U.S. economy. A report released by an economics research firm, Management Information Services, Inc, in 1987 estimated that the enactment of acid rain legislation could pump billions of dollars into the economy and create hundreds of thousands of new jobs. The net annual economic gain from the manufacturer of emissions control equipment, after accounting for job and sale losses in coal mining, would amount to between $7.5 and $13 billion, according to the study. It also stated that there would be a net gain of 100,000 to 194,000 jobs.[130] However, these benefits would not be evenly distributed, as some states producing high-sulfur coal, such as Kentucky, would come up losers, while heavily industrialized states like Michigan, would reap much of the rewards.[131]

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[129]Luoma, "Acid Murder...," p. 135.

[130]"Acid Rain Issue Heating Up," Chemical Marketing Reporter, February 9, 1987, pp. 3, 26.

[131]"A Sweet Side to Acid Rain," Time, February 16, 1987, p. 49.

SECTION 5-- THE SCENARIO FOR A SOLUTION

At this point, the reader can obviously conclude that the acid rain issue is certainly a complex dilemma. However, the problem is solvable. There is a comprehensive solution somewhere, but so far it has remained unavailable. Because of the intricacy of the task and my lack of personal expertise on the subject, I will not propose a detailed solution to the acid rain problem here. Rather, I will discuss a scenario under which an efficient and effective solution should become a reality. In other words, I will outline what events must occur for the "best possible" solution to be implemented.

I believe that there are four main events that must occur before the acid rain dilemma can be resolved: those involved in the acid rain issue must refrain from focusing solely on cost-benefit tools for analysis; the general public must become vocal on this issue; the environmentalists and the utility and business interests must soften their stands and work towards a compromise solution; and finally, an equitable method of distributing the costs of acid rain reduction must be determined.

Pollution-control programs, such as those proposed for acid rain, are appropriately analyzed in terms of their cost-effectiveness; however, the supposed clarity of numbers often masks the fallacy of the analysis. Costs of particular acid rain control strategies are relatively simple to quantify. Engineers can calculate the price of powerplant modifications to reduce sulfur dioxide emissions. It is routine to project the increase in consumer electric bills as a result of higher plant costs.[132]

At times benefits can be valued with equal precision. Risk analysis can reveal that a certain amount of SO2 reduction can reduce the number of cases of respiratory illness in the Northeast. Medical statistics can measure the treatment cost per case.

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[132]Peter A. A. Berle, "Numbers Can Fool You," Audobon, July 1988, p. 6.

Avoidance of such an illness has a monetary value that can be valued in terms of reduced hospital bills.[133]

Too frequently, however, the benefits of environmental protection (in this case acid rain reduction) are not so simple to quantify. Many of them cannot be measured at all. How can a value be placed on avoiding an uncalculated risk of an as yet unrecognized hazard? The lack of a quantifying mechanism, however, certainly does not mean that environmental protection is without value. For instance, had the use of asbestos been restricted when it first entered the marketplace, enormous health costs and significant human suffering would have been avoided. The Food and Drug Administration official who refused to allow thalidomide to be sold in this country became a heroine, but her action might not have been justifiable under benefit-cost analysis based on the data that was available at the time.[134]

A further weakness of benefit-cost analysis is that hard, cold numbers cannot define many predictable benefits. The benefit of, for example, an acid-rain reduction program that has a given cost could be a clean stream in which a father and son could fish for trout. How can a dollar value be attributed to such an experience? The sense of well-being that goes with the knowledge that drinking water from the tap is not a health hazard may not be quantifiable, but it is real.[135]

The above should illustrate that conventional benefit-cost analysis, while a useful tool, is only a partial guide to environmental policy-making. It is vital to look beyond the numbers in cases such as acid rain.[136]

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[133]Berle, p. 6.

[134]Ibid.

[135]Ibid.

[136]Ibid.

As recent as the beginning of this decade, many Americans had never heard of acid rain; of those who were familiar with it, few had any idea of the magnitude of the problem. However, the level of awareness among the citizens of this country has increased dramatically. In the summer of 1986, a major pollster reported that U.S. awareness of acid rain had reached about 90% and a reasonable majority of respondents were "gradually willing" to pay for abatement programs. In addition, recent opinion polls in this country have exhibited overwhelming support for tougher clean air legislation.[137]

It appears that public awareness of the acid rain issue is no longer a problem. The current problem is that few Americans have translated this awareness into concrete action. To this point, there has been little, if any, widespread public outcry on the acid rain problem. For whatever reason, the public has simply not rallied around this issue. The recent defeat of the Congressional pay-raise bill as a result of a public uproar is evidence that legislators sometimes heed the voice of their constituents. A similar public outcry in the form of demonstrations and thousands of letters would likely spur Congress devote more time and effort to formulating a solution to this dilemma.

Until now, the two sides in the acid rain debate, the environmentalists and the utility and business interests, have been diametrically opposed over a potential solution to this crisis. These two groups must realize that any potential answer to the acid rain problem must consider both the environment and business in order for society to be best served. As such, both sides must relax their positions somewhat and seek a compromise in order for the best possible solution to emerge. The best solution will

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[137]Phil Weller, "The Battle Against Acid Rain: Reason to Hope," Seasons, Summer 1987, p. 28.

result from a cooperative, committed effort, and not from a battle laced with distrust and name-calling.

The two main issues that will have to be decided by the environmentalists and the utility and business interests are: the amount of reduction and a timetable for reductions. Because of industry's staunch refusal to make major concessions, it appears that the environmentalists demand for substantial overall reductions may need to be altered somewhat. As an alternative likely to gain more support from industrial concerns, the amount of reduction in the initial legislation could be lowered while including provisions for future reviews of emission levels (and any resulting action depending on their outcomes) in the bill.

Concerning the timetable for reduction, it boils down to a question of the length of time to allow utilities to comply with the new emission standards. The recurring proposal of requiring immediate compliance, thus imposing an option on powerplants of utilizing scrubbers (inefficient) or switching to low-sulfur coal (forcing economic dislocations) does not appear to be part of the best possible solution. Besides the inherent difficulties of these two reduction measures, this proposal would tend to dampen further clean-coal technology efforts. It may be better to allow utilities some time to determine which measures would be most efficient for them to utilize in meeting the new emission standards. Legislation could require the utilities to submit a detailed proposal outlining their plans to achieve reduction after the enactment of the new standards.

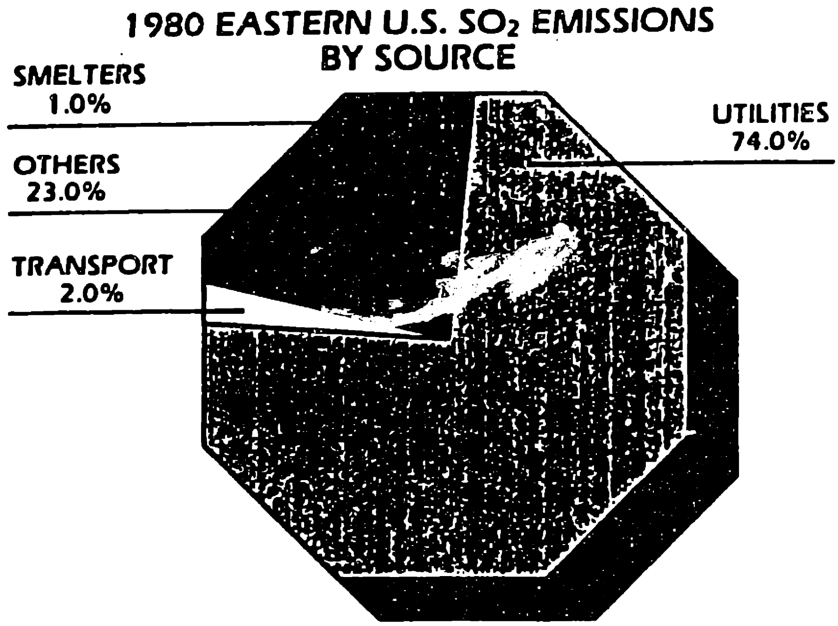
Probably the trickiest issue that must be resolved before the "best" solution to the acid rain dilemma can be discovered is the question of who will pay for the clean-up. It is clear that an equitable method of distributing the costs of abatement needs to be formulated as part of the comprehensive solution. However, referring to this task as formidable is a significant understatement.

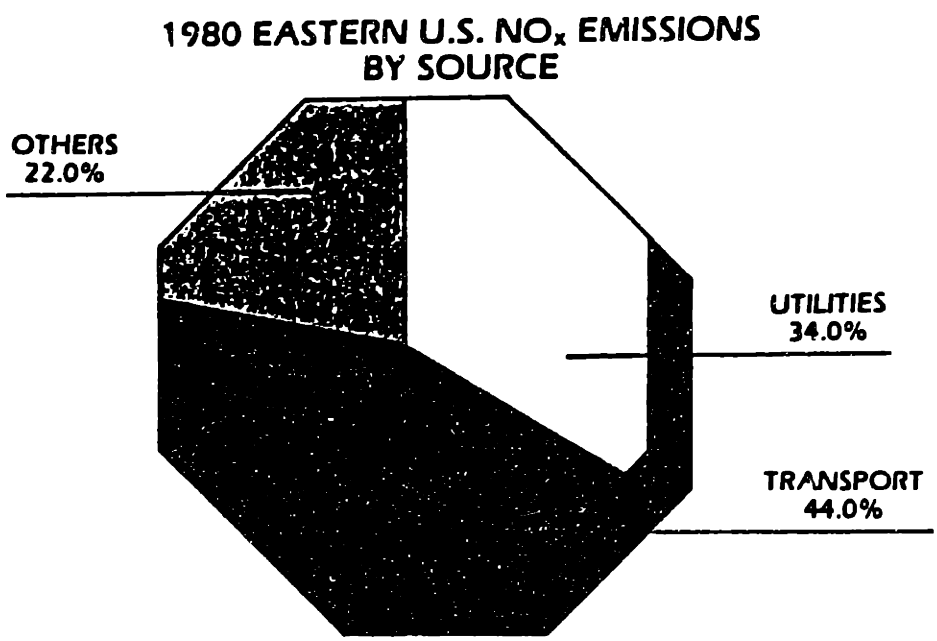
Among other ideas, many pieces of acid rain legislation have imposed the lion's share of the costs on the offending utilities and thus the surrounding communities, many of which are located in some of the poorest regions (e.g. parts of West Virginia) in the country. A more attractive alternative may be to spread the costs among the federal government, the utilities and related industrial concerns and the state governments of the offending regions. A surcharge on electric bills across the country also appears to be a concept worth further consideration.

CONCLUSION

All reports suggest that acid rain legislation will be passed by Congress in 1989. Whether this legislation will be the "best possible" remains to be seen. However, due to the sharply diverse positions of the environmentalists and the utilities and the consistent regional political battle which has raged in the legislature, the odds are not in it's favor. Without the developments outlined in the above scenario, the attack on acid rain may be initialized with an inefficient and ineffective program.

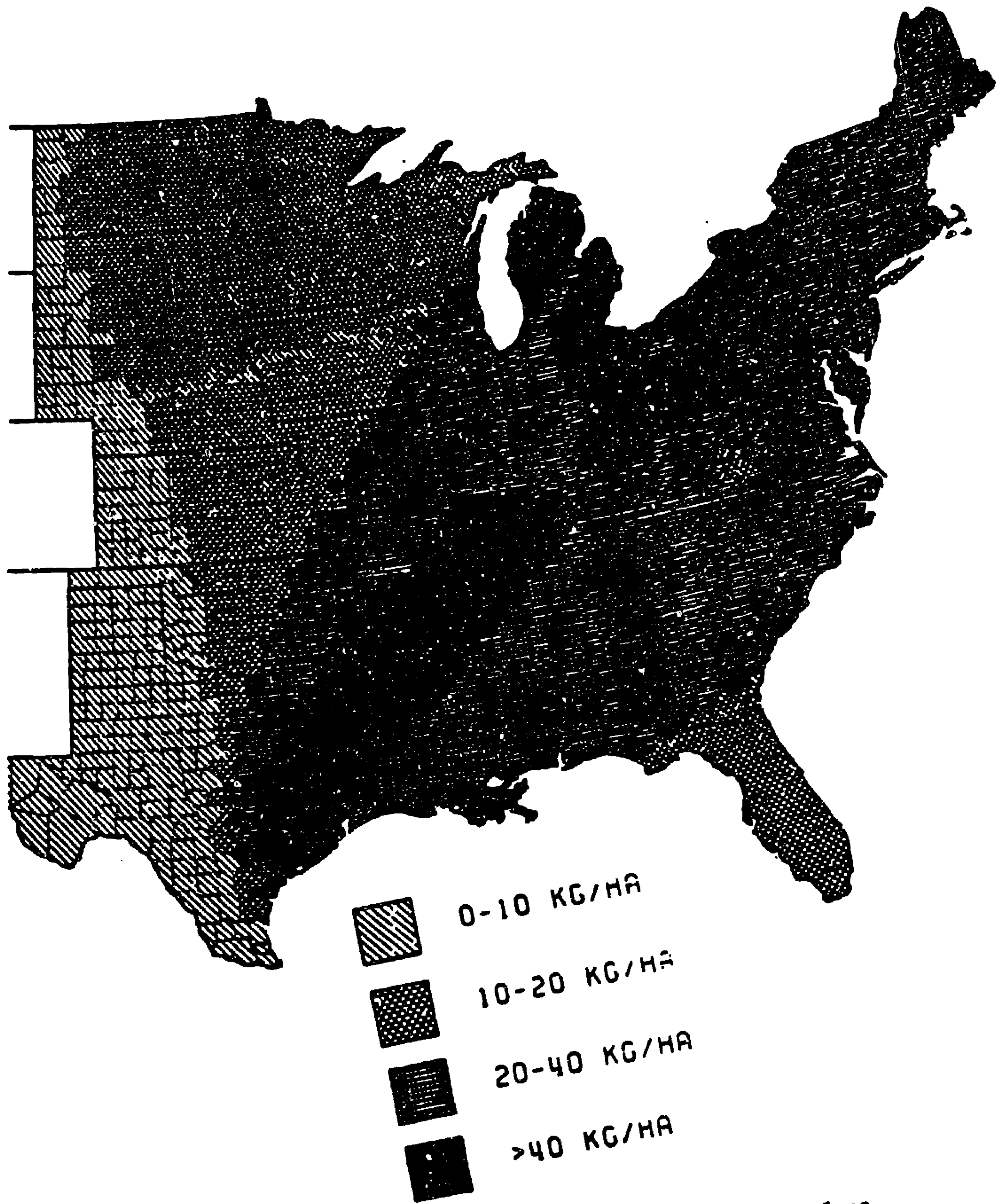
EXHIBIT 1





Source: Government of Canada, Stopping Acid Rain, 1986.

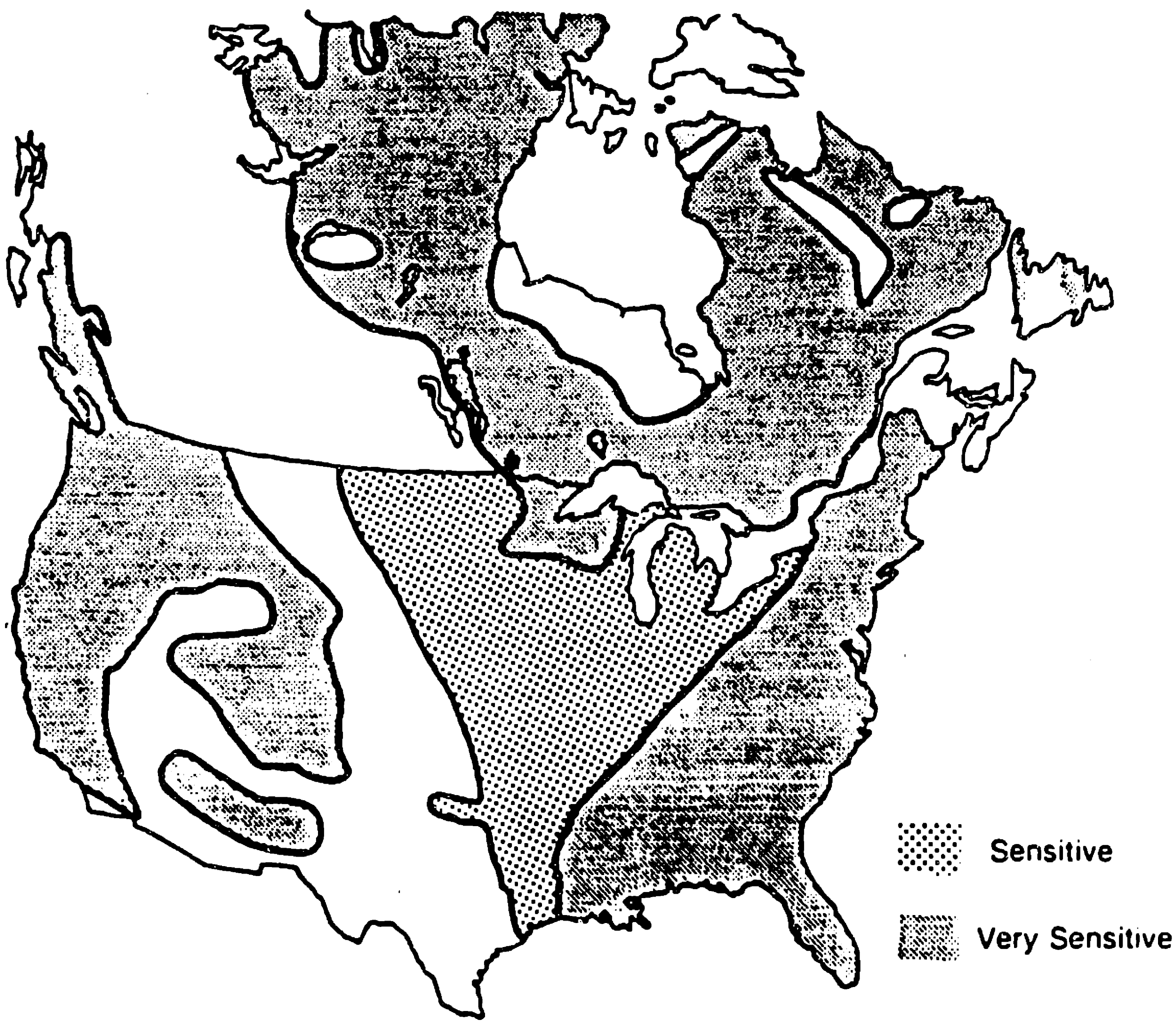
EXHIBIT 2--ANNUAL WET SULFATE DEPOSITION IN THE EASTERN U.S.



Source: Acid Rain and Related Air Pollutant Damage, Mass. Dept. of Environmental Quality Engineering, 1984.

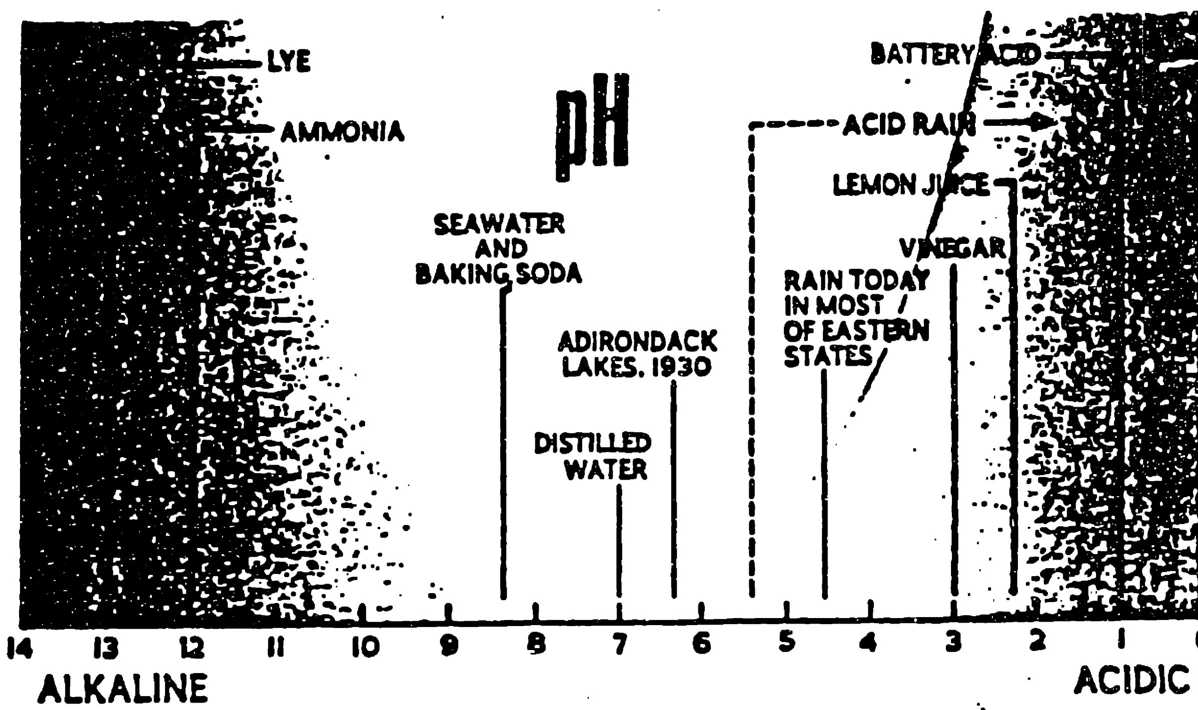
EXHIBIT 3

Acid Sensitive Areas of North America



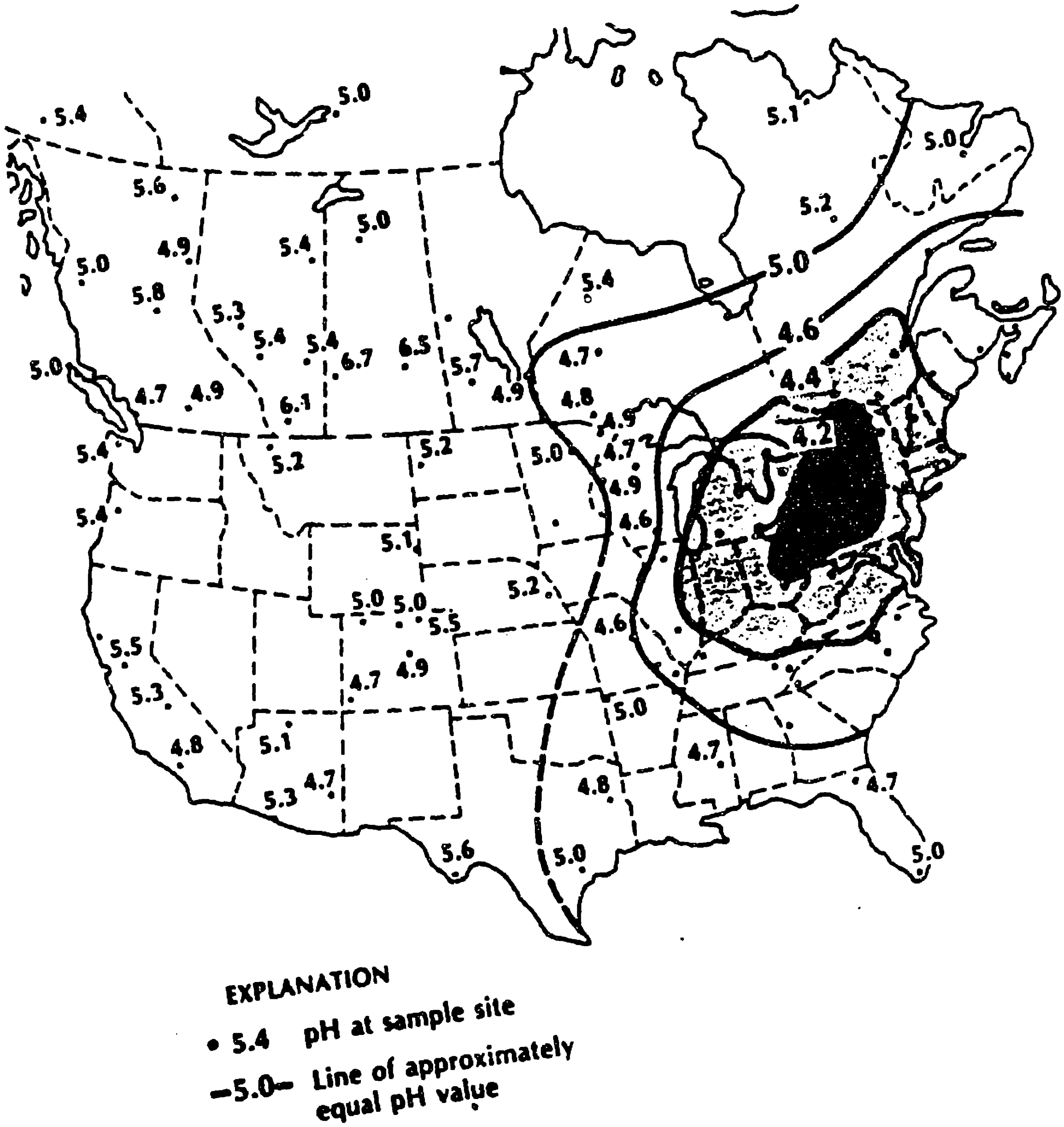
Source: Robert Osterman, Jr., Acid Rain, 1982.

EXHIBIT 4--PH SCALE



Source: National Geographic, November 1981.

EXHIBIT 5--PH OF WET DEPOSITION IN NORTH AMERICA IN 1982



Source: Acid Rain and Related Air Pollutant Damage, Mass. Dept. of Environmental Quality Engineering, 1984.

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