

EXECUTIVE SUMMARY OF FINAL REPORT
IMPLEMENTING TRADABLE EMISSIONS PERMITS FOR SULFUR OXIDES
EMISSIONS IN THE SOUTH COAST AIR BASIN

ARB Contract No. A8-141-31

Glen R. Cass, Robert W. Hahn and Roger G. Noll

Environmental Quality Laboratory
California Institute of Technology

June 30, 1982

The statements and conclusions in this report are those of the authors and not necessarily those of the California Air Resources Board. The mention of commercial products, their source or their use in connection with material reported herein is not to be construed as either an actual or implied endorsement of such products.

EXECUTIVE SUMMARY

IMPLEMENTING TRADABLE EMISSIONS PERMITS FOR SULFUR OXIDES EMISSIONS IN THE SOUTH COAST AIR BASIN

Glen R. Cass, Robert W. Hahn and Roger G. Noll

Since the mid-1970s, public policymakers have had increasing interest in making greater use of economic incentives for the purpose of improving the cost-effectiveness of environmental regulation. At the federal level, the Environmental Protection Agency has encouraged the development of so-called "controlled trading options," a series of policies for introducing more flexibility into air pollution regulation by allowing businesses to make compensating changes in emissions that reduce total abatement costs so long as the environment does not suffer. Several states have actively pursued these possibilities. And, in water pollution, one state -- Wisconsin -- is developing a tradable emissions system in some areas for discharges into rivers and lakes.

The fundamental idea of tradable emissions permits is as follows. Regulators would set ambient air quality standards for a region, and would use air quality modeling to estimate the amount of areawide emissions that could be permitted without exceeding the standard. Regulators would issue permits for emissions of this amount which would then be allocated among the sources of emissions according to a market process. Assuming that the market is sufficiently competitive, this procedure would then naturally lead to a final distribution of emissions that minimized the total costs of abatement for the airshed. The reason is that each business, in attempting to minimize its costs of production, would view the environment, through the permits market, as a scarce resource not to be wasted.

Noticeably absent from the preceding discussion is the activity that consumes a large share of the time of regulators: writing technical standards for emissions sources. In its purest form, a permits market does not require case-by-case regulation of source categories. The specific abatement technologies and quantities of emissions at each source would be selected by the business manager, based upon the costs of abatement and the price of emissions permits. In this pure form, regulators need only know how many permits are held

by each source. Inspection and enforcement activities would be set up to assure that each source emits no more than is allowed by its permits.

The advantages of a tradable emissions permits system are its simplicity and its use of incentives to achieve abatement at minimum cost to society. New sources of emissions can enter an airshed by purchasing emissions permits from older, established sources in a regularized market, rather than by going through a time-consuming permitting process. All sources can avoid the costs and uncertainties of protracted regulatory proceedings that establish source-specific standards. Regulators and the public can be assured of achieving air quality objectives, as long as an appropriate total ceiling on emissions is established and enforced.

The purpose of this project is to examine the feasibility of a system of tradable emissions permits for dealing with the problem of controlling sulfate particulates in the South Coast Air Basin. This particular problem was selected to provide a focus for what we hope is work of more general applicability. By working through the problem of how one might implement a tradable emissions permits system for this case, questions that would be relevant in any example can be articulated and methods developed and demonstrated for answering them. Sulfate particulates in Los Angeles were selected because adequate data and models of the relationship between emissions and air quality are available for doing meaningful empirical work on the issue, and because for various technical reasons the problem of sulfate particulates appears especially likely to be amenable to solution through the use of economic incentives.

While substantial work has been done on the general properties of economic incentive systems, including tradable permits, relatively little attention has been paid to the details of how such systems might actually be implemented. In reality, there are several specific and potentially important issues to be resolved about exactly how the market will be set up. The term "market" is a generic one that refers to a wide variety of institutional forms. One question regulators must face is precisely what form of market is most promising for tradable permits. Another ambiguity arises in the very definition of the permits themselves: over what geographic area can they be traded, how long will they be effective, and what controls, if any, will be placed on who can own them -- and on who must own them? Still another question is how the market will be initialized. Will the government organize the initial sales, or will it stand by passively and let industry develop a market by negotiating trades? Will participation in the markets be voluntary or mandatory? And who will sell the permits -- the existing polluters (and if so, how will their initial holdings be determined), or the state?

The feasibility of tradable emissions permits depends on a number of performance features of the system that is adopted. Tradable permits are an attractive alternative to source-specific

standards only if they reduce the costs of regulation -- both compliance costs and the costs of the regulatory process -- without sacrificing air quality objectives. Their feasibility will also depend on the degree to which they are perceived to be a fair and equitable approach to the problem of controlling pollution, which in turn depends in part on who benefits and who loses from the switch to a tradable permits scheme. Finally, there is a question of legal feasibility -- what changes, if any, must be made in regulatory law before a true tradable permits system can be enacted?

The object of our research was to perform the work necessary to evaluate alternative forms of markets on the basis of their expected performance with respect to these design questions. Our aim was to find out as much as we could about the effect on the performance of a permits market of choices among the different ways a market could be organized. Such information would be useful to regulatory policymakers and the general public in understanding the tradable permits approach and selecting a reasonable method for implementing it. Currently, regulatory attention is focused largely on problems of implementing EPA's controlled trading options; however, by taking a more general approach, we hope to shed light on not only the reform proposals of immediate concern, but also on other approaches that, while similar in spirit to the current approach, are in some ways quite different. This report, then, seeks to be a kind of manual concerning the range of possibilities for setting up markets for emissions permits, with the sulfate particulate problem in the South Coast Air Basin providing the data for illustrating how one can approach the design questions raised above.

Our approach to assessing the feasibility of tradable emissions permits is as follows. First, we attempted to identify the potential pitfalls of a market approach to regulating air pollution. Second, we undertook research to determine whether these potential pitfalls are empirically important in the case of sulfate particulates in Los Angeles. In so doing, we illustrate the methods of analysis that would be necessary to perform a similar assessment for other pollutants and/or other regions. Third, for the problems that appear to be serious for Los Angeles, we investigate whether they can be avoided or substantially ameliorated by the details of the design of the tradable emissions permits system.

For ease of exposition, we have categorized the problem areas that we face as follows: (1) technical -- relating to issues of modeling the relationship of emissions to air quality and actually achieving air quality targets; (2) structural -- relating to problems that might prevent a market from working smoothly and efficiently; (3) distributional -- relating to the effects of an emissions market on industrial structure and wealth in the region; and (4) legal -- relating to the congruence between legislative and regulatory law and the concept of a tradable emissions permit system. Each of these problem areas are analyzed separately in the project report and are summarized here.

We believe that this is the most comprehensive study of the feasibility of implementing tradable emissions permits that has been undertaken to date. Several studies have dealt with the general case for the use of economic incentives, including tradable permits, and the problem of designing a theoretically perfect market -- that is, a market that guaranteed maximal economic efficiency. These provide a solid conceptual starting point for the kind of work reported here, but the practical problems of designing a system that works satisfactorily and performs better than the current regulatory system are far removed from the theoretical problems of characterizing a perfect system. In addition, a few studies have dealt with practical problems of a specific pollutant. These studies do not have as extensive empirical information about costs and air quality models as has been used in this project, nor do they examine a range of different approaches to setting up a market. Finally, we are aware of no study that has pretested alternative market arrangements by use of simulations and small group experiments.

Two studies deserving of special note are a Rand Corporation research project on implementing a market for chlorofluorocarbon emissions to control ozone depletion, and a project at the University of Wisconsin to analyze the implementation of a market for BOD emissions into a Wisconsin river basin system. The former study examines closely the distributional equity of a permits approach, an issue that is often overlooked in feasibility studies. The latter has led to the actual implementation of an auction for water pollution emissions permits by the State of Wisconsin. While neither study closely links market performance to environmental outcomes by the use of modeling, both are good examples of examining the effects of a particular approach to tradable emissions -- selling the permits.

With this background, we will now proceed to summarize our results.

THE INSTITUTIONAL ALTERNATIVES

For the remainder of the 1980s, the key policy issue is not whether tradable emissions permits will be implemented, but how extensively they will be used. EPA's banks, bubbles and offsets are now firmly established in several states as a means for introducing greater flexibility (and hence lower costs) into environmental regulation, and their use is spreading.

The basic philosophy of EPA's controlled trading options is to overlay the possibility of trades onto the existing regulatory structure. The starting point for all sources is the set of technical standards that are established through the formal regulatory process. Some standards are written in terms of emissions rates, but more commonly they specify a technology: low sulfur fuel, scrubbers, etc. But in all cases, source-specific standards are a permit to emit an explicit or implicit amount of pollutants. The controlled trading

options then allow regulators to rewrite these permits to effect mutually beneficial tradeoffs between sources that are proposed by the traders and that do not undermine environmental objectives.

The pure tradable permits system would dispense with source-specific standards altogether. Regulators would not specify control techniques for sources, even as a baseline for further trading. Compliance activities would focus on checking whether actual emissions at a source were at or below permit holdings. Of course, disputes over the performance characteristics of control technologies would still emerge and be the focus of regulatory activity, but it would be in the context of enforcement, rather than standard-setting and permitting. The real-world regulatory analog is the regulation of foods, where the focus of regulation is the purity of the product and the legal debate about a firm's production methods takes place in the enforcement of the purity standards.

In establishing a permits market, some specific features of the design must be explicitly decided. One is the definition of a permit in dimensions other than the rate of emissions (usually in pounds per day) that it allows. Theoretical perfection requires separate permits (and permits markets) for every receptor that suffers pollution in a region. Air quality is not monitored everywhere, so this can be interpreted as a need for a separate "permit to pollute" at every monitoring station. A business in the South Coast Air Basin would then have to participate in seventeen distinct permits markets. Practically speaking, this is not a viable alternative because of its complexity and cost; however, it is worth knowing whether there is a great loss of efficiency and/or air quality in adopting a simpler approach. Hence, part of our work deals with the performance differences between a single, basin-wide market and seventeen separate markets.

A second feature of the definition of a permit is its duration — how long is it good for, and how can the total ceiling on emissions be changed? One possibility is to define a permit as a perpetual "right to pollute." The state could then reduce total emissions permits only by something like a condemnation proceeding: paying market value for them in either voluntary or mandatory transactions. Another possibility is to make their duration indefinite, but subject to alteration through a regulatory process. This is the approach taken in the source-specific standard-setting system, and in the implementation of controlled trading options. All permits are regarded as contingent on an ambient air quality standard. If the AAQS changes, or if the current emissions that result from the established source-specific standards do not succeed in achieving air quality goals, source-specific standards can be tightened (implicitly reducing the amount of emissions permitted at each source). A third alternative is a permit of fixed duration. If permits periodically expire, the expiration date becomes a convenient focal date for revising either the total emissions ceiling or the ambient air quality standard, and thereby altering the number of outstanding permits.

This is the approach being taken in the Wisconsin market for permits to emit phosphates in waterways. These permits are issued quarterly through an auction. The holdings for a particular source in one quarterly period have no implications for the holdings in the next quarter; each auction is a wholly separate event. And, at each auction, the number of permits can be varied.

Once the permits have been defined, a decision must be made on how to distribute the permits initially. One approach is "grandfathering." This means making explicit the emissions permitted according to some set of source-specific standards, and giving each polluter permits based upon these emissions. The basis for the initial distribution can be precontrol emissions of all sources, the emissions from current source-specific standards, or emissions from some other hypothetical set of standards. The amount of permits need not equal the amount of emissions from the baseline standards; each firm can be given some fraction of these emissions as their baseline permits holdings. For example, in the South Coast Air Basin, giving each source permits equal to somewhat less than half of current emissions would bring the region into compliance with State AAQS for sulfate particulates.

Another approach to initialization is to auction the permits to the highest bidders, as is the case in Wisconsin. This implies a mandatory requirement to participate in the permits markets if a firm is to produce any emissions (or emissions above whatever threshold above zero a regulatory agency may adopt as the rate triggering regulatory concern). Auctions, of course, raise the question of what to do with the revenues collected from the sale; grandfathering does not raise such an issue because the permits are initially given away.

The final design decision has to do with the operation of the market after the permits are initially distributed. One alternative is regulatory passivity: trades would occur to the extent that polluters found each other and negotiated a trade. Regulators would become a source of information about who holds how many permits, but they would play no role in encouraging trades. This is the normal approach regulators have taken towards controlled trading options. It is naturally paired with grandfathering as an initialization policy.

Another alternative is for regulators to organize the market. In this case, permits markets would take place regularly according to market rules established by the agency. Firms could submit regular reports to regulators about their willingness to buy or sell, and regulators could then act as brokers to consummate transactions (perhaps charging a commission to cover their costs). Or, regulators could schedule periodic auctions at which all permits offered for sale (with a minimum sales price stated by the seller) were sold to the highest bidders. Participation in these periodic markets could be voluntary or mandatory. A mandatory auction is most naturally associated with permits of fixed duration that are initially distributed by an auction as well.

The remainder of this report contains our analysis of the relative merits of these alternatives. The selection among them is not a purely theoretical question, for as we will explain the system that is more promising for any given pollution problem depends on the technical details of the problem and the legal and political environment in which it must operate.

Before proceeding with our results, a few important caveats are in order. We have not systematically dealt with the issue of air pollution "episodes" -- e.g. periods in which atmospheric conditions are especially ripe for severe air pollution. We are assuming that these will continue to be dealt with as emergencies requiring specific regulatory interventions, although in principle they, too, are attractive possibilities for a market. We have also not dealt systematically with interactions among pollutants and control technologies. Some control methods reduce several kinds of emissions, and so their economic attraction to an industry is related to the overall structure of regulation, not just the structure for one pollutant, sulfur oxides. Moreover, sulfur oxides contribute to four distinct environmental problems: SO₂ (usually a localized problem near a specific source), sulfate particulates, total suspended particulates (TSP), and acid rain. We assume that source-specific standards (such as minimum stack height) will continue to be applied to control SO₂, and that TSP and acid rain considerations will not cause further changes in sulfate regulation if the State AAQS for sulfate particulates is achieved. Thus, we are treating sulfate particulates as an independent pollutant.

With these caveats in mind, we proceed to our analysis of market alternatives. Some of the potential problems of an emissions permit market are analyzed in terms of their immediate effects on abatement costs, the distribution of emissions, and air quality. In order to undertake these analyses, two types of information were needed: the costs of all of the important abatement methods available to sources in the air shed, and a model of the relationship between emissions and air quality. The next section reviews the collection and use of these data.

TECHNICAL ASPECTS

The problem of sulfur oxides abatement in the South Coast Air Basin was chosen as the practical focus for this study of transferable permits to emit air pollutants because it is an attractive candidate for analysis. First, the State of California's air quality objectives for particulate sulfates have yet to be attained in the Los Angeles area. Thus, improvements in this problem are a matter of current public policy interest. Second, the effect of emission sources on observed sulfate air quality can be modeled mathematically in a way that provides an accurate means for testing the effect of altered emission controls on future air quality. The number of source categories of emissions involved in this problem is small enough to

make the problem tractable but numerous enough to hold promise of supporting a competitive market for licenses to emit air pollutants. Finally, control measures are technically feasible that would be sufficient to limit SO_x emissions to a level consistent with attaining State air quality objectives. Thus, the principal question is to identify the best control alternative -- which is exactly the problem that a free market in emission permits is designed to solve -- and to decide whether this alternative imposes acceptable costs.

A technical description of the Los Angeles sulfur oxides air quality problem is provided by Cass, and is described in Chapter 2 of our report. As a result of that study, a mathematical model was formulated and tested that relates sulfur oxides emissions to observed sulfate air quality. Sulfur oxides emissions to the Los Angeles area atmosphere were surveyed within more than thirty classes of mobile and stationary source types. These emission sources were located spatially within the grid system shown in Figure 1. Large off-grid power plants and other major source types within the entire domain of Figure 1 also were included in the air quality model calculations. The air quality model then was used to compute the sulfate and total sulfur oxides concentrations that would prevail in the presence of historically observed emissions patterns (see Figure 2). Model results were tested against observed sulfate concentrations in order to confirm the accuracy of air quality model predictions, as shown in Figure 3. The validated emissions to air quality model can then be used to study the effect on sulfate air quality of altering the magnitude and spatial distribution of SO_x emissions that would occur in response to a system of transferable emission permits.

The air quality model developed by Cass was used to test the effect of emission source redistribution on observed sulfate air quality. One key question to be addressed is whether the SO_x emissions pattern that results from a transferable permits system will lead to anomalous hot spots with high sulfate levels, or continue to produce a fairly uniform spatial distribution of air quality as has historically been the case (see Figure 2). In short, can permits be traded widely between sources on the basis of tons per day of sulfur oxides emissions without creating serious air quality distortions? A related question is the magnitude of the calculation error if rollback calculations are used to predict the effect of altered emissions on sulfate air quality.

In order to explore future air quality quantitatively, a projection of the potential for sulfur oxides emissions in the Los Angeles area in the early 1980s was assembled. Future SO_x emissions are highly dependent on natural gas supply constraints. A base case was chosen in which the effects of either a high or low level of natural gas supply could be examined. The emission projection was supplied to the air quality model, and a base case level of sulfate air quality was computed. As seen by comparing Figure 2 and Figure 4, it was determined that even a total shift of fuel burning sources to oil would not result in much perturbation of sulfate concentration

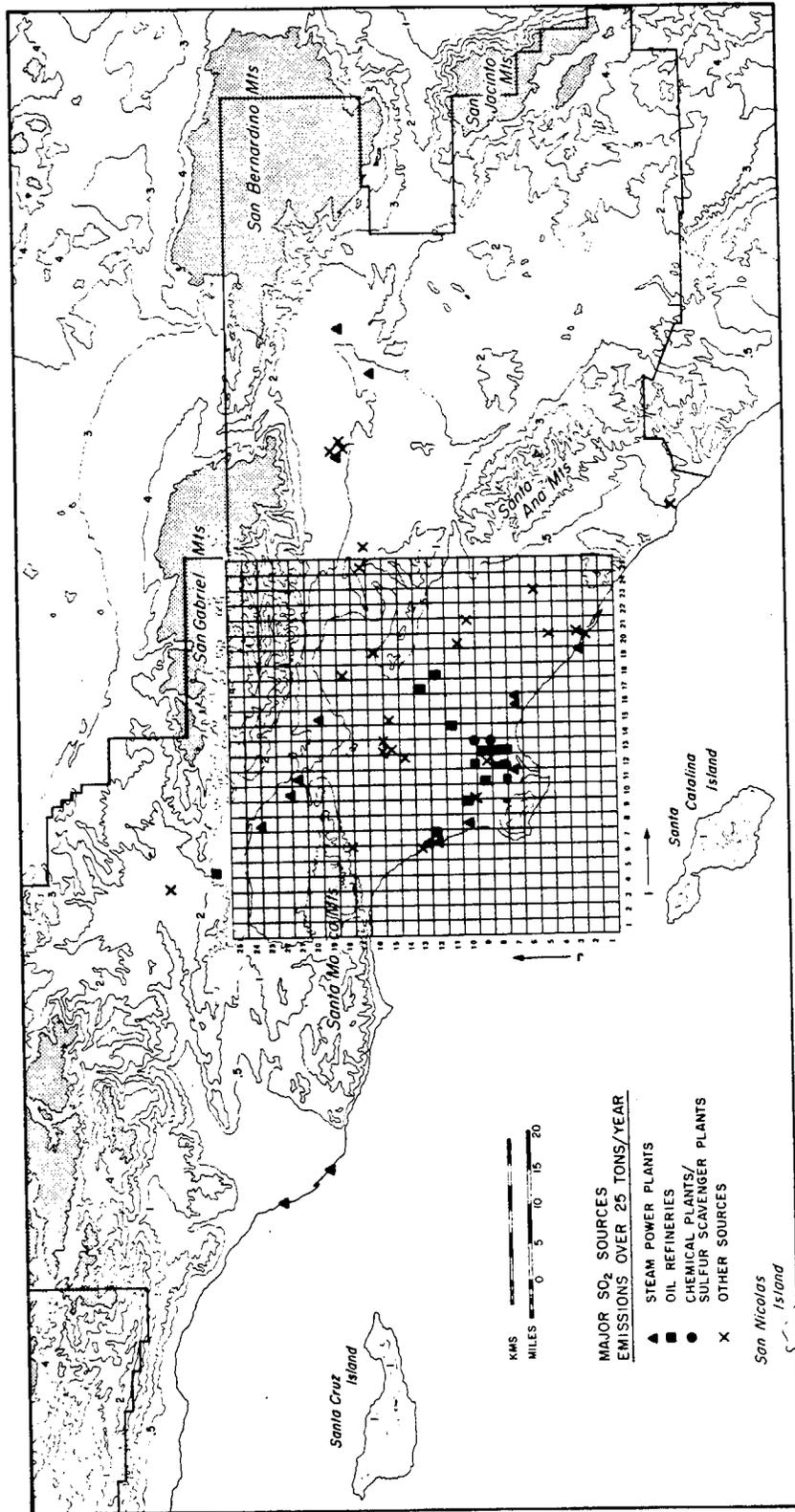
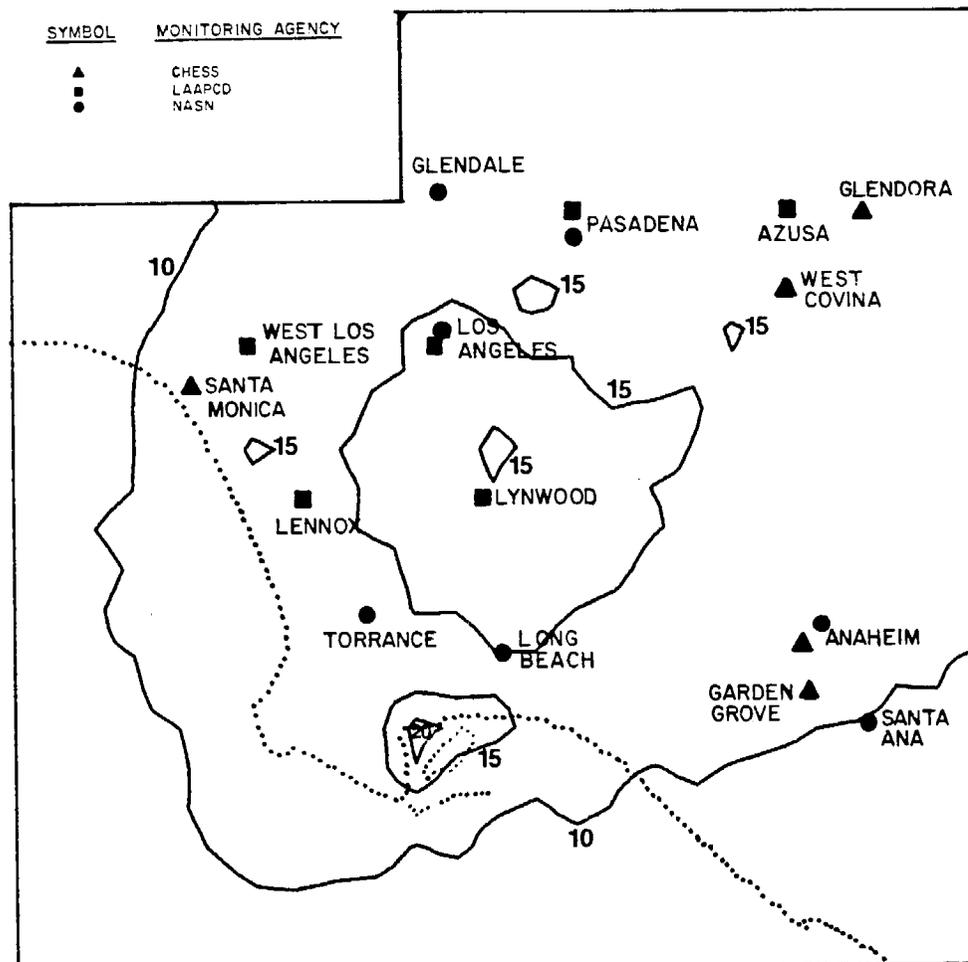


FIGURE 1
The Central Portion of the South Coast Air Basin
Showing the Grid System Used

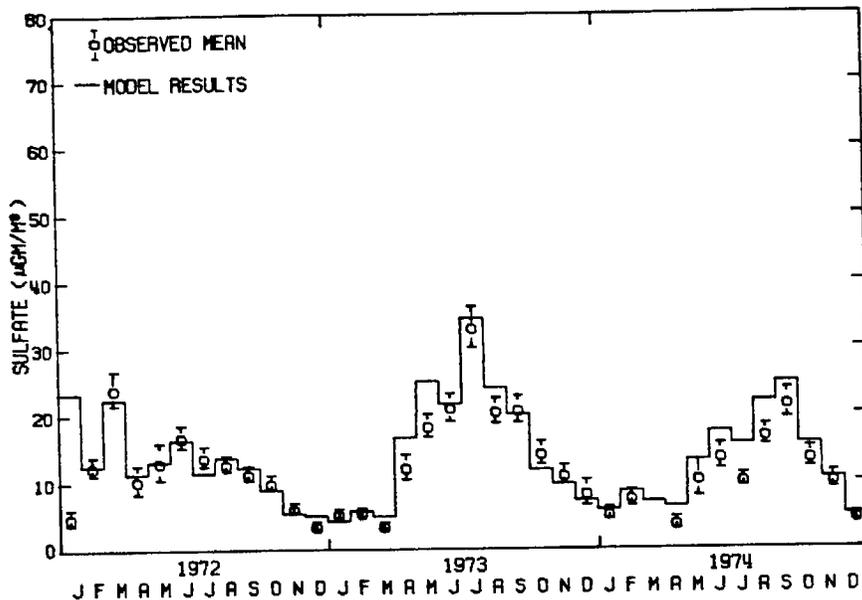
AVERAGE SULFATE CONCENTRATIONS ($\mu\text{GM}/\text{M}^3$)



CALENDAR YEAR 1972

FIGURE 2

MONTHLY ARITHMETIC MEAN SULFATE CONCENTRATIONS AT GLENDORA (CHESS)
 AIR QUALITY MODEL RESULTS VS. OBSERVED VALUES



SOURCE CLASS CONTRIBUTION TO SULFATE CONCENTRATIONS
 OBSERVED AT GLENDORA (CHESS)

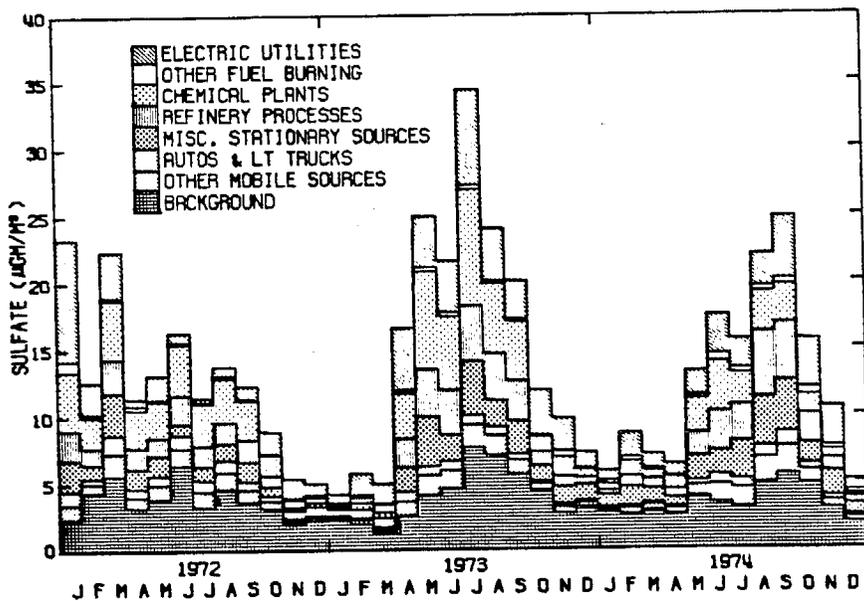
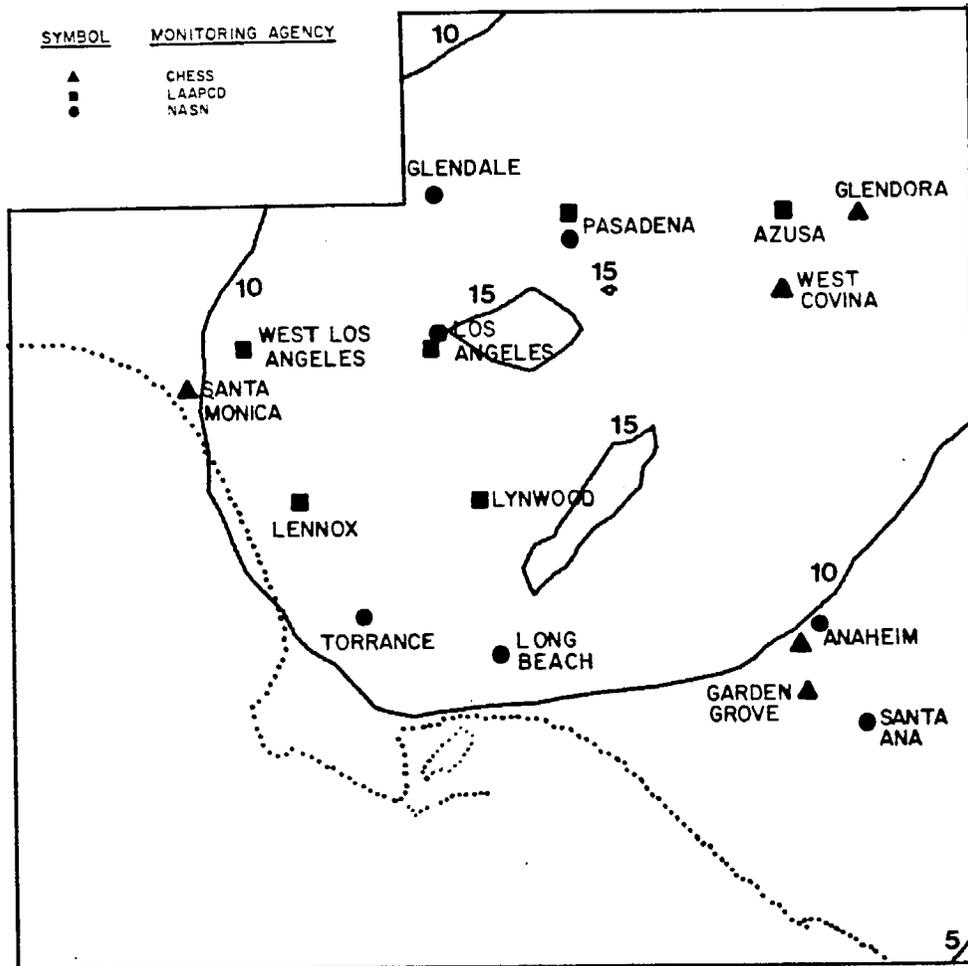


FIGURE 3

LONG TERM AVERAGE SULFATE CONCENTRATIONS ($\mu\text{GM}/\text{M}^3$)
 UNDER LOW NATURAL GAS SUPPLY CONDITIONS



EARLY 1980'S - COMPOSITE OF THREE TEST YEARS

FIGURE 4

patterns from those observed in the mid-1970s when gas was more available than is assumed in the simulation for the early 1980s.

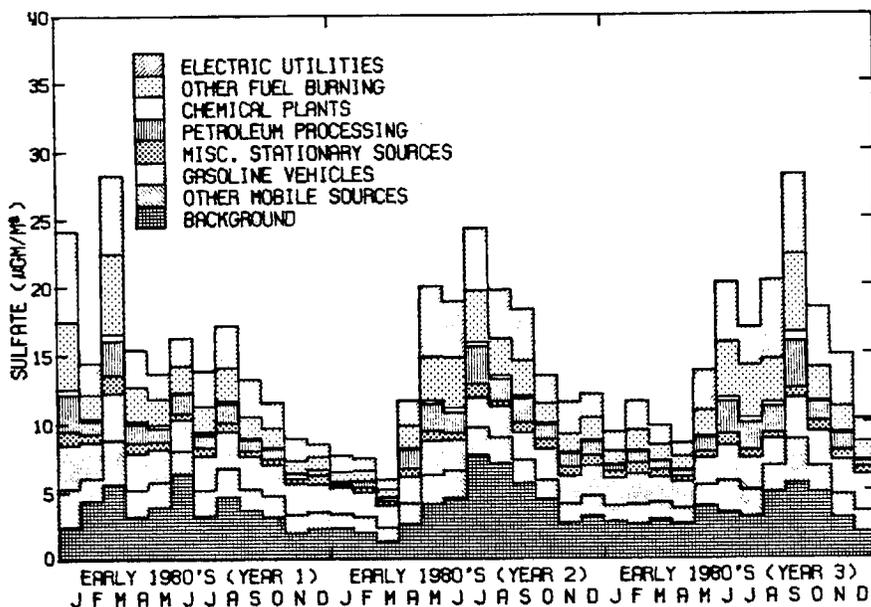
The air quality model is capable of distinguishing the effect of each emission source type on air quality at each monitoring site (Figure 5). Consequently, the distribution of emissions that results from any given ceiling on total emissions that is then allocated through a market (or any other procedure) can be evaluated in terms of its effects on air quality.

In order to calculate what this distribution of emissions would be, a model predicting the behavior of firms in a permits market is required. If a competitive market for permits can be established, it will have the property that for the entire air shed the total costs of abating sulfur emissions will be minimized for any given total ceiling on emissions. Hence, the problem of detecting the pattern of emissions in a well-functioning market is the same as the problem of finding the minimum-cost method of achieving any given emissions target.

To find minimum cost solutions to the abatement problem requires finding the costs of all significant abatement alternatives available to all source categories. Research was undertaken by surveying the published literature, the records in regulatory proceedings, and the important sources of sulfur oxides emissions in the air shed directly through personal interviews as to the range of abatement possibilities available. From this information, an abatement cost function -- e.g. a mathematical relationship between the amount of emissions abated and the total cost of abatement -- was constructed for each source. The minimum-cost solution to the problem of achieving any emissions target can then be calculated, including the distribution of emissions among sources. These emissions were then entered into the air quality model to forecast the results in terms of the geographic pattern of concentrations of sulfate particulates.

Once these two models -- abatement costs and air quality -- are in place, they can be used to examine the effects of a variety of different conditions. Abatement costs obviously depend on the availability of natural gas, a fuel with essentially no sulfur content and so an extremely cost-effective approach to abatement. The availability of natural gas also affects the emissions that will result from the existing set of standards. To obtain information on the range of conditions under which a market, or any other system of regulation, might be called upon to operate, markets and air quality results were simulated for a range of emissions targets and states of natural gas availability. For natural gas, three cases were studied: low availability and allocation priorities established by regulations that were expected, but did not materialize, in the late 1970s; historical availabilities and allocations in 1973, when natural gas was in somewhat tight supply because of price regulation but not as restricted as was then being forecast; and high gas availability, in which gas is still not freely available at market prices, but is

SOURCE CLASS CONTRIBUTION TO SULFATE CONCENTRATIONS
 EXPECTED AT DOWNTOWN LOS ANGELES (NASN) MONITORING STATION
 UNDER LOW NATURAL GAS SUPPLY CONDITIONS



SOURCE CLASS CONTRIBUTION TO SULFATE CONCENTRATIONS
 EXPECTED AT PASADENA (NASN) MONITORING STATION
 UNDER LOW NATURAL GAS SUPPLY CONDITIONS

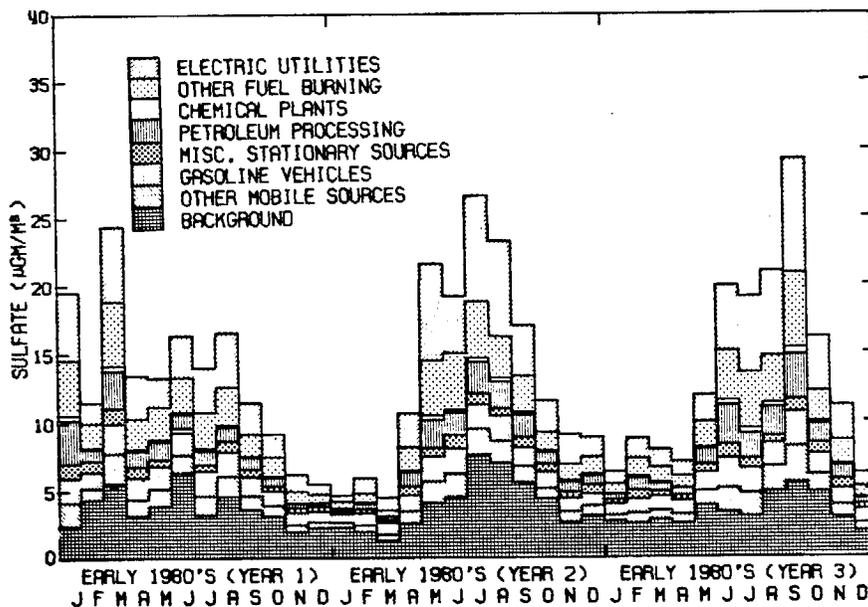


FIGURE 5

nearly so. The case of high availability seems to be developing now due to the partial deregulation of prices and the ensuing "gas bubble." Each of these supply assumptions was then combined with a series of alternative total ceilings on emissions, ranging from the situation that would result if current standards were in force but natural gas supplies were severely curtailed, down to the 150 tons per day of SO₂-equivalent emissions that, according to rollback models, would satisfy the State AAQS for sulfate particulates. The important benchmark emissions targets are shown in Table 1.

The major technical question is whether competitive permits markets would create local hot spots in air pollution. To test this proposition, the minimum cost distribution of permits was calculated for a simple permits market, in which permits can be traded freely throughout the airshed, and for the theoretically superior system in which separate permits must be traded for every receptor point.

Table 2 presents some of the results of these simulations. The case analyzed here is one in which natural gas availability is low. This case is likely to produce the greatest differences in abatement costs among various methods for organizing the permits market. If gas supplies are available in intermediate quantities, abatement costs tend to be about 60 percent of the costs if natural gas supplies are low. Column A shows the annualized expenditures on abatement costs in the Los Angeles area under the competitive equilibrium distribution of permits if there is no geographical fine-tuning of the permit system. Column B shows the costs if firms are required to buy pollution permits for each of the seventeen measuring stations in the airshed, subject to the conditions that the air quality results at each station will be the same as the outcome from the system reported in Column A. Thus, the difference between A and B is the gain, if any, arising solely from geographical relocation of permits in a system that takes account of the specific polluting effects of emissions from each location in the region. Column C further relaxes the system, allowing pollution at all measuring stations to be constrained only by the air quality achieved at the most polluted station under the allocation corresponding to Column A. Thus, emissions can be reallocated and total emissions increased as long as pollution does not increase beyond that found at the location that is most polluted under the Column A allocation.

The general result from the analysis is that there is little to be gained from fine-tuning the definition of permits. The reasons are twofold: the simple market allocates emissions relatively evenly over the region, and leaves relatively small differences among measuring stations in terms of the air quality results. Hence, there is little opportunity in terms of either lower costs or better air quality for improving the efficiency of the allocation through adopting a more complicated market system.

TABLE 1
SELECTED AIR QUALITY TARGETS FOR THE SOUTH COAST AIR BASIN
in tons SO_x/day^a

TARGET	ALLOWABLE EMISSIONS
1. Achieve California Sulfate Air Quality Standard of 25 micrograms/cubic meter over a 24 hour averaging time.	149
2. Violate California Sulfate Air Quality Standard 3-5% of the time.	238
3. No additional controls with an above average natural gas supply.	335
4. No additional controls with a low natural gas supply.	421

TABLE 2
 COMPARISON OF UNIVERSAL AND RECEPTOR-SPECIFIC PERMITS
 (costs in millions of 1977 \$)

Baseline Emissions Target in Tons/Day SO ₂ Equivalent	<u>Annualized Costs of Competitive Equilibrium Abatement for:</u>		
	<u>Receptor-Specific Permits that Produce:</u>		
	A. Universal Permits	B. Same Air Quality For Each Receptor	C. Uniform Air Quality Equal to Worst Receptor
150	682	682	682
250	565	557	545
300	515	513	505

MARKET STRUCTURE PROBLEMS

One issue to be attacked is the possibility that the market will not achieve the competitive ideal. The first step in addressing this issue is to simulate the competitive, minimum-cost allocation of permits, and then see if the result shows an especially high degree of concentration of holdings. Numerous market simulations have been made under varying assumptions about ambient air quality standards and the availability of substitutes for petroleum fuels, and are reported in the main report. Three examples will be presented here. One assumes that the state's ambient air quality standards will be satisfied all of the time; the second assumes that the standards will be violated approximately two weeks per year; and the third assumes that the emissions allowed under regulations now in place become freely tradable. All cases assume an intermediate availability of natural gas. Under this assumption, the controls on sulfur oxides emissions that were established in 1977 would produce emissions of about 300 tons of SO_2 equivalent per day in Los Angeles; to meet the standard all of the time requires that emissions be cut in half, but to meet it all but two weeks per year, on average, requires a reduction of only about 50 tons per day. Thus, the three cases represent a major change, a minor reduction, and no change in currently enacted (but not yet fully in place) source-specific standards.

The single largest source of emissions is an electric utility. In 1973, prior to controls, this source accounted for approximately 28 percent of emissions in Los Angeles. Table 3 shows the share of permits that this firm would be expected to hold under two simulated market structures for the cases described above.

The shares reported in Table 3 should not be taken too literally. Among the major source categories in Los Angeles, abatement costs are best known -- and least likely to be overestimated -- for electric utilities. This means that even greater efficiency gains may be possible by substituting abatement elsewhere for the emissions reductions at utilities that are calculated from the existing cost data.

With this caveat in mind, the results in Table 3 illustrate the possibility of serious market imperfections, depending upon the selection of an emissions target and an initial allocation of the permits. Column A shows the cost-minimizing allocation of permits under the three emissions targets described above. This allocation is the competitive (cost-minimizing) equilibrium. If the initial allocation process is an auction so that all firms are buyers, the share of the largest source is the share shown in Column A. Other initial allocations can raise this figure substantially. For example, suppose all sources are allocated a proportion of their precontrol emissions that is calculated to retain present total emissions. In this case, the largest source, assuming the market were competitive, would seek to increase its share of holdings by 20 percent of the total number of permits (the difference between 48 percent on Line 1

TABLE 3
FRACTION OF TOTAL EMISSIONS ACCOUNTED FOR
BY LARGEST PERMIT HOLDER IN LOS ANGELES

	A. <u>Competition</u> (percent)	B. <u>Monopsony</u> (percent)
1. Make existing permits tradable with historical gas supplies	48	33
2. Violate standard two weeks/year with historical gas supplies	43	40
3. Satisfy standard all of the time with historical gas supplies	32	32

Column A and the 28 percent share of precontrol emissions). This would make this source an almost complete monopsonist, e.g. the only source of demand for permits at the competitive equilibrium price (almost all other firms would be sellers). The potential inefficiency of a monopsonist is that it will systematically understate its demand in order to force down the price of permits. This is achieved by engaging in excessive abatement, the extra costs of which are made up in the savings to the monopsonist of pushing down permit prices.

Column B shows the results from the most extreme degree of monopsony that is possible for each of the three cases. Here it is assumed that the largest source has an initial allocation of no permits, and that all other firms are given permits in a manner that causes them to seek to be sellers at any price equal to or above the monopsony equilibrium. The pattern of the results shows a greater divergence between competitive and monopsony shares for higher total limits on emissions. The reason is that in the range of the competitive equilibrium for emissions limits around the most stringent standard, the supply of permits from other firms to the largest source is very sensitive to price changes. This undermines the opportunity of the monopsonist to take advantage of its high market share: overabatement will not force much of a drop in permit prices, and hence the gains from the latter will not generate much of an offset against the higher abatement costs that are necessary to allow the firm to reduce its demand for permits.

The tentative conclusion from this analysis is that for the particular case at hand, monopsony appears to be a serious design concern only if regulators do not conform to the existing ambient air quality standards. The actual allocation rule is certain to be less likely to cause monopsony than the extreme case analyzed here; yet, even under this extreme assumption, imperfections in the permit market appear relatively unimportant if the emissions limit is low. Market imperfections could be important if existing permits were simply made tradable unless the initial allocation were designed to guard against it. An auction process, however, would put all firms on the same (demand) side of the market, and would therefore have less chance of leading to monopolistic behavior.

Another major potential source of failure in the permits market is that transactions will be too infrequent to convey meaningful price signals to polluting firms, to make relatively easy the acquisition of permits for entry and expansion of polluting facilities, and to allow a firm to avoid the expense of organizing the market and engaging in extensive bilateral negotiation every time it desires to make a trade. This is an especially difficult design problem to get a firm grip on in advance of operating the market, for the indicators of the extent of market transactions are so crude. One measure is the number of firms accounting for existing and expected emissions. In Los Angeles ten companies account for approximately 85 percent of the sulfur oxides emissions under current standards, assuming mobile sources are assigned to the oil refiners operating in

the airshed. Most major industrial polluters emit relatively small amounts of sulfur oxides so that the market for small quantities of permits is likely to be reasonably well-functioning; however, a major expansion or entry of an oil refinery, an offshore oil terminal, or an electric utility generation facility would be especially difficult to accommodate because so few sources have sufficient numbers of permits to be potentially significant sellers to the new source.

A second problem in anticipating the extent of a problem of market thinness is that there is likely to be a systematic tendency to underestimate the possibilities for transactions. A substantial source of demand and supply in the market for permits will be factors that are not measurable in advance. Examples are innovations in abatement technology, entry, exit, contraction and expansion of polluting entities, and opportunities for more efficient abatement methods that may be known to existing sources but that have not yet appeared in the public domain (e.g. process changes).

In Los Angeles, the problem is even more difficult because the local air pollution control authority has explicitly adopted the policy of attempting to write standards in inverse order of their costs per unit of abatement. Thus, with few exceptions, the standards in place are the least expensive possibilities. Of course, regulators are not prescient, and have missed some possibilities for cost-minimization, but the overall performance in Los Angeles is quite good. Consequently, most of the demand for trades, and the gains from a permits market, are unlikely to be measured using existing cost information because present standards tend to be based upon similar cost data. Therefore, our approach to estimating the extent to which the thinness of the market is a potential problem is likely to be unduly pessimistic.

In any case, whether the market is thin, initially and in the future, depends in part on the design of the system. A few examples illustrate this point. (1) If existing emissions (or some proportion of them) are simply made tradable, a thin market is more likely than if an auction process is used for the initial allocation because the latter induces more firms to participate. (2) Fine-tuned, multiple-market systems are more likely to face a problem of thinness than single markets defined over a broad geographic area because not all firms need participate in all markets. (3) If permits are perpetual with no periodic reallocation process, a decision to make a major purchase or sale would then require that the firm wishing to make a market undertake the time and expense of organizing and negotiating a trade. At the other extreme, if permits have a fixed life and are reallocated by auction, a convenient time and place is established for facilitating major redistributions of permits should changes in underlying economic and technological conditions warrant it.

DISTRIBUTIONAL ISSUES

The political feasibility of a system of tradable emissions permits depends in part on the perceptions members of society have on their fairness and equity. Two issues strike us as important in this regard: the effects of a permits market on the industrial structure of a region, and the effects of a permits market on the distribution of wealth. The third equity issue normally associated with emissions permits — that they are inherently an immoral or inequitable idea for pollution because they convey a right to pollute — is in some ways beyond the scope of this project, although in a technical sense the argument is not strictly correct. Tradable emissions permits imply no necessary relaxation in the controllability of pollution or the assertion of society's right to regulate it, although they could (mistakenly) be so designed. The principal design alternatives considered here — tradable, grandfathered emissions permits or auctions of permits of a fixed life — are still well within the control of the state, as are the controlled trading options of EPA. What is required is that permits be defined carefully enough to avoid conveying a diminution of the public's control of air resources.

We have undertaken extensive analysis of the cost impact of tradable emissions permits on industry. Before summarizing it, a general point should be made: imposing roughly similar costs on all business in a region simultaneously is far less damaging to local industry than regulating each firm on a case-by-case basis, with cost increases taking place sequentially over many years. The reason is that the former does not damage one firm in relation to its competitors. Simultaneous cost increases to all businesses will cause some reduction in sales and profits, but nothing like the effect if one firm experiences a cost increase while its competitors do not. One source of intense resistance of regulated businesses to environmental regulation is the threat in a case-by-case regulatory approach that your firm will come out treated more harshly than the competition.

Another general point is that the tradable emissions permits system causes all firms to experience similar cost increases, as well as simultaneous cost increases. This is because of the consequence of trading in the market: firms with relatively high costs of additional abatement can avoid them by buying permits from firms with relatively low marginal abatement costs, the net effect being greater abatement by firms with lower costs. Hence a tradable emissions permit system for any given stringency of control over total emissions will have a more even financial impact across firms and industries than a standard-setting approach.

The principal effect of a relatively pure tradable permits system is that permits to emit become a valuable intangible asset to their owners, thereby affecting the distribution of wealth in society. Our market simulations find that a permit to emit one ton of sulfur oxides per day for a year in Los Angeles would be worth between

\$400,000 and \$1.5 million, depending on the availability of natural gas, if the State AAQS is to be satisfied. If the 150 tons per day were auctioned, the revenues per year from the sale would amount to between \$60 million and \$225 million dollars, respectively. Moreover, as the economy grows, these numbers can only be expected to rise.

These numbers are comparable in magnitude to total abatement costs for the same cases. Satisfying State AAQS will cost between \$100 million and \$600 million dollars per year in additional abatement costs, over pre-1977 standards, again depending on the availability of natural gas. Thus, if firms actually have to pay for emissions permits through a state-run auction, the effect will be to increase the costs of air pollution regulation to the firm by a substantial amount. By contrast, the immediate cost savings from shifting from the current system to a system of tradable emissions permits are a reduction of on the order of \$20 million per year in abatement costs, plus whatever costs can be saved by a more streamlined regulatory process, by facilitating entry, exit and expansion of sources, and by providing an additional incentive for businesses to find new technologies to lower their abatement costs. In any case, the reduction in abatement costs, at least in the short run, is likely to be more than offset for most firms by purchases of permits if a state-run auction is used. This strikes us as of potentially great political importance, for it is likely to be the case that business will strongly oppose the system because the new "tax" (e.g. permits sales) will more than offset the cost savings.

Grandfathering existing emissions, or some fraction of them, as a means to initialize the system does not face this problem. Here the valuable permits are given away. Trades take place only if both sides can reduce their total costs by trading. The act of trading permits is, in essence, the act of the buyer abating the seller's pollution rather than his/her own because it is cheaper to do so.

The industry studies we have examined have addressed the question of the ability of these industries to withstand higher abatement costs without leaving the region. Each of the industry studies compares the cost of compliance in the competitive allocation of permits with the total cost structure of the firms, and asks whether the cost increase required is greater than the costs of relocating elsewhere and transporting the goods to this region from another locality. The general finding is negative. The major pollution sources in Los Angeles have a substantial margin of cost increases that they could absorb before being driven from the area. This is not to say that these costs are unimportant or trivial; indeed, businesses would experience a decline in their net value to stockholders from a major cost increase due to more stringent environmental standards. It is the narrow question of plant closings and relocations that we have examined, and these would not appear to be a major issue, especially if the process of selling permits caused funds to be reallocated among businesses, rather than collected by the state.

Recognition of the substantial value of these permits caused us to turn our attention to developing a market that combined the attributes of a periodic auction of permits with fixed duration with the property of grandfathering — e.g. allowing the asset value of the permits to remain with business, rather than accrue to the state through the auction. The institution that we have developed is the "Zero Revenue Auction." It proceeds as follows. Each existing source is allocated an initial holding of permits equal to some fraction of its holdings in the expiring permits (e.g. the existing source-specific standards). The exact value of this fraction depends on the decision of the regulator about the new target level of total emissions. These initial allocations establish the wealth positions of business, but not their entitlements to the permits themselves. Each firm is then required to report its willingness to pay for various quantities of permits. It can report these demands with any complexity it wants, but a standard approach would be to report a series of discrete alternatives: for example, a willingness to pay \$5 million to emit one ton per day, \$8 million to emit two tons per day, and \$10 million to emit three tons per day or any greater amount. These reports would constitute the "bids" in the auction for permits. The state would then calculate the price that causes the number of permits demanded to be exactly equal to the number of permits the regulator is willing to allow. Permits would then be distributed to the firms according to the number they were willing to buy at that price. Each firm would then make a net payment to the regulator of this auction price times the difference between the final allocation and the initial, grandfathered allocation. Thus, if the firm in the preceding example had an initial allocation of one ton per day and if the final auction price were \$4 million per ton per day, the firm would receive new permits for two tons per day and would make a net payment of \$4 million. However, if all other conditions were the same but the firm's initial allocation were permits for three tons per day, then the firm would still get permits for two tons per day from the auction — and would, in addition, receive four million dollars.

This institution has very attractive properties. The net revenue collection by the state from the auction is zero -- the auction serves only to redistribute revenues among firms, with firms increasing their emissions paying firms who are decreasing theirs. That is, the polluters pay the abaters to abate. Nevertheless, the problems of grandfathered permits — intermittent and infrequent trades and the possibility of monopsony — are avoided by the second, auction stage.

LEGAL PROBLEMS

Perhaps the most difficult problems to overcome in setting up a tradable permits market is that it flies in the face of regulatory law — both environmental and public utility. The Clean Air Act and amendments are the first hurdle. They set up the source-specific standards process, and give to the federal government the

responsibility for "technology forcing" new source performance standards. The idea is to require new sources always to use up-to-date abatement technologies, even if the cost per unit of abated pollution is higher than for old sources. Whereas the federal government has been relatively lenient in letting states allow trades of emissions from old sources, it has not yet shown a willingness to be flexible with respect to new source performance standards.

A relatively pure tradable emissions permits market can be established within the limits of the new source performance standards. Old sources can still make mutually beneficial trades, and new sources will still have to acquire permits through the market for any emissions that they produce while in compliance with NSPS. But a major potential advantage of the permits system is that it could make entry of new sources easier still by ignoring NSPS and retaining regulatory focus solely on total basin-wide emissions.

The second major legal problem has to do with public utility regulation. Regulation of the prices and profits of utilities is designed to prevent monopoly profits from accruing to utilities as a consequence of their franchised service monopolies. Thus elaborate accounting procedures have been set up to prevent utilities from recovering anything from ratepayers beyond the true economic cost of doing business. Intangible assets are an especially suspicious item to utility regulators, because they are a means of padding the rate base to earn higher profits.

Unfortunately, tradable permits are an intangible asset. Moreover, a grandfathering approach would establish the value of permits for ratemaking purposes equal to their acquisition cost -- namely, nothing. And, if a utility sold a permit for more than its book value (nothing), the entire revenue from the sale would have to be passed through to ratepayers in price cuts. This obviously undermines the incentives of utilities to participate in permits markets.

After studying the precedents, accounting techniques and asset categories of utility regulation, we have discovered a number of promising possibilities. One is treating permits as leases, and making use of the mandate for innovative regulatory techniques to account for broader social policies that was established in the Public Utilities Regulatory Policies Act. These are discussed in detail in our main report, as are the changes in environmental legislation needed to implement a full-fledged tradable permits system.

CONCLUSIONS

We believe that a tradable emissions permit market for sulfur oxides emissions in Los Angeles is feasible. Three general approaches are possible: a grandfathered system in which the regulators passively permit trades; an auction in which the state keeps the

revenues; and the zero-revenue auction based on grandfathered initial allocations of the asset values of the permits. Grandfathered systems have the political advantage of causing the cost-savings of the switch to a tradable permits system to be kept by industry, and by avoiding the debate about taxes that would inevitably accompany the straight auction. Yet auctions are more efficient. Consequently, we would recommend that the zero-revenue auction be tried. We have designed a small-group experiment to explore the properties of this institution. Our preliminary experiments are promising. They indicate that our expectations that it achieves an efficient result are correct.

With respect to the other design issues, we see no reason to do anything more complicated than have a homogeneous, areawide emissions permit, rather than to "fine tune" the system with a series of geographically specified submarkets. To facilitate adjustment of the ceiling on emissions and the entry of new sources into the basin, we believe that the permits should be of fixed duration. An illustrative approach would be to assign a life of nine years to permits, and have one-third expire every three years. Thus, relatively frequent auctions could be held to adjust the number of permits, facilitate entry of new sources, and reallocate emissions; but the duration of the permits would be long enough to provide stability to their holders, and a rational decision about long-term investments in abatement equipment.

The results of this study are applicable to other regions having similar conditions. The key features of an environmental problem that make it attractive for an experiment in marketing emissions rights are:

- (1) the problem is likely to be solvable at reasonable costs,
- (2) a sufficiently large number of sources contribute significantly to the problem so that a competitive market can be established,
- (3) emissions are or can be effectively monitored at reasonable cost, and
- (4) the existing situation, owing to costs of compliance and environmental degradation, is widely recognized as undesirable.

The Zero Revenue Auction needs very little else in the way of informational requirements. When combined with upper bound constraints on emissions at any single source to guard against localized pollution hot spots, it guarantees that improvements in compliance costs will be made without environmental degradation -- or no significant trading (and hence no problems) will emerge. When combined with reduced total emissions, it can also guarantee improvements in air quality in the region.