# Phosphates and the Environmental Free Lunch

W. Kip Viscusi

THE FREE LUNCH is not without its advantages. Consider, for example, a chance to ameliorate an environmental problem without closing a factory or costing the taxpayer any money. Surely this would be one of those "best things in life" that is free. Free indeed. Until, that is, we get around to examining the price.

My target is a modest one: the increasingly popular practice of banning phosphates from laundry detergents. Phosphates can be environmentally harmful, and banning them seems costless because phosphate-free detergents are available. Attracted by this free-lunch rationale, Wisconsin recently reimposed a ban after spirited debate, joining five other states that also have bans in force. North Carolina, Maryland, and Virginia are currently weighing bans. Many other states have at least flirted with the idea at one time or another.

But is a detergent ban really costless? A look at its implications in two states with very different conditions, North Carolina and Wisconsin, provides a broad perspective on what the free lunch really costs.

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### Selling the Free Lunch

The environmental rationale for a detergent-phosphate ban is straightforward enough. Phosphates are pollutants because, ironically enough, they are biodegradable. In fact, living things thrive on them. Excessive phosphate levels in lakes and streams promote rapid growth of algae, and so speed up the natural aging process (called eutrophication) of these waterways. The clarity of the water declines, oxygen levels drop, and in extreme cases fish die. The watershed, in short, can become a swamp—rich in primitive plant and animal life, but not at all like the pristine waters that humans prefer to swim and fish.

What could be more appealing than a legislative ban of phosphates in detergents? The payoff: clearer water at no cost whatsoever to the taxpayer. Indeed, some even suggest that the ban offers a financial *advantage* to consumers, because some generic nonphosphate detergents cost less than the brand-name phosphate detergents consumers now buy. The free lunch, in other words, is freer than free. No wonder some state legislators are eager to dine.

But for those interested in environmental protection, not political pabulum, some irritating seasoning comes along with the meal. First, even if the lunch is free, it is not a substantial repast. Detergent phosphates are only small contributors to the overall phosphate levels. Second, the lunch is not free. A fact apparently overlooked by some state legislatures is that consumers adjust their behavior in response to the phosphate ban. And when all is said and done, washing without phosphates is quantifiably more expensive than washing with them.

### The Light Lunch

Detergent phosphates, to start with, are only a minor contributor to waterway eutrophication. Homes that have septic tanks (about half in North Carolina and one-quarter in Wisconsin) contribute little phosphate pollution of any sort, because a properly operating septic tank is an excellent phosphate remover. About half of phosphates that *do* reach waterways come from "non-point sources"—fertilizer runoffs from farmers' fields, for example. The other half, delivered from "point sources" such as sewer systems, originate mostly from human wastes, and no regulator has yet dared to suggest any restriction on pollution of that type. When all is said and done, no more than 12 to 15 percent of total phosphorus in waterways is attributable to detergents.

And this fact, standing alone, ensures that the environmental benefits of detergent phosphate bans are slight. In two states—Wisconsin and Minnesota—the impact of bans was assessed in follow-up studies, and in both instances no significant effect on water quality was found. Phosphate levels *did* decline, but not enough to make any real difference. A one-seventh reduction in phosphorus levels is rarely enough to reduce eutrophication sufficiently to affect the value of water resources for fishing or recreation. And in Wisconsin the costs of removing phosphorus at wastewater treatment plants dropped very little after the ban, while the amount of phosphorus in water leaving the treatment plants declined perceptibly at less than one-third of the plants.

## After the Free Lunch

So much for the environmental benefits of a phosphate-detergent ban. What does the free-lunch ban really cost?

The first cost is as might be expected. Detergent manufacturers do not add phosphates for the exclusive and malicious purpose of eutrophying lakes and streams. Phosphate detergents also provide cleaner clothes. Researchers in academia as well as in the detergent and washing-machine industries have confirmed that sodium carbonate, the usual substitute for phosphates, is less effective at doing what a detergent is supposed to do: releasing and suspending soil and reducing water hardness. Within five to ten washings, the differences between colored shirts washed with phosphate or with nonphosphate granular detergents are readily apparent to any casual observer: the buildup of sodium carbonate residue gives the Brand X shirts a faded appearance that goes far beyond the ring-around-the-collar that TV-homemakers have learned to abhor. As a result, consumers discard their clothes prematurely.

To be sure, liquid nonphosphate detergents do better than granular ones, though still not as well as the phosphate brands. But liquids are much more costly too. The annual cost of switching from the best-selling granular phosphate detergent to the best-selling nonphosphate liquid has been put at $38 per household.

What is the dollar cost to consumers who switch to granular nonphosphate detergents and then endure laundry that is not quite so clean? For those who just glumly contemplate the results, we can only guess. If they value their wash quality only half as much as consumers who decide to take corrective action, the loss from the phosphate ban is, as we shall see, perhaps $30 a year.

The $30 figure is concededly speculative, but the cost of corrective action that other more enterprising consumers *do* take is not. A phosphate ban will impel about 20 percent of consumers to raise water temperature and increase their use of bleach, fabric softener, and wash pretreatments. The resultant annual costs are not trivial—about $11 per household in Wisconsin, $8 in North Carolina (weighted by the fraction of households taking corrective action). Moreover, some of the costs of using nonphosphate detergents arise whether or not the consumer takes corrective action. Carbonate buildups from the granular variety cause washing-machine repair problems and related consumer complaints to be much greater in phosphate-ban states and repair costs to be higher. Based on an appliance industry study, I estimate the present value of annual repair costs to be $12 per household in Wisconsin, $5 in North Carolina. Finally, carbonate buildup on clothes increases fabric wear. Drawing on results obtained by consumer science research-

ESTIMATED PHOSPHATE REDUCTION COSTS
(dollars per household per year)

| Method | Wisconsin | North Carolina |
|---|---|---|
| DETERGENT BAN | | |
| Energy and laundry additives | 11 | 8 |
| Increased machine repair | 12 | 5 |
| Fabric wear | 22 | 10 |
| | 45 | 23 |
| Laundry time* | 4 | 4 |
| Decreased wash quality* | 30 | 30 |
| Total | 79 | 57 |
| CHEMICAL TREATMENT | | |
| Total cost | 1.50 | 24 |
| Unit cost (based on level of phosphate removed) | 1.50 | 3–4 |

*Cost estimates for these items are more speculative.

ers at the University of California, I estimate these annual costs to be $22 per household in Wisconsin, $10 in North Carolina. The bottom line: the cost of actual out-of-pocket outlays and after-the-free-lunch corrective action averages $45 a year for Wisconsin households and $23 for North Carolina households. (The cost differences between the two states derive from differences in energy costs and water hardness.)

There's more. Using laundry additives requires extra laundry time, and phosphate-free detergents entail extra ironing as well, because they damage the permanent press qualities of fabrics. Putting a price on this is difficult. One minute a week at a price of $5 per hour should, however, provide a conservative estimate of the annual lost-time cost—$4 per household.

Now it must be conceded that these several costs, summarized in the table, are not likely to bankrupt the average American household. But the advocates of a detergent-phosphate ban miss the mark when they assert that the costs do not exist. Perhaps the implicit assumption is that consumers don't "really" care about cleaner wash, fabric wear, time spent ironing, and so on. But they manifestly do. Detergents containing phosphates are the dominant consumer choice in markets where they are available. After Wisconsin's ban came into effect there was a rapid upsurge in complaints to operators of coin laundries. Washing machine manufacturers also witnessed an increase in complaints about wash quality. Some consumers understood the real cause of the problem and crossed state lines to stockpile phosphate detergents. Prisons and commercial laundries took the more direct route of obtaining statutory exemptions from the ban.

### The Cheaper Lunch

When the free lunch turns out to be nothing of the sort, we should inquire if there might be a cheaper one—most particularly, a cheaper one that offers better fare. With phosphate pollution, as luck would have it, there is.

The chemical treatment of wastewater can eliminate 90 percent of phosphate levels in sewage—about six times as much, in other words, as a phosphate-detergent ban. And the cost is comparatively modest. In states such as North Carolina, which have not yet invested in central wastewater treatment facilities, the annual cost would be about $24 per household. In Wisconsin, where the needed facilities are already in place, the cost of achieving the same phosphate reduction as a phosphate ban would be about $1.50.

As the table reveals, these figures suggest that wastewater treatment in Wisconsin can remove as much phosphate as a phosphate-detergent ban at about 1/30th of the readily quantifiable costs of the ban. In North Carolina there is a six-fold improvement at about the same price as a phosphate-detergent ban. A very rough extrapolation from the North Carolina and Wisconsin experiences indicates that the national cost of wastewater phosphate treatment might be about $1 billion, while the consumer cost of a phosphate-detergent ban would be about $2.8 billion. In Wisconsin, North Carolina, and nationally, the comparative cost advantages of wastewater treatment is perhaps twice as large again if one also takes into account what I have so far omitted—the costs of increased laundry time and decreased wash quality. And the comparative cost advantage of wastewater treatment increases even more when one looks at what really counts—the dollar cost per unit of pollution removed.

Why then does the expensive free lunch of a phosphate-detergent ban remain so popular? The reasons are not hard to find. The cost of wastewater treatment facilities are visible, and therefore are political as well as economic. By contrast, the costs of a phosphate-detergent ban are not easily attributed to the ban, so the political costs are correspondingly slight. In addition, a ban hits that most popular of political targets, the out-of-state corporate villain. Direct controls on a much more important source of phosphates—the fertilizers used by in-state farmers—would reduce phosphate levels more effectively but at a far higher political cost.

Yet the facts are clear. In the case of phosphate detergents, the "defect" attacked by the ban is in fact a product attribute that is significantly valued by consumers, and for good reason. Banning phosphate detergents is "free" only to the legislator worried about the next election. Treatment plants do not offer any free lunch either, but they do achieve much more pollution control at less or, at worst, comparable cost. And *that*, for once, is indeed pure gravy. ■

**The I Ching of Acid Rain**

Peter Huber

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dred. But if percentages had been stated instead in terms of the neutrally defined eastern area in which acid rain falls, the OTA-TIE percentage would probably have been lowered by a factor of five or more.

More fundamentally, the measure of the "extremely vulnerable" or "already acidified" water area depends entirely on how fairly the "brand X" referent was chosen. That, in turn, depends on our very poor understanding of what makes areas "similar" for purposes of acid-alkali bookkeeping. Geology is certainly important, and the TIE study attempted to match the two regions it compared on that basis. But we can say with confidence that two regions are similar in all important respects other than acid rain deposition only if we fully understand all the important contributors to the acid-alkali economy. Identifying truly similar regions, in other words, depends on our ability to count the acid and alkali beans in a given ecological bag. And as already noted, that is a task well beyond current capabilities. Numerous variables other than geology may contribute to the acid balance, and no one has a clear idea of precisely what they all are, or just how important each one is.

*Predicting the future.* When we lack a clear picture of how acidified we are today, predictions about where we will be tomorrow start at a certain disadvantage. This has not, however, deterred people from trying to make them. The easiest (and therefore most popular) approach has been to set about determining how many lakes are "sensitive" or "vulnerable" to further acid precipitation. The technique is simple enough—current levels of alkalinity in lakes are measured, and the lakes with low levels are declared to be sensitive.

This type of investigation formed the basis of the recent OTA-TIE study, which concluded:

> About 17,000 lakes and 112,000 miles of streams lie within . . . sensitive areas. As a "best guess," about half of these lakes and streams have such limited ability to neutralize acid that they will acidify if enough acid pollutants are deposited.

Once again, one may pass over the percentage figure ("about half") as a pure artifice of TIE's own selection of what region to study. Much more dubious is the definition of just which bodies of water are "critically acidified" or "sensitive" to further acid deposition. Recall that man-made emissions deliver something on the order of 0.1 ounce of $SO_2$ per square yard of surface a year. If that surface is a lake, the TIE study labels it sensitive to the acid deposition if about two feet of the lake's depth currently contain insufficient alkali to neutralize that equivalent amount of acidity.* The method is delightfully simple. Too simple.

To begin with, the two-foot figure seems more than a little arbitrary. Why not two inches or twenty feet? More important, however, is that water alkalinity levels tell us absolutely nothing about the condition of the surrounding soil, bedrock, and chemistry of the ecology, and all scientists agree that those factors play a central role in the acidification dynamic. Lakes collect water not only from direct precipitation on to the lake's surface, but from the entire local watershed. Total acid deposition per unit area of lake will thus be much larger than that from rainfall directly on to its surface—but the alkali available to neutralize the acid can also be vastly larger than what is already in the lake.

In short, TIE's "best guess" of how many lakes will acidify if "enough" pollutants are deposited is certainly a guess; "best," no doubt, is an assertion of sincerity and good faith, but not an indication of good or even adequate underlying science. To be sure, it may be extraordinarily difficult to make a better guess. But a mechanical measurement of current alkalinity levels in the water nevertheless tells us very little. The crucial questions are where that alkalinity came from, how much more is available, or where alkali levels will go if acid depositions continue. Those questions are simply not answered or yet answerable. "All is flux," wrote Heraclitus two thousand years ago, "it is not

*The study does not use the two-foot figure as such. Instead, it labels a lake "sensitive" if the alkalinity concentrations fall below 200 micro-eq/l. A two-foot depth of water contains about 500 $l/m^2$ of surface. Combining the two numbers, the lake is labeled sensitive if a two-foot depth contains alkalinity of less than 100 $meq/m^2$. And 100 $meq/m^2$ is very roughly the alkaline equivalent of about 0.1 oz. of $SO_2$ per square yard. I use yards, ounces, and feet of lake depth not because these are the conventional scientific units but because they are likely to be more familiar measures to most readers. My numbers are all very approximate, and deliberately so.

possible to step twice into the same river." The same is true for an acid lake in 1984. Today's state of the lake is a poor predictor of tomorrow's conditions, most especially when the prediction is that they will be very different.

## Environmental Impacts

The last and surely most important question is why anyone cares whether rain, lake, or soil acidity is changed. Five categories of risk from acidification are usually flagged for closer attention.

*Aquatic resources.* If acid rain does culminate in the acidification of water systems, there is little doubt that at least some environmentally adverse consequences will follow. Fish and other biota do not take well to acid lakes. Acidity can disrupt the fish's own internal chemistry to the point where it is unable to function, or may injure fish eggs and fry. Acidification can also mobilize metals such as aluminum from the soil and bedrock, and these can also be toxic to fish. Of particular concern is "acid shock" from high concentrations of pollutants delivered suddenly into lakes during snowmelt. There is, in short, a reasonably firm consensus that if wide-scale acidification of lakes and streams occurs, it will have significantly adverse ecological impacts. These, in turn, can adversely affect sport fishing, tourism, and other economic or aesthetic values.

*Forests.* The second large ecological issue concerns the impact of acid rain on forests and woodlands. The Electric Power Research Institute (EPRI)—an institution funded by electric utilities—notes:

> Trees, primarily conifers, have been damaged or are dying at unusually rapid rates in recent decades in certain areas of the northeastern United States and Europe. According to quantitative documentation, red spruce have declined atop summits in Vermont's Green Mountains, a decline that has also been observed in New Jersey's Pine Barrens. And in West Germany, large areas of Norway spruce and fir have died or appear to be injured. What troubles researchers is that all these areas receive large amounts of acid rain and other pollution.

It is not difficult to postulate mechanisms by which acid deposition could affect forests—both favorably and unfavorably. Some forests are sulfur-poor, so $SO_2$ deposition there may promote growth. In others, acid deposition may remove nutrients stored in leaves or in the soil. Most forest soils exhibit no deficiencies in the types of nutrients that acid deposition would leach out, but a study of the Adirondack Mountain forest suggests that some northeastern forests are notable exceptions. Finally, acid deposition may mobilize toxic metals such as aluminum that are also harmful to trees.

But both EPRI and OTA agree that there are other possible causes for the impacts on forests that have already been observed, and that the link between acid deposition and forest damage is speculative in all but the most severe cases of acid deposition. (The widely discussed damage to the forests in Germany is associated with exceptionally high levels of $SO_2$ loading.) In the vast majority of instances, acid rain, ozone, heavy-metal deposition, drought, severe winters, or a combination of these factors are all possible causes of the observed forest damage. OTA concludes:

> To summarize the potential for long-term forest productivity effects from both acid deposition and gaseous pollutants, at the present time OTA can state only that such interactions might occur and that their probability of occurrence is greatest in . . . regions of the Eastern United States. . . . The mechanisms involved and the relative importance of those mechanisms to forest growth must be studied further in order to better describe and eventually quantify these potential effects.

*Agriculture.* No direct link between acid rain and crop damage has been established in the field. The evolving consensus has been summarized in the 1982 annual report of the National Acid Precipitation Assessment Program: "The most consistent conclusion to be drawn from agricultural research at all scales and with all species has been 'no effect' at current average ambient pH levels of 4.0 to 4.2." This is not surprising in light of the high levels of acidic fertilizers and alkaline lime that farmers regularly add to their soils.

*Materials.* Sulfur dioxide and other air pollutants can corrode a broad range of materials, including stone, metals, textiles, leather, and paint. Damage can occur to both culturally significant statues, structures, and monuments, and to routinely used construction materials. The damage is qualitatively similar to that resulting from natural weathering, so estimating its extent and severity is very difficult.

One recent study (produced by Mathtech Inc. for EPA's Office of Air Quality Planning, 1982) estimated that a 30 percent reduction in current ambient $SO_2$ levels would produce about a $300 million savings annually for about half of the households and a tenth of the production sector. The calculation as it stands contains large uncertainties; it cannot, in any event, be extrapolated to the nation as a whole. Apart from this study, there is abundant anecdotal and qualitative information about the potential for pollution-induced damage, but almost nothing that is reliably quantitative.

One might list, along with materials damage, impairment of visibility. Once again, this is not a problem of acid rain proper, but is linked to its precursors, $SO_2$ and sulfate. There is little doubt that pollution impairs visibility.

*Human health.* In high enough concentrations, sulfur dioxide itself (as distinguished from acid rain) may have harmful health effects, particularly to members of the population already suffering from respiratory disease. Some researchers have found a significant association between $SO_2$ levels and mortality, though others conclude there is no substantial link. But in any event, health problems from $SO_2$ itself are already addressed through EPA's ambient $SO_2$ standard and are quite distinct from the issue of acid rain.

Sulfuric acid and ammonium sulfate particles, the atmospheric byproducts of $SO_2$ chemistry that *are* part of acid rain, could conceivably have independent health effects of their own. It is also possible that these pollutants act synergistically with others, such as metallic ions, nitrates, and fine soot particles, to cause observable health effects. There is, however, no direct evidence showing any detectable human health effects from the highest concentrations of sulfuric acid or sulfate particles presently found in the environment.

Acidic water can dissolve aluminum, copper, lead, mercury, and other toxic metals from the soil, and from plumbing systems. While the chemistry suggests that a problem here is conceivable, once again no direct link between drinking water contamination and acid rain has been established. In any event, the acidity of municipal water systems can be monitored and corrected quite easily.

## Uncertainty and Ideology

All of which leaves us nowhere in particular. While it is not difficult to describe acid rain's possible environmental consequences in the abstract, it is enormously difficult to assess them quantitatively. There is certainly no scientific consensus on how widespread, imminent, or irreversible the ecological damage might be.

Much of the current alarm about acid rain is voiced in the pseudo-science of "maximum conceivable harm" or some synonym thereof. This is a weapon that has been used to devastating effect against the electric power industry at least once before, in the attack on nuclear generation. One must keep in mind, however, that "maximum conceivable harm" measures nothing but the fertility of the human imagination. The maximum conceivable accident in a single bathtub is one in which the citizens of the nation line up, fall in, and drown, one at a time. This particular terror, "conceivable" though it manifestly is, has yet to attract widespread regulatory attention, and perhaps for good reason.

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When we cannot say with confidence *whether* science supports regulatory action, there is bound to be more than a little disagreement over *how quickly* regulatory action should be taken. Damaged forests and lakes certainly do not recycle quickly, at least not without expensive help, but it is most uncertain whether we are in fact on the brink of any widespread injury from acid rain. Those who adopt the most pessimistic interpretation of the available scientific evidence readily conclude that prompt reductions in $SO_2$ emissions are urgently required; even maintaining emissions at current levels will lead to serious cumulative damage. Those who read the evidence in a more optimistic light can conclude, equally readily, that if the acid rain problem exists at all, it is not a problem that calls for hasty change in the regulatory climate.

Even more uncertain is how quickly ecological benefits would be realized if emissions were reduced. This last scientific question of the acid rain debate is of considerably more than academic interest, though it is often given little attention. If a new regulatory initiative were followed by prompt, visible, improvement in environmental conditions, there would, of course, be little more to debate. But, as Chris Whipple of EPRI has pointed out, the *failure* to see prompt environmental improvement following the implementation of a new regulatory program could be interpreted as proof that either (1) the controlled sources were not the cause of the problem or (2) a larger control program was needed. Undoubtedly a certain sense of *déjà vu* would accompany this dilemma if it were to arise.

Why, one might ask, has acid rain generated such large amounts of political heat from so little scientific light? Environmentalists, of course, have little affection for the coal economy and much aversion to air pollution. And Canada and a number of northeastern states are seriously and legitimately worried about the environmental effects of acid rain. Their concern is greatly amplified by the perception —not fanciful, but not solidly anchored in science either—that it is not primarily *their* acid rain (which conveniently blows out over the Atlantic) but rather acid rain from numerous power plants in the Midwest that is causing the problem. Environmental ideology and interregional rivalries of this character strongly affect where and how dogmatically most of us come down on the unresolved scientific questions.

## II. THE REGULATORY OPTIONS

The gravity of the acid rain problem—a measure of the potential benefits in a regulatory calculus—involves scientific questions that are far from settled. But if we *are* to regulate acid rain, a largely distinct question is how we should set about doing so. Some of the technical aspects of the regulatory options are mundane enough. But the policy planner can nevertheless take delight in the rich range of opportunity for regulating wisely or foolishly, frugally or profligately, progressively or so as to entrench the acid rain problem forever.

### Tear down the Stacks?

Let me start where no one else seems willing to begin. The acid rain controversy is fueled largely by inter-regional and international finger-pointing. So why not bring the nub of the dispute back home? The average height of utility smokestacks has tripled in the 1970–84 period, largely to meet EPA "ambient air standards" by dispersing pollutants very broadly rather than by curtailing their emission. We *could* just cut the tall stacks back down to size. Short smokestacks keep pollution closer to home, where, in fairness, it would seem to belong.

I recognize, however, that shorter smokestacks are not high on anyone else's list of preferred regulatory options. Moreover, dilution may in fact be a very good control strategy. As countless cancerous rats might attest, many things are harmful in large concentrations but innocuous or even beneficial in smaller ones. It would be a pity to tear down the stacks if the result were an increase in local harm greater than the offsetting benefit at remote locations.

Tall stacks, it is therefore plain, are likely to remain tall. But Congress did respond to the tall-stack problem in 1977, so in the future at least, dilution is likely to be used less often as a strategy for attaining local ambient standards. The Clean Air Act Amendments of that year deny polluters emission control "credit" for the locally favorable effects of smokestacks built taller than would be dictated by "good engineering practice." Prodded by a federal court order, EPA recently proposed new rules that will require some tall-stack emitters to add pollution control equipment or switch to cleaner fuel. The rules are expected to eliminate between 0.8 and 2.8 million tons of $SO_2$ emissions a year, costing industry from $0.9 to 4.6 billion in capital expenditures and from $0.3 to 1.4 billion in annual operating expense.

### Control Possibilities and Prices

In the larger picture, however, tall stacks are only a regulatory idiosyncrasy. And so we turn to emission controls. Sulfur dioxide can be contained or controlled at almost every stage of the fuel cycle—in the choice of fuel at the outset, during the combustion process, or after deposition in a lake or forest.

*Changing fuel.* The first possible answer to excess emissions of $SO_2$ is to work with a lower-sulfur fuel. Natural gas, hydroelectric power, uranium, and most oils are all obvious candidates. But natural gas is expensive, and its use for electric power generation has been discouraged by federal law. Oil is expensive too. Hydroelectric power is not much of an option in the flat Midwest where $SO_2$ emissions are highest. Uranium is the sulfur-free fuel most engineers would probably select as the alternative of choice, but it too is believed by some to entail unacceptable environmental consequences.

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This would appear to leave only coal as the main short-term alternative fuel to coal—a distressingly narrow range of choice. Still, some coals are much cleaner than others, and coal switching can cut emissions considerably. But clean coal sells at a premium price, and the premium would be likely to rise if regulatory requirements were tightened. Coal switching can also cut plant efficiency, because boilers are often designed to perform optimally only with fuel of particular quality. One broadly cited estimate (by PEDCo. Environmental Inc. for the Department of Energy) suggests that switching coal to cut annual $SO_2$ emissions by 6 million tons would cost utilities about $1.4 billion a year (1982 dollars), or about $250 per ton of $SO_2$ removed. Coal switching also entails indirect costs for producers of dirty coal in northern Appalachia and the Midwest, at the same time that it represents a boon for producers of clean western coal.

A separate fuel-switching option is to buy dirty coal and clean it before burning it. The technology of physical coal cleaning is already available and in use. A Department of Energy study estimates that coal cleaning could yield a 1.5 million ton additional reduction in $SO_2$ emissions, at about $580 per ton of $SO_2$ removed. Other coal-processing options, including chemical cleaning and coal gasification, are also under study, but not yet at the stage where they can be priced or quickly put into effect.

*Combustion and emission controls.* The next possibility is cleaner burning. Several types of potentially efficient and cheap new technologies—the limestone multistage burner and the fluidized bed combustor—are under development, but none is yet in widespread commercial use. As a result, no very reliable estimates of their costs are available. One EPRI publication suggests that emission reductions might be achievable at about $800 per ton of $SO_2$ removed.

Scrubbing flue gases comes next in the chain of control possibilities. The smoke from the burner is sprayed with large volumes of an alkaline water-limestone mixture, the sulfur is chemically captured, and the large volumes of scrubber sludge are carted off to landfills. The technology is already well developed—EPA requires scrubbers in all new coal-fired power plants—but costs are high. Up front capital costs for a mid-size plant are typically in the range of $80 to $200 million—with higher unit costs for attaching scrubbers to smaller boilers. Scrubber operation is also expensive. Typical bottom line costs are in the range of $700 to $1,000 per ton of $SO_2$ removed.

And this brings us to a critical variable that cuts across all the regulatory options—the question of timing. Retrofitting scrubbers on to old plants—a favorite quick fix in some quarters—costs 10 to 40 percent more than building scrubbers into new plants as the old ones are retired. And a uniform, do-it-now, scrubber prescription also precludes the phased introduction of nonscrubber control technologies that are potentially cheaper and even cleaner. The owner of an old power plant with a new scrubber, like the owner of an old car with a recently installed new transmission, has a strong incentive to nurse the plant along for as many more years as possible, to recoup the investment that has been made. One cannot place any certain figures on the price of a hasty or prescriptive cleanup program, but EPRI has estimated that savings of $4 billion a year are possible under a regulatory program that encourages the use of new technology and permits a phased reduction in emissions.

*Watershed management.* Once $SO_2$ goes up the stack, little more can be done until it comes down again. But acidity can be neutralized in lakes themselves, or environments can be managed to cope with higher levels of acidification. Sweden, for example, has conducted an intensive liming program for several years, in which large amounts of crushed limestone or lime are added to the water or applied to the adjacent soil or forest. Smaller scale liming has also been attempted in Norway, Canada, and the United States.

The costs of liming lakes in New York have ranged widely from $30 to $300 an acre. A recent study placed a $2 to $4 million a year price tag on liming several hundred acidified lakes in the New York Adirondacks. This is very cheap as acid rain solutions go. But liming is a simple and straightforward solution to precisely the same extent that acid rain is a simple and straightforward problem—which is not at all. Nevertheless, if lake acidification ultimately proves to be a largely localized and uncommon problem, liming may still prove to be a viable control option. The introduction of acid-resistant breeds of fish is yet another possible response to low levels of acidification.

### The Economists Dream On

The variety and complexity of the emission- and damage-control alternatives suggests that choosing among them is a task that is much too delicate to be resolved efficiently by the visible hands in Washington. If there is to be regulation, perhaps the market might play some small role in shaping its final form.

Suppose that Congress in its wisdom should decide to shoot for what has already been proposed in the most ambitious bills—a 10-million ton cut in annual $SO_2$ emissions. The accompanying table contains OTA's (in my view optimistic) estimates of total and marginal costs of a least-cost emission control program. The marginal cost for the last million tons of $SO_2$ emission reduction would be in the vicinity of $1,000 per ton. This pleasantly round figure therefore represents a reasonable guess about the "right" price to place on $SO_2$ emissions under a tax-incentive regulatory scheme.

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Now there is no doubt that congressional enactment of a pollution tax is about as likely as a visit from the Tooth Fairy. Hostility to emission taxes runs deep in industry as well as among many environmentalists, and with enemies as varied as that, who needs the friendship of a few economists? But the idea of an emission tax nevertheless provides some food for thought.

The tax would put at least one emission control strategy into effect within days of its enactment—years faster, in other words, than scrubbers, and months faster than coal-switching alternatives. Utilities currently use "economic dispatching" of power supplies—that is, as daily demand rises and falls, cheaper generating units are brought on line first, and turned off later, than more expensive ones. But dirt, under the current regulatory structure, is cheap, so dirtier units are often used in preference to cleaner ones. The obvious alternative is to use the cleaner units first and most, the dirtier ones last and least. An emission tax immediately encourages this "environmental dispatching" option.

More important is that a regulatory tax surely promises much more environmental improvement than any prescriptive program. Avoiding taxes, as most of us discover every April, brings out the

COSTS OF REDUCING $SO_2$ EMISSIONS IN THIRTY-ONE EASTERN STATES
(costs in 1982 dollars)

| **Allowable Emissions** (lb. $SO_2$/MMBtu) | **Emissions Reduced** (million tons $SO_2$) | **Total Cost** ($ billions/yr.) | **Average Cost of Reductions** | **Costs per Marginal Ton Reduced** |
|---|---|---|---|---|
| 2.5 | 4.6 | 0.6–0.9 | 170–240 | 320 |
| 2.0 | 6.2 | 1.1–1.5 | 200–280 | 440 |
| 1.5 | 8.0 | 1.8–2.3 | 260–330 | 700 |
| 1.2 | 9.3 | 2.6–3.4 | 310–400 | 740 |
| 1.0 | 10.3 | 3.2–4.1 | 350–440 | 830 |
| 0.8 | 11.4 | 4.2–5.0 | 400–480 | 1,320 |

**Note:** Estimates exclude costs to meet current state implementation plans or to offset future emissions growth; they assume that each utility chooses the most cost-effective control method.

**Source:** Office of Technology Assessment, *Acid Rain and Transported Pollutants*, p. 169.

very best and most creative that human ingenuity and cupidity have to offer. The scrubber-only regulatory proposals recently considered in Congress would have cut off 10 million tons of annual emissions in a one-shot, unimaginative solution—and thus would have left 17 million tons entirely untouched. An emission tax, in contrast, would maintain a steady pressure for more control, even while it permitted regulatees to select control strategies efficiently in time. A tax has the added advantage of fairness, since it could be assessed not only against giant electric utilities—everybody's favorite deep-pocket target—but also against other polluters who account for almost one-third of total $SO_2$ emissions.

To be sure, an emission tax also has some potential problems. First, emissions must be monitored. This is administratively less convenient than supervising the one-time installation of a scrubber. But with potential savings from efficient regulation in the billions of dollars it would certainly be possible to afford the necessary inspectors and monitoring equipment.

A second possible difficulty concerns managerial psychology. Most utilities are regulated monopolies, reimbursed by ratepayers on a "cost-plus" basis. It is conceivable that industry executives would simply pass the emission tax on to their consumers and worry no more about acid rain. But not likely. Public utility commissions do not pass through to ratepayers costs incurred through "imprudent" management choices. If cost-effective control strategies are readily available, pollution as usual would surely be discouraged.

The real difficulty with a pollution tax is choosing the "right" marginal rate. All one can say is that this would be much less of a problem than setting out a command-and-control regulatory program in all its detail. And readjusting a poorly chosen tax would surely be much easier than excising 1,000 pages of prescriptive regulation from the *Federal Register.*

**Where's the Pork?**

The emission tax is surely a thing of market beauty, but it is also political poison. The first problem with a \$1,000-per-ton tax on $SO_2$ would be too much revenue—about \$20 billion a year, from the residual 20 million tons or so of emissions not eliminated. Spread over 50 million eastern and midwestern households the resultant rate shock (partly in consumer electric bills, and partly in increased costs for goods manufactured by electric-intensive industries) would be in the range of \$400 per year—this in addition to \$150 or so attributable to emission-control expenditures by utilities.

But the emission-tax revenue could, of course, simply be returned to the utilities, and hence to the consumers. The refund obviously would not be in proportion to the amount of $SO_2$ each utility emits, but rather in proportion to the amount of electricity each generates. The marginal cost of $SO_2$ emissions would then remain close to \$1,000 per ton, while the industry-wide average cost of generating electricity would not increase at all. Dirtier-than-average utilities would simply subsidize cleaner ones, and inter-utility environmental dispatching would be encouraged.

The regulatory burden would nevertheless still fall particularly hard in the Midwest, where $SO_2$ emissions are highest. And the evolving consensus seems to be that because acid rain falls equally on the just and unjust, the just must share equally in the cost of doing something about it. This notwithstanding the fact that it is the unjust who earlier absconded with the umbrella. It may seem perverse to ask the consumers served by clean utilities to subsidize cleanup efforts by dirty ones, most especially since clean generation already (not surprisingly) costs more. But if we should decide to regulate, Congress would probably insist that the polluted pay along with the polluters. One proposal has been a tax on eastern non-nuclear electricity consumption to create a trust fund for buying scrubbers.

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But why be so specific about how the money is to be spent? Even under a "polluters-are-paid" principle, the inefficiencies of command-and-control regulation could be avoided. The mirror image of the emission tax is a subsidy for not emitting. If each utility's 1985 emission levels were grandfathered onto the books, a $1,000-per-ton payment for emissions reduced would create efficient pollution-control incentives almost as well as a tax on emissions at the same rate. (But not quite as well. A tax on pollution emitted would increase the price of electricity and so lower electricity consumption and $SO_2$ emissions more than a subsidy for pollution reduction at the same marginal rate.)

Regrettably, the baksheesh would probably not stop even here. Any incentive structure that encourages cost-efficient reductions in $SO_2$ emissions will end up weighing heavily on eastern producers and miners of dirty coal, because burning clean coal is by far the cheapest way to limit emissions. Which means that if polluters *are* to be paid, the miners of dirty coal will also be in the receiving line.

Once again, the money can be raised from whomsoever Congress thinks should pay—most likely all eastern consumers of fossil-generated electricity. The question then will be *how* to deliver this particular kickback. The expensive way is to insist on the use of scrubbers as the means for controlling emissions. We already do this with new power plants, in a monstrosity of regulatory policy crafted by a bizarre legislative alliance between environmentalists and dirty-coal producers. This indirect form of subsidy has worked all right, but, as Paul Portney has calculated, at a trifling price of $320,000 a year for each coal miner's job protected (*Regulation*, November/December 1982).

Surely the miners and producers of dirty coal can be bought off for somewhat less. The key is to pay them in cash, rather than in the specie of command-and-control regulation. Once again, it may be perverse to reward people for not doing something judged to be antisocial—the very idea gives a tantalizing new meaning to "wages of sin." Be that as it may, it is certainly insane to spend more for the purpose than is absolutely necessary.

**The Regulation-as-Usual Impasse**

Whether it takes the form of efficient tax or inefficient prescription, direct regulation of coal-fired power plants can undoubtedly curtail some part of acid rain emissions. Some part indeed—a relatively small one. Even at $5 to $10 billion a year, the most ambitious proposed programs would leave almost two-thirds of current $SO_2$ emissions untouched. Regulation-as-usual will thus, more than anything else, largely preserve and entrench the status quo—with at least 17 million tons of $SO_2$ still emitted into the atmosphere every year.

With electric power, in other words, the promise of more regulation has finally reached a dead end, a result that should be wholly unsatisfactory to *both* environmentalists and electric utilities. How do we come to find ourselves in such a fix?

Nature, to start with, has been less than kind. The sulfur in coal most undoubtedly is of natural origin, derived either from coal's vegetable precursors in the Carboniferous period of this continent's history, or from the geological habitat these plants selected for their anaerobic graves. Technology is also less than perfect. Electric power plants (or even electricity conservation measures) of any description always entail environmental consequences of some type: perfect cleanliness, like perpetual motion, still eludes us. But the regulatory system itself can also claim some large measure of credit for bringing us to where we are now—glumly contemplating a gigantically expensive dose of regulatory medicine that promises, at best, only a one-third cure.

Our electricity supply, it must be remembered, was not always so tightly linked to coal. Electricity can also be generated using oil, gas, hydroelectric power, or nuclear fuel, or even (conceivably) some of the "renewables" such as solar or wind power. There is, in addition, the option to stretch what we have further through efficient use and conservation. But in recent years, ample reserve capacity and modest demand have impelled our legislators and regulators to say no to almost everything but coal. We reject natural gas as an electric generator fuel because it may be in short supply for home heating. We reject oil because its use increases our dependence of foreign supply. We reject hydroelectric power because it floods valleys or threatens anadromous fish, the furbish lousewort, or the snail darter. And we reject uranium because Jane Fonda and Meryl Streep tell us it's too dangerous.

Which may explain why about all that is left and economically feasible in 1984 is coal;

after all, the "no" pigeons having been shot from the sky, the "yes" pigeon finally came home to roost. But coal, it would appear, may mean acid rain. And acid rain may prove for the environment to be the least acceptable choice of all. The environmental-regulatory complex, in short, spent the last twenty years forcing utilities to use what may prove to be the most environmentally damaging generating technologies, and is now exhorting them to spend the next twenty crafting a silk purse of clean electricity from the sow's ear of dirty coal. When you see environmental regulation of this character, reach for your gas mask. And grab your wallet.

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## The Deregulatory Option

There are limits to what can be achieved through regulation. This is a lesson that has been learned the hard way once before. Five hundred years ago environmental regulators made it a capital offense to burn coal in London. It was already clear then that coal burning emitted noxious fumes, whereas there was abundant "clean" wood available. In the end, of course, people switched to coal anyway, once England's forests had all been consumed for fuel. The forests never returned.

Today, ironically, it is the continued use of coal that threatens forests on this side of the Atlantic. All of the extant acid rain proposals accept the perpetuation of a coal-dominated electric economy, and all provide for still more regulation of coal furnaces. What is most striking about the numbers in these proposals is that even the most ambitious offer so very little. As noted earlier, the prescriptive, scrubber-based scheme for controlling acid rain is (at its most optimistic) a 10-million-ton bandaid on a 27-million-ton per year $SO_2$ hemorrhage. If environmental impacts of acid rain are cumulative, as many environmentalists suggest they are, the scrubber-retrofit proposal is a fraud that would only postpone, for a few years, the inevitable environmental catastrophe they expect.

There is another way to curtail acid rain—less visible than a new, multi-billion-dollar regulatory program, certainly less dramatic, but in the longer term more effective. In a comprehensively regulated industry such as electric power, where all the statutory presumptions are against new technology and new generating capacity, far-reaching change demands a selective *deregulation* of environmentally preferable alternatives.

Federal regulatory reform could do much to encourage the use of cleaner fuels, including gas, uranium, and water. State public utility commissions have the power in their hands to facilitate the capital turnover needed to speed the retirement of old (dirty) plants and their replacement with new (cleaner) ones. The courts, by curtailing the opportunities for litigating every new initiative to death, could help restore to the electric power industry the confidence that is needed to encourage technological experimentation and change. Technological change and capital turnover are inseparably linked to environmental protection; only a regulatory system receptive to the former can achieve much with the latter.

Better generating technologies are in fact already available or on the engineering horizon. Limestone injection and the fluidized bed furnace hold out the promise for both cleaner and more efficient coal combustion. The helium-cooled fission reactor is essentially incapable of meltdown, and so might displace a good bit of coal while answering some of the current concerns about water-cooled nuclear power systems. There are still possibilities for more (and more efficient) development of hydroelectric power. Safer and more effective means of conservation can also be found.

None of these solutions is environmentally perfect, and many have yet to be proved in commercial operation. Some will surely not live up to environmental or economic expectations when they are tried. But if we confront acid rain's uncertain science honestly, we must recognize that there is no real choice but to seek out and experiment aggressively with these new alternatives. If acid rain *does* present a real and long-term problem, we must search for equally real and long-term regulatory solutions.

## III. DRAWING THE YARROW STRAWS

In the end, the scientific side of the coal-sulfur economy and the existing proposals for new regulation must of course be weighed together. Where does the cost-benefit balance come out? It is still impossible to say.

The costs of regulating acid rain are certainly clear enough. All the regulatory proposals are unquestionably expensive. But the environmental stakes are very large as well, even though they remain much more uncertain.

The fairest conclusion on the scientific side of acid rain—the benefit half of the regulatory calculus—is that for North American conditions, no fair conclusion can yet be reached. It is quite clear that acid rain has already caused some damage; it is equally clear that evidence of the damage is still confined to very small regions of this country and Canada. There can be no disputing that acid rain "might" in the future cause severe and widespread ecological harm, because this is not a disputable statement of fact or science. "Mays" and "mights" are issues of faith and ideology; scientific claims are made of the much sterner stuff of stated and defended probabilities. The scientific community is as yet unwilling to reach firm conclusions about the likelihood of the widespread ecological risks of acid rain that some have hypothesized.

Scientific uncertainty about the impact of acid rain is, however, not a reason to take sides on the proposals to regulate it. Cost-benefit balancing, it has been charged, is no more objective or neutral than the literacy tests in the old South. To give lie to that colorful claim, we must concede that certainty on the cost side of the scales does not necessarily outweigh uncertainty on the benefit side. Scientific uncertainty, like science itself, is—or at least should be—politically neutral. Ignorance supports "emissions as usual" no more (and no less) than it supports a firm change in regulatory policy. In many areas of regulation—with drugs, pesticides, food additives, nuclear power, and aircraft, for example—ignorance about health, safety, and environmental consequences is translated by statutory presumption into a regime of strict—not lenient—regulation. There is no scientific reason why the imponderables of acid rain should, or should not, be treated any differently.

One thing, in any event, is quite clear: If we *do* conclude that a new regulatory initiative is in order, we must recognize that, from the national perspective, there are distinctly better and worse ways of implementing it. The short-term, scrubber-based remedies that have been proposed are built on the unsupportable speculation that a 10-million ton a year quick fix is both necessary and sufficient to make a difference. While some fragments of scientific analysis have been wheeled out to rationalize this particular regulatory target, they have found few adherents in the mainstream scientific community. Real, long-term solutions to acid rain lie instead in the aggressive promotion of cleaner coal and noncoal technologies. The regulatory system has a large role to play here. Over the past two decades, environmentally regressive regulatory pressures have driven utilities inexorably toward an all-coal, old-technology electric economy. These pressures should be relieved. Regulators will have to learn to do less, not more, with regard to those technologies that hold out the best promise for environmental progress.

So where *should* one stand on acid rain? It is still largely a matter of faith. Recall that the *I Ching* believer draws yarrow straws to determine the yin-yang hexagrams that will control his life and demeanor. The science of the process is certainly important, and oriental sages have spent much time and effort analyzing the sixty-four arcane patterns that the yarrow straws can combine to create. But because the science itself is more than a little cloudy, the faith of the drawer also plays a crucial role in the exercise. And so it still is with acid rain. ■

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