NATIONAL ASSESSMENT OF VOC, CO, AND NO_x CONTROLS, EMISSIONS, AND COSTS

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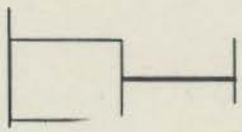
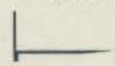
Figure 1

Ozone Nonattainment Control Cost Summary

1995 Costs



2000 Costs



EXECUTIVE SUMMARY

INTRODUCTION

The Clean Air Act mandated deadline of December 31, 1987, elapsed with a long list of areas still not attaining national ambient air quality standards (NAAQS) for ozone and carbon monoxide (CO). In anticipation of this shortfall, the U.S. Environmental Protection Agency (EPA) developed a program to address the likelihood that many areas would not attain the NAAQS and published this proposed policy in the Federal Register November 17, 1987. This announcement prompted much interest among state and local air pollution control agencies and at EPA to determine what effect this new policy might have on the remaining nonattainment areas. A substantial number of volatile organic compound (VOC) (precursors of ozone) and CO control measures have been imposed since the Clean Air Act was passed, especially in the large metropolitan areas of the United States.

Legislation introduced before Congress in 1987 and 1988 to address some of the same issues included in the EPA nonattainment policy prompted calls for quantitative analyses of each of the Congressional bills and proposals as well as the EPA policy. Initial interest among the Congressional alternatives focused on S. 1894, introduced by Senator George Mitchell and otherwise known as the Mitchell bill. In the House, a bill introduced by Rep. Henry Waxman (H.R. 3054) presented some alternative nonattainment provisions. These were followed by another proposal formulated by nine Congressmen, which has come to be known as the Group-of-Nine Proposal. This report presents a quantitative assessment of the control costs and emission reductions that might be expected from each of these three Congressional alternatives and compares them with what would be expected to happen under the EPA policy.

MODELING METHODS

In reviewing analytic tools available for performing an analysis of VOC, oxides of nitrogen (NO_x), and CO control costs for different ozone and CO nonattainment control approaches, it was found that no single model was available for any of the three pollutants that could perform all of the required analyses in a timely fashion. Therefore, new models were developed to meet the specific objectives of this project. These models vary in complexity, with the NO_x analysis being the simplest, VOC the most complex, and CO somewhere in between. Most of the analytical effort in this study was spent on modeling estimated future year VOC emissions and costs, so this summary focuses primarily on that part of the analysis.

The Emission Reduction and Cost Analysis Model for VOC (ERCAM-VOC) was developed to analyze alternative measures for reducing emissions of VOCs, precursor to ozone. The model runs on a personal computer and is programmed in dBase III Plus. It is designed to simulate the process that states and metropolitan areas might use to move toward attainment of the ambient ozone standard (the ozone NAAQS) under alternative policies.

The modeling data base is the 1985 NEDS point and area source emission inventory of VOC sources, which was augmented to provide the best possible representation of ozone season emissions and controls in place. This data base was chosen because it was the product of a multi-year research effort to develop an accurate and comprehensive inventory of 1985 emissions. The 1985 inventory was also selected because it matches the time period of the air quality data used in the study. Emissions and control data were organized by source classes designed to reflect common emission and control characteristics of different sources.

The organization of the emissions data input to the model is by Metropolitan Statistical Area (MSA) and by attainment/nonattainment area (as well as source category). Nonattainment areas are categorized according to the level of severity of their nonattainment problems.

The first modeling step is to compare 1985 NEDS listed control levels with those mandated by state and local regulations. Control costs and emission reductions are then estimated for all sources not in compliance with these regulations.

New source growth is estimated using Bureau of Economic Analysis growth rates by industry for stationary sources and vehicle miles traveled projections for mobile sources. The applicable New Source Performance Standards (NSPSs) and state and local regulations for each source category are used to estimate new source emission rates and control costs. Federal motor vehicle emission standards affect future motor vehicle emissions in all areas.

Scenario files allow individual control options beyond those already being applied for each source category to be selected. Discretionary control measures included in the analysis include methanol-fueled cars, more stringent vehicle inspection and maintenance programs, tighter vehicle emission standards, consumer solvent controls, and restrictions on hazardous waste treatment, storage, and disposal facility emissions. The model has been used to assess the VOC control cost and emission impacts for projection years 1995 and 2000. Model results are at the national, state, and Metropolitan Statistical Area (MSA) levels by industry and source type.

CAVEATS

Any analysis that attempts to estimate how future laws or regulations will affect the behavior of individuals, firms, and state and local regulatory agencies must incorporate simplifying assumptions. In addition, data bases are employed which may not be perfectly designed for the analysis being performed. The most important caveats and assumptions associated with this analysis are listed below. The most important of these caveats is that, as a general rule, the model results presented in this study are more useful for comparing the relative impacts of alternative policies and bills than they are in estimating absolute values.

- Growth in motor vehicle travel is estimated using national averages for all areas. These national average growth rates are different for each of the four vehicle types modeled (light-duty gasoline vehicles, light-duty gasoline trucks, heavy-duty gasoline vehicles, and heavy-duty diesel vehicles). Area specific growth rates are typically available, but they do not permit separate rates to be specified for the four vehicle types modeled so they were not used. In any case, motor vehicle projections in this analysis will not capture city-by-city differences in travel.

- New stationary source growth is estimated using Bureau of Economic Analysis values published in 1985. These rates may overestimate growth in areas with petroleum-based economies.

- New source costs include all the costs of going from zero to the indicated level of control. Some controls may be undertaken for economic, process, or non-ozone related, non-pollution control reasons. Therefore, total cost estimates probably overestimate the costs of the policies/bills for new sources.

- The modeling approach used in this study may also be biased toward estimating higher costs to existing sources than might actually occur. Whenever a controlled existing source is forced to increase its control level, ERCAM-VOC estimates the cost of the new control equipment without taking into account the salvage value or reduction in operating cost associated with the previous control technique. Less costly upgrades to current control systems are also not considered.

- The 1985 NEDS VOC emission estimates for some area source categories were adjusted downward to account for likely (but not recorded) control levels in nonattainment areas. This change affected emission estimates for the following area source categories: paper surface coating, degreasing, rubber and plastics manufacturing, and stage I gasoline marketing. This change makes 1985 VOC emission estimates lower and provides less opportunity for future emission reductions. No adjustments were made to base year motor vehicle VOC emission estimates to try to include excess evaporative and running loss emissions because quantitative estimates of these values were not available during the study period.

- Rule effectiveness is almost always less than originally predicted. The proposed EPA policy states that areas can take only 80 percent emission reduction credit for various measures. The effect of this 80 percent rule effectiveness provision in the policy is not modeled in this analysis.

- Where bills and policies call for control measures which have not been previously demonstrated or studied, there is considerable uncertainty in control costs. To avoid omitting important source types from the analysis, default cost per ton values have been adopted for a number of different control options, including controls for miscellaneous point sources, consumer solvent controls, and discretionary controls beyond those for which there are some data.

- Ozone and CO design values from 1983 to 1985 data have been used in this study. The presence of the generally high values measured in 1983 is to some extent representative of the high values that have been measured in the summer of 1988. Nevertheless, estimated control requirements by MSA would change if more recent data were used. Note also that these control requirements have been estimated with a simplified ozone trajectory model with considerable uncertainty.

- Not all of the policy and bill provisions could be explicitly included in this analysis. For instance, no attempt was made to quantify the effects of changing new source review procedures. Future effects of cold start certification testing for motor vehicles were also not included in this analysis.

- The point source data file used in this analysis has incomplete data for plants that emit less than 100 tons per year of VOC. Therefore, this study may underestimate emission reductions associated with regulatory approaches that make smaller VOC emitters subject to controls.

- Control of emissions in ozone transport regions as defined in the bills is not assumed to assist in reaching attainment. Ozone transport regions contain attainment areas that contribute emissions through atmospheric transport to other areas not in attainment. Thus, while costs are estimated for controls in these regions, any benefits are not included.

- NO_x costs have only been estimated for the explicit provisions of the Waxman and Mitchell bills that require NO_x controls. Additional NO_x controls may be undertaken in some areas under the proposed EPA policy or the Group of Nine proposal, but no attempt has been made to capture these costs. The effects of NO_x control on ozone concentrations (plus or minus) have been ignored in all cases. These assumptions could lead to overestimating or underestimating NO_x control costs and benefits, depending on the area involved.

RESULTS

Costs to attain the ozone NAAQS and the CO NAAQS were analyzed using the ERCAM models for VOC and CO and a similar but simplified analysis method for NO_x. This summary briefly highlights the results. The reader should consult Chapter IX for attainment costs by MSA and by state.

Ozone Nonattainment

Because attainment/progress requirements affect emission reductions and costs of the policies/bills, those requirements are summarized first in Table I. Note that while the Mitchell bill does not require areas with ozone design values above 0.27 parts per million (ppm) to attain by 2000, the yearly percentage reduction requirements of that bill effectively force all areas to attain by then.

Figure 1 shows how the estimated ozone precursor control costs differ among the EPA policy and the alternative Congressional bills and proposals. Both 1995 and 2000 cost estimates are shown. Expected additional ozone control cost expenditures under the pre-1988 EPA policy are delineated in the figure as part of the total EPA policy cost. Although estimates of the total costs of the EPA policy and the alternative Congressional bills/proposals are presented, Figure 1 is most useful for showing the relative costs of the different control approaches. The total costs should be used with caution because they do not include the historical costs of VOC control such as Federal Motor Vehicle Control Program costs and costs of existing controls for stationary sources.

While Figure 1 shows the Group of Nine costs to be lower in 2000 than the expected EPA policy costs, this lower value depends in part on high levels of consumer solvent VOC emissions control being achievable by 2000 at $2,000 per ton. This is a lower cost per ton than that used to estimate the cost of reducing "residual" tons for the other alternatives. The consumer solvent control level is limited in the other simulations. This issue is discussed more fully in Chapter VIII.

When costs of the different policies/bills are compared, so should the number of remaining ozone nonattainment areas. Table II presents ERCAM-VOC estimates of residual nonattainment areas in 1995 and 2000. Thus, of the three legislative approaches, the lower costs of the Group of Nine Proposal must be balanced against the longer list of expected nonattainment areas. Note also that the Table II list of residual nonattainment areas represents what the policies/bills require and is not an

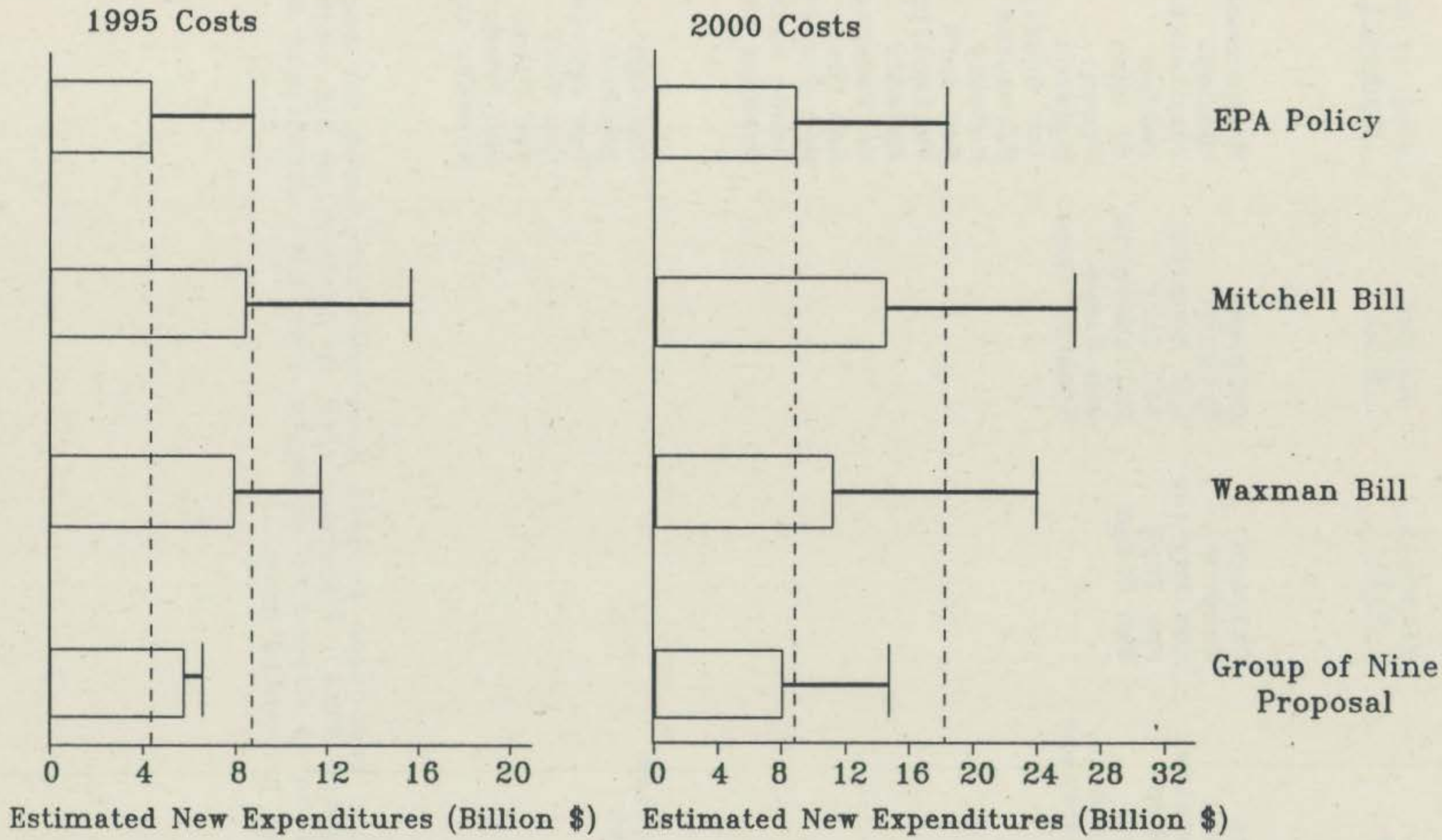
Table I

Ozone NAAQS Attainment/Progress Requirements of Proposals Analyzed

	1995	2000
EPA Policy	Attain Standard or achieve 3% per year reductions, whichever is binding	Attain Standard or achieve 3% per year reductions, whichever is binding
Waxman	Moderate and Serious must attain Severe areas must reduce emissions by 10% of the reduction required to attain the standard each year	All areas must attain
Mitchell	Moderate must attain Serious and Severe must achieve a 55% reduction or attain whichever is less stringent	All except areas with design values above 0.27 ppm must attain
Group of Nine	Moderate I and II must attain Serious must achieve 78% of attainment target Severe must achieve 41% of attainment target	All except Severe must attain Severe must achieve 71% of attainment target

Figure 1

Ozone Nonattainment Control Cost Summary



Ranges reflect costs of controlling residual tons using a range of $2,000 to $10,000 per ton.

Pre-1988 EPA Policy costs are not included here but can be found in Chapter V.

Table II

Residual Ozone Nonattainment Areas by Projection Year*

EPA Policy	Mitchell Bill	Waxman Bill	Group of Nine Proposal
1995			
Chicago	Chicago	Chicago	Massachusetts
Houston	Houston	Houston	Chicago
Los Angeles	Los Angeles	Los Angeles	Cincinnati
Milwaukee	New York	New York	Dallas
New York	San Diego	Philadelphia	El Paso
San Diego		San Diego	Fresno
San Francisco		Greater Conn.	Houston
			Los Angeles
			Milwaukee
			Modesto
			New York
			Philadelphia
			Phoenix
			Sacramento
			San Diego
			San Francisco
			Santa Barbara
			Greater Conn.
2000			
Los Angeles			Chicago
New York			Houston
			Los Angeles
			New York
			San Diego
			San Francisco
			Greater Conn.

*Emission reduction targets have been estimated for each urban area using EKMA. Uncertainties in estimating how much emission reduction is needed to bring an area into attainment affect the results presented here.

expectation of when specific areas might attain the ozone standard.

One of the important findings of this study (and other similar studies) was that there are not enough identifiable control measures to calculate how much it might cost for all metropolitan areas to attain the ozone NAAQS. Therefore, the cost of controlling "residual" tons after all identifiable controls are applied was estimated using a range of $2,000 to $10,000 per ton. Thus, ranges of cost estimates are presented for each of the policies/bills in Figure 1 and Table III.

Carbon Monoxide Nonattainment

Because a number of areas not attaining the CO standard were also ozone nonattainment areas, costs of measures to help MSAs (and non-MSAs) attain the CO ambient standard presented in Chapter IX are those in addition to what is estimated to be spent to comply with the ozone related provisions of the policy or bill. This effort to avoid double counting control costs affects I/M costs. Thus, the bill with the most stringent I/M requirements for CO may not have the highest costs, because similarly stringent ozone requirements have probably already accounted for most of the cost increase in areas that violate both standards.

Table IV summarizes estimated CO costs by control measure for the EPA policy and the three legislative approaches. CO costs of the EPA policy are much lower than the costs of the three legislative approaches. The only CO control measure modeled as if it were mandated by the EPA policy is enhanced I/M. While the proposed EPA policy mentions 17 ppm as a possible cutoff for requiring enhanced I/M, a lower cutoff was used in this analysis because preliminary simulations showed that many areas with design values below 17 ppm would not be able to demonstrate short-term attainment without new measures. Thus, enhanced I/M is modeled as if it would be the preferred "discretionary control measure" adopted by urban areas to attain the standard under the EPA policy.

Total CO costs for the Mitchell bill, the Waxman bill, and the Group of Nine Proposal are similar in magnitude. The cost burden is distributed differently for each legislative approach, however. The Mitchell bill places more of the cost burden on stationary sources. The Group of Nine proposal costs affect only motor vehicles.

All of the policies/bills have additional I/M costs. These costs can include improving the effectiveness of existing I/M programs and establishing new I/M programs in areas where they currently do not exist. Both the Mitchell bill and the Group of Nine proposal have alternative fuel programs in severe CO nonattainment areas. These programs are estimated to cost $27 million. The alternative fuels case modeled is a CO season

Table III

Ozone Nonattainment Control Cost Summary*
Estimated New Expenditures (Billion $)

	1995	2000
EPA Policy	4.2 - 8.6	8.9 - 18.3
Mitchell Bill	8.3 - 15.5	14.7 - 26.5
Waxman Bill	7.8 - 11.5	11.0 - 24.0
Group of Nine Proposal	5.8 - 6.3	8.5 - 14.8

* Ranges of costs reflect costs of controlling residual tons using a range of $2,000 to $10,000 per ton. Costs of pre-1988 policy requirements are not included here but can be found in Chapter V.

Table IV

Additional Carbon Monoxide Control Costs*
1995 Projection Year
(millions)

Control Measures	EPA Policy	Mitchell Bill	Waxman Bill	Group of Nine Proposal
	Policies/Bills			
Motor Vehicle Measures				
Enhanced I/M	$38	$67	$128	$132
Alternative Fuels**	--	27	--	27
Stationary Source Controls	0	40	0	0
Emission Fee	0	34	13	0
Totals	$38	$168	$141	$159

* Costs are those in addition to what is estimated to be spent to comply with ozone provisions.

** The alternative fuels case modeled is a CO season (winter) switch from straight gasoline to an ethanol blend.

Note: Effects of cold start certification testing for motor vehicles have not been included in this analysis.

(winter) switch from straight gasoline to an ethanol blend. This program is similar to the one currently being used in the Front Range of Colorado.

The CO stationary source controls called for by the Mitchell bill are estimated to cost $40 million. These are the costs of applying the control techniques listed in Table III.1 to serious and severe CO nonattainment areas.

Stationary source emission fees of $100 per ton are applied in both the Mitchell and Waxman bills. Costs are higher for the Mitchell bill because the fee is applied in both serious and severe nonattainment areas. The Waxman bill only has an emission fee for sources in severe nonattainment areas.

Estimates of expected attainment dates depend on which source types are assumed to be contributing to observed CO standard exceedances. With the assumption that mobile sources and a percentage of stationary area sources (20 percent) affect the design value monitor, there are three residual CO nonattainment areas in 1995 in the simulations for the proposed EPA policy and the Waxman bill. The Mitchell bill and Group of Nine proposal simulations show one remaining CO nonattainment area in 1995. If all sources within an MSA are assumed to contribute equally to CO standard exceedances, many more areas are projected to fail to attain the standard by 1995.

Note also that MOBILE3 modeled CO I/M credits are higher than what has been observed in recent surveys (Sierra Research, 1988). If I/M programs are less successful than indicated by MOBILE3, the number of remaining CO nonattainment areas in 1995 will increase.

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I INTRODUCTION

A. BACKGROUND AND PURPOSE

A substantial number of volatile organic compound (VOC) and carbon monoxide (CO) control measures, especially in the large metropolitan areas of the United States, have been imposed since the Clean Air Act was passed. Despite this, the Clean Air Act mandated deadline of December 31, 1987, elapsed with a long list of areas still not attaining national ambient air quality standards (NAAQS) for ozone and CO. In anticipation of this shortfall, the U.S. Environmental Protection Agency (EPA) developed a program to address the likelihood that many areas would not attain the NAAQS, publishing the proposed policy in the Federal Register November 17, 1987. This announcement prompted much interest among state and local air pollution control agencies and at EPA to determine what effect this new policy might have on the remaining nonattainment areas.

The introduction of bills in Congress in 1987 and 1988 to address some of the same issues included in the EPA nonattainment policy prompted calls for quantitative analyses of each of the Congressional bills and proposals as well as the EPA policy. Initial interest among the Congressional alternatives focused on S. 1894, introduced by Senator George Mitchell and otherwise known as the Mitchell bill. In the House, a bill introduced by Rep. Henry Waxman (H.R. 3054) presented some alternative nonattainment provisions. These were followed by another proposal formulated by nine Democratic Congressmen, which has come to be known as the Group-of-Nine Proposal. This report presents a quantitative assessment of the control costs and emission reductions that might be expected from each of these three Congressional alternatives and compares them with what would be expected to happen under the EPA policy.

In reviewing analytic tools available for performing an analysis of VOC, oxides of nitrogen (NO_x), and CO control costs for different ozone and CO nonattainment control approaches, it was found that no single model was available for any of the three pollutants that could perform all of the required analyses in a timely fashion. Therefore, new models and analysis tools were developed to meet the specific objectives of this project. These models and tools vary in complexity, with the NO_x analysis being the simplest, VOC the most complex, and CO somewhere in between. Effort in the NO_x analysis focused on developing current cost equations for Reasonably Available Control Technology (RACT) (low NO_x burner) and Best Available Control Technology (BACT) (selective catalytic reduction (SCR)). These cost equations were then applied to sources in the 1985 National Emissions Data System (NEDS) emission inventory to estimate costs of various bill provisions. For VOC, a more complete model was developed that included current control information, control cost equations, and new source growth emission projections. Scenario files were designed to allow different levels of VOC controls in areas depending on the severity of their nonattainment problem. Results can be provided by Metropolitan Statistical Area (MSA), by state and industry, and by source category for the entire United States.

The CO model is similar in design to the VOC model, but it was a much simpler model to construct and operate because of the limited number of important CO source categories and control options. New source growth and control was incorporated into the CO model for motor vehicles and other area source emitters; point source controls and costs were evaluated for only the existing set of sources.

B. ORGANIZATION OF THE REPORT

The organization of this report is such that modeling methods are presented first for each of the three pollutants (VOC, CO, and NO_x) followed by results for the EPA policy and the three legislative alternatives. Sensitivity analyses and a list of study caveats are provided following the results chapters.

With most of the attention in this study on costs to attain the ozone standard, much effort was spent developing a VOC control cost model. VOC model input data and calculation procedures are described in Chapter II. Discussed in this chapter are the base year emission inventories, control cost equations, growth projections, emission constraints, and results reporting. Chapter III presents similar information for the CO model. Although a model was not developed for the NO_x control cost analysis, organization of the NO_x emission data base and development of NO_x control cost equations are explained in Chapter IV.

Chapters V through VIII present analysis results for the EPA policy, Mitchell bill, Waxman bill, and the Group of Nine Proposal, respectively. Summary results for all policies/bills are presented in Chapter IX. Because CO control costs are much lower than those for VOC and NO_x, they are only reported in Chapter IX. Because results are sensitive to the growth rates used in the VOC model, a sensitivity analysis was performed. The results of this analysis are presented in Chapter X. Key analysis caveats are delineated in Chapter XI.

II VOC MODEL DEVELOPMENT

Photochemical oxidants (measured as ozone) are products of atmospheric reactions involving organic pollutants, nitrogen oxides, oxygen, and sunlight. All of the evidence presently available shows that in and around urban centers that have severe ozone pollution, anthropogenic organics and NO_x are the major contributors. The photochemical formation of ozone is the result of two coupled processes: (1) a physical process involving dispersion and transport of precursors to ozone (e.g., organics and NO_x), and (2) the photochemical reaction process. Both processes are strongly influenced by meteorological factors such as dispersion, solar radiation, temperature, and humidity.

The Emission Reduction and Cost Analysis Model for VOC (ERCAM-VOC) described in this chapter was developed to analyze alternative measures for reducing emissions of VOCs, precursor to ozone. The model runs on a personal computer and is programmed in dBase III Plus. It is designed to simulate the process that states and metropolitan areas might use to move toward attainment of the ambient ozone standard (the ozone NAAQS) under alternative policies.

ERCAM-VOC does not include an air quality modeling component. Instead, it uses as input VOC emission reduction targets estimated from an ozone trajectory model.

A. MODELING OBJECTIVES

The major objectives in developing the model were that it be a PC based model that can be used by other parties, that it provide quick turnaround analyses, that it report results on various geographical levels (national, state, and MSA), and that control selection be exogenous to the model.

While the first objective (use by other parties) has not yet been realized, once the model is documented and some of the computer code developed to respond to quick turnaround issues is reprogrammed, PC users familiar with dBase III should be able to run ERCAM-VOC. While a normal disadvantage of a PC based model maintenance (I/M) programs (U.S. EPA, 1987d). The regulations are specified by pod/control strategy combinations. This pair is then matched to the cost equation file to obtain emission reduction and cost information. In cases where the specified reduction is more stringent than the existing level of control for a source as specified in NEDS, emissions are reduced to the level specified and the additional control cost is estimated.

Scenario control strategies are next applied to existing source emissions. A separate file is used for existing and new source scenario constraints on emissions. For simplicity and because most of the proposed new VOC control provisions are stipulated by nonattainment severity, the scenario file is organized by attainment category. Attainment areas are one classification while nonattainment areas are divided into separate classes depending on nonattainment severity. For each attainment classification and pod, a control strategy (including zero control) is specified in an input file. In simplified form, for sources in the data file not already controlled to the level indicated (after applying regional constraints), scenario level emissions and costs are calculated.

There are two exceptions to this form. A penetration factor (the percentage of sources in a cost pod affected by a regulation) is used for solvent evaporation area sources to reflect the fact that some sources are small and may be exempt from control by the chosen technique because of their size. This factor is used to calculate the resulting control level for the pod. The second exception is for point source RACT controls. These include controls on all point sources for which Control Technique Guidelines (CTGs) have not been published. For these sources, a size cutoff is specified. Sources under the size cutoff and sources which are already controlled are not subject to the scenario file constraint.

Additional scenario control measures outside of the attainment classification and pod framework may also be analyzed using the model. Gasoline Reid Vapor Pressure (RVP) reductions, onboard controls, and new motor vehicle emission standards are modeled on the national level. Emission fees are applied to sources above a size cutoff by attainment classification. Expansion of nonattainment areas to the Consolidated Metropolitan Statistical Area (CMSA)/MSA level involves applying SIP regulations to the entire CMSA/MSA rather than specific counties. Ozone transport region controls are specific measures mandated for regions believed to significantly impact the ozone concentrations in surrounding areas. Costs are estimated for controls that might be mandated in these areas, but no credit is given to areas downwind whose emissions may not have to be reduced as much because transported ozone is less.

New source emissions (except motor vehicle) are projected using Bureau of Economic Analysis (BEA) growth rates by industry and MSA (BEA, 1985). Growth factors are applied to 1985 uncontrolled VOC emissions for each MSA/state/pod/industry category combination to estimate future year uncontrolled VOC emissions. Future year motor vehicle emissions are estimated using national average vehicle miles traveled (VMT) growth (EEA, 1987) and changes in future year emission factors (Lorang, 1988; U.S. EPA, 1984 and 1987a).

After calculating new growth emissions, NSPS (Battye et al., 1987) and SIP constraints are applied. NSPS regulations apply to all areas and are designated by pod and control strategy. The methodology in applying the constraints is the same as for existing source constraints except that average cost per ton values are used in estimating control costs since source size specific information is not determined. The average cost per ton values for each cost pod were estimated by applying the cost equation to the average sized new source (Battye et al., 1987).

After applying NSPS and SIP constraints, new sources are then subject to possible further emission reductions via the scenario constraints. Again, this calculation parallels that of the existing sources except that the dollar per ton values are used to estimate control costs.

Results reporting is on three geographical levels: national, state, and MSA. National level results are provided by is that runtime is much longer than it would be for a comparable mainframe model, an ERCAM-VOC national simulation runs in 2 hours on a PC with an 80286 microprocessor using the dBase compiler Clipper, which significantly reduces runtime.

The objective of providing quick turnaround analyses was realized, as the model has been used to provide EPA with analyses of proposed policy and bills within a few days. Model results are available by source category and attainment category on the national level. State level results are reported by industry. Emission and cost totals may be reported by MSA. (Sources are categorized by pollution and control characteristics and several source categories may exist within an industry.)

ERCAM-VOC was developed to analyze regulatory alternatives for attaining the ozone standard. It was designed so that combinations of measures are selected for analysis rather than having the model select the most cost efficient set of measures. An endogenous control measure selection is less desirable in a situation where all available controls (or more) are necessary to meet control targets. Also, some of the provisions of the proposed alternatives in this study specify controls that must be used in areas according to nonattainment severity, thus it is necessary to design a model in which controls are specified and analyzed according to various attainment classifications rather than as a least cost analysis. (Controls mandated may not always be the most cost effective or even necessary for a specific area.)

B. MODEL OVERVIEW

1. Definitions

Two terms used frequently in the text need to be well understood before reading the VOC model discussion. These terms are "cost pod" and "design value."

Control and cost information for the model is organized by cost pod. A cost pod is a group of source types, as defined by NEDS Source Classification Codes (SCCs) or NEDS area source categories, which have similar emission characteristics, control techniques, and control costs. A cost pod may have one or several control strategies (which consist of control option, efficiency, and cost information). All sources inventoried are classified into cost pods. In all, the model comprises 42 point source and 23 area source cost pods. All of the emission reduction and control cost calculations are performed at the cost pod level.

The ozone design value is a measure of the maximum ozone concentration expected to occur within an area. Any area with a design value of 0.125 ppm or greater is considered nonattainment. This means that an area is expected to exceed the 0.12 ppm standard more than once per year on average. In general, the higher the design value the greater the VOC reduction requirement to reach attainment (although this varies depending on the amount of NO_x present and other factors). Design values are important in this analysis both for determining VOC emission reduction requirements and for classifying areas into attainment and nonattainment categories.

2. Modeling Methods Summary

Six primary inputs are used to estimate the effect of current and future regulations on VOC emissions and costs:

- 1985 VOC emission inventory,
- existing source regulations,
- scenario control strategies,
- set of control cost equations,
- set of growth factors, and
- NSPS regulations.

The interrelationship of these inputs is diagrammed in Figure II.1 and a brief description follows. A more detailed description is contained in the following sections.

The 1985 VOC emission inventory is taken from the 1985 NEDS point and area source inventories. From the point source inventory, source specific information was retained for sources emitting more than 50 tons per year. Smaller sources were aggregated by MSA/state region and cost pod into 0 to 25 ton per year sources and 25 to 50 ton per year sources. Changes were made to the control efficiencies for combustion sources and sources within the state of Texas because they were believed to attainment category and cost pod. State level results are reported by industry. This level of information may be useful for an economic analysis. Costs and emissions totals can be provided for each MSA. This output is useful in determining whether necessary emission reductions toward achievement of the ozone standard are being met and in estimating what additional costs might have to be incurred to make adequate progress toward compliance.

C. 1985 EMISSION INVENTORY

The base year emissions data file was developed from the 1985 NEDS point and area source files. The 1985 NEDS Emissions Inventory was selected for use in this study because it was the product of a multi-year research effort to develop an accurate and comprehensive inventory of 1985 emissions from sources thought to be important in acid deposition processes. Therefore, quality control procedures for this inventory were much more rigorous than those employed in other NEDS data files. The 1985 inventory was also selected because it matches the time period of the air quality data used in the study.

The data elements in the emissions data base are outlined in Table II.1. The state, SCC and controlled emission levels are taken directly from the NEDS emission inventory. The uncontrolled emissions were calculated based on the controlled emissions and reported control efficiency. MSA is a four digit code referring to the metropolitan statistical area and is based on the state and county. The pod indicates the source types for emission reduction and costing purposes. The industrial category code is a two-digit grouping based on the Standard Industrial Classification (SIC) code for point sources and an assigned two digit code for area sources. The attainment category is used for modeling purposes and is determined from the ozone design value for an area. This element is analysis specific. The number of vehicles is used for motor vehicle control cost estimates (all other costs are based on uncontrolled emissions). A set of SIP regulations are available for each MSA, but the applicability of

Table II.1
Basic Structure of Emission Data Base

Element Name	Description
ATTCAT	Attainment category (ozone design value dependent)
AEROSSTATE	AEROS State code
MSA	Metropolitan Statistical Area code
POD	Cost Pod Identifier
SQQ	Industry identifier
SCC	NEDS SCC code*
NVOC	1985 NEDS VOC emissions
UVOC	1985 uncontrolled VOC emissions
NUMVEH	Number of motor vehicles
SPSW	SIP switch

*includes codes for additional sources not covered by NEDS

** indicates whether sources within an MSA are located in counties with existing SIP regulations these regulations may not extend to all counties within the MSA. The SIP switch indicates whether the emissions are from sources subject to or exempt from the set of SIP regulations for the MSA. Other elements are added to the data base to hold calculation results.

Source specific information was retained for sources shown as emitting 50 tons per year or more in the 1985 NEDS point source inventory. Smaller sources were aggregated by cost pod, industrial category, and MSA/state region code into two types of records. The first type includes sources emitting 25 to 50 tons per year. The second type includes sources emitting less than 25 tons per year. Coverage of smaller sources within the 1985 NEDS point source inventory is limited since attention was focused on 100 ton-per-year emitters. Emissions from smaller stationary sources are represented by area source categories.

Two changes were made to point source records in the base year emissions data file. First, many combustion sources (zero pod) had reported VOC efficiencies, many over 90 percent. Since fuel combustion is in itself, a VOC control, it seems unlikely that additional controls are put on these sources. Since future emissions are projected using uncontrolled emissions, this produced high future emissions and no control techniques were available for reducing these emissions. The uncontrolled emissions were set equal to the controlled emissions (simulating no control devices) for all combustion point sources to keep growth within a reasonable bound.

In early runs of the model, some areas in Texas showed higher VOC emissions in the forecast years than in 1985, even with all available controls being added. This occurred because current VOC control efficiencies for many point sources were unrealistically high. Texas Air Control Board point source emission inventory surveys do not ask about control efficiencies, only emissions and control equipment data are collected. Then, Texas assigns default control efficiencies for sources based on control equipment type and SCC. These control efficiencies were higher than the maximum reported in other areas for the same type of process and control equipment in many cases.

Uncontrolled emissions are based on the reported controlled emissions and the control device efficiency. If the efficiency is overestimated, uncontrolled emissions will also be overestimated. For example, a 100 ton per year source with a 98 percent efficient control device will have uncontrolled emissions of 5,000 tons per year. If the control equipment efficiency is overestimated at 99 percent, uncontrolled emissions will be estimated as 10,000 tons per year. If the efficiency is overestimated to 99.9 percent, uncontrolled emissions will be 100,000 tons per year. If growth of 3 percent per year is applied for 10 years, new emissions assuming the 99.9 percent control efficiency will be 34,400 tons. When using the correct efficiency of 98 percent, new growth will be only 1,700 tons. Texas control efficiencies were adjusted to more reasonable levels as outlined in Table II.2 and Table II.3.

New control efficiencies for Texas were established in two ways. First, for cost pods specific to industries, i.e., pods 2 through 36, control levels were set equal to either the level of control achieved by similar pods in other nonattainment areas or to the level of control specified in the Texas SIP. These changes are documented in Table II.2. For sources in pod 90 (miscellaneous sources) a different approach was used. Each source or source/control device combination was evaluated separately and engineering judgment was used to establish a likely limit on device effectiveness. The engineering judgment was based on both the magnitude and characteristics of the VOC emissions and the probable effectiveness of the control equipment. The changes made to these sources are documented in Table II.3.

Changes were also made to the NEDS area source inventory. First, the solvent evaporation and gasoline marketing categories were separated into smaller categories for control purposes. The solvent evaporation emissions are apportioned among eight

Table II.2

Changes in Texas Control Levels by Pod and Control Device

Pod	Source Category Name	Control Device	Number of Sources	NEDS Control (%)	Revised Control (%)
2	Printing/publishing	19-Catalytic Afterburner	1	99.0	86
4	Fixed roof crude tanks	47-Vapor Recovery	3	99.5	98
5	Fixed roof gasoline tanks	47-Vapor Recovery	10	99.0	96
7	Floating roof gasoline tanks	47-Vapor Recovery	1	99.0	95
10	Bulk gasoline terminals	51-Gas Absorption	1	99.0	90
17	Terephthalic acid mfg.	23-Flaring	1	99.9	98
20	Refinery fugitives	13-Gas Scrubber	2	99.0	70
		23-Flaring	1	99.9	70
		47-Vapor Recovery	3	99.0	70
		48-Carbon Absorption	1	99.9	70
22	Styrene-butadiene rubber	52-Spray Tower	1	99.9	98
		47-Vapor Recovery	1	99.0	94
23	Polypropylene mfg.	47-Vapor Recovery	1	99.0	98
24	Polyethylene mfg.	47-Vapor Recovery	1	99.0	98
25	Ethylene mfg.	47-Vapor Recovery	6	99.0	98
26	Refinery WW treatment	47-Vapor Recovery	1	99.0	95

Table II.3

Texas Miscellaneous Point Source (Pod 90)
VOC Control Efficiency Changes

SCC	Control Device Code/Description	1985 NEDS % Control	Change
30100104	13-Gas Scrubber	99.0	Delete
30100799	47-Vapor Recovery	99.0	--
30101199	47-Vapor Recovery	99.9	Delete
30101801	50-Gas Absorption	99.0	--
30103399	13-Gas Scrubber	99.0	--
30103399	47-Vapor Recovery	99.9	99
30109101	48-Carbon Adsorption	99.0	--
30109153	13-Gas Scrubber	99.0	--
30112001	53-Venturi Scrubber	99.0	98
30112005	47-Vapor Recovery	99.0	--
30112011	13-Gas Scrubber	99.0	95
30112599	52-Spray Tower	99.0	98
30115380	47-Vapor Recovery	99.0	90
30117613	47-Vapor Recovery	99.9	99
30118105	52-Spray Tower	99.9	99
30125001	60-Proc. Gas Recover	99.9	95
30125099	47-Vapor Recovery	99.0	--
30125099	23-Flaring	99.9	98
30199999	47-Vapor Recovery	99.9	90
30199999	53-Venturi Scrubber	99.9	90
30300399	23-Flaring	99.9	--
30699999	13-Gas Scrubber	99.0	--
30699999	47-Vapor Recovery	99.0	--
30699999	48-Carbon Adsorption	99.9	90
40400204	46-Process Change	90.0	--
40400250	47-Vapor Recovery	99.0	90
40688801	47-Vapor Recovery	99.0	95
40688801	23-Flaring	99.9	95
40700816	47-Vapor Recovery	99.0	95
40782001	23-Flaring	99.9	--
40899999	53-Venturi Scrubber	99.0	--
50390006	19-Afterburner	99.0	Delete

categories based on national average factors (Battye et al., 1987). The breakdown of this category is as follows:

- architectural surface coating (12.1 percent),
- paper surface coating (4.2 percent),
- degreasing (17.4 percent),
- dry cleaning (7.6 percent),
- printing (4.4 percent),
- rubber and plastics manufacture (3.3 percent),
- commercial and consumer solvents (25.7 percent), and
- miscellaneous solvent use (25.3 percent).

Gasoline marketing was divided into underground tank evaporative losses, or stage I (38.4 percent), and self service refueling losses, or stage II, plus spillage (61.6 percent), based on the emission factors used to estimate gasoline marketing emissions in the 1985 NEDS area source inventory (Kimbrough, 1988). Emissions are estimated by multiplying gasoline throughput by the emission factors for stage I, stage II, and spillage. The ratio of the emission factors will equal the ratio of emissions for the three emission sources.

NEDS solvent evaporation emission estimates are based on the solvent usage for each county. It is assumed that all solvent used is emitted to the atmosphere. Many areas have SIPs regulating solvent evaporation sources in such a way that the solvent is destroyed (i.e., incineration). If this is the case for an area, solvent evaporation emissions will be overestimated by NEDS. Therefore, adjustments were made to solvent evaporation emissions for nonattainment areas with SIP regulations for those sources to better reflect the actual emissions in 1985 (Johnson, 1988).

Emissions for gasoline marketing, stage I and stage II, are estimated in NEDS using uncontrolled emission factors. Many current state regulations require the use of stage I controls (usually on sources above 120,000 gallons per year throughput) which control emissions by 95 percent. Emissions in areas designated as having stage I controls (Battye, 1987) were adjusted to reflect these controls. Stage II controls are already in place in Los Angeles, San Francisco, and the District of Columbia. Base year stage II emission estimates were adjusted to the estimated control level of 86 percent.

Motor vehicle emissions for 1985 are estimated by county in NEDS and include the effects of I/M programs. NEDS uses MOBILE3 to estimate 1985 highway vehicle emissions for four vehicle types: light-duty gasoline-powered vehicles (LDGVs), light-duty gasoline-powered trucks (LDGTs), heavy-duty gasoline-powered vehicles (HDGVs), and heavy-duty diesel-powered vehicles (HDDVs). Reductions in VOC (and other pollutant) emissions that should be observed in areas with I/M programs were also simulated in NEDS using MOBILE3, with MOBILE3 program inputs being determined by summaries of I/M program characteristics by area provided by EPA's Office of Mobile Sources. It is believed that the MOBILE3 credit calculated for I/M programs is overestimated (Sierra Research, 1988). Emissions were adjusted for areas having I/M based on national averages. Emissions were adjusted from a 22 percent credit to a 15 percent credit for basic I/M.

The number of vehicles for each MSA/state/pod combination were also added to records for motor vehicle pods. National totals of vehicle registrations by vehicle type for 1985 (EEA, 1987) were apportioned to individual MSA/state combinations by population (U.S. Bureau of the Census, 1985). The number of vehicles is used to estimate costs for many motor vehicle control options.

A summary of the ERCAM VOC emissions data base is shown in Table II.4. Included are the VOC emissions and the 1985 level of control by source category.

D. CONTROL COST EQUATIONS

The starting point for the control cost equation data file is the set of equations developed for the ozone NAAQS Cost Model by Alliance (Battye et al., 1987). These include equations for 34 point source and 7 area source categories (cost pods). Cost equations were developed from model plant data using linear and exponential least squares curve fitting techniques.

Table II.5

Sample of Cost Equation Input File

Pod	CS	Pod Name	CS Name	Reduction (%)	Capital Cost Coefficient	Capital Cost Exponent	O&M Coefficient	O&M Exponent	Recovery Credit Intercept	Recovery Credit Slope	Cost*
21	0	Cell. Acetate	No Control	0	0	0	0.0	0.0	0	0	0
21	1	Cell. Acetate	Carbon Adsorber	54	90,809	0.60	10614.0	0.600	0	320	537.0
21	2	Cell. Acetate	Carbon Adsorber	72	115,789	0.60	12110.0	0.600	0	448	579.8

* COST = $/uncontrolled ton for stationary sources
= $/vehicle for motor vehicles

NOTES:

Equations use uncontrolled VOC emissions as independent variable
Capital and O&M cost equations are exponential
Recovery credit equations are linear

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* COST = $/uncontrolled ton for stationary sources
= $/vehicle for motor vehicles

NOTES:

Equations use uncontrolled VOC emissions as independent variable
Capital and O&M cost equations are exponential
Recovery credit equations are linear

Table II.6

NEDS SCCs Added to Cost Pods

Pod/Source Type	NEDS SCCs
1- Degreasing	40100306
2- Printing and Publishing	40500211, 12 40500311, 12 40500411, 12 40500412, 13
4-Fixed Roof Tank, Crude Oil	40301011
5-Fixed Roof Tank, Gasoline	40301002, 03, 08, 09
6-Floating Roof Tank, Crude Oil	40301103, 04
20-Petroleum Refinery Fugitives	30600811-20 30688801-05
21-Cellulose Acetate Manufacture	30102501
33-Automobile Surface Coating	40201601, 06, 31
35-General Surface Coating	40201901

f. Charcoal Manufacturing

Charcoal manufacturing was identified as a large emitter at 37,200 tons in 1985. EPA's AP-42 emission factor document (U.S. EPA, 1985) states that the use of an afterburner can reduce emissions by an estimated 80 percent. The default cost for afterburners from the Radian VOCM is $1,685 per ton (Radian, 1985). While charcoal manufacturing is a large national emitter, it is not a significant source in nonattainment areas.

g. Miscellaneous and Combustion Point Sources

No other point source categories were identified as being large emitters and having readily available control information. The remaining sources were classified as pod 90, miscellaneous point sources, except for combustion. Since it is unlikely that additional VOC controls are placed on combustion sources because combustion is a VOC control, these were categorized separately as pod 0. The sources in the miscellaneous pod have an average level of control around 90 percent. Future growth from this category is large because of high growth rates and high uncontrolled VOC emissions in the base year, so future emissions must be reduced or the growth will offset reductions achieved in other categories. A default cost of $1,250 per ton reduced was assigned at a 90 percent control level. This cost was chosen to represent an average RACT level control cost for sources which did not involve surface coating.

2. Area Sources

All area sources were also classified into pods. Control cost equations were developed if information was available. In addition to the 6 area source pods defined for the NAAQS model (Battye et al., 1987), 11 new pods were developed including the pods for the new sources added to the inventory (TSDFs, etc.). Area fuel combustion sources (except wood stoves) were combined with point fuel combustion sources.

a. Gasoline Marketing-Stage II

Gasoline marketing-stage II can be controlled using vapor balance systems, onboard controls, or both. Vapor balance at maximum enforcement can yield reductions of 86 percent at an estimated cost of $900 per ton reduced (U.S. EPA, 1987a). This cost estimate is based on applying stage II in 11 nonattainment areas. The cost per ton varies greatly depending on size cutoffs (i.e., exempting those emitters with throughputs below a specified level) and slightly with the number of areas involved. Costs for nationwide stage II with no size cutoffs can be in excess of $1,800 per ton reduced. This type of system is already being used in Los Angeles, San Francisco, and the District of Columbia. A reduction of 95 percent was assumed when combining both vapor balance and onboard controls.

b. Architectural Surface Coating

Emissions from architectural surface coating can be reduced by reformulating to waterborne coatings. The Federal Implementation Plan (FIP) study (U.S. EPA, 1987c) estimates an overall reduction of 52 percent at little or no additional cost. A draft CTG (U.S. EPA, 1981) estimates an overall reduction of 23 percent at a savings of $1,250 per ton. This means that the cost for waterborne coatings will be an estimated $1,250 less per ton of VOC emitted than solvent borne coatings. It is assumed that many of the coatings yielding large savings have already been reformulated, so the more recent FIP study information was used in this analysis. For modeling purposes, a cost of zero dollars per ton reduced was used.

c. Commercial and Consumer Solvents

Emissions from commercial and consumer solvent use totaled 1.2 million tons in 1985. These emissions come from a wide variety of products, each accounting for a small portion of emissions, forming a large source category when aggregated. A breakdown of consumer products ranked by average total emissions in California is shown in Table II.7. Control options for reducing emissions include product reformulation and banning. A report on reducing VOC from underarm products (CARB, 1987) estimates that emissions from these products can be reduced by 54 percent at a cost of $300 per ton reduced. Underarm deodorants are only a fraction of all consumer solvents, however, so this

Table II.7

Consumer Product Subcategories Ranked in Order of Average Total Emissions (for California)

Consumer Product Sub-Category	Total VOC Emissions (tons) Per Year in California
Paints, primers, varnishes (aerosols)	11,408
Hair sprays	8,095
All purpose cleaners	6,463
Insect sprays	5,558
Car polishes & waxes	4,625
Room deodorants & disinfectants	4,650
Consumer adhesives	3,830
Caulking & sealing compounds	2,380
Moth control products	2,098
Window & glass cleaners	1,970
Herbicides, fungicides	1,803
Personal deodorants	1,614
Auto antifreezes	1,165
Carburetor & choke cleaners	1,051
Brake cleaners	1,032
Engine degreasers	1,088
Engine starting fluids	949
Rug & upholstery cleaners	930
Lubricants and silicones	913
Metal cleaners & polishes	660
Waxes & polishes	621
Tile & bathroom cleaners	590
Pharmaceuticals	550
Styling mousse	543
Windshield deicer	501
Insect repellents	396
Starch & fabric finish	365
Auto cleaners	354
Floor waxes or polishes	309
Colognes	303
Shaving lathers	271
Animal insecticides	255
Aftershaves	205
Undercoatings	188
Oven cleaners	185
Shoe polishes, waxes & colorants	183
Paints-other related products	170
Perfumes	135
Spot removers	127
Waxes & polishes liquids	97
Hair care products - shampoos	89
Carpet deodorizers	69
Suntan lotions	41
Depilatories	11
Anti-static sprays	3
	68,840

Source: U.S. EPA, 1987c

gives an overall reduction of only 2 percent for all commercial and consumer products. Since no other control cost information is available at this time, a default cost of $2,000 per ton reduced is used for various control levels as specified by the analyses. It is likely that regulations reducing emissions from consumer solvents will be in the same form as suggested by California for underarm products. Emissions may be reduced by limiting the vapor pressures, relative evaporation rates, or amount of VOCs in a product. The impact these types of regulations will have on individual products is difficult to assess since the formulations may vary widely. Some products may already meet the standards, some probably can be easily reformulated, and others would have to be dropped from a company's product line.

d. Hazardous Waste Treatment, Storage, and Disposal Facilities (TSDFs)

Emissions from TSDFs can be controlled using capture and control techniques such as storage tank covers and carbon adsorption. It is estimated that emissions can be reduced by 90 percent at a cost of $900 per ton reduced (Bunyard, 1988).

e. Bakeries

The Bay Area Air Quality Management District has examined the control of VOC emissions from bakeries. Preliminary results show that emissions can be reduced by 90 percent via incineration at an estimated cost of $1,275 per ton reduced (Cutino, 1987). This cost is based on the control of ethanol from a large bread baking establishment with five ovens.

f. Cutback Asphalt

Emissions from cutback (petroleum based) asphalt can be eliminated by switching to emulsified (water based) asphalts. The cost difference depends on the price of petroleum and generally results in a cost savings (U.S. EPA, 1978). A 100 percent reduction at zero cost was used for modeling purposes.

g. Publicly Owned Treatment Works (POTWs)

It is believed that the most cost effective ways to reduce emissions from POTWs are those that reduce the VOC content of the industrial wastewater upstream before it reaches the POTW. It is expected that emissions can be reduced by 90 percent at an estimated cost of $1,000 per ton reduced (Bunyard, 1988). This is based on the estimated cost for firebox covers at refinery wastewater treatment units. The cost will vary depending on the selected control technique. For example, costs for steam stripping are expected to be higher than the costs used in this analysis.

h. Railroad Engines

Costs for locomotive diesel-engine controls were estimated using Radian (1988a). This study evaluated both new and existing engine controls and assumed that the technologies used to control emissions from other types of diesel engines would be transferrable. Control techniques for existing engines are assumed to be applied during a rebuilding process. New engine controls were evaluated at both intermediate (achievable in 3 years) and advanced (involving further research and development) levels. Costs and emission reductions applied in this study represent imposing intermediate technology emissions standards both on new and existing locomotives. Emission controls reduce both VOC and NO_x. VOC reductions range from 37.5 percent for new engines to 51.2 percent for existing engines. The cost effectiveness of these controls depends on whether VOC and NO_x reductions are considered individually or collectively. NO_x emissions are reduced more than VOC emissions, so if VOC reductions are considered alone in estimating cost effectiveness, the cost per ton ranges from $19,600 (existing) to $26,200 (new). Costs used in the model were for VOC plus NO_x and ranged from $1,073 (new) to $1,332 (existing) per ton reduced.

i. No Available Control Costs

Cost equations have not been developed for the remaining new area source pods. These pods include (1) off-highway vehicles, (2) aircraft and vessels, (3) open burning, forest fires, and prescribed burns, and (4) incineration. It should be noted that emissions from open burning, forest fires, and prescribed burns are assumed to remain constant with time in ERCAM-VOC.

j. Miscellaneous Surface Coating

In addition to developing the new area source pods, the cost data for pod 45, miscellaneous surface coating, was updated based on information specific to the individual source types in the category. This category comprises emissions from auto refinishing, miscellaneous industrial solvent use, and miscellaneous surface coating. Two control strategies have been developed for the analysis. The first is the control of automobile refinishing emissions. Preliminary findings (Blaszczak, 1988) indicate an overall reduction of 75 percent can be achieved by using three techniques: an enclosed cabinet to recycle cleanup solvent, replacement of the application technique to improve transfer efficiency, and the elimination of lacquers. All of these options result in a cost savings due to decreased solvent usage. An overall savings of $3,260 per ton of emissions reduced can be expected. Based on the percentage breakdown of the pod into the three emission categories, an overall reduction of 14 percent of total miscellaneous surface coating emissions can be achieved by controlling automobile refinishing sources.

The second control strategy modeled combines auto refinishing control with reductions in industrial solvent use emissions. These emissions are generally reduced by decreasing solvent consumption through better working practices. Since no control cost information was available, a cost of $2,000 per ton was used. A 25 percent reduction of industrial solvent emissions was used translating to a 10 percent overall reduction for the pod. Combining this with the automobile refinishing control option gives an overall reduction of 24 percent at a savings of $1,070 per ton of emissions reduced.

3. Motor Vehicles

Control strategies and costs were developed for motor vehicle pods to match the provisions for these sources outlined in the EPA policy and the bills being studied. The control strategies modeled include basic I/M, enhanced I/M, a gasoline

RVP reduction from the current average of 11.5 psi to 9.0 psi, new motor vehicle emission standards, and alternative fuels.

a. Inspection and Maintenance

Basic I/M is available for reducing emissions from light duty gasoline vehicles (LDGVs) and light duty gasoline trucks (LDGTs). The average credit for basic I/M is 15 percent (Sierra Research, 1988) at a cost of $20.20 per vehicle (U.S. EPA, 1987b). Enhanced I/M is available for LDGV, LDGT, and heavy duty gasoline vehicles (HDGVs). Although cost estimates were available for heavy duty diesel vehicle (HDDV) I/M, this control strategy was not used in this analysis as there is no evidence of achievable emission reductions.

An incremental reduction and cost for enhanced I/M of 7 percent and $6.48 per vehicle over basic I/M is used for LDGV and LDGT. An emission credit of 13 percent and a cost of $19 per vehicle is used for HDGV (Lorang, 1985). In a recent APCA paper (Wright and Klausmeier, 1988), potential emission reductions for including HDGV in an I/M program were estimated at 8 percent for light-HDGV and 11 percent for medium HDGV for 1988. The exact reduction depends on the mix of light versus medium HDGV, the mix of model years, and the VMT of each type.

b. Reid Vapor Pressure (RVP) Reductions

Emissions from gasoline fueled motor vehicles can be reduced by reducing the RVP of the gasoline. This option was modeled assuming a national regulation. Costs per ton of VOC emissions reducted could be significantly higher if only certain areas adopted RVP limits. It is expected that decreasing the RVP of gasoline to 9.0 psi will result in an incremental cost of 0.225 cents per gallon of gasoline (Weiser, 1988). Based on the average fuel consumption by motor vehicle type derived from information in the Motor Fuel Consumption Model (EEA, 1987), the resulting per vehicle annual costs are $1.20 for LDGV, $1.08 for LDGT, and $2.76 for HDGV. The emission reductions are modeled through changes in projection year emission factors for motor vehicles and are discussed in Section II.E, Growth Projections.

c. Onboard Controls

Onboard controls can be expected to reduce refueling emissions by 95 percent but this technique takes time to phase in due to vehicle fleet turnover. The cost for onboard controls is attributed to new motor vehicles at an average cost of $14 per vehicle for gasoline powered motor vehicles (U.S. EPA, 1987b). The regulatory impact analysis (U.S. EPA, 1987a) of the gasoline marketing regulation estimated that a little over 50 percent of consumption would be controlled by onboard controls in 1995 assuming that the controls began in model year 1989. It is assumed onboard controls will have full impact by the year 2000.

d. New Motor Vehicle Standards

Motor vehicle emissions can also be reduced by establishing more stringent new motor vehicle standards. These reductions are also modeled by adjusting the projection year emission factor. Expected costs per new motor vehicle are $83.5 for LDGV, $92.4 for LDGT, and $164.7 for HDGV (U.S. EPA, 1987b). The standards are not expected to reduce VOC emissions from HDGV but are expected to reduce NO_x emissions. Per vehicle costs include the costs of reducing all applicable pollutants, so they include CO and NO_x control costs, as well as those for VOC. Both CO and NO_x control have been shown to be of benefit in reducing ozone levels in some areas. These benefits have not been accounted for in ERCAM-VOC projections of emission reductions needed to reach attainment.

e. Alternative Fuels

Strategies have been incorporated in the VOC model that simulate the cost and emission reductions of burning less polluting fuels in motor vehicles. The costs of these measures can vary a great deal depending on the assumptions made, especially for future fuel prices. Two situations are modeled in the bills that were examined. One is a provision that would require fleet vehicles (taxis, corporate vehicles) to use less polluting engines or fuels. There are a number of options available, but for modeling purposes, it was assumed that fleet vehicles would meet this requirement by adding a capability to burn compressed natural gas (CNG). A typical conversion of a gasoline powered vehicle to natural gas uses two cylinders for gas storage at a cost of about $2,500 (Flynn, 1985). The payback period for this conversion depends on the price spread between natural gas and gasoline. The yearly fuel savings were estimated using a natural gas price of $5.08 per MMBtu and a gasoline price of $7.70 per MMBtu. The resulting net annual cost per vehicle of CNG conversion was $55 per year. Fleet conversions to CNG are assumed to affect LDGVs and LDGTs. Fleet vehicles are assumed to constitute 5 percent of the total number of vehicles, but 13 percent of the vehicle miles traveled (Lorang, 1988). VOC emissions from CNG vehicles are estimated to be 60 percent of those with gasoline engines (U.S. EPA, 1988a).

Bill provisions that call for alternative fuels/engines on a percentage of all vehicles in the fleet are analyzed using a different set of assumptions. The most likely situation was judged to be the production of methanol fueled vehicles that would begin to be sold in nonattainment areas sometime after 1995.

A number of studies by government agencies, private companies, and independent evaluators have pointed out the significant potential of methanol (compared with other potential alternative fuels) as the most likely near term replacement for petroleum. Methanol contains about 50 percent of the energy content of gasoline. Efficiency improvements are achievable through the properties of methanol like its higher octane value and its capability to be burned at very lean air-to-fuel ratios. Price comparisons between methanol and gasoline presented here take these factors into account.

In practice, it is expected that a small amount of gasoline (15 percent) would be added to the pure methanol, making fuel methanol (M85). Gasoline is added to the pure methanol to improve engine starting and as a safety measure to reduce in-vehicle tank explosion hazard and to add luminosity to the flame. The emission characteristics of vehicles using M85 were modeled in this study.

These methanol fueled vehicles would replace both gasoline and diesel powered vehicles. The key item in estimating costs for methanol vehicles is the price difference between methanol and either unleaded gasoline or diesel fuel. Apparently, the additional cost of methanol can be estimated to be anywhere from a net savings to a net cost of 70 cents per gallon. A more narrow range for modeling seemed to be 0 to 10 cents additional per gallon so 10 cents per gallon was used in the simulations to provide a reasonable cost estimate. Per vehicle capital costs for methanol versus gasoline (or diesel) can vary depending on the number of vehicles that are manufactured in a year with methanol capability. If many cars are being produced, the capital cost is no different. If there is limited production, methanol fueled vehicles are estimated to cost $400 per vehicle more than gasoline vehicles. The cost difference for methanol versus diesel is $300, but this represents the cost of a catalyst, not a production cost difference. The $400 and $300 per vehicle costs for gasoline and diesel, respectively, were used along with the 10 cent per gallon fuel difference in the VOC model to estimate costs for the methanol option.

f. <u>Application of Motor Vehicle Control Costs</u>

All motor vehicle control options are costed on a per vehicle basis. Costs for options applying to all registered vehicles (I/M, enhanced I/M, RVP) are calculated by multiplying the per vehicle cost by the number of vehicles for each MSA/state combination. Options which apply only to new motor vehicles (onboard, new motor vehicle standards) are evaluated by applying the per vehicle cost to the number of new vehicles sold each year for the MSA/state combination. The number of new vehicles is calculated by multiplying the fraction of registered vehicles for the area (number of vehicles for the area divided by the total number of registrations) by the total number of new vehicles sold each year (U.S. EPA, 1987b). Costs for options applying to specific fractions of vehicles (alternative fuels), are calculated by applying this fraction to the per vehicle cost and then multiplying by the number of vehicles.

A complete listing of the control strategies available in ERCAM-VOC for each source category is given in Table II.8. Included is the control technique, estimated reduction, and average cost.

E. GROWTH PROJECTIONS

New growth emissions for stationary sources are estimated using Bureau of Economic Analysis (BEA) projections of income by industry and MSA (BEA, 1985). The current growth file contains factors for projecting emissions to the years 1995, 2000, and 2010. The industrial category breakdown and the corresponding match to the BEA data is given in Table II.9. The growth factors are applied to uncontrolled 1985 VOC emissions to estimate future year uncontrolled emissions. Average annual percentage growth rates over the time period of the analysis are shown in Table II.10.

Motor vehicle emission projections are based on national averages of growth in VMT and changes in VOC emission factors. The VMT projections for the study years are from the Motor Fuel Consumption Model and are shown in Table II.11. The emission factors used are dependent on the control options being simulated. Base emission factors simulate the effects of the Federal Motor Vehicle Control Program. Other options include RVP and new motor vehicle emission standards. The emission factors for each option modeled are shown in Table II.12.

The motor vehicle emission factors in Table II.12 for 1985, 1995 Base, 2000 Base, and 2010 Base were estimated using MOBILE3. These are weighted average emission factors estimated using three different vehicle speeds (20, 45, and 55 mph). The fraction of travel at each of these three speeds is used to estimate a composite emission factor for each vehicle type. This method is used to try to match the calculation procedure used in the NEDS Area Source File to estimate base year motor vehicle emissions.

Emission reductions that might be achieved in restricting RVP of gasoline to 9.0 psi are estimated using weighted national average hydrocarbon (HC) emission factors from the gasoline

Table II.8
Cost Pods and Control Options

Cost Pod	P/A*	Description	Control Technique	VOC Emission Reduction (%)	$/Ton***
0	P	Combustion			
1	P	Solvent metal cleaning			
		Solvent metal cleaning	Freeboard cover	23	-483
		Solvent metal cleaning	Refrigerated freeboard	42	-364
		Solvent metal cleaning	Carbon adsorber	54	-104
2	P	Printing and publishing			
		Printing and publishing	Carbon adsorber	75	-139
		Printing and publishing	Carbon adsorber	85	-113
3	P	Dry cleaning			
		Dry cleaning	Recovery dryers	70	65
4	P	Fixed roof crude tanks			
		Fixed roof crude tanks	Internal floating roof	98	-39
5	P	Fixed roof gasoline tanks			
		Fixed roof gasoline tanks	Internal floating roof	96	-245
6	P	EFR crude tanks			
		EFR crude tanks	Secondary seal	90	2722
7	P	EFR gasoline tanks			
		EFR gasoline tanks	Secondary seal	95	-11
8	P	Bulk terminals - Splash			
		Bulk terminals - Splash	Submerged loading	59	-206
		Bulk terminals - Splash	Submerged,balanced,carbon adsorber	78	-175
		Bulk terminals - Splash	Submerged,balanced,carbon adsorber,testing	91	-188
9	P	Bulk Terminals - Balanced			
		Bulk Terminals - Balanced	Carbon adsorber	67	-198
		Bulk Terminals - Balanced	Carbon adsorber/truck testing	87	-212
10	P	Bulk Terminals - Submerged			
		Bulk Terminals - Submerged	Balanced,carbon adsorber	46	-76
		Bulk Terminals - Submerged	Balanced,carbon adsorber,truck testing	79	-154
11	P	Stage I			
		Stage I	Vapor balance	95	52
12	P	Stage II			
		Stage II	Vapor balance - minimal enforcement	56	893
		Stage II	Vapor balance - maximum enforcement	86	900
15	P	Ethylene oxide manufacture			
		Ethylene oxide manufacture	Incineration	98	246
16	P	Phenol Manufacture			
		Phenol Manufacture	Incineration	98	703
17	P	Terephthalic acid manufacture			
		Terephthalic acid manufacture	Incineration	98	830
18	P	Acrylonitrile manufacture			
		Acrylonitrile manufacture	Incineration	98	176
19	P	SOCMI fugitives			
		SOCMI fugitives	Equipment and maintenance	37	-63
		SOCMI fugitives	Equipment and maintenance	56	68
20	P	Petroleum refinery fugitives			
		Petroleum refinery fugitives	Equipment and maintenance	69	-111
		Petroleum refinery fugitives	Equipment and maintenance	80	38
		Petroleum refinery fugitives	Equipment and maintenance	93	2035

Table II.8 (cont.)
Cost Pods and Control Options

Cost Pod	P/A*	Description	Control Technique	VOC Emission Reduction (%)	$/Ton***
21	P	Cellulose acetate manufacture			
		Cellulose acetate manufacture	Carbon adsorber	54	994
		Cellulose acetate manufacture	Carbon adsorber	72	805
22	P	Styrene-butadiene manufacture			
		Styrene-butadiene manufacture	Incineration	70	103
23	P	Polypropylene manufacture			
		Polypropylene manufacture	Flare	98	52
24	P	Polyethylene manufacture			
		Polyethylene manufacture	Flare	98	84
25	P	Ethylene manufacture			
		Ethylene manufacture	Flare	98	24
26	P	Pet ref wastewater treatment			
		Pet ref wastewater treatment	Firebox covers	95	-156
27	P	Pet ref vacuum distillation			
		Pet ref vacuum distillation	Firebox piping	100	15
28	P	Vegetable oil manufacture			
		Vegetable oil manufacture	Stripper and equipment	42	-64
29	P	Paint and varnish manufacture			
		Paint and varnish manufacture	Afterburner	92	301
30	P	Rubber tire manufacture			
		Rubber tire manufacture	Carbon adsorber	70	133
		Rubber tire manufacture	Carbon adsorber	83	203
31	P	Green tire spray			
		Green tire spray	Solvent change	90	1
32	P	Carbon black manufacture			
		Carbon black manufacture	Flare	90	938
33	P	Automobile surface coating			
		Automobile surface coating	High solids coating	79	3356
		Automobile surface coating	Incineration	88	6261
34	P	Beverage can surface coating			
		Beverage can surface coating	Incineration	57	899
35	P	General surface coating			
		General surface coating	Process change	70	410
36	P	Paper surface coating			
		Paper surface coating	Incineration	78	-153
		Paper surface coating	Incineration	83	-166
36	P	Paper surface coating	Incineration	90	-160
37	P	Miscellaneous surface coating			
		Miscellaneous surface coating	Incineration	90	2969
40	A	Paper surface coating			
		Paper surface coating	Incineration	78	4776
		Paper surface coating	Incineration	83	4525
		Paper surface coating	Incineration	90	4124
41	A	Degreasing			
		Degreasing	Freeboard cover	83	-2
42	A	Dry cleaning			
		Dry cleaning	Recovery dryers	70	2577

Table II.8 (cont.)
Cost Pods and Control Options

Cost Pod	P/A*	Description	Control Technique	VOC Emission Reduction (%)	$/Ton***
43	A	Printing			
		Printing	Carbon adsorber	75	-133
		Printing	Carbon adsorber	85	-104
44	A	Rubber and plastics mfg			
		Rubber and plastics mfg	Carbon adsorber	70	238
		Rubber and plastics mfg	Carbon adsorber	83	334
45	A	Miscellaneous surface coating			
		Miscellaneous surface coating	Auto refinishing control	14	-3260
		Miscellaneous surface coating	Auto ref and industrial solvent control	24	-754
46	A	Stage I			
		Stage I	Vapor balance	95	745
47	A	Stage II			
		Stage II	Vapor balance - minimal enforcement	56	893
		Stage II	Vapor balance - maximum enforcement	86	900
48	A	Architectural surface coating			
		Architectural surface coating	Reformulate to waterborne	52	0
49	A	Consumer solvents			
		Consumer solvents	Default reduction	20**	2000
50	P	Coke ovens - door and topside			
		Coke ovens - door and topside	Incineration	90	373
51	P	Coke oven by-product plants			
		Coke oven by-product plants	Inspection and maintenance	63	92
52	P	Aircraft surface coating			
		Aircraft surface coating	High solids coating	79	4898
		Aircraft surface coating	Incineration	88	7020
53	P	Whiskey fermentation - aging			
		Whiskey fermentation - aging	Carbon adsorption	85	32
54	P	Charcoal manufacturing			
		Charcoal manufacturing	Incineration	80	1688
55	P	Marine vessel loading			
		Marine vessel loading	Vapor balance	90	2000
60	A	Light duty gasoline vehicles			
		Light duty gasoline vehicles	I&M	15	7669
		Light duty gas vehicles	Enhanced I&M	7	5725
		Light duty gas vehicles	Alternate fuels to fleet vehicles	6	2610
		Light duty gas vehicles	Alternate fuels to regular vehicles	10	15332
		Light duty gas vehicles	Waxman alternate fuels	5	11259
61	A	Light duty gasoline trucks			
		Light duty gasoline trucks	I&M	15	4556
		Light duty trucks	Enhanced I&M	7	3141
		Light duty trucks	Alternate fuels to fleet vehicles	6	1545
		Light duty trucks	Alternate fuels to regular vehicles	10	8582
		Light duty trucks	Waxman alternate fuels	5	6304
62	A	Heavy duty gasoline vehicles			
		Heavy duty gasoline vehicles	Enhanced I&M	13	4534
		Heavy duty gasoline vehicles	Alternate fuels to regular vehicles	10	14734
		Heavy duty gasoline vehicles	Waxman alternate fuels	5	10735

Table II.8 (cont.)
Cost Pods and Control Options

Cost Pod	P/A*	Description	Control Technique	VOC Emission Reduction (%)	$/Ton***
63	A	Heavy duty diesel vehicles			
		Heavy duty diesel vehicles	Alternate fuels to regular vehicles	10	80853
		Heavy duty diesel vehicles	Waxman alternate fuels	5	59343
64	A	Off highway vehicles			
		Off highway vehicles	Default	90	2000
65	A	Railroads			
		Railroads	Control of existing engines	51	1150
		Railroads	Control of new engines	38	1150
66	A	Burning and fires			
67	A	Area source incineration			
68	A	Aircraft and marine vessels			
70	A	TSDF			
		TSDF	Covers and carbon adsorption	90	900
71	A	Bakeries			
		Bakeries	Afterburners	90	1278
72	A	Cutback Asphalt			
		Cutback asphalt	Switch to emulsified asphalts	100	0
73	A	Public treatment works			
		Public treatment works	Covers and carbon adsorption	90	1111
90	P	Miscellaneous point			
		Miscellaneous point	Default reduction	90	1250

* P/A: P=point source A=area source

** Higher reductions than 20 percent are required (and modeled) as part of the Group of Nine Proposal.

*** Cost per ton for point sources is estimated by applying the cost equation to the average sized new source (Battye et al., 1987).

Cost per ton for motor vehicle control options are based on a 1995 projection year. Cost per ton increases in 2000 since motor vehicle emissions per vehicle decrease as a result of the Federal Motor Vehicle Control Program. Cost per ton also increases if RVP or new motor vehicle control options are applied.

Table II.9

VOC Model Industrial Categories

VOC Model Industrial Category	Description	BEA Industrial Designation for MSA Projections
Food and Agriculture	SIC 1,2,7,8,9,20,21 bakeries	Agricultural Services, Forestry, Fisheries, and Other
Mining Operations	SIC 10,11,12,14	Mining
Wood Products	SIC 24,25,26	Manufacturing - Durable Goods
Printing and Publishing	SIC 27, printing	Manufacturing - Nondurable Goods
Chemicals	SIC 28 rubber & plastics mfg	Manufacturing - Nondurable Goods
Petroleum Refining	SIC 29	Manufacturing - Nondurable Goods
Mineral Products	SIC 32	Manufacturing - Durable Goods
Metals	SIC 33,34	Manufacturing - Durable Goods
Machinery & Equipment Mfg.	SIC 35,36,37,38,39	Manufacturing - Durable Goods
Crude Oil Production, Storage, and Transfer	SIC 13	Mining
Electric Utilities	SIC 49	Transportation and Public Utilities
Other Fuel Combustion	Other fuel combustion	Total Earnings
Petroleum Product Prod., Storage, and Transfer	SIC 51,55	Wholesale Trade
Other Transportation	Off highway vehicles, rail, air, & water trans.	Transportation and Public Utilities
Dry Cleaning	SIC 72, dry cleaning	Services
Other	All other sources	Total Earnings

Table II.10

Earnings Projections by Industry
United States Totals

SIC Code	Industry	Average Annual Percentage Growth*
07	Agricultural Services	4.1%
10-14	Mining	3.4
15-17	Construction	3.4
20-39	Manufacturing	3.4
	Nondurable goods	2.4
20	Food	1.5
26	Paper	2.3
27	Printing	2.8
28	Chemicals	3.0
29	Petroleum	2.5
	Durable goods	4.0
24	Lumber	3.6
32	Stone, clay & glass	3.3
33	Primary metal	3.3
34	Fabricated metal	4.5
40-49	Transportation	3.5
70-84	Services	4.0

* The average annual percentage growth was computed over the period 1983-1995. All industries are not included in this table, just an illustrative sample.

Source: Bureau of Economic Analysis, 1985

Table II.11

Current and Projected Nationwide Vehicle Miles Traveled by Year and Vehicle Type

VMT (billions)

	1985	1995	2000	2010
LDGV	1,354.9	1,748.4	1,898.7	2,199.3
LDGT	286.8	484.9	578.4	965.4
HDGV	80.1	93.1	104.3	126.7
HDDV	109.7	158.3	188.0	247.5
Totals	1,831.5	2,484.7	2,769.4	3,538.9

Equivalent Annual Growth Rates

	1985-1995	1995-2000	2000-2010
LDGV	2.6%	1.7%	1.5%
LDGT	5.4	3.6	5.2
HDGV	1.5	2.3	2.0
HDDV	3.7	3.5	2.8
Average	3.1%	2.2%	2.5%

Source: EEA, 1987

Table II.12

Motor Vehicle Emission Factors by Year and Control Option

	Emission Factor (grams/mile)			
	LDGV	LDGT	HDGV	HDDV
1985	2.20	4.13	9.82	2.01
1995 Base	1.06	1.91	3.49	0.93
1995 RVP	0.79	1.56	2.98	----
1995 RVP and New Standards	0.77	1.50	----	----
2000 Base	0.97	1.53	3.09	0.85
2000 RVP	0.79	1.30	2.75	----
2000 RVP and New Standards	0.75	1.19	----	----
2010 Base	0.95	1.42	2.93	0.83
2010 RVP	0.79	1.28	2.66	----
2010 RVP and New Standards	0.75	1.16	----	----

Sources: Lorang, 1988
U.S. EPA, 1984
U.S. EPA, 1987a

volatility study performed by EPA (U.S. EPA, 1987a). The relationship between weighted national average emission factors at 9.0 psi and 11.5 psi was used to estimate the emission reductions that might be achieved by RVP limits. A separate calculation was performed for each of the three gasoline-powered vehicle types.

In addition to projecting future year emissions for motor vehicles, the number of vehicles must also be projected for costing purposes. Vehicle numbers are elevated based on national growth in vehicle registrations. Projections of the number of vehicles by type and year are shown in Table II.13.

F. ESTIMATING EMISSION REDUCTIONS AND COSTS

1. SIP Regulations

The SIP regulations were taken from the file (Battye, 1987) developed for the ozone NAAQS Cost Model which specifies SIP applicability by state/county and cost pod and from information on existing and planned I/M programs (U.S. EPA, 1987d). The file indicates for each county which source categories are currently regulated. Each pod is assigned a SIP control level corresponding to an available cost equation. If an existing source does not meet the requirements of the corresponding regulation, the emissions are reduced and a control cost calculated.

2. NSPS File

The NSPS file is a file of pod and control strategy combinations designed to simulate the effects of NSPS regulations. The pods and control levels specified as NSPS regulations are those designated for the NAAQS model (Battye et al., 1987). Since some source categories do not have NSPSs, but are regulated, SIP regulations are also applied to new sources. It is assumed in the ERCAM simulations that all new sources will be controlled to at least the same level as existing sources.

Table II.13

Number of Motor Vehicles by Year and Vehicle Type

	Millions of Vehicles			
	1985	1995	2000	2010
LDGV	111.983	135.748	147.638	171.418
LDGT	34.835	55.190	65.836	87.128
HDGV	5.297	6.270	6.829	7.947
HDDV	4.922	6.900	8.065	9.423

Source: EEA, 1987

3. Expansion of Nonattainment Areas and Ozone Transport Region Controls

MSA-specific regulations are modeled in the same way as are SIP regulations. Two examples which have been modeled are expansion of nonattainment areas to the MSA/CMSA level and ozone transport region controls. Expanding the nonattainment area classification to the MSA/CMSA level is modeled by subjecting all sources in each county within the MSA or CMSA to SIP regulations. Ozone transport region controls specify controls for areas which may contribute to the nonattainment status of neighboring areas. For example, controls may be specified for the entire Northeast Corridor in an effort to reduce ozone in areas such as New York City and Boston. Controls for all MSAs in the northeast region are added for each category specified by the measure. These controls are applied to both new and existing sources.

4. Scenario Control Measures

Scenario constraints are organized to apply future controls to sources by attainment area classification for simplicity and because most of the proposed new VOC control provisions are stipulated by nonattainment severity. Attainment areas are handled as one class while the other classifications are based on ozone design values. The exact definition of nonattainment can differ according to the particular provisions being examined. The attainment categories which have been used in the analyses are shown in Table II.14.

The scenario constraint file is designed so that controls can be specified for each pod by attainment/nonattainment area class. Separate scenario files are created for existing and new sources. As an example, one facet of the proposed EPA policy is potentially requiring enhanced I/M on LDGV and LDGT in nonattainment areas with ozone design values above 0.16 ppm. This would be simulated by indicating enhanced I/M as the motor vehicle control option for serious and severe nonattainment areas.

Table II.14

Ozone Attainment Categories

Category	Design Values (ppm)
EPA Proposed Policy, Mitchell Bill, Waxman Bill	
Attainment	≤ 0.12
Moderate Nonattainment	0.13, 0.14
Serious Nonattainment	0.15 to 0.18
Severe Nonattainment	> 0.18
Group of Nine Proposal	
Attainment	≤ 0.12
Moderate I Nonattainment	0.13
Moderate II Nonattainment	0.14, 0.15
Serious Nonattainment	0.16 - 0.18
Severe Nonattainment	≥ 0.19

5. National Control Measures

Several national options for motor vehicles control have been included in this study. These options include the following:

- Base case -- simulating the effects of the Federal Motor Vehicle Control Program (FMVCP),
- RVP -- simulating the effects of FMVCP combined with reductions in gasoline RVP,
- RVP plus new motor vehicle standards -- simulating the effects of RVP combined with new emission standards for motor vehicles.

6. Miscellaneous Measures

Emission fees can be used as a resource to help maintain regulatory programs. The revenue generated can be used to fund the program and help develop new control techniques. Fees are also considered to be technology forcing measures in that they encourage emitters to develop cost effective ways to reduce emissions and thus the emission fee. ERCAM-VOC applies emission fees to the remaining emissions from existing stationary sources after all other controls have been applied. Varying dollar per ton fees are applied based on size cutoffs and selected attainment categories.

A RACT cutoff can also be simulated by ERCAM, and is included in some modeling cases. Any non-CTG stationary source below the size cutoff will not be subject to any controls specified in the scenario file. This cutoff is only used for point source emissions. No attempt was made to determine what fraction of area source emissions are affected by size cutoffs.

G. RESULTS REPORTING

The VOC model currently provides aggregated results at the national, state, and MSA level of detail. National level results are reported by attainment category and cost pod. This report is used to compare national costs for specific provisions of the bills and policies being examined. It can also be used to identify source categories where additional reductions might be achieved. A sample of an attainment category/pod output is shown in Table II.15.

State level results are reported by industry category. An example of this report is given in Table II.16. This level of information may be used as a predecessor to economic analysis. It will show what industries in each state will be expected to bear costs under the provisions being examined.

Cost and emission totals are reported in the MSA level output as shown in Table II.17. This report is useful in determining which MSAs will reach attainment or meet the progress requirements mandated by the policy or bill being examined. A simplified version of a trajectory ozone model (EKMA) is used to estimate the required reduction to reach attainment for each area based on the ozone design value, an assumed amount of transported ozone, and the ambient nonmethane organic compounds (NMOC) to NO_x ratio. A list of MSAs and corresponding ozone design values and required VOC emission reductions is shown in Table II.18. EKMA calculations are not part of ERCAM-VOC, though. Required VOC emission reductions from Table II.11 are an input to the model.

The ozone design values in Table II.18 were taken from 1983 to 1985 monitoring data. These years were chosen because of the relatively high concentrations measured in 1983 and because the ambient data matched the time period of the emission inventory. Note also that the design value monitors are not always physically located in the MSAs listed -- concentrations are transport design values which are often downwind of the urban area.

It should be noted that only the attainment status of nonattainment areas identified via 1983 to 1985 ambient ozone data has been investigated in this study. It is likely that some attainment areas will grow into nonattainment and require additional controls. This model does not attempt to predict where this would occur or what the cost would be to bring these areas back into attainment.

Table II.15

Attainment Category/Pod Report

ERCAM VOC VERSION S2-5/88
SCENARIO:TEST MODEL REF:M85
CASE YEAR:1995 FEE: $ 100
RUN DATE:05/17/88 TIME:18:16:49
GRLAB:RN RVP:yes NWMVC:yes DOSIP:yes
BSIM:20 RACTCUT:25 FEECUT:3
*** ATTAINMENT CATEGORY/POD REPORT ***

POD	POD NAME	1985 NEDS EMISSIONS (TONS/YEAR)	PROJECTED BASE EMISS. AT CASE YR. (TONS/YEAR)	SCENARIO CONTROLLED EMISSIONS (TONS/YEAR)	SCEN PCT. RED.	SIP + SCENARIO COST (1000$)	COST EFF. FROM PROJCTD BASE LEVEL ($/TON)
**	1.ATTAINMENT AREA						
0	ZERO POD	153761	205074	205074	0.0	0	0
1	SLV.MET.CLN	21492	40606	34376	15.3	-1912	-307
2	PRT+PUB	50693	218273	56195	74.3	-12745	-79
3	DRY CLNING	48	60	17	71.7	3	64
4	FXRFTK-CRD	39617	63138	30495	51.7	-3086	-95
5	FXRFTK-GASO	19915	27651	15827	42.8	-4432	-375
6	EFR-CRD	9493	12497	5235	58.1	27880	3839
7	EFR-GASO	14482	42154	9761	76.8	2627	81
8	BGT-SPL	474	716	302	57.8	-17	-41
9	BGT-SUB/BAL	577	1220	411	66.3	-110	-136
10	BGT-SUB/NOBL	15397	19596	13773	29.7	-410	-70
15	ETHLOX-MFG	29	39	29	25.6	2	242
17	TERACID-MFG	3990	26762	4446	83.4	18514	830
18	ACRYLON-MFG	1842	36487	2535	93.1	5972	176
19	SOCMI-FUGS	8074	25553	15765	38.3	664	68
20	PETREF-FUGS	23161	104573	42423	59.4	-6952	-112
21	CELACT-MFG	23034	31136	26762	14.0	4351	995
22	STYBUT-MFG	11323	31493	17374	44.8	1455	103
23	POLYPRP-MFG	2109	3588	3588	0.0	0	0
24	POLYETH-MFG	19887	157593	157593	0.0	0	0
25	ETHYLEN-MFG	6868	15881	15881	0.0	0	0
26	PETREF-WW	17909	22892	13470	41.2	-1501	-159
27	PETREF-VACDS	13313	18666	12762	31.6	130	22
28	VEGOIL-MFG	5272	27031	27031	0.0	0	0
29	PNT&VAR-MFG	3572	6257	6257	0.0	0	0
30	RUBRTIRE-MFG	7142	8337	4606	44.8	1641	440
31	GRNTIRE-MFG	3201	3492	2177	37.7	3	2
32	CRBNBLK-MFG	31937	43435	43435	0.0	0	0
33	AUTOSRF-COAT	83499	122911	40634	66.9	485592	5902
34	BEVCAN-MFG	19142	26589	16972	36.2	9881	1027
35	GENSURF-COAT	24762	30978	30978	0.0	0	0
36	PAPRSRF-COAT	21997	30691	10220	66.7	-1799	-88
37	MISCSRF-COAT	83576	119455	119455	0.0	0	0
40	PAPRSRF-COAT	55985	62678	60411	3.6	9373	4134
41	DEGREASING	295971	323697	301977	6.7	-43	-2

Table II.16

State/Industry Category Report

ERCAM VOC VERSION S2-5/88
SCENARIO:TEST MODEL REF:M85
CASE YEAR:1995 FEE: $ 100
RUN DATE:05/26/88 TIME:13:01:08
GRLAB:RN RVP:yes NWMVC:yes DOSIP:no
BSIM:20 RACTCUT:25 FEECUT:3
*** STATE/INDUSTRY CLASS REPORT ***

INDSTRY CLASS NUMBER	INDUSTRY CLASS	1985 NEDS EMISSIONS (TONS/YEAR)	PROJECTED BASE EMISS. AT CASE YR. (TONS/YEAR)	SCENARIO CONTROLLED EMISSIONS (TONS/YEAR)	SCEN PCT. RED.	SIP + SCENARIO COST (1000$)	COST EFF. FROM PROJCTD BASE LEVEL ($/TON)
** STATE: Alabama							
2	FOOD & AGRICULTURE	853	906	704	22.3	258	1275
24	WOOD PRODUCTS	11216	14022	13141	6.3	1028	1166
27	PRINTING+PUBLISHING	3974	6011	4900	18.5	732	659
28	CHEMICALS	23480	167941	40065	76.1	158648	1241
29	PETROLEUM REFINING	3404	82671	25799	68.8	-3763	-66
32	MINERAL PRODUCTS	240	274	101	63.1	216	1249
33	METALS	23493	30717	23976	21.9	16635	2468
35	MACHINERY & EQPT MFG	2437	7251	1914	73.6	31450	5893
44	CRD.OIL PRD,STOR& TR	720	893	737	17.5	195	1248
49	ELECTRIC UTILITIES	6979	11409	9566	16.2	2303	1250
50	OTHER FUEL COMBUSTRS	1110	1565	1565	0.0	0	0
51	PETROL.PRODUCT PRD.	11776	15594	1703	89.1	3946	284
60	LIGHT DUTY GASO VEHS	68562	28886	26875	7.0	36201	18002
61	LIGHT DUTY GASO TRKS	29499	13205	12414	6.0	14158	17899
62	HVY DUTY GASO VEHS	5008	1539	1492	3.1	1540	32756
63	HVY DUTY DIESEL VEHS	5646	3443	3443	0.0	0	0
64	OTHER TRANSPORTATION	33824	44986	44986	0.0	0	0
72	DRY CLEANING	5654	6106	6106	0.0	0	0
99	OTHER	110976	118999	99361	16.5	14515	739
** Subtotal **							
		348851	556418	318848		278059	
** STATE: Alaska							
2	FOOD & AGRICULTURE	102	108	108	0.0	0	0
27	PRINTING+PUBLISHING	239	299	299	0.0	0	0
28	CHEMICALS	179	243	243	0.0	0	0
50	OTHER FUEL COMBUSTRS	1289	1817	1817	0.0	0	0
51	PETROL.PRODUCT PRD.	2049	2479	1027	58.6	0	0
60	LIGHT DUTY GASO VEHS	4964	2271	1960	13.7	4790	15403
61	LIGHT DUTY GASO TRKS	6401	3039	2724	10.4	1866	5924
62	HVY DUTY GASO VEHS	1077	331	331	0.0	129	0
63	HVY DUTY DIESEL VEHS	917	559	559	0.0	0	0
64	OTHER TRANSPORTATION	9562	12718	12718	0.0	0	0
72	DRY CLEANING	412	444	444	0.0	0	0
99	OTHER	9967	10663	9994	6.3	602	899

Table II.17

MSA Summary Report

ERCAM VOC VERSION S2-5/88
SCENARIO:TEST MODEL REF:M85
CASE YEAR:1995 FEE: $ 100
RUN DATE:05/26/88 TIME:13:01:08
GRLAB:RN RVP:yes NWMVC:yes DOSIP:no
BSIM:20 RACTCUT:25 FEECUT:3
*** MSA SUMMARY REPORT ***

MSA No.	PMSA Region	1985 NEDS EMISSIONS (TONS/YEAR)	PROJECTED BASE EMISS. AT CASE YR. (TONS/YEAR)	SCENARIO CONTROLLED EMISSIONS (TONS/YEAR)	SCENARIO PERCENT REDUCTN	SIP + SCENARIO COST (1000$)	COST EFF. FRM PRJCTD BASE LEVEL ($/TON)
60	ABILENE, TX MSA	8810	7651	6857	10.4	1055	1329
80	AKRON, OH PMSA	47616	48448	30747	36.5	29412	1662
120	ALBANY, GA MSA	9190	8884	7559	14.9	1594	1203
160	ALBANY-SCHENECTADY-TROY, NY MSA	49051	124988	112696	9.8	30133	2451
200	ALBUQUERQUE, NM MSA	34628	25646	23175	9.6	3946	1597
220	ALEXANDRIA, LA MSA	8317	7486	6370	14.9	3460	3100
240	ALLENTOWN-BETHLEHEM, PA-NJ MSA	45639	45486	25476	44.0	29985	1498
280	ALTOONA, PA MSA	7338	6494	5250	19.2	4310	3464
320	AMARILLO, TX MSA	29704	30413	26079	14.3	1955	451
360	ANAHEIM-SANTA ANA, CA PMSA	145929	128331	90405	29.6	64346	1697
380	ANCHORAGE, AK MSA	12873	12038	10469	13.0	5186	3305
400	ANDERSON, IN MSA	13052	13370	7141	46.6	29434	4725
405	ANDERSON, SC MSA	11679	10594	9367	11.6	1506	1227
440	ANN ARBOR, MI PMSA	21252	22527	11888	47.2	18856	1772
450	ANNISTON, AL MSA	7087	6011	5331	11.3	1184	1741
460	APPLETON-OSHKOSH-NEENAH, WI MSA	37975	39692	27694	30.2	12377	1032
480	ASHEVILLE, NC MSA	12606	11249	9814	12.8	1564	1090
500	ATHENS, GA MSA	9354	7490	6632	11.5	1328	1548
520	ATLANTA, GA MSA	181599	179977	94643	47.4	155900	1827
560	ATLANTIC CITY, NJ MSA	16891	16422	10263	37.5	9375	1522
600	AUGUSTA, GA-SC MSA	26702	24291	21787	10.3	3854	1539
620	AURORA-ELGIN, IL PMSA	23687	23263	13840	40.5	19911	2113
640	AUSTIN, TX MSA	46185	38264	34392	10.1	5858	1513
680	BAKERSFIELD, CA MSA	42360	41576	20498	50.7	29730	1410
720	BALTIMORE, MD MSA	136178	139053	83973	39.6	110576	2008
733	BANGOR, ME NECMA	8539	8003	6172	22.9	4556	2488
760	BATON ROUGE, LA MSA	84069	156031	33475	78.5	106548	869
780	BATTLE CREEK, MI MSA	10318	9605	7383	23.1	4735	2131
840	BEAUMONT-PORT ARTHUR, TX MSA	130875	424140	54972	87.0	157015	425
845	BEAVER COUNTY, PA PMSA	12235	12486	5395	56.8	9818	1385
860	BELLINGHAM, WA MSA	12156	11698	10596	9.4	1391	1262
870	BENTON HARBOR, MI MSA	12136	11073	8723	21.2	5399	2297
875	BERGEN-PASSAIC, NJ PMSA	84457	77597	49903	35.7	44335	1601
880	BILLINGS, MT MSA	12732	12718	11162	12.2	1780	1144
920	BILOXI-GULFPORT, MS MSA	13200	11391	10440	8.3	1627	1711
960	BINGHAMTON, NY MSA	18369	16424	13182	19.7	3557	1097
1000	BIRMINGHAM, AL MSA	62086	58095	37817	34.9	50942	2512

Table II.18

Ozone Design Values and Emission Reduction Requirements

STAR NUM	MSA/CMSA	MSA CODE	1983-1985 OZONE DES.VALUE	NMOC/NOX* RATIO	1985 NEDS VOC EMISSIONS	REQUIRED** REDUCTION (%)
6022	Massachusetts	22	0.17	7.6	384,796	36
3901	Allentown-Bethlehem, PA-NJ	240	0.13	10.4	45,639	8
1101	Atlanta, GA	520	0.16	7.7	181,599	32
3101	Atlantic City, NJ	560	0.16	10.4	16,891	40
502	Bakersfield, CA	680	0.16	10.4	42,360	40
2101	Baltimore, MD	720	0.17	6.1	136,178	27
1901	Baton Rouge, LA	760	0.16	14.9	84,069	48
4502	Beaumont, TX	840	0.17	11.6	130,875	49
101	Birmingham, AL	1000	0.13	9.8	62,086	8
0	Bradenton, FL	1140	0.13	10.4	9,527	8
5001	Charleston, WV	1480	0.13	10.4	23,607	8
3402	Charlotte-Gastonia, NC-SC	1520	0.13	10.4	77,904	8
4401	Chattanooga, TN-GA	1560	0.13	16.7	40,689	8
6014	Chicago CMSA	1602	0.25	8.5	529,572	58
6036	Cincinnati CMSA	1642	0.17	9.1	121,743	42
3604	Cleveland CMSA	1692	0.14	7.5	190,252	21
4505	Dallas CMSA	1922	0.16	13.0	266,233	47
3606	Dayton-Springfield, OH	2000	0.13	10.4	71,385	8
603	Denver CMSA	2082	0.13	8.2	140,469	8
2301	Detroit CMSA	2162	0.13	10.4	318,674	8
4506	El Paso, TX	2320	0.16	12.0	35,069	44
3904	Erie, PA	2360	0.13	10.4	17,710	8
504	Fresno, CA	2840	0.17	10.4	37,700	46
102	Gadsden, AL	2880	0.13	10.4	9,707	8
2303	Grand Rapids, MI	3000	0.13	10.4	47,777	8
3905	Harrisburg-Lebanon, PA	3240	0.13	10.4	33,779	8
4509	Houston CMSA	3362	0.25	10.8	370,531	65
5002	Huntington-Ashland, WV-KY-OH	3400	0.14	10.4	31,976	20
1504	Indianapolis, IN	3480	0.13	10.9	121,961	8
1002	Jacksonville, FL	3600	0.14	10.4	55,784	20
5103	Janesville-Beloit, WI	3620	0.13	10.4	12,817	8
1701	Kansas City, MO-KS	3760	0.14	9.2	125,335	16
1903	Lake Charles, LA	3960	0.14	24.3	26,294	30
4510	Longview, TX	4420	0.15	10.4	22,015	33
6005	Los Angeles CMSA	4472	0.36	10.4	824,055	69
1802	Louisville, KY-IN	4520	0.15	10.4	77,299	33
4404	Memphis, TN	4920	0.15	13.9	65,116	36
6010	Miami CMSA	4992	0.14	13.3	157,426	19
6051	Milwaukee CMSA	5082	0.17	10.4	109,465	46
2402	Minneapolis-St. Paul, MN-WI	5120	0.15	10.4	189,531	33
506	Modesto, CA	5170	0.16	10.4	20,050	40
2305	Muskegon, MI	5320	0.14	10.4	15,822	20
4405	Nashville, TN	5360	0.14	10.4	73,025	20

Table II.18

Ozone Design Values and Emission Reduction Requirements

STAR NUM	MSA/CMSA	MSA CODE	1983-1985 OZONE DES.VALUE	NMOC/NOX* RATIO	1985 NEDS VOC EMISSIONS	REQUIRED** REDUCTION (%)
6033	New York CMSA	5602	0.24	11.7	887,534	67
4801	Norfolk, VA	5720	0.14	10.4	78,350	20
6039	Philadelphia CMSA	6162	0.20	6.8	344,747	41
301	Phoenix, AZ	6200	0.16	10.4	114,562	41
3909	Pittsburgh CMSA	6282	0.13	10.4	122,802	8
3803	Portland CMSA	6442	0.13	10.4	95,120	8
4101	Providence, RI	6483	0.15	10.4	57,881	33
3910	Reading, PA	6680	0.13	10.4	22,933	8
4802	Richmond-Petersburg, VA	6760	0.13	11.1	66,718	8
511	Sacramento, CA	6920	0.18	10.4	87,463	50
2601	St. Louis, MO-IL	7040	0.16	9.6	185,377	38
4602	Salt Lake City, UT	7160	0.15	10.3	72,379	32
513	San Diego, CA	7320	0.21	10.4	126,559	58
6006	San Francisco CMSA	7362	0.19	10.4	375,354	52
516	Santa Barbara, CA	7480	0.16	10.4	28,805	40
5109	Sheboygan, WI	7620	0.17	10.4	8,586	46
519	Stockton, CA	8120	0.15	10.4	25,799	33
1007	Tampa-St. Petersburg, FL	8280	0.13	10.4	107,549	8
3702	Tulsa, OK	8560	0.13	14.4	54,034	8
521	Visalia-Tulare-Porterville, CA	8780	0.13	10.4	19,478	8
901	Washington, DC	8840	0.17	8.2	168,375	38
1008	West Palm Beach, FL	8960	0.14	13.3	43,946	19
3914	York, PA	9280	0.13	10.4	28,161	8
522	Yuba City, CA	9340	0.13	10.4	9,836	8
6007	Greater Connecticut CMSA	9999	0.19	6.1	127,499	34

Source: U.S. EPA, 1988b

* A ratio of 10.4 to 1 was assumed for MSAs with no available data.

** Estimated using EKMA with carbon bond 3 chemistry. While this is a relatively sophisticated technique, more complex models such as AIRSHED may estimate different reduction requirements. Uncertainties associated with using different chemistries in EKMA (carbon bond 4 instead of carbon bond 3) have not yet been quantified.

Table II.18

Ozone Design Values and Emission Reduction Requirements

CMSA	MSA CODE	1983-1985 OZONE DES.VALUE	NMOC/NOX* RATIO	1985 NEDS VOC EMISSIONS	REQUIRED** REDUCTION (%)
ork CMSA	5602	0.24	11.7	887,534	67
k, VA	5720	0.14	10.4	78,350	20
elphia CMSA	6162	0.20	6.8	344,747	43
x, AZ	6200	0.16	10.4	114,562	41
rgh CMSA	6282	0.13	10.4	122,802	0
d CMSA	6442	0.13	10.4	95,120	0
nce, RI	6483	0.15	10.4	57,881	33
PA	6680	0.13	10.4	22,933	0
-Petersburg, VA	6760	0.13	11.1	66,718	0
to, CA	6920	0.18	10.4	87,463	[illegible]
s, MO-IL	7040	0.16	9.6	185,377	[illegible]
City, UT	7160	0.15	10.3	72,379	32
, CA	7320	0.21	10.4	126,559	34
isco CMSA	7362	0.19	10.4	375,354	[illegible]
ara, CA	7480	0.16	10.4	28,805	[illegible]
WI	7620	0.17	10.4	8,586	[illegible]
CA	8120	0.15	10.4	25,799	[illegible]
etersburg, FL	8280	0.13	10.4	107,549	23
	8560	0.13	14.4	54,034	0
are-Porterville, CA	8780	0.13	10.4	19,478	0
DC	8840	0.17	8.2	168,375	0
ach, FL	8960	0.14	13.3	41,944	30
	9280	0.13	10.4	28,161	29
	9340	0.13	10.4	9,836	0
cticut CMSA	9999	0.19	6.1	127,499	0

PA, 1988b

4 to 1 was assumed for MSAs with no available data

EKMA with carbon bond 3 chemistry. While this is a
isticated technique, more complex models such as [illegible]
fferent reduction requirements. Uncertainties [illegible]
chemistries in EKMA (carbon bond 4 instead of carbon bond [illegible]
n quantified.

III CARBON MONOXIDE (CO) MODEL DEVELOPMENT

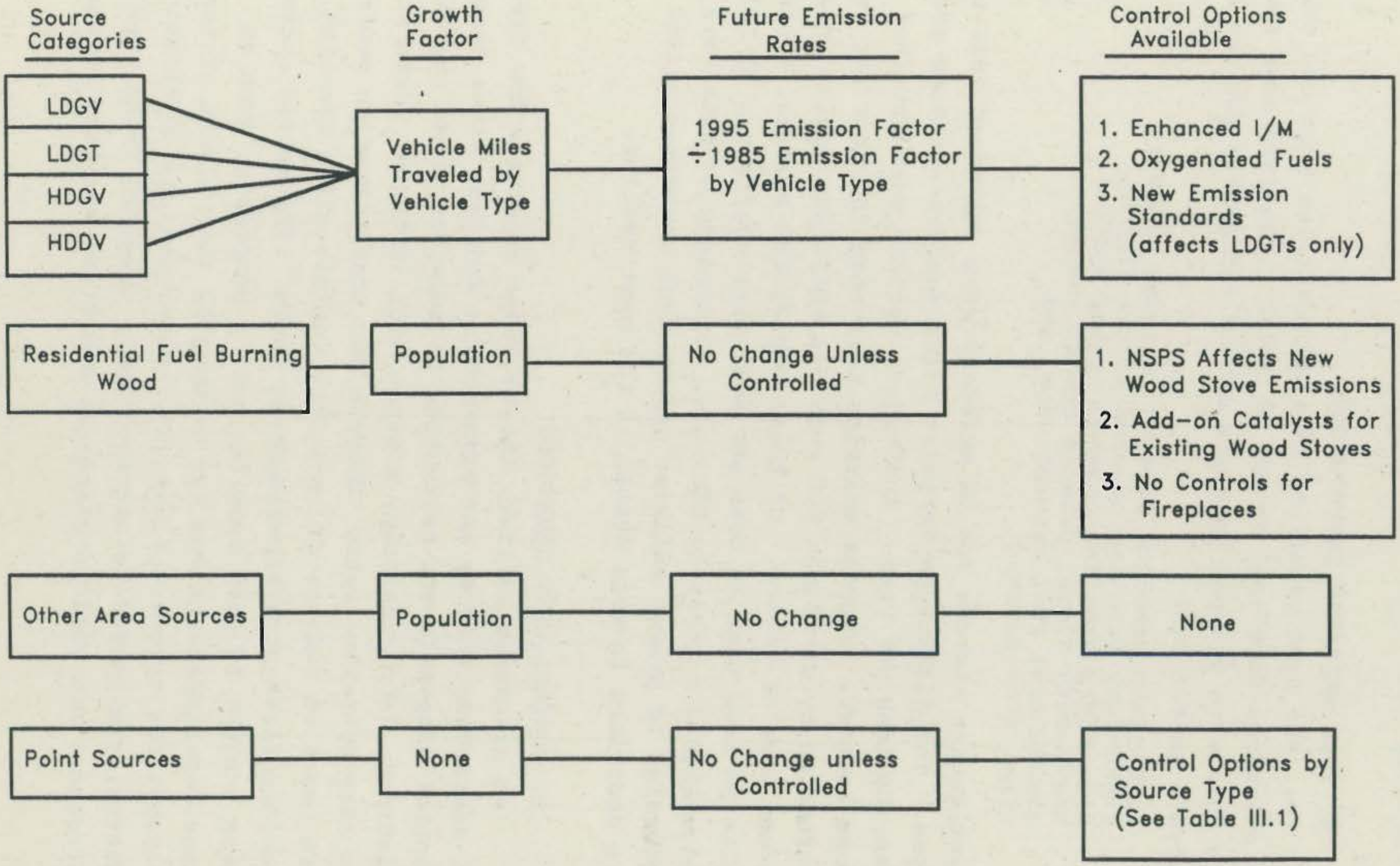
In conjunction with the ozone (VOC and NO_x) nonattainment analyses a CO model was developed, following the same basic design criteria as the VOC model discussed in Chapter II of this report. ERCAM-CO is a nonoptimizing, deterministic data base management system for performing comparative analysis of the regional and industry costs and CO emissions effects of proposed bills and regulatory policies. The model's primary data base consists of approximately 18,000 records, containing CO emissions data in tons for area and stationary sources at the state, county, MSA, and SIC level of detail. The model is written in dBase III Plus for IBM-compatible personal computers and uses the Clipper dBase compiler for computing efficiency. Figure III.1 shows a flowchart of the salient data and analytic characteristics of the model.

A major difference between the VOC and CO models is that the CO model separates the stationary sources from area sources (mainly transportation) sources both in terms of data file management and the internal model logic and cost equations. This segregation was done mainly because the most stringent and complex CO regulations proposed under pending legislation are for area sources (transportation and residential fuel use), rather than stationary sources.

The CO model was designed to be run in tandem with the VOC model for the same scenario or bill. Certain rules governing the interrelationships between VOC and CO controls and costs were followed. Control strategies which affect both CO and VOC are treated as if the CO-related aspects were costed in the VOC model, to prevent double counting of cost elements in reporting results. This applies mainly to the application of vehicle I/M programs and possible new motor vehicle emission standards which affect both pollutants. Basic I/M programs are not costed for CO if they are specified under the VOC provisions of a bill. If basic I/M is already in effect and the VOC aspects of the bill do not increase the I/M level but the CO aspects of the bill do,

Figure III.1

Carbon Monoxide Model Organization



then an incremental cost of the enhanced-minus-basic I/M program is included as a cost.

A. 1985 EMISSION INVENTORIES

The 1985 NEDS point and area source files were the source of the emissions data used in the CO model. The 1985 area source file data were grouped into six source categories for the analysis as follows:

- light-duty gasoline powered vehicles (LDGVs),
- light-duty gasoline powered trucks (LDGTs),
- heavy-duty gasoline powered trucks (HDGVs),
- heavy-duty diesel powered trucks (HDDVs),
- residential fuel burning-wood, and
- other area sources.

Point source records for CO emitters were organized into three types. The first type includes point sources emitting greater than 100 tons per year. Individual records were retained for these sources. Sources emitting less than 100 tons per year were aggregated by six digit SCC code and MSA/state region into the second type of record. Of these aggregated sources, those emitting less than 10 tons per year were aggregated by MSA/state and assigned a separate SCC code. Groupings of SCCs were according to common emission and control characteristics. These are described in more detail in the next section.

B. CONTROL COST EQUATIONS

As discussed earlier, the CO model separates the treatment of stationary sources and area/mobile sources, since current control proposals and estimating methods for these sources are distinct. For stationary sources, for instance, costs are based on size/operating rates, whereas for transportation sources, they are based on numbers of vehicles, vehicle miles traveled, and vehicle fleet growth/replacement rates. The mobile sources have been subject to many specific policy proposals, such as requirements/incentives for oxygenated fuel blends or neat alcohol for targeted fleet use. Motor vehicle CO emissions are generally expected to continue their downward trend, due to more stringent new vehicle standards and fleet turnover between 1985 and either 1995 or 2000. This section discusses the cost and emissions control reduction methodology in detail, first for stationary, then area/mobile sources.

1. Stationary Sources

Point source controls have rarely been considered an important part of any urban area CO control plan. CO standard exceedences have usually been associated with motor vehicle emissions, and in some cases with residential wood combustion. Thus, there has been little recent work to examine control efficiencies and costs for CO stationary source controls. Fortunately, for the most recent CO regulatory analysis, capital and annualized costs of CO control systems were estimated for a number of industrial processes (PEDCo, 1979). This information was reviewed and judged to be appropriate for application in this analysis after being updated to reflect current dollars. Equations were put in exponential form for each combination of industrial process and control equipment type. This information is summarized in Tables III.1 and III.2.

As can be seen in the tables, all of the carbon monoxide control devices are highly efficient. With the exception of the O_2 analyzers, installing the appropriate control equipment can potentially reduce CO emissions from 90 percent to 99.5 percent over the uncontrolled rate. This leads to a relatively low cost efficiency in comparison with the control of other pollutants, such as NO_x or SO_2.

The stationary CO sources for which control costs were estimated fall into four general industry classifications:

- iron and steel,
- aluminum,
- solid waste disposal, and
- chemicals.

The most common CO control method is to use some form of thermal incineration, either in conjunction with primary heat recovery, primary and secondary heat recovery, or no heat recovery. Incineration achieves from 90 percent to 99.5 percent CO reduction, depending on the source type.

Table III.1

Carbon Monoxide Control Cost Equations
for Retrofit Applications
(1985 Dollars)

CO Source	Control Device	Retrofit Capital		Retrofit O&M		Control	Default
		a	b	a	b	Eff. (%)	Cost/Ton
Carbon Black	Incin. w/PR	35.0	0.98	4.07	0.94	99.5	3
Carbon Black	Incin. w/PR & CO Boiler	449.0	0.85	-37.20	1.06	99.5	-47
Iron Ore Sinter Plant-Windbox	Incin. w/PR	276.0	0.73	39.60	0.82	90.0	172
Iron Ore Sinter Plant-Windbox	Incin. w/P&SR	206.0	0.76	-0.06	1.32	90.0	-288
Carbon Steel Electric Arc Furnace	Direct Shell Evacuation	534.0	0.65	40.60	0.74	90.0	248
Gray Iron Cupola	Thermal Incin.	4,160.0	0.15	0.99	0.91	90.1	5
Conical Wood Burner	02 Analyzer	8,060.0	0.00	4,310.00	0.00	50.0	9
Municipal Incinerator	02 Analyzer	272.0	0.40	138.00	0.42	50.0	102
Basic Oxygen Furnace	Open Hood System	229.0	0.73	-1.51	0.99	95.0	-21
Prebake Aluminum Cells	Incin. w/PR	65.1	1.06	41.20	1.10	99.0	824
Aluminum Anode Baking	Incin. w/PR	2.3	1.09	0.62	1.10	99.0	83
Maleic Anhydride	Incin. w/PR	3,100.0	0.57	57.10	0.93	98.0	50
Maleic Anhydride	Incin. w/P&SR	1,630.0	0.65	2.93	1.22	98.0	45
Coke Oven Charging	Stage Charging	458,000.0	0.04	8,650.00	0.30	99.0	2,613
Cyclohexanol	No Heat Recovery	10,600.0	0.24	68.00	0.64	98.0	38
Cyclohexanol	Incin. w/PR	110,000.0	0.11	334.00	0.49	98.0	43
Ethlyene Dichloride	Incin. w/PR	254.0	0.60	1.08	1.00	98.0	--

NOTES: Equations are of the form COST = a*(SIZE)^b
Incin. w/PR is a Thermal Incinerator with Primary Heat Recovery
Incin. w/P&SR is a Thermal Incinerator with Primary and Secondary Heat Recovery

Table III.2

Carbon Monoxide Control Cost Equations
for New Applications
(1985 Dollars)

CO Source	Control Device	New Capital a	New Capital b	New O&M a	New O&M b	Control Efficiency (%)
Carbon Black	Incin. w/PR	26.9	0.98	4.07	0.94	99.5
Carbon Black	Incin. w/PR & CO Boiler	345.0	0.85	-37.20	1.06	99.5
Iron Ore Sinter Plant-Windbox	Incin. w/PR	230.0	0.73	39.60	0.82	90.0
Iron Ore Sinter Plant-Windbox	Incin. w/P&SR	172.0	0.76	-0.06	1.32	90.0
Carbon Steel Electric Arc Furnace	Direct Shell Evacuation	445.0	0.65	40.60	0.74	90.0
Gray Iron Cupola	Thermal Incin.	3,210.0	0.15	0.99	0.91	90.1
Conical Wood Burner	02 Analyzer	7,330.0	0.00	4,310.00	0.00	50.0
Municipal Incinerator	02 Analyzer	249.0	0.40	138.00	0.42	50.0
Basic Oxygen Furnace	Open Hood System	176.0	0.73	-1.51	0.99	95.0
Prebake Aluminum Cells	Incin. w/PR	59.2	1.06	41.20	1.10	99.0
Aluminum Anode Baking	Incin. w/PR	2.1	1.09	0.62	1.10	99.0
Maleic Anhydride	Incin. w/PR	2,820.0	0.57	57.10	0.93	98.0
Maleic Anhydride	Incin. w/P&SR	1,480.0	0.65	2.93	1.22	98.0
Coke Oven Charging	Stage Charging	352,000.0	0.04	8,650.00	0.30	99.0
Cyclohexanol	No Heat Recovery	9,640.0	0.24	68.00	0.64	98.0
Cyclohexanol	Incin. w/PR	100,000.0	0.11	334.00	0.49	98.0
Ethlyene Dichloride	Incin. w/PR	230.0	0.60	1.08	1.00	98.0

NOTES: Equations are of the form COST = a*(SIZE)^b
Incin. w/PR is a Thermal Incinerator with Primary Heat Recovery
Incin. w/P&SR is a Thermal Incinerator with Primary and Secondary Heat Recovery

The greatest variety of control methods occurs within the iron and steel industry. In addition to thermal incineration for emissions from iron ore sinter plant windboxes and gray iron cupolas, three other control methods are available. For carbon steel electric arc furnaces, a direct shell evacuation system is the control device considered. Although this system primarily controls particulate emissions with a fabric filter, it also controls up to 90 percent of the CO emissions by aspirating air through an air gap and then combusting the CO. Using an open hood system, 90 percent of the CO emissions from basic oxygen furnaces can be removed. In such a system, CO emissions are collected in an open hood and air is added to insure complete burning of the CO in the hood. After the gas is cooled, it passes through an electrostatic precipitator to remove particulates and then the cleaned gas passes out of the stack. The final control method applied to this industry is stage charging which can control up to 99 percent of the CO emissions which occur during coke oven charging. This control method, whereby coal is charged at a reduced rate and suction on the oven is maintained during the charging, is a modification of the typical coke oven charging technique. By making these modifications, CO emissions should remain within the oven collection system without leaking to the atmosphere.

In the solid waste disposal category, the two source types both use O_2 analyzers and recorders to optimize combustion. It is expected that by optimizing combustion, approximately 50 percent of the CO emissions can be reduced.

The remaining source categories, the aluminum and chemical industries, all utilize forms of thermal incineration. The SCC codes to which all the above mentioned control measures are applied in the model are listed in Table III.3.

Cost components for installing appropriate control systems on major stationary sources of CO emissions were used (PEDCo, 1979). For each source, costs were reported for installing controls on two different facility sizes. The facility sizes

Table III.3

Applicable SCC Codes for Stationary Source CO Categories

Category	Applicable SCCs
Iron & Steel Industry	
Basic Oxygen Furnace	30300913, 14
Carbon Steel Electric Arc Furnace	30300904, 08 30400304 30400701
Coke Oven Charging	30300302
Gray Iron Cupola	30400301
Iron Ore Sinter Plant Windbox	30300813
Solid Waste Disposal	
Conical Wood Burner	50100508 50200105 50300105
Municipal Incinerator	50100101, 02
Aluminum Industry	
Aluminum Anode Baking	30300105
Prebake Aluminum Cell	30300101-03
Chemical Industry	
Carbon Black	30100503, 04
Cyclohexanol	30115801-03 30115821, 22, 80
Ethylene Dichloride	30112501, 02 30112504-06 30112509
Maleic Anhydride	30110002

were chosen to be representative of a large plant and a small plant. The costs for each facility were broken down as follows:

- Capital Cost
  - Direct
  - Indirect
  - Contingency
  - Total Cost of New Installation
  - Retrofit Factor
  - Total Cost with Retrofit

- Annualized Cost
  - Direct
  - Indirect
  - Credit
  - Total Annual Cost for New Installation
  - Total Annual Cost with Retrofit

The retrofit factor ranged from 10 percent to 30 percent of the total capital cost of a new installation depending on the difficulty associated with applying a control system to an existing source. The credit component of the annualized cost represents any cost savings due to such factors as improved process efficiency, decreased fuel costs, lowered steam requirements, or other process improvements. The indirect portion of the annualized cost was assumed to be the annualized capital cost. Therefore, the total O&M cost used was the sum of the direct and credit components of the annual cost.

Before developing the cost equations, the total capital costs and the total O&M costs were escalated from 1978 dollars to 1985 dollars using the Chemical Engineering economic index (Chem. Engr., 1988). To develop the cost equations from the available cost data (PEDCo, 1979), it was assumed that the control cost varied with the facility size in the form $COST = a*(SIZE)^b$ where a and b are constants, SIZE is the facility size or operating rate in tons of product per year, and cost is in 1985 dollars. The cost and size data were converted to logarithmic values and linear regression was used to find the best line fitting the equation. Separate equations were developed for capital cost and O&M costs. The exception to this method was for ethylene dichloride costs. The data included only one source size, and so it was assumed that capital costs would vary with size to the 0.6

power and that O&M costs would be linear. The annual cost for each source in the model was calculated by multiplying the capital cost by the capital recovery factor of 0.09 and adding the O&M cost. Table III.1, referred to earlier, listed the equation constants for retrofit applications and Table III.2 listed the constants for new applications (only retrofit equations were used in this analysis).

To calculate the control costs for sources falling in the categories covered by the equations but with no plant size listed in the emission inventory, default cost effectiveness values were computed. For each source category, the capital, O&M, and annualized (net annualized portion of both capital and O&M costs) costs were calculated for a plant considered to be of the average size for its type. The emission factor for that source type (U.S. EPA, 1985) was multiplied by the average source size and the control efficiency to find the tons of CO emissions reduced. The total annual cost divided by the tons of CO reduced gave the cost effectiveness for that source type. This figure was then used as a default for all plants in that category with missing source sizes. By multiplying the default cost efficiency by the uncontrolled emissions for a source, an estimate of the annual cost could be made. It was necessary to have this default because a significant number of sources in the data base had missing values or zero as the source size while the uncontrolled emission rate was almost always included.

2. Area/Mobile Sources

In the current version of the model, area sources comprise the four motor vehicle categories (LDGV, LDGT, HDGV, HDDV) plus residential fuel burning, with wood stoves and fireplaces broken out for specific control measures, and an "all other area source" category.

Five motor vehicle control options are available for selection in the CO model. Other potential CO control options which have not been analyzed include transportation control measures (VMT reductions) and increasing passenger vehicle occupancy.

a. <u>New Motor Vehicle Emission Standards</u>

New motor vehicle emission standards are a control option linked to the VOC model. New motor vehicle standards affect all three pollutants (VOC, NO_x, and CO) and are costed solely in the VOC model. These more stringent emission standards are expected to reduce CO emissions only from light-duty gasoline trucks. The emission reduction is modeled by changes in future year emission factors rather than an emission reduction percentage. This is discussed in more detail in Section III.C, Growth Projections.

b. <u>Inspection and Maintenance (Basic and Enhanced)</u>

CO reductions for basic and enhanced I/M programs are based on MOBILE3 values and are listed in Table III.4. The estimated cost for a basic I/M program is $20.20 per vehicle (LDGV and LDGT). The incremental cost for enhanced I/M is $6.48 per vehicle.

One of the more complex aspects of the CO modeling is to ensure that no double counting of costs occurs for I/M. If basic or enhanced I/M is already in place in an area according to the VOC provisions of a bill, an emission credit is given in the CO model at no cost. An extract of the VOC regional constraint file is used to determine which areas already have basic or enhanced I/M programs due to SIPs, expansion of nonattainment areas to the MSA/CMSA level, and ozone transport region controls. In addition, the user also specifies which ozone related attainment categories have enhanced I/M according to the VOC provisions of the policy or bill being examined. This information is used in the CO model to give emission and cost credits where appropriate.

c. <u>Alternative Fuels</u>

Two different alternative fuel options are available for selection in the CO model. Either a 10 percent ethanol blend or a Methyl Tertiary Butyl Ether (MTBE) blend may be selected. It is assumed that these blends will affect all gas-powered vehicles and be used one-third of the year (winter). A 10 percent ethanol blend will reduce CO emissions from gasoline vehicles by an estimated 21.95 percent in 1995 and 19.30 percent in 2000 at an incremental cost of 0.5 cents per gallon (after the federal

Table III.4

CO Reductions for I/M Programs

	1985	Projection Years	
	Basic I/M	Basic I/M	Enhanced I/M
LDGV	13%	37%	44%
LDGT	12%	42%	49%

Source: MOBILE3

subsidy). Based on the average fuel consumption by motor vehicle type, the resulting per vehicle costs are $2.69 per LDGV, $2.43 per LDGT, and $6.15 per HDGV applied to one-third of the vehicles.

MTBE blends are expected to reduce total gasoline vehicle emissions by an estimated 13.45 percent in 1985 and 12.30 percent in 2000. The incremental cost for fuel is 3.2 cents per gallon resulting in per vehicle costs of $5.74 per LDGV, $5.17 per LDGT, and $13.12 per HDGV assuming the fuel is used one-third of the year.

d. Residential Wood Burning

Residential wood burning includes burning in both fireplaces and wood stoves. Controls examined are for reducing CO emissions from woodstoves only. No controls are analyzed for reducing CO emissions from fireplaces. It is assumed that one-third of existing wood stoves can be retrofit with a catalyst at a cost of $150 per stove. Based on average emissions from a wood stove, the estimated cost becomes $50 per ton of CO reduced. All new stoves are controlled also at an annual cost of $50 per ton of CO reduced. The expected reduction over uncontrolled stoves is 65 percent. It is also assumed for modeling purposes that of total residential woodburning emissions, 33 percent is from fireplaces and 67 percent from wood stoves. This split was derived from NEDS emission estimates for an "average" county.

C. GROWTH PROJECTIONS

Growth factors are used to produce future year estimates of motor vehicle and area source emissions. For simplicity and since point sources are not considered a major contributor to CO nonattainment, point source emissions show zero growth in the CO model. It is important to produce future year estimates of motor vehicle and area source emissions since these have a greater impact on CO nonattainment and since the most stringent and complex CO regulations which have been proposed are for these sources.

1. Motor Vehicles

Growth in motor vehicle emissions is based on the joint effects of estimates of VMT and the CO emission rate in grams per mile. Since motor vehicle control costs are based on fixed estimates in dollars per vehicle, a growth rate is also required for the number of registered vehicles, in addition to VMT. All of the motor vehicle growth parameters are based on national averages. Future year emission factors for CO are presented in Table III.5. Future year VMT and vehicle registrations are the same as those found in the VOC model.

There is one special case in the growth rate calculation. If new vehicle standards for CO are required, a special (lower) regulated new vehicle emissions rate, given in parentheses in the table, is used. This control option affects only light-duty gasoline trucks.

2. Area Sources

All other area source CO emissions are projected to grow in proportion to (national) population growth. Thus, there are no MSA or state growth rates used to account for regional growth differences for these sources. Total population estimates for the model projection years are shown in Table III.6.

Table III.5

Motor Vehicle CO Emission Factors

Year	Emission Factor (grams CO/mile) LDGV	LDGT	HDGV	HDDV
1985	12.11	21.64	87.72	5.20
1995	5.46	9.78 (9.41)	23.08	2.52
2000	5.06	7.86 (7.11)	17.28	2.43
2010	4.97	7.58 (6.58)	14.84	2.35

* ( ) indicates CO emission factor used if new motor vehicle standards are in effect.

Table III.6

Total Population Estimates by Projection Year

Year	Population
1985	232,300,000
1995	252,200,000
2000	259,800,000
2010	274,800,000

IV NO_x COST ESTIMATES

No model was developed for the NO_x portion of the analysis; instead, existing (1985) stationary source NO_x emitters were evaluated to determine control costs and emission reductions for different control levels proposed by the Waxman and Mitchell bills. Effort in the NO_x analysis focused on developing current cost equations for RACT (low NO_x burner) and BACT (SCR) level controls. This chapter describes how the 1985 NEDS point source file and the control cost equations were organized to perform the NO_x portion of this analysis.

A. EMISSION INVENTORY

Preparing the 1985 NEDS point source emission inventory for this analysis involved two major tasks (after all non-NO_x emitters were removed from the file). The first task was to sort the data by MSA/CMSA and indicate for each source whether it was in a moderate, serious, or severe nonattainment area or in an attainment area. Secondly, data file information for boilers had to be organized differently than that for other sources for costing purposes because boilers burn more than one type of fuel in most instances. Thus, it was necessary to identify a primary fuel for each multiple fueled boiler. The primary fuel was estimated by establishing a hierarchy of fuel types, and choosing from this hierarchy the likely primary fuel.

To gain some perspective on ozone nonattainment area NO_x emissions, Figure IV.1 summarizes how much of the 1985 point source NO_x emissions are in ozone attainment versus nonattainment areas and in different NO_x emitting source categories. Of the 9.6 million tons of NO_x emitted by point sources in 1985, almost 70 percent is in attainment areas and would not be affected by any of the bill provisions to control NO_x emissions. Figure IV.1 also shows that utility boilers are the predominant point source of NO_x emissions in both areas. Industrial boilers are also a major NO_x source in both attainment and nonattainment areas. Gas turbines and refinery process heaters are the only source types

Figure IV.1

1985 Point Source NOx Emissions by Source Type
Attainment Area vs Nonattainment Area

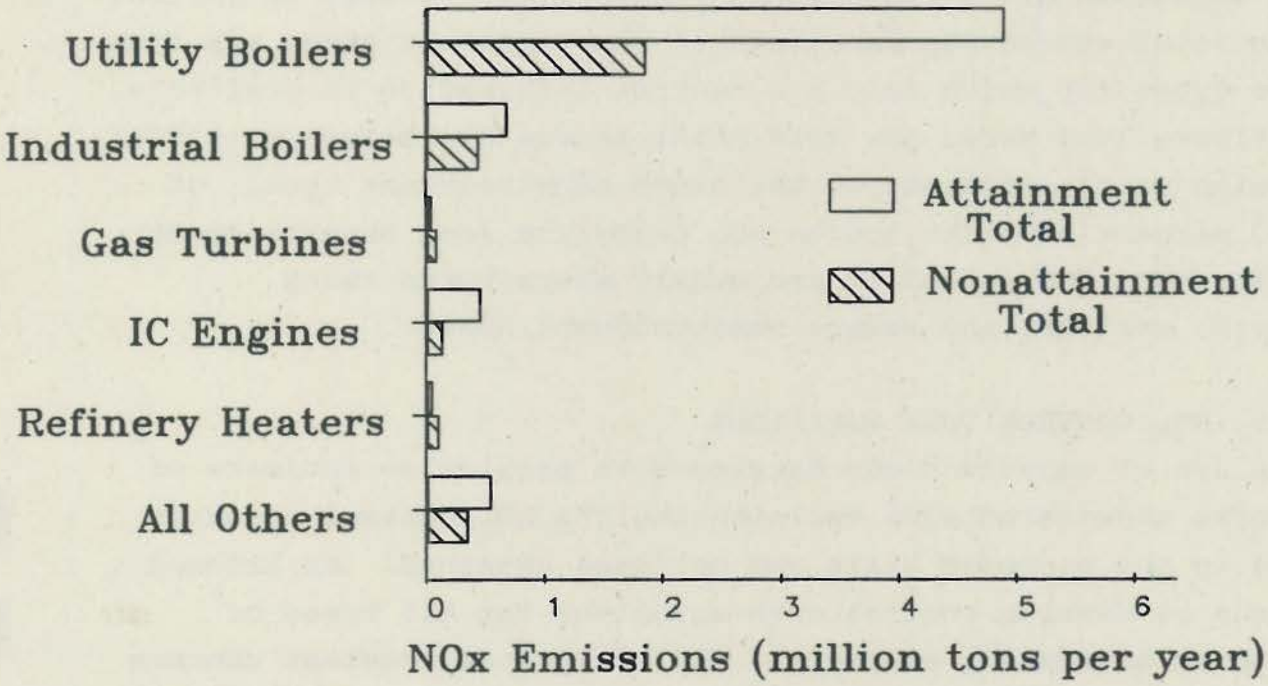
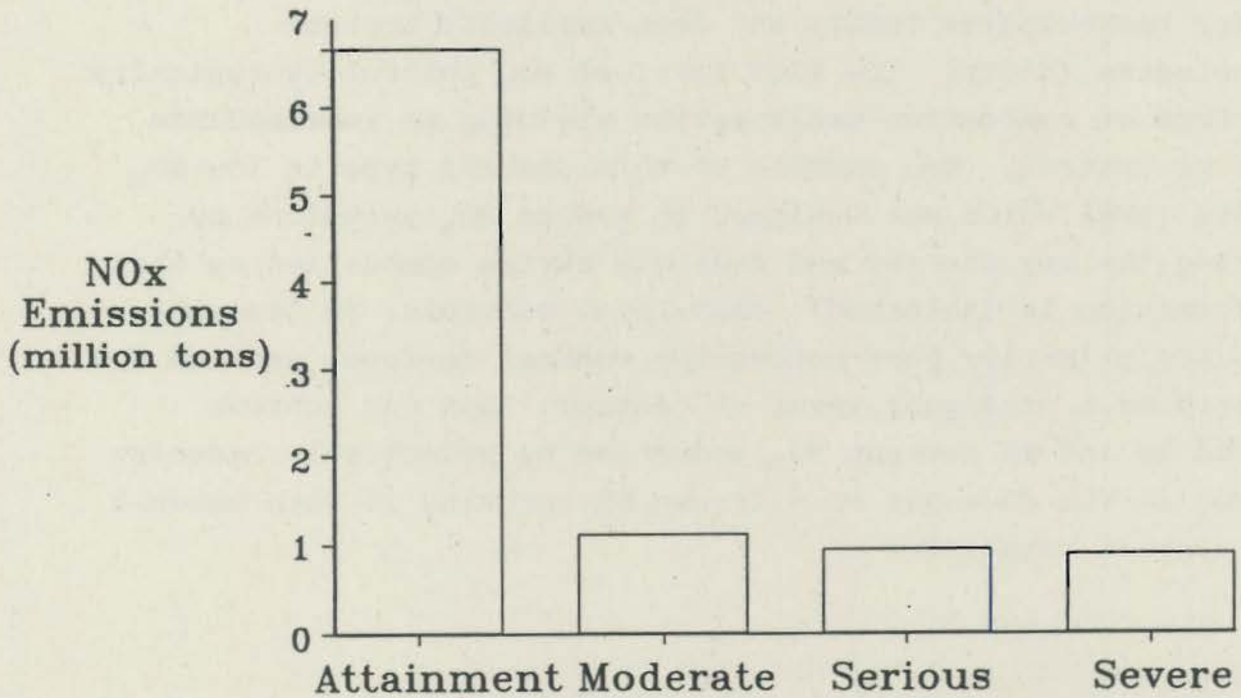


Figure IV.2

1985 Point Source NOx Emissions by
Ozone Nonattainment Area Severity



with greater emissions in nonattainment areas than in attainment areas.

Control cost equations were developed for five source types, whose emissions are delineated in Figure IV.1. Almost 90 percent of the point source NO_x emissions in nonattainment areas are from source types for which cost and control information is available.

Figure IV.2 shows how 1985 point source NO_x emissions differ according to the severity of the ozone nonattainment area. Of the 30 percent of point source NO_x emissions from nonattainment area sources, the emissions are evenly distributed among moderate, serious, and severe nonattainment areas.

B. NO_X CONTROL COST EQUATIONS

A set of equations was developed to provide an estimate of the costs associated with implementing the NO_x control measures listed in the proposed bills and policies examined. No attempt was made to develop control cost equations for all types of stationary source NO_x emitters. The sources of greatest concern for this model were those contributing significant amounts of NO_x emissions and for which NO_x control techniques have been demonstrated with available cost and control information.

The options for controlling NO_x emissions from stationary sources fall into two general categories: Reasonably Available Control Technologies (RACT) and Best Available Control Technologies (BACT). The RACT level of NO_x control is typically some form of combustion modification yielding an intermediate level of control. One example of this control type is low NO_x burners (LNB) which are designed to reduce NO_x emissions by altering the way the air and fuel mix during combustion so that NO_x formation is inhibited. BACT level controls, on the other hand, are primarily post-combustion control devices, such as SCR, and produce a stringent level of control. SCR can achieve between 80 and 90 percent NO_x reduction by selectively reducing the NO_x in the flue gas to nitrogen by reacting it with ammonia over a metal catalyst.

For each source category, one NO_x control method was chosen from the RACT level control options and one from the BACT level control options. SCR was chosen as the BACT control device for each of the source groupings except for gas turbines for which SCR was used in conjunction with water injection. At the RACT level, LNB was the desired control method because of its proven ability to remove significant amounts of NO_x at a relatively low cost. In cases where no cost information was available on LNB, the best available option in the intermediate control range was chosen. Control cost equations were developed for the following source categories of NO_x emitters:

- utility boilers,
- industrial boilers,
- internal combustion engines,
- gas turbines, and
- process heaters.

The NEDS source classification codes (SCC) belonging to each of these source categories are listed in Appendix A.

Within each source category, data were generally available in the literature for the capital costs and the O&M costs of controlling two or more source sizes typical for that category. All costs were converted to 1985 dollars using the <u>Chemical Engineering</u> economic indices (Chem. Engr., 1988). The desired object was to put the cost information in the following equation form:

$$y = ax^b$$

where

y = capital or O&M cost (1985$)
x = boiler design capacity (MMBtu/hr) for boilers and either design rate (SCC units/hr) or operating rate (SCC units/yr) for other source types
a,b = equation constants

The exponent of the equation indicates the degree to which economies of scale exist. For all of the capital cost equations, b is less than 1. This indicates nonlinearity in the costs due to a savings for large pieces of equipment. The O&M costs, on the other hand, are more nearly linear since the operating costs are typically proportional to the design or operating rate of the unit with no economies of scale. A variance from 1.0 in the O&M cost equation exponent indicates the presence of a fixed cost component.

A description of how the cost equations were derived is given in Appendix A. The resultant equations for the control of NO_x emissions from stationary sources are listed in Tables IV.1 and IV.2. For boilers, the equation variable is the boiler design capacity, given in MMBtu/hr. For the other source types, the equation variables used are the maximum hourly design rate or the annual operating rate of the unit. These variables are defined by their SCC units (Stockton and Stelling, 1987). SCC units are assigned according to the production variable of a process responsible for its emissions. For a utility boiler, the SCC units would be the amount of fuel burned (e.g., tons of coal or barrels of oil). For an industrial process, emissions would be primarily determined by amount of raw material or amount of product produced (e.g., tons of pulp produced by a pulp and paper mill).

C. USE OF DEFAULT VALUES

The 1985 NEDS point source file has many instances of missing boiler design capacities, design rates, and operating rates, as well as many instances where these variables are incorrectly listed as zero. Nevertheless, the NO_x emission rate is almost always listed. To prevent the omission of a large number of units from the NO_x cost analysis, a default cost-effectiveness value in \$/ton NO_x removed was calculated for each of the equations. By multiplying this default value by the NO_x emission rate and the control efficiency, an estimate of the annual cost was obtained. To calculate the default values, a typical or average sized unit was chosen to represent each source category. These source sizes are listed in Table IV.3. Using the equations listed in Tables IV.1 and IV.2, the net annual cost for each of these units was calculated, using a capacity utilization factor of 65 percent to calculate the annual operating rate from the design rate. The amount of NO_x which

Table IV.1

NOx Control Cost Equations for Utility and Industrial Boilers

Source Type	Control Device	Capital Cost Equations: Coefficient	Capital Cost Equations: Exponent	Operating & Maintenance Cost Equations: Coefficient	Operating & Maintenance Cost Equations: Exponent	Control Eff. %	Default Cost Per Ton
Utility Boilers							
PC - Wall/Opposed	LNB	7,860	0.72	393	0.72	50	87
PC - Tangential	LNB	232,400	0.40	11,620	0.40	50	232
Residual Oil	SCA	10,480	0.62	600	0.84	42	353
Gas	FGR	6,610	0.43	450	1.00	31	983
Stoker	LEA	3,730	0.44	-67	1.11	21	-525
Coal	SCR	292,400	0.60	4,500	1.00	80	2911
Oil/Gas	SCR	265,800	0.50	2,370	1.00	80	3120
Industrial Boilers							
Pulverized Coal	SCA	1,910	0.70	186	0.96	36	2198
Stoker	LEA	3,730	0.44	-67	1.11	21	-337
Residual Oil	SCA	10,480	0.62	600	0.84	42	827
Distillate Oil	LEA	3,960	0.36	-690	1.00	36	-4592
Gas	FGR	6,610	0.43	450	1.00	31	1025
Coal	SCR	147,900	0.70	4,600	0.95	80	3278
Oil/Gas	SCR	134,450	0.60	2,425	0.95	80	3667

NOTES: All equations are of the form COST = COEFFICIENT*(BOILER DESIGN CAPACITY)^EXPONENT
Units for BOILER DESIGN CAPACITY are in MMBtu/hr
All costs are in 1985 dollars

Table IV.2

NOx Control Cost Equations for IC Engines, Gas Turbines, and Process Heaters

SOURCE	CONTROL METHOD	CAPITAL COST EQUATIONS	O&M COST EQUATIONS	CONTROL EFF(%)	DEFAULT COST PER TON
IC Engines					
Gas	Change A/F Ratio	0	574*(OPRATE)	30	1126
Oil	Change A/F Ratio	0	65.8*(OPRATE)	30	935
Gas	SCR	8,802,000*(DESRATE)^0.86	131*(OPRATE)+5,355,000*(DESRATE)	80	964
Oil	SCR	1,556,000*(DESRATE)^0.86	18.1*(OPRATE) + 714,000*(DESRATE)	80	936
Gas Turbines					
Gas	Water Injection	1,393,000*(DESRATE)^0.52	174*(OPRATE)	70	1560
Oil	Water Injection	508,000*(DESRATE)^0.52	22.1*(OPRATE)	70	1020
Gas	SCR+Water Injection	10,031,000*(DESRATE)^0.74	179*(OPRATE)+1,700,000*(DESRATE)	94	3730
Oil	SCR+Water Injection	2,283,000*(DESRATE)^0.74	23.1*(OPRATE) + 227,000*(DESRATE)	94	2480
Process Heater					
Gas	SCA	47,260*(DESRATE)^0.67	-65,100*(DESRATE)	45	-306
Oil	SCA	12,830*(DESRATE)^0.67	-9,300*(DESRATE)	45	-110
Gas	SCR	5,774,000*(DESRATE)^0.60	221*(OPRATE)	90	7810
Oil	SCR	1,780,000*(DESRATE)^0.60	29.8*(OPRATE)	90	2760

NOTES: DESRATE is the maximum design rate in SCC units per hour
OPRATE is the operating rate in SCC units per year
All costs are in 1985 dollars

Table IV.3

Default Cost per Ton Values for NO_x Emitters

Source Type	Primary Fuel	Average Design Rate Used*	Default Cost Per Ton ($/ton NOx)
RACT Level Control			
Utility Boiler, Wall/Opposed	Pulverized Coal	5,250	87
Utility Boiler, Tangential	Pulverized Coal	5,250	232
Utility Boiler, Stoker	Coal	5,250	-525
Utility Boiler	Residual Oil	5,250	353
Utility Boiler	Natural Gas	5,250	983
Industrial Boiler	Pulverized Coal	250	2,198
Industrial Boiler, Stoker	Coal	250	-337
Industrial Boiler	Residual Oil	250	827
Industrial Boiler	Distillate Oil	250	-4,592
Industrial Boiler	Natural Gas	250	1,025
IC Engine	Natural Gas	0.0214	1,126
IC Engine	Oil	0.15	935
Gas Turbine	Natural Gas	0.15	1,560
Gas Turbine	Oil	1.125	1,020
Process Heater	Natural Gas	0.066	-306
Process Heater	Oil	0.463	-110
BACT Level Control			
Utility Boiler	Coal	5,250	2,911
Utility Boiler	Oil/Natural Gas	5,250	3,120
Industrial Boiler	Coal	250	3,278
Industrial Boiler	Oil/Natural Gas	250	3,667
IC Engine	Natural Gas	0.0214	964
IC Engine	Oil	0.161	936
Gas Turbine	Natural Gas	0.15	3,730
Gas Turbine	Oil	1.125	2,480
Process Heater	Natural Gas	0.066	7,810
Process Heater	Oil	0.463	2,760

*Design Rate for boilers is in MMBtu/hr
Design Rate for other source types is in SCC units/hr

would be reduced each year was calculated using the control efficiencies listed in Tables IV.1 and IV.2 and published emission factors (Stockton and Stelling, 1987). The resultant default costs per ton are also listed in Tables IV.1 and IV.2.

Establishing default values was essential for performing a NO_x cost analysis for Texas sources. Design capacities and operating rates are confidential data items in the Texas emission inventory system and are, therefore, not submitted to EPA.

V EPA NONATTAINMENT POLICY ANALYSIS

Estimates of the costs of the proposed EPA policy were of special interest for two reasons: it was necessary to know what additional cost might be incurred to control emissions when compared with the pre-1988 ozone program, and the costs of the proposed policy were used as the baseline for estimating costs for the Congressional bills analyzed. Primary differences between the current (pre-1988) EPA ozone policy and the proposed policy are outlined in Table V.1. All the provisions mentioned were modeled explicitly here except the possibility of NO_x controls. While the costs and benefits of NO_x controls as part of an ozone reduction strategy are not explicitly modeled, it is recognized that NO_x controls may be cost effective in helping some areas reach attainment for ozone.

The emission reductions and costs associated with the proposed EPA ozone policy were calculated as those above what would be achieved via the current policy. Thus, the first step in the analysis was to simulate the costs and future emission levels for each MSA under the provisions of the current EPA policy. Projected 1995 costs of the pre-1988 EPA ozone policy are presented in Table V.2 for four different policy provisions. The increase in the cost of planned I/M programs between 1995 and 2000 results from an increase in the number of vehicles being inspected.

Table V.3 summarizes ERCAM net annual cost estimates for 1995 and 2000 by VOC control measure. Among the national measures, architectural surface coating is listed as having no cost. Switching from solvent borne to waterborne coatings is estimated to be at no cost. The negative numbers for an auto body refinishing CTG represent cost savings.

The ERCAM simulation of the cost of the EPA policy is performed in two parts. First, all of the explicit (mandated) provisions of the policy are modeled. Then, each MSA is evaluated with respect to the 3 percent per year and attainment requirements to see if these have been met. Additional

Table V.1

Key EPA Ozone Policy Provisions

1. Nonattainment area boundaries expand to equivalent of MSA or CMSA

2. National measures include the following:
   A. RVP control
   B. Onboard VOC control
   C. TSDF control
   D. POTW control
   E. Architectural surface coating control
   F. Other possible national measures (CTGs) - autobody refinishing

3. Annual 3 percent emission reduction requirement until attainment

4. For NMOC/NO_x ratios above 10:1, areas are required to consider NO_x control as part of its ozone control strategy

5. Enhanced I/M in all areas with design values $\geq$ 0.16 ppm for ozone

Note that while some of the above provisions have been assumed by this analysis to be adopted as final for modeling purposes, they are not proposed as explicitly in the policy.

Table V.2

Costs of Pre-1988 EPA Ozone Policy*
National Summary

	1995 Cost (million $)	2000 Cost (million $)	Provisions Included
Stationary Sources	$ 878	$1,213	NSPS
	449	449	Non-CTG RACT
	3,137	4,407	LAER for new sources expected to be > 100 tpy
Motor Vehicles	712	926	Planned I/M programs not in effect in 1985
Totals	$5,176	$6,995	

* Costs presented in this table are not historical control costs, and therefore do not capture costs of meeting motor vehicle emission standards or costs of stationary source controls in place in 1985. Current air pollution control expenditures are approximately $33 billion per year. More than one-third of this cost is for motor vehicle emission controls.

Table V.3

EPA Ozone Policy Costs*
National Summary

	Net Annual Costs (billion$) 1995	2000
National Measures		
Architectural Surface Coating	$0	0
Hazardous Waste Treatment, Storage, and Disposal Facilities (TSDF)	0.82	0.90
Publicly Owned Treatment Works (POTW)	0.02	0.02
RVP Control	0.24	0.27
Onboard Control	0.19	0.19
New CTGs		
Autobody Refinishing	-0.41	-0.46
Additional Measures		
Bringing all Existing Sources into compliance with SIPs	0.61	0.61
CTGs Not Already in Place	0.10	0.10
Expansion of Nonattainment Area to MSA or CMSA Level	0.01	0.01
Enhanced I/M in Serious and Severe Nonattainment Areas	0.68	0.76
Discretionary Controls Applied to Serious and Severe Nonattainment Areas**	0.81	4.20
Cost for All Areas to Meet 3 Percent Line or Attain (at $2,000 to $10,000 per ton)	1.11 to 5.57	2.34 to 11.72
Total	$4.17 to $8.63	$8.94 to $18.32

* All costs are incremental to the cost of the pre-1988 ozone policy.

** Discretionary controls applied in this analysis are listed in Table V.4

discretionary VOC controls are applied in the second ERCAM simulation to areas not meeting their emission reduction targets. Because controls in the ERCAM scenario file cannot be put on individual areas, discretionary controls were put on all serious and severe nonattainment areas. All severe and most serious nonattainment areas had difficulty meeting their 1995 and 2000 targets. The cost of discretionary controls in serious and severe nonattainment areas is estimated to be $0.81 billion in 1995 and $4.20 billion in 2000. The dramatic increase in discretionary control costs from 1995 to 2000 results from serious and severe nonattainment areas beginning to see market penetration of methanol-fueled vehicles into the vehicle fleet sometime shortly after 1995, such that 30 percent of vehicles in these areas are methanol-fueled by 2000. The $3.18 billion cost estimate for alternative fuels to all vehicle types reflects an assumed 10 cent per gallon price difference between methanol and gasoline. (Some forecasts show no expected price difference between the two fuels. If the latter assumption is used, the cost of methanol-fueled vehicles is negligible.) Estimated costs for all the discretionary controls included in the analysis of the EPA policy are shown in Table V.4. The "more stringent existing source controls" option shown in Table V.4 refers to applying the most efficient control technique to each cost pod. Only five source categories were found that were not already required to control to the highest levels.

Even after all discretionary controls (that can be identified) are applied, not all areas have met their attainment/progress requirements.

Because emission reduction targets cannot be achieved in all areas even with currently available controls applied, it was necessary to assign a cost to the residual tons of VOC beyond those for which explicit cost equations exist. An analysis of this issue proceeded in four steps: (1) determining the source categories that have opportunities for further control in 1995 and 2000, (2) assessing costs of possible control technologies that might be applied to these sources, (3) estimating how the

Table V.4

Discretionary Controls for EPA Policy

Option	Cost (billion $) 1995	2000
RACT to 50 tpy	0.04	0.05
More Stringent Existing Source Controls*	0.06	0.07
Industrial Solvents	0.16	0.21
Consumer Solvents	0.24	0.30
Enhanced I/M on HDGV	0.04	0.05
Railroad Engines	0.05	0.07
Bakeries	0.03	0.04
Alternative Fuels to Fleet Vehicles	0.18	0.23
Alternative Fuels to All Types	--	3.18

* Affects Synthetic Organic Chemicals Manufacturing Industry (SOCMI) fugitives, petroleum refinery fugitives, cellulose acetate manufacture, paper surface coating, and aircraft surface coating

Note: Costs are for all serious and severe nonattainment areas not meeting attainment/progress requirements candidate residual tons to be reduced might be allocated among the controllable categories, and (4) using the results of steps 1 through 3 to estimate an average cost per ton reduced.

Table V.5 provides information about which major source categories are candidates for additional emission reductions in the projection years. The 1995 and 2000 VOC emission totals are from an EPA policy simulation after discretionary controls have been applied. Percentage reductions are from 1985 uncontrolled levels. Table V.5 suggests that controllable VOC emissions will be concentrated in three categories: solvent use, consumer solvents, and mobile sources. These three categories constitute 68 percent of the 1985 emissions inventory and 77 percent of the year 2000 emissions inventory. These categories have relatively low levels of control as well.

Among the remaining categories in the emission inventory, point sources, service stations and miscellaneous point sources are essentially completely controlled. Any further control would have to come from improved capture and ducting systems, incineration, and flaring technologies which would be at least as expensive as those discussed below for solvents. New area source categories are also subject to very little additional control, because this consists of several sources (TSDFs) that are or will be controlled to the maximum extent possible, and several sources (forest fires) that are essentially uncontrollable.

The analysis concentrates, therefore, on the kinds of controls that might be applied to (industrial) solvent use, consumer solvents, and mobile sources. Incineration is the only method of getting consistently high control of emissions from solvent use. Options that are less universally applicable include switching to conforming coatings (at little or no cost) or switching to water soluble cleaning materials (where controls in the 90 percent plus range cannot be guaranteed). Costs for the latter two options are lower than incineration costs, but control levels may not be high enough to ensure that VOC reduction targets are met. Therefore, cost estimates were made for a hypothetical incinerator on a 10 and a 25 ton per year VOC

Table V.5

Summary of VOC Emissions by Category for Ozone Nonattainment Areas

Source Category	VOC Emissions 1985 (tons)	VOC Emissions 1985 Percentage Reduction	VOC Emissions 1995 (tons)	VOC Emissions 1995 Percentage Reduction	VOC Emissions 2000 (tons)	VOC Emissions 2000 Percentage Reduction
Point Sources	792,339	82	406,147	93	473,920	92
Solvent Use	1,743,165	12	1,134,202	57	1,248,270	57
Service Stations	333,703	38	35,279	95	38,890	95
Consumer Solvents	682,629	0	735,617	20	811,811	20
Mobile Sources	3,429,299		1,828,113		1,818,079	
New Area Source Categories	1,242,182	0	513,038	68	547,674	69
Misc. Point Sources	391,322	87	284,186	93	319,806	92
	=========	==	=========	==	=========	==
	8,614,639	44	4,936,582	72	5,258,450	73

Projection year (1995 and 2000) emissions are those after all EPA policy provisions and discretionary controls have been applied. Percentage reductions are from 1985 uncontrolled levels.

emitter. The Economic Analysis Branch (EAB) Control Cost Manual (U.S. EPA, 1986b) was used to estimate the costs for thermal and catalytic incinerators handling a waste gas flow rate of 5,000 cubic feet per minute (the smallest source size to which the equations can be applied). The annual cost derived for this source was used to calculate dollar per ton values assuming a 90 percent reduction. The cost for thermal incineration ranged from $2,550 per ton for a 25 ton per year source to $6,390 per ton for a 10 ton per year source. For catalytic incinerators, the resulting costs were $2,310 per ton and $5,770 per ton for a 25 and 10 ton per year source, respectively. These four estimates of incineration costs based on two technologies and two source sizes can be averaged to obtain a value of $4,255 per ton.

There are no good estimates of the cost of controls on consumer solvents. Industry sources claim costs as high as $30,000 per ton. The basis for these numbers is being examined by EPA to see if they are at all reasonable. For purposes of this analysis, the considerably more cautious assumption has been made that these controls can be accomplished at an average of $2,000 per ton.

Additional mobile source reductions must come primarily from one of two sources: Transportation Control Measures (TCMs), or additional reductions through greater use of alternative fuels, such as methanol or natural gas.

Table V.6 is information supplied by EPA's OAQPS on a TCM analysis of a typical SIP (Kansas City). A simple average of the measures for which cost data are supplied yield a figure of $107,000 per ton. Excluding all measures costing in excess of $100,000 per ton, this average becomes $17,500 per ton. Figures from Dallas and Tarrant counties for which tons as well as costs are available are $21,500 and $6,300 per ton, respectively. The average of these estimates is $15,000. If it is assumed, to be conservative, that two thirds of this cost per ton could be offset by other benefits (such as CO control), the net cost is about $5,120.

Table V.6

Transportation Control Measures Analyzed
for Kansas City

Measures	Cost Effectiveness and Main Drawbacks
1. Short-Range Public Transit Improvements	$ 62,060/Ton of reduction (TOR)
2. Pedestrian/Transit Mall	$491,800/TOR
3. Light Rail Transit	$485,720/TOR
4. Expand Regional Rideshare Program	$ 2,777/TOR
5. Encourage Bicycling to Work Through Employer-Based Program	$ 9,910/TOR
6. Encourage Commuters to Use Transit or Carpools One Day Each Week	Voluntary Program
7. Encourage the Use of Variable Work Schedule	$ 2,818/TOR
8. Encourage the Use of the 4 Day Work Week	Voluntary Program
9. Improve Traffic Signalization	$146,000/TOR
10. Improve Highway Surveillance and Information	Increases VOC Through 1990
11. Truck Delivery Restrictions in Central Business Districts	$ 7,941/TOR
12. Institute More One-Way Streets, Where Feasible	Only 3.1 TPY reduction
13. Switch Traffic Control Devices to Flashing Mode During Off-Peak Hours	Only 0.6 TPY reduction
14. Prohibit Left Turns on Congested Streets	Only 3.1 TPY reduction
15. Adjust Speed Limits to Reduce Congestion on Selected Streets	Safety Problems
16. Reduce Amount of On-Street Parking and Improve Enforcement of On-Street Parking Controls in Downtown Areas and Along Congested Streets	$16,380/TOR

Table V.6 (continued)

Transportation Control Measures Analyzed for Kansas City

17.	Implement Education Program on Vehicle Idling	$ 2,151/TOR
18.	Restrict Truck Idling	$ 24,500/TOR
19.	Encourage the Substitution of Communications for Transportation	This will occur without public sector involvement.
20.	Encourage Home Delivery of Goods	$ 31,710/TOR

Source: Kansas City State Implementation Plan

The range of options on use of alternative fuels is reasonably well captured by conversion of fleet vehicles to natural gas, and use of methanol. Natural gas conversion can be accomplished for $2,000 to $4,400 per ton. The cost of methanol controls depends heavily on the relative cost of gasoline and methanol. Assuming a $0.10 per gallon fuel price difference and a $400 per gasoline powered vehicle capital cost difference, methanol use would yield reductions at $20,000 per ton.

It seems unlikely that TCMs will be used to achieve the bulk of the reductions required of motor vehicles. Localities have been reluctant to rely on them, and when they have, the measures account for relatively small reductions in the inventory. If it is assumed that TCMs would account for no more than a third of all required residual tons gained from mobile sources, the three mobile source numbers ($5,120 for TCMs, $3,200 average for natural gas, and $20,000 for methanol) can be averaged to give an average cost of $9,440 per ton for mobile source reductions.

To allocate residual tons to controllable categories, this analysis assumes that the residual tons required to attain will be drawn from the three "controllable" categories in proportion to the relative share of each category in the total "controllable" inventory. If, for example, the controllable inventory (i.e., the sum of the tons in the controllable categories) consisted of 30 percent solvent use, 20 percent consumer solvents, and 50 percent mobile sources, these proportions could be used to allocate required residual tons to these three categories.

This general allocation principle can be improved slightly by accounting for the fact that the relative proportion of the controllable inventory may shift somewhat over time. Table V.5 suggests, for example, that solvent use is increasing as a percentage of the inventory over time, while mobile sources are declining. To reflect this fact, this analysis averaged the proportions of the 1995 and 2000 "controllable" inventory. This procedure yields an allocation of residual tons to controllable categories as follows: 33 percent to solvent use, 20 percent to consumer solvents, and 47 percent to mobile sources.

The results in the previous steps can be combined by multiplying the costs per ton for each controllable category by the proportions listed above. This yields an average of $6,200 per ton. Given all the uncertainty in the assumptions, the possibility of new lower cost control technologies being developed, balanced against the possibility of much higher costs for consumer solvent controls, a range of $2,000 per ton to $10,000 per ton was used to estimate costs for controlling remaining VOC emission after all available controls have been applied. The $2,000 per ton scenario reflects a situation where much of the reductions of residual tons can be achieved through switching to conforming coatings, switching to water soluble cleaning materials, reducing per motor vehicle VOC emissions even further through cost effective methods, and the development of new, less polluting technologies. At the other end of the spectrum, the $10,000 per ton case reflects a scenario where there are problems achieving emission reductions from consumer solvent use, higher levels of control are needed to reach attainment than the less expensive, moderate efficiency controls can achieve, and time is too short for new technologies to penetrate the market in significant quantities.

Model results show that besides the alternative fuel cost already discussed above, the biggest difference between 1995 and 2000 cost estimates is in the cost to meet the 3 percent per year reduction requirements or attain. Because all of the controls except alternative fuels have been imposed by 1995, new source growth overtakes reductions in emission rates to show a net increase in VOC emissions between 1995 and 2000 for many areas. Onboard vehicle evaporative VOC controls will continue to provide net emission reductions past 1995, but most other controls, including motor vehicle tailpipe emission standards, may reduce per source emissions, but not the total emissions for a category. Thus, many areas which are predicted to meet their 1995 emission targets exceed their 2000 targets. MSA-level calculations of VOC emissions and 3 percent reduction versus attainment targets are illustrated in Tables V.7 and V.8. The equation used to calculate 1995 3 percent line emission targets was as follows:

0.82 (Revised 1985 Base) - Federal Measure Reductions

where the revised 1985 base emissions are those after all current SIP requirements are complied with. Federal measures for which areas get no reduction credit (toward the 3 percent reduction requirement) include Federal motor vehicle emission standards and existing I/M programs, plus RVP limits and onboard vehicle evaporative emission controls. Note that Federal measures do not include TSDF controls or municipal landfill controls in this simulation.

Year 2000 3 percent line emission targets shown in Table V.8 were estimated using the equation shown above with the 0.82 coefficient changed to 0.67 to reflect five more years of emission reductions at 3 percent per year. Under these assumptions, the proposed EPA policy would force all ozone nonattainment areas except two, Los Angeles and New York, to attain by 2000.

Table V.7

Additional Reductions Needed to Meet Attainment/3 Percent Line
1995 EPA Policy

VOC Emissions (tons)

CMSA Name	1985	Revised Baseline	Federal Measures	Attainment Target	3 Percent Target	1995*	Additional Reduction Needed
Massachusetts	384,796	353,163	80,142	246,269	209,452	299,398	53,129
Allentown, PA-NJ	45,639	41,610	9,510	41,988	24,610	32,531	0
Atlanta, GA	181,599	162,577	49,241	123,487	84,072	121,551	0
Atlantic City, NJ	16,891	16,572	5,047	10,135	8,542	11,526	1,391
Bakersfield, CA	42,360	34,212	10,344	25,416	17,710	23,710	0
Baltimore, MD	136,178	129,262	30,633	99,410	75,362	98,076	0
Baton Rouge, LA	84,069	41,819	8,884	43,716	25,408	40,536	0
Beaumont, TX	130,875	58,353	7,911	66,746	39,938	57,184	0
Birmingham, AL	62,086	58,317	14,482	57,119	33,338	46,046	0
Bradenton, FL	9,527	8,883	2,572	8,765	4,712	8,013	0
Charleston, WV	23,607	19,505	3,795	21,718	12,199	18,198	0
Charlotte, NC-SC	77,904	69,787	18,583	71,672	38,642	64,818	0
Chattanooga, TN-GA	40,689	32,394	7,393	37,434	19,170	36,429	0
Chicago CMSA	529,572	458,393	102,165	222,420	273,717	316,346	42,629
Cincinnati CMSA	121,743	103,335	26,941	70,611	57,794	70,018	0
Cleveland CMSA	190,252	178,864	41,918	150,299	104,750	135,356	0
Dallas CMSA	266,233	248,808	74,931	141,103	129,092	177,834	36,731
Dayton, OH	71,385	64,343	14,603	65,674	38,158	50,131	0
Denver CMSA	140,469	135,251	42,154	129,231	68,752	102,177	0
Detroit CMSA	318,674	281,305	65,314	293,180	165,356	213,016	0
El Paso, TX	35,069	32,447	10,687	19,639	15,920	19,580	0
Erie, PA	17,710	16,386	3,500	16,293	9,937	12,888	0
Fresno, CA	37,700	35,174	9,172	20,358	19,671	26,431	6,073
Gadsden, AL	9,707	6,633	1,754	8,930	3,685	4,820	0

Table V.7

Additional Reductions Needed to Meet Attainment/3 Percent Line
1995 EPA Policy

VOC Emissions (tons)

CMSA Name	1985	Revised Baseline	Federal Measures	Attainment Target	3 Percent Target	1995*	Additional Reduction Needed
Grand Rapids, MI	47,777	45,195	8,900	43,955	28,160	41,840	0
Harrisburg, PA	33,779	32,969	8,681	31,077	18,354	24,578	0
Houston CMSA	370,531	277,022	67,482	129,686	159,676	255,757	96,081
Huntington, WV-KY-OH	31,976	26,313	4,774	25,581	16,803	23,457	0
Indianapolis, IN	121,961	79,063	18,311	112,204	46,521	78,735	0
Jacksonville, FL	55,784	53,176	12,540	44,627	31,064	43,317	0
Janesville, WI	12,817	9,119	2,064	11,792	5,414	7,480	0
Kansas City, MO-KS	125,335	104,167	22,733	105,281	62,684	83,939	0
Lake Charles, LA	26,294	14,532	2,781	18,406	9,135	12,986	0
Longview, TX	22,015	16,821	4,410	14,750	9,383	14,011	0
Los Angeles CMSA	824,055	789,525	168,297	255,457	479,114	581,450	102,336
Louisville, KY-IN	77,299	65,417	15,153	51,790	38,489	50,417	0
Memphis, TN	65,116	55,227	12,681	41,674	32,605	41,982	308
Miami CMSA	157,426	147,539	44,080	127,515	76,902	108,024	0
Milwaukee CMSA	109,465	100,599	20,860	59,111	61,631	72,096	10,465
Minneapolis, MN-WI	189,531	158,431	40,716	126,986	89,197	121,867	0
Modesto, CA	20,050	18,271	5,438	12,030	9,544	13,166	1,136
Muskegon, MI	15,822	10,900	2,226	12,658	6,712	8,856	0
Nashville, TN	73,025	59,022	14,223	58,420	34,175	48,196	0
New York CMSA	887,534	852,933	192,644	292,886	506,761	586,087	79,326
Norfolk, VA	78,350	67,694	17,079	62,680	38,430	53,516	0
Philadelphia CMSA	344,747	303,863	68,265	203,401	180,903	215,599	12,198
Phoenix, AZ	114,562	108,336	30,242	67,592	58,594	83,762	16,170
Pittsburgh CMSA	122,802	110,833	27,323	112,978	63,560	77,859	0

Table V.7

Additional Reductions Needed to Meet Attainment/3 Percent Line
1995 EPA Policy

VOC Emissions (tons)

CMSA Name	1985	Revised Baseline	Federal Measures	Attainment Target	3 Percent Target	1995*	Additional Reduction Needed
Portland CMSA	95,120	89,309	19,776	87,510	53,457	75,626	0
Providence, RI	57,881	53,631	11,156	38,780	32,821	40,026	1,246
Reading, PA	22,933	20,726	4,611	21,098	12,384	16,324	0
Richmond, VA	66,718	53,384	13,467	61,381	30,308	45,906	0
Sacramento, CA	87,463	80,840	23,924	43,732	42,365	55,997	12,265
St. Louis, MO-IL	185,377	153,137	38,216	114,934	87,356	114,257	0
Salt Lake City, UT	72,379	69,377	21,088	49,218	35,801	45,499	0
San Diego, CA	126,559	121,385	34,212	53,155	65,324	89,336	24,012
San Francisco CMSA	375,354	358,562	82,807	180,170	211,214	261,539	50,325
Santa Barbara, CA	28,805	25,884	6,283	17,283	14,942	19,933	2,650
Sheboygan, WI	8,586	8,035	1,707	4,636	4,882	6,090	1,208
Stockton, CA	25,799	24,089	7,633	17,285	12,120	16,643	0
Tampa, FL	107,549	103,609	29,522	98,945	55,437	80,379	0
Tulsa, OK	54,034	50,281	15,801	49,711	25,429	37,499	0
Visalia, CA	19,478	18,430	4,399	17,920	10,714	14,665	0
Washington, DC	168,375	162,274	49,566	104,392	83,499	98,926	0
West Palm Beach, FL	43,946	43,168	10,534	35,596	24,864	38,253	2,657
York, PA	28,161	27,175	5,855	25,908	16,428	22,208	0
Yuba City, CA	9,836	9,502	1,834	9,049	5,958	7,952	0
Greater Conn. CMSA	127,499	123,427	29,113	84,149	72,097	89,230	5,081
	8,614,639	7,690,585	1,865,083	5,129,002	4,441,198	5,811,878	557,417

* 1995 VOC after discretionary controls are applied where needed

The reader is cautioned that MSA level results are even more uncertain than national level results

Table V.8

Additional Reductions Needed to Meet Attainment/3 Percent Line
2000 EPA Policy

VOC Emissions (tons)

net of growth 3%/yr

CMSA Name	1985	Revised Baseline	Federal Measures	Attainment Target	3 Percent Target	2000*	Additional Reduction Needed
Massachusetts	384,796	353,163	79,688	246,269	156,931	329,542	83,273
Allentown, PA-NJ	45,639	41,610	9,200	41,988	18,679	34,137	0
Atlanta, GA	181,599	162,577	48,335	123,487	60,592	117,834	0
Atlantic City, NJ	16,891	16,572	5,089	10,135	6,014	12,458	2,323
Bakersfield, CA	42,360	34,212	10,260	25,416	12,662	25,178	0
Baltimore, MD	136,178	129,262	29,680	99,410	56,926	94,163	0
Baton Rouge, LA	84,069	41,819	8,903	43,716	19,116	38,106	0
Beaumont, TX	130,875	58,353	7,796	66,746	31,301	52,784	0
Birmingham, AL	62,086	58,317	14,136	57,119	24,936	50,380	0
Bradenton, FL	9,527	8,883	2,589	8,765	3,363	9,312	547
Charleston, WV	23,607	19,505	3,772	21,718	9,296	18,407	0
Charlotte, NC-SC	77,904	69,787	18,245	71,672	28,512	74,980	3,308
Chattanooga, TN-GA	40,689	32,394	7,295	37,434	14,409	42,845	5,411
Chicago CMSA	529,572	458,393	99,450	222,420	207,673	330,915	108,495
Cincinnati CMSA	121,743	103,335	26,351	70,611	42,883	73,063	2,452
Cleveland CMSA	190,252	178,864	40,610	150,299	79,229	143,458	0
Dallas CMSA	266,233	248,808	73,818	141,103	92,883	193,586	52,483
Dayton, OH	71,385	64,343	14,190	65,674	28,920	52,985	0
Denver CMSA	140,469	135,251	41,184	129,231	49,434	113,796	0
Detroit CMSA	318,674	281,305	63,275	293,180	125,199	223,956	0
El Paso, TX	35,069	32,447	10,423	19,639	11,316	20,533	894
Erie, PA	17,710	16,386	3,417	16,293	7,562	13,642	0
Fresno, CA	37,700	35,174	8,884	20,358	14,683	28,389	8,031
Gadsden, AL	9,707	6,633	1,688	8,930	2,756	5,195	0

Table V.8

Additional Reductions Needed to Meet Attainment/3 Percent Line
2000 EPA Policy

VOC Emissions (tons)

CMSA Name	1985	Revised Baseline	Federal Measures	Attainment Target	3 Percent Target	2000*	Additional Reduction Needed
Grand Rapids, MI	47,777	45,195	8,645	43,955	21,636	45,419	1,464
Harrisburg, PA	33,779	32,969	8,499	31,077	13,590	26,271	0
Houston CMSA	370,531	277,022	66,785	129,686	118,820	293,201	163,515
Huntington, WV-KY-OH	31,976	26,313	4,676	25,581	12,954	24,388	0
Indianapolis, IN	121,961	79,063	17,771	112,204	35,201	90,007	0
Jacksonville, FL	55,784	53,176	12,304	44,627	23,324	47,069	2,442
Janesville, WI	12,817	9,119	2,058	11,792	4,052	7,988	0
Kansas City, MO-KS	125,335	104,167	22,050	105,281	47,742	89,308	0
Lake Charles, LA	26,294	14,532	2,815	18,406	6,921	12,916	0
Longview, TX	22,015	16,821	4,361	14,750	6,909	13,544	0
Los Angeles CMSA	824,055	789,525	158,489	255,457	370,493	618,240	247,747
Louisville, KY-IN	77,299	65,417	14,742	51,790	29,087	48,211	0
Memphis, TN	65,116	55,227	12,685	41,674	24,317	45,753	4,079
Miami CMSA	157,426	147,539	43,702	127,515	55,149	119,865	0
Milwaukee CMSA	109,465	100,599	20,173	59,111	47,228	75,477	16,366
Minneapolis, MN-WI	189,531	158,431	39,682	126,986	66,467	116,956	0
Modesto, CA	20,050	18,271	5,441	12,030	6,801	14,198	2,168
Muskegon, MI	15,822	10,900	2,141	12,658	5,162	9,339	0
Nashville, TN	73,025	59,022	14,127	58,420	25,418	52,056	0
New York CMSA	887,534	852,933	187,054	292,886	384,411	617,939	233,528
Norfolk, VA	78,350	67,694	16,720	62,680	28,635	59,458	0
Philadelphia CMSA	344,747	303,863	66,126	203,401	137,462	227,290	23,889
Phoenix, AZ	114,562	108,336	30,232	67,592	42,353	93,179	25,587
Pittsburgh CMSA	122,802	110,833	26,496	112,978	47,762	82,237	0

Table V.8

Additional Reductions Needed to Meet Attainment/3 Percent Line
2000 EPA Policy

VOC Emissions (tons)

CMSA Name	1985	Revised Baseline	Federal Measures	Attainment Target	3 Percent Target	2000*	Additional Reduction Needed
Portland CMSA	95,120	89,309	19,472	87,510	40,365	82,716	0
Providence, RI	57,881	53,631	10,808	38,780	25,125	42,572	3,792
Reading, PA	22,933	20,726	4,451	21,098	9,435	17,365	0
Richmond, VA	66,718	53,384	13,185	61,381	22,582	51,577	0
Sacramento, CA	87,463	80,840	23,515	43,732	30,648	58,985	15,253
St. Louis, MO-IL	185,377	153,137	37,072	114,934	65,530	108,186	0
Salt Lake City, UT	72,379	69,377	20,655	49,218	25,828	48,542	0
San Diego, CA	126,559	121,385	33,790	53,155	47,538	96,263	43,108
San Francisco CMSA	375,354	358,562	78,938	180,170	161,299	278,749	98,579
Santa Barbara, CA	28,805	25,884	6,221	17,283	11,121	21,398	4,115
Sheboygan, WI	8,586	8,035	1,659	4,636	3,724	6,443	1,807
Stockton, CA	25,799	24,089	7,521	17,285	8,619	15,895	0
Tampa, FL	107,549	103,609	28,943	98,945	40,475	89,593	0
Tulsa, OK	54,034	50,281	15,510	49,711	18,178	41,405	0
Visalia, CA	19,478	18,430	4,280	17,920	8,068	15,786	0
Washington, DC	168,375	162,274	48,472	104,392	60,252	104,129	0
West Palm Beach, FL	43,946	43,168	10,585	35,596	18,338	42,860	7,264
York, PA	28,161	27,175	5,656	25,908	12,551	23,685	0
Yuba City, CA	9,836	9,502	1,802	9,049	4,564	8,373	0
Greater Conn. CMSA	127,499	123,427	28,255	84,149	54,441	95,064	10,915
	8,614,639	7,690,585	1,816,842	5,129,002	3,335,850	6,179,539	1,172,835

* 2000 VOC after discretionary control are applied

The reader is cautioned that MSA level results are even more uncertain than national level results

VI MITCHELL BILL ANALYSIS

S. 1894 is a bill sponsored by Sen. George Mitchell (D-ME) to amend the Clean Air Act to establish new requirements for areas that have not yet attained health-protective ambient air quality standards. The legislation would provide new deadlines for such attainment, delay the imposition of sanctions, attempt to better protect against interstate transport of pollutants, to control existing and new sources of acid deposition, and for other purposes. This bill is organized into five parts, or titles: Title I -- Requirements for Nonattainment Areas, Title II -- Acid Deposition Control, Title III -- Mobile Source and Other Federal Controls, Title IV -- Ambient Air Quality Standards, and Title V -- Hazardous Air Pollutants. The analysis reported on in this chapter covers costs and emission reductions associated with Title I and III.

An outline of the key provisions of the Mitchell bill is shown in Table VI.1. As is shown in this table, the nonattainment area (MSA/CMSA level) definition is the same in the Mitchell bill as it is in the proposed EPA policy. Significant parts of the Mitchell bill that differ from the EPA policy include more stringent motor vehicle emission standards, alternative fuels and engines to a portion of the vehicle fleet, emission fees, stationary source NO_x emission controls, and ozone transport regions (where some controls are imposed on sources in attainment areas directly upwind of nonattainment areas).

An explicit list of all the national measures and new CTGs proposed by the Mitchell bill is shown in Table VI.2. National measures are applied to sources in all areas of the country, while new CTGs are only applied in nonattainment areas. The effect of some of the national measures and new CTGs were not included in this analysis, because the base year emission inventory did not include explicit emission estimates for those source types. Those source categories are indicated on Table VI.2.

Table VI.1

Outline of Key Mitchell Bill Provisions

1. Nonattainment area definition is the same (MSA/CMSA) as in EPA policy

2. National level controls include the following:
   - A. RVP controls
   - B. Onboard control of VOC
   - C. Mobile source emission standards changes
     - -LDV Hydrocarbon (HC) to 0.25 gpm in 1992
     - -LDV NO_x to 0.4 gpm in 1990
     - -HDV NO_x to 4.0 g/bhp-hr in 1991, then to 1.7 g/bhp-hr in 1995
     - -LDT NO_x and VOC to 0.5 gpm in 1990
     - -LDTs less than 6,000 lbs are LDVs

3. Nonattainment areas in three categories

   Moderate: Attainment deadline is Dec. 31, 1992

   Requirements include the following:
   - -Enhanced I/M
   - -Gasoline vapor recovery (Stage II)
   - -RACT on all VOC and NO_x sources emitting 25 tpy or more
   - -No netting
   - -New or modified sources meet LAER
   - -Alternative fuels for fleet vehicles
   - -RACT for new CTG categories

   Serious: Attainment deadline is Dec. 31, 1997

   Requirements include the following:
   - -Moderate nonattainment area requirements plus
   - -TCMs to offset growth in mobile emissions
   - -5% per year VOC and NO_x reduction
   - -$100 per ton emission fee
   - -2:1 offsets
   - -Reduction targets of 33% by 12/91, 50% by 12/94, 65% by 12/97, and an additional 15% for each 3 year period thereafter
   - -These same reduction requirements apply to major stationary source individually

   Severe: Attainment deadline is Dec. 31, 2002

   Requirements include the following:
   - -Moderate and Serious nonattainment area requirements plus
   - -Passenger vehicle occupancy to 1.5
   - -15% of fleet to alt. fuels by 12/97
   - -40% of fleet to alt. fuels by 12/02
   - -Commercial/resid. > 1 tpy emitters install max practicable control by 12/90
   - -Emission limits for stationary engines and off-hwy vehicles as stringent as those for LDVs

4. Establishes ozone transport regions consisting of the following states:

   (A) CT, DC, DE, ME, MD, MA, NH, NJ, NY, OH, PA, RI, VT, VA

   (not all of NY and VA are included)

   (B) IL, IN, MI, WI

Table VI.2

Mitchell Bill National Measures and New CTGs

National Measures

Commercial and Consumer Solvents
Architectural Surface Coating
RVP Controls
Onboard Controls
New Mobile Source Emission Standards
Pesticide Application*
Traffic Marking Coatings*
Metal Parts Coating in Military and Aerospace Applications*

New CTGs

Wood Furniture Coating
Autobody Refinishing
Hazardous Waste Treatment, Storage, and Disposal Facilities (TSDF)
Bakeries
Publicly Owned Treatment Works (POTW)
Coke Oven By-product Plants
Metal Rolling*
SOCMI Distillation*
SOCMI Batch Process*
Web Offset Lithography*
Plastic Parts Coating*

* Effects of controls on these source categories were not included in the modeling analysis.

Table VI.3 presents a national summary of the incremental costs of the Mitchell bill, i.e., those costs above what were estimated to be incurred to comply with the proposed EPA policy. New motor vehicle emission standards are estimated to cost $1.2 billion per year more than the current set of emission standards. (Costs of VOC, NO_x, and CO control are all included in this number.) Costs to reach the attainment/progress requirements for 1995 add another $1.5 billion to the estimated 1995 cost of the bill. S. 1894 requires all moderate ozone nonattainment areas to attain by 1995. Serious and severe nonattainment areas must achieve a 55 percent emission reduction or attain, whichever is less stringent.

It should be noted that when estimating progress toward attainment or meeting interim reduction requirements of the Mitchell bill in this analysis, no emission reduction credit is given for NO_x emission reductions or for VOC emission reductions in ozone transport regions or any upwind area outside the nonattainment MSA/CMSA. Costs to attain the ozone standard may be lower if NO_x emission reductions reduce ozone production or if there is less transported ozone. Costs may be higher, however, in cases where ratios are low.

NO_x costs increase dramatically between 1995 and 2000. To simulate applying RACT to greater than 25 ton per year emitters in nonattainment areas, a moderate RACT definition has been used, so 1995 costs are not high. By the year 2000, though, severe nonattainment areas will have been required to reduce major stationary source emissions by 65 percent or more. RACT level controls will not achieve this, so SCR or a similar technology at 80 percent to 90 percent control will have to be applied to these sources. Costs to achieve NO_x reductions above 50 percent are high.

Note also that NO_x control requirements will probably produce some fuel switching. These effects have not been captured in this analysis. The cost for all areas to attain by 2000 in Mitchell (all areas are effectively required to attain by 2000 by the 5 percent per year reduction requirement) is

Table VI.3

Incremental Cost of Mitchell Bill
National Summary

	Annual Cost (billion $)*	
	1995	2000
1. RACT Level NO_x Controls	$0.40	0.40
2. SCR Level NO_x Controls in Severe Nonattainment Areas	--	2.90
3. New Motor Vehicle Standards	1.20	1.20
4. Ozone Transport Region Controls	0.61	0.77
5. Consumer Solvent Controls	0.41	0.41
6. Stage II in all NA Areas	0.29	0.32
7. Enhanced I/M in all NA Areas	0.51	0.56
8. RACT Cutoff to 25 tpy Sources	0.07	0.06
9. Alternate Fuel to Fleet Vehicles in NA Areas	0.10	0.09
10. Wood Furniture Coating and Bakery CTGs	0.02	0.02
11. Cost for all Areas to Attain or Meet 5 Percent Line	0.44 to 3.30	-0.96 to 1.43
Total	$4.05 to $6.91	$5.77 to $8.16

* Costs are those above what were estimated to be incurred to comply with the proposed EPA policy

indicated as a small negative number in Table VI.3. This does not indicate that attainment costs are small, merely that costs are not much different than those under the EPA policy, which are already high. The Mitchell bill effectively requires all sources to attain by 2000 because the bill requires a 65 percent reduction in 1997, and 5 percent per year every year thereafter. The maximum VOC emission reduction target is 67 percent.

An overall comparison of the attributes of the Mitchell bill and the EPA policy shows that the primary cost differences are for the NO_x controls, new more stringent motor vehicle emission standards, and ozone transport region controls. In the year 2000, these three Mitchell bill provisions account for almost 80 percent of the cost difference between the EPA policy and this bill. Most of the rest of the cost difference can be attributed to controls applied in moderate nonattainment areas under S. 1894, which are not shown to be necessary to enable these areas to attain in the EPA policy analysis, and represent over control. Thus, much of the additional cost of the Mitchell bill would be borne by moderate nonattainment areas.

Of the 34 moderate nonattainment areas, in 1995, only one is estimated to be nonattainment under the proposed EPA policy case and attainment with the provisions of the Mitchell bill. With this one exception, the Mitchell bill makes moderate nonattainment areas control more of their VOC emissions than are needed to reach attainment of the ozone NAAQS. In 1995, this overcontrol costs about $950 million.

The year 2000 simulation shows that under the proposed EPA policy, six moderate nonattainment areas have VOC emissions increases to the point that they need additional discretionary controls to continue meeting the standard. (Only two of these areas have the same problem under the provisions of the Mitchell bill.) About 21,000 tons of VOC would need to be reduced in the six areas for all moderate nonattainment areas to demonstrate attainment by 2000. If it is assumed that these 21,000 tons can be reduced at an average cost of $2,000 per ton, the cost to moderate nonattainment areas of overcontrolling VOC is $1 billion. Because serious and severe nonattainment areas need all available controls, plus new as yet unidentified controls in many cities, their costs are nearly the same under the Mitchell bill as they are under the EPA policy.

VII WAXMAN BILL ANALYSIS

The Waxman bill (H.R. 3054) offers amendments to the Clean Air Act that specifically address ozone and carbon monoxide nonattainment problems. This bill addresses the same areas covered by Title I and III of the Mitchell bill, i.e., new attainment deadlines, stationary source control requirements, and it proposes changes to the current motor vehicle emission standards.

An outline of the key Waxman bill provisions is shown in Table VII.1. The Waxman bill provision that differs most from the EPA policy and the Mitchell bill is the requirement for catalytic control technology on all greater than 25 ton per year emitting boilers in severe nonattainment areas by 1991 (natural gas, methanol, and ethanol fired boilers are exempted). National measures are the same as those in the Mitchell bill. There are not as many prescribed measures in Waxman as there are in Mitchell, but the attainment deadlines are shorter. Assumed new CTGs for Waxman are the same as those included in the Mitchell bill simulations listed earlier in Table VI.2.

A national summary of the incremental cost of the Waxman bill in 1995 and 2000 is shown in Table VII.2. As expected, the cost of applying catalytic controls to boilers in severe nonattainment areas is substantial -- about $2 billion. The incremental cost of new motor vehicle emission standards is $1.2 billion, the same cost estimated for S. 1894. The cost of ozone transport region controls required by the Waxman bill are $0.53 billion in 1995 and $0.60 billion by 2000. These costs are slightly lower than those for Mitchell because S. 1894 includes some Midwestern states in its ozone transport region that are not covered by Waxman.

Costs of including heavy-duty gasoline-powered vehicles in enhanced I/M programs are small in 1995 and no different from the EPA policy in 2000 because enhanced I/M is adopted as a discretionary control in serious and severe nonattainment areas under the EPA policy to meet attainment/progress requirements.

Table VII.1

Outline of Key Waxman Bill Provisions

1. Nonattainment area definition is the same (MSA/CMSA) as in EPA policy

2. National measures include the following:
   A. New motor vehicle emission standards
   B. RVP restrictions
   C. Onboard control
   D. Commercial and consumer solvent controls
   E. Architectural coatings
   F. Pesticide applications
   G. Traffic coatings
   H. Military specification coating

3. Nonattainment areas in three categories

   Moderate: Attainment deadline is 3 years after enactment
   Requirements include the following:
   - Achieve the specified percentage reduction in VOC and NO_x emissions until attainment

   Serious: Attainment deadline is 5 years after enactment
   Requirements include the following:
   - Moderate nonattainment area requirements plus
   - Enhanced I/M

   Severe: Attainment deadline is 10 years after enactment
   Requirements include the following:
   - Moderate and serious nonattainment area requirements plus
   - Alternative fuel capability in 30 percent of newly registered vehicles by 1997
   - Emission fee for greater than 25 ton per year emitters
   - Stage II vapor recovery
   - Selective catalytic reduction on all greater than 25 ton nongas fired boilers

4. Establishes ozone transport regions (Northeast Corridor)

Table VII.2

Incremental Cost of Waxman Bill
National Summary

	Annual Cost (billion $)* 1995	2000
1. Catalytic Controls on Boilers in Severe NA Areas	$2.00	$2.00
2. New Motor Vehicle Standards	1.20	1.20
3. Ozone Transport Region Controls	0.53	0.60
4. Consumer Solvent Controls	0.41	0.41
5. Stage II in Severe NA Areas	0.09	0.10
6. Enhanced I/M on HDGV in Serious and Severe Nonattainment Areas	0.03	--
7. Wood Furniture Coating and Bakery CTGs	--	0.02
8. Cost for Moderate and Serious Areas to Attain and Severe Areas to Reach 60 Percent of Reduction Toward Attainment (at $2,000 to $10,000 per ton)	-0.68 to -1.32	--
9. Cost to Bring All Areas into Attainment (at $2,000 to $10,000 per ton)	--	-2.23 to 1.33
Total	$3.58 to $2.94	$2.10 to $5.66

* Costs are those above what were estimated to be incurred to comply with the proposed EPA policy

The base motor vehicle costs under the Waxman bill (before residual tons are costed) are lower than those of Mitchell and the EPA policy because of the way alternative fuel costs are estimated. The Mitchell bill says that by December 31, 1997, not less than 15 percent, and by December 31, 2002, not less than 40 percent of the total registered motor vehicle fleet shall have been converted to alternative fuels or power sources in severe nonattainment areas. The Waxman bill, though, requires that low emission vehicles constitute at least 30 percent of new motor vehicles registered by 1997. Therefore, for the year 2000 simulations, it was estimated that 30 percent of the vehicle fleet would be methanol fueled under the Mitchell bill provisions, but only 11 percent would be methanol fueled under the Waxman bill provisions. Thus, the explicit provisions of the Waxman bill cost less and remove less VOC than the explicit provisions of the Mitchell bill. EPA policy costs for alternative fuels are higher than those of the Waxman bill because the discretionary controls applied to serious and severe ozone nonattainment areas assume 30 percent methanol fuel penetration into the vehicle fleet by 2000.

VIII GROUP OF NINE PROPOSAL ANALYSIS

Nine Democratic members of the House Committee on Energy and Commerce developed a proposal that addresses both ozone and CO nonattainment problems. This approach has come to be known as the Group of Nine Proposal. This proposal starts by recognizing that nonattainment, particularly for ozone, is a long-term problem that will take more than a decade to solve in some areas, and that emission reductions from many different source types will be needed to achieve attainment.

Table VIII.1 outlines the key Group of Nine Proposal provisions from a cost and emissions reduction perspective. National level consumer solvent controls called for are different from those in other bills. A 25 percent reduction by 1995 and a 50 percent reduction by 2000 are stipulated. It was assumed in this analysis that these reductions are from 1985 emission levels, so with growth included, actual emission reductions in 1995 and 2000 are greater than 25 and 50 percent. Motor vehicle emission standard changes proposed by the Group of Nine are somewhat different than those provided for in the Waxman and Mitchell bills, so they are delineated in Table VIII.2. Note also that the Group of Nine proposal does not include the heavy-duty vehicle emission standard changes required by the other bills.

In the Group of Nine Proposal, nonattainment areas are categorized according to the degree to which they exceed the air quality standard. There are four categories for ozone and three for CO. Group of Nine Proposal ozone nonattainment categories, design values, and attainment deadlines are shown in Table VIII.3.

The Group of Nine Proposal calls for new CTGs for 11 source categories. These new CTGs would be applied in all nonattainment areas except the Moderate I class. Other more stringent measures to be applied in moderate, serious, and severe nonattainment areas are as outlined in Table VIII.1.

National level results of the Group of Nine Proposal simulations are shown in Table VIII.4. Proposal provisions with an estimated cost of more than $1 billion include new motor

Table VIII.1

Outline of Group of Nine Proposal Provisions

1. Nonattainment area definition is the same (MSA/CMSA) as in EPA policy

2. National level measures include the following:
   A. RVP controls
   B. Onboard control of VOC
   C. Consumer solvent controls
      - 25% reduction in VOC by 1995
      - 50% reduction in VOC by 2000
   D. Mobile source emission standard changes
      - same as Waxman and Mitchell Standards except this proposal does not include HDV Standard changes

3. Nonattainment area controls
   A. New CTGs for 7 source categories
      - SOCMI distillation
      - Auto body refinishing
      - Landfills
      - Industrial wastewater
      - Clean-up solvents - industrial
      - SOCMI batch process
      - Marine vessels - loading and unloading
      - Hazardous Waste TSDFs
      - Wood Furniture Coating
      - Bakeries
      - Coke Oven By-product Plants

4. Nonattainment areas in 4 categories

   Area 2: Moderate I: Attainment deadline is 3 years after enactment

   Requirements include continuing to apply current regulations as long as attainment deadline is met, but new CTGs are not applied in these areas

   Area 3: Moderate II: Attainment by 12/31/95
   Requirements include the following:
   - RACT applied to all VOC sources
   - CTGs applied to all 50 tpy or larger sources
   - Basic I/M

   Area 4: Serious: Attainment by 12/31/97
   Requirements include the following:
   - RACT applied to all VOC and NO_x sources (exemption for NO_x allowed)
   - CTGs applied to all 50 tpy or larger sources
   - Enhanced I/M
   - Stage II for large volume gas stations
   - Alternative fuels program (fleet vehicles only) or TCMs

   Area 5: Severe: Attainment by 12/31/2005
   Requirements include the following:
   - same as Area 4 plus
   - each VOC emitter of 25 tpy or more must reduce emissions by 6% every 3 years or pay $2,000 per ton emitted

Table VIII.2

Group of Nine Proposal
Motor Vehicle Emission Standards

Vehicle Type	Start Model Year	HC (gm/mile)	NO_x (gm/mile)
Light-Duty Gas	1993*	0.25	0.7
Light-Duty Truck	1993*	0.50	0.8

* New motor vehicle emission standards are phased in starting with the 1993 model year. Each manufacturer must have 30 percent of 1993 model year vehicles, 60 percent of 1994 model year vehicles, and 90 percent of 1995 or newer model year vehicles meeting the listed standards.

Table VIII.3

Group of Nine Proposal
Attainment/Nonattainment Categories

Ozone Nonattainment Categories	Design Value (ppm)	Attainment
Moderate I	.13	1992
Moderate II	0.14, 0.15	1995
Serious	0.16, 0.17, 0.18	1997
Severe	≥ 0.19	2005

Table VIII.4

Incremental Cost of Group of Nine Proposal
National Summary

		Annual Cost (billion $)*	
		1995	2000
1.	New Motor Vehicle Standards	$1.04	$1.16
2.	Consumer Solvent Controls	1.21	2.09
3.	Savings from not having TSDF and POTW Controls in Moderate I Areas	-0.15	-0.15
4.	Lost Savings for not Having Autobody Refinishing in Moderate I Nonattainment Areas	0.07	0.08
5.	Industrial Clean-up Solvent CTG	0.04	0.02
6.	Additional I/M Cost	0.12	0.14
7.	RACT to 50 tpy	0.03	0.03
8.	Stage II in Serious and Severe Nonattainment Areas	0.19	0.21
9.	$2,000/ton Emission Fee for > 25 tpy Sources in Severe Nonattainment Areas	0.15	0.15
10.	Alternate Fuel to Fleet Vehicles in Serious and Severe Nonattainment Areas	0.01	-0.04
11.	Attainment/Progress Requirements	-1.13 to -5.04	-4.13 to -7.23
	Total	$1.59 to $-2.34	$-0.44 to $-3.54

* Costs are those above what were estimated to be incurred to comply with the proposed EPA policy.

vehicle emission standards and consumer solvent controls. Meeting attainment and progress requirements of the Group of Nine Proposal is less costly than meeting those of the proposed EPA policy because the attainment schedule is not as strict and because the simulation allows a higher level of consumer solvent controls in the Group of Nine Proposal modeling than it does under the EPA policy. EPA policy simulations limit consumer solvent controls to a 20 percent emissions reduction. This forces MSAs to adopt controls that are more expensive than $2,000 per ton (the cost of consumer solvent reductions) to meet progress requirements or attain. Thus, estimates of costs to be incurred under the Group of Nine Proposal may be biased downward relative to EPA policy or Mitchell or Waxman bill costs.

The EPA policy case used a 20 percent VOC emission reduction assumption because it was judged to be realistic and potentially achievable in the time horizon of the emission projections in this study.

IX SUMMARY OF RESULTS

A. OZONE NONATTAINMENT

Previous chapters have presented results separately for the proposed EPA policy, the Mitchell bill, the Waxman bill, and the Group of Nine Proposal. This chapter summarizes the results for the analyses of all the policies and bills. Because attainment/progress requirements affect emission reductions and costs of the policies/bills, those requirements are summarized first in Table IX.1. Note that while the Mitchell bill does not require areas with ozone design values above 0.27 ppm to attain by 2000, the yearly percentage reduction requirements of that bill effectively force all areas to attain by then.

Figure IX.1 shows how the estimated ozone precursor control costs differ among the EPA policy and the alternative Congressional bills and proposals. Both 1995 and 2000 cost estimates are shown. Expected additional ozone control cost expenditures under the pre-1988 EPA policy are delineated in the figure as part of the total EPA policy cost. While estimates of the total costs of the EPA policy and the alternative Congressional bills/proposals are presented, Figure IX.1 is most useful for showing the relative costs of the different control approaches. The total costs should be used with caution because they do not include the historical costs of VOC control such as Federal Motor Vehicle Control Program costs.

While Figure IX.1 shows the Group of Nine costs to be lower in 2000 than the expected EPA policy costs, this lower value depends on high levels of consumer solvent VOC emissions control in 2000 at $2,000 per ton. The consumer solvent control level is limited in the other simulations. This issue is discussed more fully in Chapter VIII.

When costs of the different policies/bills are compared, so should the number of remaining ozone nonattainment areas. Table IX.2 presents ERCAM-VOC estimates of residual nonattainment areas in 1995 and 2000. Thus, of the three legislative approaches, the lower costs of the Group of Nine Proposal must be balanced

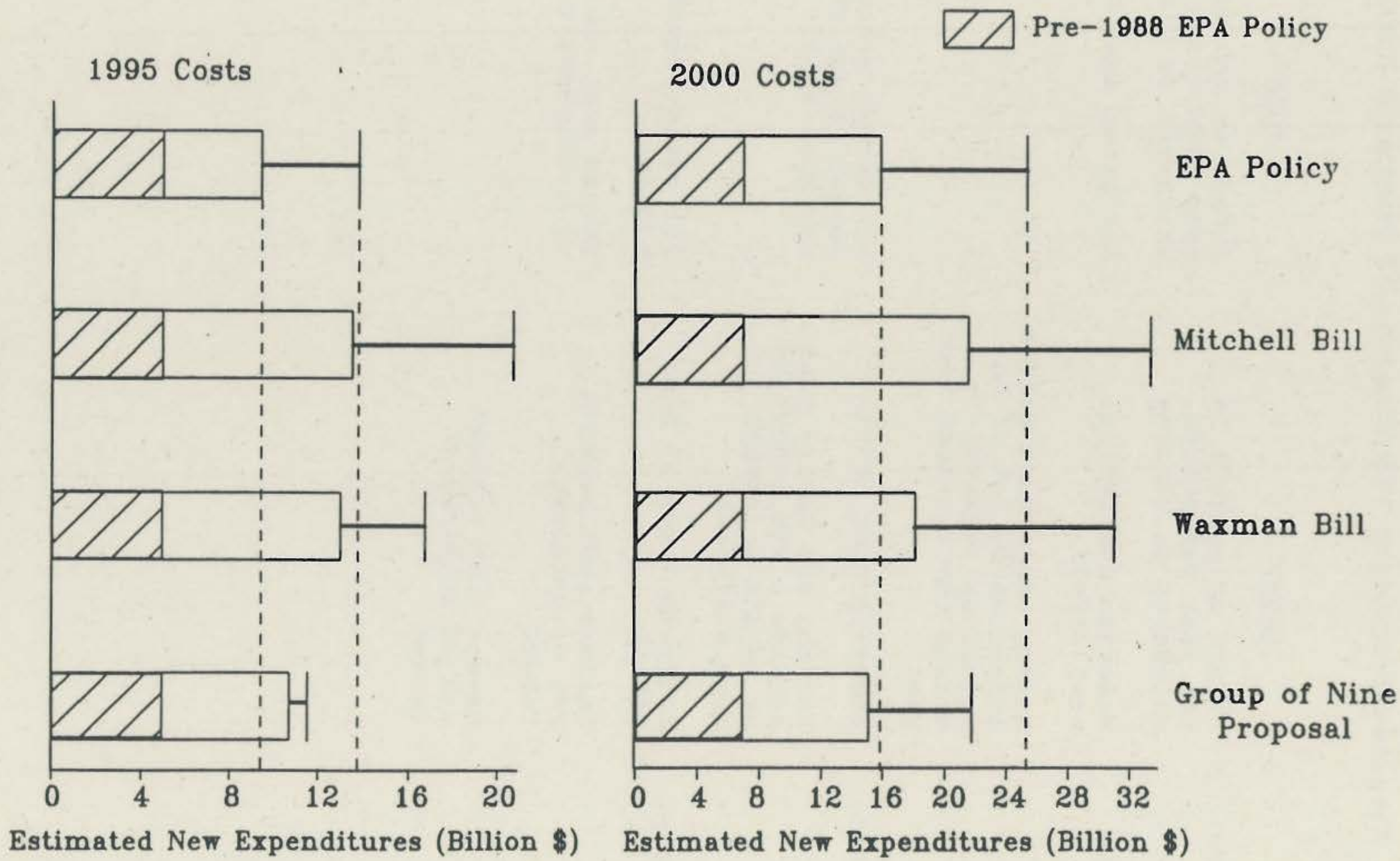
Table IX.1

Attainment/Progress Requirements of Proposals Analyzed

	1995	2000
EPA Policy	Attain or achieve 3% per year reductions, whichever is binding	Attain or achieve 3% per year reductions, whichever is binding
Waxman	Moderate and Serious must attain	All areas must attain
	Severe areas must reduce emissions by 10% of the reduction required to attain the standard each year	
Mitchell	Moderate must attain	All except areas with design values above 0.27 ppm must attain
	Serious and Severe must achieve a 55% reduction or attain whichever is less stringent	
Group of Nine	Moderate I and II must attain	All except Severe must attain
	Serious must achieve 78% of attainment target	Severe must achieve 71% of attainment target
	Severe must achieve 41% of attainment target	

Figure IX.1

Ozone Nonattainment Control Cost Summary



Ranges reflect costs of controlling residual tons using a range of $2,000 to $10,000 per ton.

Serious & Severe

Table IX.2

Residual Ozone Nonattainment Areas by Projection Year*

EPA Policy	Mitchell Bill	Waxman Bill	Group of Nine Proposal
1995			
Chicago	Chicago	Chicago	Massachusetts √
Houston	Houston	Houston	√Chicago
Los Angeles	Los Angeles	Los Angeles	~~Cincinnati~~
Milwaukee	New York	New York	Dallas √
New York	San Diego	Philadelphia	~~El Paso~~
San Diego		San Diego	~~Fresno~~
San Francisco		Greater Conn.	√Houston
			√Los Angeles
			√Milwaukee
			~~Modesto~~
			√New York
			√Philadelphia
			Phoenix √
			Sacramento √
			√San Diego
			San Francisco √
			~~Santa Barbara~~
			√Greater Conn. (Hartford)
			√Baltimore
2000			
Los Angeles			Chicago
New York			Houston
			Los Angeles
			New York
			San Diego
			San Francisco
			Greater Conn.

√ = alt. fuels bases

*Emission reduction targets have been estimated for each urban area using EKMA. Uncertainties in estimating how much emission reduction is needed to bring an area into attainment affect the results presented here.

against the longer list of expected nonattainment areas. Note also that the Table IX.2 list of residual nonattainment areas represents what the policies/bills require and is not an expectation of when specific areas might attain the ozone standard.

Table IX.3 shows how VOC control costs are distributed between new and existing sources for 1995 and 2000 for each of the four alternatives studied. In all cases, new source costs are higher than those for existing sources. New source costs increase in the year 2000 because of growth. Existing source costs increase between 1995 and 2000 only for the Group of Nine Proposal. This occurs because the Group of Nine Proposal calls for 50 percent reductions in consumer solvent emissions by 2000 while the 1995 emission reduction requirement for this source category was only 25 percent.

The difference between costs for new and existing sources is highest for the EPA policy, with new source costs almost three times higher than existing source costs in 1995 and four times higher in 2000. For the Congressional alternatives, new source costs are roughly twice existing source costs in 1995 and two to three times existing source costs in 2000.

Unless existing source regulations are made more stringent in the future, new source costs will almost always be higher than existing source costs because costs of existing source controls are only estimated for sources which have to install additional controls to meet regulatory requirements in future years. Thus, if all existing sources in a category are controlled to 90 percent efficiency, and any regulations expected to affect this category require no more than 90 percent control, there will be no control costs estimated for existing sources. Costs are estimated for all new source emissions affected by a regulation.

While the above may lead to concern that new source costs are overstated, this is not necessarily so. Because NSPS Background Information Documents are used to develop cost equations for many point source categories, and recovery credits are taken into account in these equations, it is unlikely that

Table IX.3

New Versus Existing Stationary Source Costs*
(billion $)

	1995		2000	
	Existing Source Control Costs	New Source Control Costs	Existing Source Control Costs	New Source Control Costs
EPA Policy	1.48	4.12	1.48	5.77
Mitchell Bill	2.47	4.38	2.47	6.14
Waxman Bill	2.12	4.33	2.12	6.07
Group of Nine Proposal	3.03	4.59	3.56	6.69

* Includes costs for current policy requirements

costs are overstated for these categories. Problems are more likely to occur for the miscellaneous point source category, where cost equations have not been developed for specific combinations of source type and control equipment. For miscellaneous point sources, a generic cost per ton value is applied to estimate new source control costs. For industries not well represented by this generic cost, costs will be in error.

Cost equations were not developed for the many source types categorized as miscellaneous point sources because in some cases there are so few plants of that type that it is impossible to specify a general relationship between controls and costs. Each individual facility may be of a design different to such a degree that the control techniques applied differ from plant to plant.

As a general rule, it is important to look closely at analysis results to see why emission projections and costs differ. If differences occur largely for categories where results are very sensitive to analysis assumptions, and not that much is known about controls and costs for those categories, then actual differences may not be as great as the analysis shows.

Tables IX.4 and IX.5 show total ozone precursor and CO control costs for each alternative by CMSA for 1995 and 2000, respectively. Note that only CO control costs are reported for CMSAs which are in attainment with the ozone standard but not in attainment with the CO standard. Many areas have cost ranges reported. This is due to the costing of residual tons necessary to meet ozone attainment/progress requirements. A range of $2,000 to $10,000 per ton reduced was used to estimate these costs.

Tables IX.6 and IX.7 contain the same information given by state. Attainment/progress requirement costs for CMSA's crossing state boundaries were apportioned among the states according to county population (U.S. Bureau of the Census, 1985). The state level costs include costs for both ozone precursors and CO for all areas within the state, both attainment and nonattainment.

Table IX.4

Ozone and CO Nonattainment Control Cost Summary by CMSA

CMSA	1995 Cost (million$)			
	EPA Policy	Mitchell Bill	Waxman Bill	Group of Nine Proposal
Albuquerque, NM*	9.6	10.0	9.6	10.0
Allentown-Bethlehem, PA-NJ	15.8	35.7	27.8	22.5
Anchorage, AK*	1.1	1.3	1.1	1.3
Atlanta, GA	151.5	187.1	172.7	198.8
Atlantic City, NJ	8.2-19.3	14.1-27.3	12.5-27.0	11.2-11.7
Bakersfield, CA	25.6	45.8	29.0	33.4
Baltimore, MD	89.6	129.5	119.5	132.2
Baton Rouge, LA	97.1	109.5	101.3	107.7
Beaumont, TX	111.3	139.1	114.3	122.3
Birmingham, AL	22.2	58.6	29.2	27.3
Boise City, ID*	1.0	1.2	1.0	1.1
Bradenton, FL	2.1	8.2	3.4	4.1-9.7
Charleston, WV	35.5	50.6	37.3	37.3
Charlotte-Gastonia, NC-SC	38.8	69.3	57.6	51.1-51.7
Chattanooga, TN-GA	16.1	33.4	19.6	23.0-34.7
Chicago CMSA	403.4-712.0	629.1-1,265.1	982.0	527.1
Chico, CA*	0.0	0.1	0.0	0.0
Cincinnati CMSA	70.9	102.5-102.6	85.8-86.3	103.2
Cleveland CMSA	81.9	155.6	106.9	133.8
Colorado Springs, CO*	0.0	1.9	1.8	0.0
Dallas CMSA	260.4-554.2	335.7-677.8	313.7-693.6	290.0-396.5
Davenport-Rock Island, IA-IL*	0.0	0.0	0.0	0.0
Dayton-Springfield, OH	24.6	60.3	33.0	34.8
Denver CMSA	31.4	63.8	46.9	45.8
Des Moines, IA*	0.0	0.0	0.0	0.0
Detroit CMSA	212.8	323.8	251.1	250.2
Dubuque, IA*	0.0	0.0	0.0	0.0
El Paso, TX	16.9	25.5-28.2	23.5-33.2	25.4
Erie, PA	4.0	15.2	13.9	6.9
Fort Collins, CO*	0.9	1.1	0.9	1.0

Table IX.4

Ozone and CO Nonattainment Control Cost Summary by CMSA

CMSA	1995 Cost (million$)			
	EPA Policy	Mitchell Bill	Waxman Bill	Group of Nine Proposal
Fresno, CA	45.2-93.7	54.2-106.0	51.4-107.5	46.9-67.6
Gadsden, AL	3.1	7.5	3.8	3.5
Grand Rapids, MI	28.5	54.4	35.0	42.0-58.6
Greater Connecticut CMSA	47.8-88.4	90.3-143.4	165.5	80.7
Greeley, CO*	2.8	3.0	2.9	2.9
Greensborough, NC*	0.1	0.4	0.1	0.1
Harrisburg-Lebanon, PA	4.3	25.3	23.9	8.4
Houston CMSA	763.8-1,532.4	902.5-1,666.0	855.8-1,285.3	693.5
Huntington-Ashland, WV-KY-OH	36.8	51.5	39.2	46.4
Indianapolis, IN	91.1	137.3	101.0	100.4
Jacksonville, FL	10.2	43.4	16.4	32.6
Janesville-Beloit, WI	32.7	38.4	33.9	34.2
Kansas City, MO-KS	88.3	146.6	132.5	157.1
Lake Charles, LA	16.2	21.2	17.5	18.3
Las Vegas, NV*	2.8	3.9	3.5	3.2
Lexington, KY*	0.0	0.1	0.0	0.0
Longview, TX	25.4	32.5	26.8	27.0
Los Angeles CMSA	471.6-1,290.0	907.6-2,687.2	909.0-1,922.5	508.5
Louisville, KY-IN	43.8	62.9	52.2	51.3
Manchester, NH*	1.5	0.3	0.0	1.8
Massachusetts	378.6-803.7	504.1-980.8	513.2-1,042.8	456.4-663.7
Medford, OR*	0.8	1.1	0.8	0.9
Memphis, TN	23.1-23.3	37.7-38.4	31.5-32.5	34.8-53.2
Miami CMSA	35.2	139.6	57.7	115.8
Milwaukee CMSA	62.6-146.3	98.3-211.1	89.7-221.8	79.1-98.9
Minneapolis-St. Paul, MN-WI	110.5	153.9	137.6	183.1
Modesto, CA	13.1-22.2	17.9-29.4	16.7-30.3	16.3
Muskegon, MI	9.0	17.3	10.4	13.7
Nashville, TN	41.4	69.4	49.0	59.9
New York CMSA	368.8-398.6	674.4-748.4	1,170.6-1,200.6	702.3

Table IX.4

Ozone and CO Nonattainment Control Cost Summary by CMSA

CMSA	1995 Cost (million$) EPA Policy	Mitchell Bill	Waxman Bill	Group of Nine Proposal
Norfolk, VA	34.1	79.5	76.2	69.1
Oklahoma City, OK*	0.0	5.3	5.1	0.0
Peoria, IL*	0.0	0.4	7.9	6.0
Philadelphia CMSA	256.6-263.5	354.7-364.1	582.8	377.7
Phoenix, AZ	69.6-198.9	103.0-255.2	94.1-259.2	89.0-152.0
Pittsburgh CMSA	34.0	86.6	78.8	45.8
Portland CMSA	18.7	49.0	36.1	28.6
Providence, RI	24.7-34.6	40.7-55.7	39.6-61.7	36.9-57.6
Provo, UT*	1.2	1.8	1.9	1.4
Raleigh-Durham, NC*	3.2	3.8	3.2	3.6
Reading, PA	7.9	20.3	19.3	11.3
Reno, NV*	1.1	1.3	1.1	1.3
Richmond-Petersburg, VA	83.4	115.3	110.5	88.5
Rockford, IL*	0.0	0.0	0.0	0.0
Sacramento, CA	55.5-153.6	75.7-179.9	70.1-187.9	59.0-85.8
Salem, OR*	0.0	0.1	0.0	0.0
Salt Lake City, UT	22.0	38.0	30.8	29.8-30.0
San Diego, CA	98.5-290.6	148.9-421.2	103.7-188.7	89.6
San Francisco CMSA	262.2-664.8	423.4-1,122.9	386.5-510.7	261.6
Santa Barbara, CA	18.7-39.9	25.4-52.0	23.7-53.7	21.1-26.8
Seattle, WA*	0.2	23.9	20.1	8.5
Sheboygan, WI	5.8-15.4	8.7-20.1	7.9-21.9	7.1-12.0
Spokane, WA*	0.0	33.6	1.9	0.0
Steubenville, OH-WV*	0.0	25.0	3.4	2.6
Stockton, CA	12.4	18.3	15.6	14.9
St. Cloud, MN*	0.0	4.0	3.7	2.8
St. Louis, MO-IL	136.5	181.9	157.6	182.5
Tampa-St. Petersburg, FL	19.6	91.3	34.3	30.8
Toledo, OH*	0.0	0.1	0.0	0.0
Tucson, AZ*	0.0	3.1	3.0	0.0

Table [illegible]

[illegible] Cost Summary by CMSA

[illegible]	[illegible]	[illegible] Bill	Waxman Bill	Group of Nine Proposal
			[illegible] Cost (million$)	
[illegible]	[illegible]	[illegible]	33.6	32.8
[illegible]	[illegible]	[illegible]	4.9	4.3
[illegible]	[illegible]	[illegible]	104.1	117.7
[illegible]	[illegible]	[illegible]	14.2-25.0	25.6-26.2
[illegible]	[illegible]	[illegible]	3.9	4.0
[illegible]	[illegible]	[illegible]	11.1	7.6
[illegible]	[illegible]	[illegible]	1.9	1.4

[illegible] costs unless otherwise noted. [illegible] requirements at $2,000 [illegible]

[illegible] of the ozone standard. Costs reported for [illegible]

Table IX.5

Ozone and CO Nonattainment Control Cost Summary by CMSA

CMSA	2000 Cost (million$)			
	EPA Policy	Mitchell Bill	Waxman Bill	Group of Nine Proposal
Albuquerque, NM*	9.6	10.0	9.6	10.0
Allentown-Bethlehem, PA-NJ	18.8	39.7	28.6	28.5
Anchorage, AK*	1.1	1.3	1.1	1.3
Atlanta, GA	178.3	221.0-238.2	209.8-245.7	240.7
Atlantic City, NJ	11.4-30.0	18.4-41.5	15.3-39.9	18.7-38.0
Bakersfield, CA	29.5	51.3-55.8	36.7-51.0	40.1-43.6
Baltimore, MD	111.2	152.8	135.4-146.6	164.3
Baton Rouge, LA	126.9	139.8	132.5-138.0	139.6
Beaumont, TX	140.9	169.0	144.0	153.4
Birmingham, AL	25.5	65.0	32.8	33.6
Boise City, ID*	1.0	1.2	1.0	1.1
Bradenton, FL	3.6-8.0	9.2	4.2-5.3	7.6-23.4
Charleston, WV	42.1	58.1	44.0	44.5
Charlotte-Gastonia, NC-SC	51.6-75.1	77.8	65.0	80.8-149.4
Chattanooga, TN-GA	21.7-32.5	39.1-43.8	24.9-34.2	40.1-101.6
Chicago CMSA	561.4-1,347.0	1,602.5-2,456.6	1,360.5-2,296.7	643.6-782.7
Chico, CA*	0.0	0.1	0.0	0.0
Cincinnati CMSA	79.7-80.1	110.9-111.9	95.3-96.7	125.2-143.8
Cleveland CMSA	92.9	165.4	118.6	159.8
Colorado Springs, CO*	0.0	1.9	1.8	0.0
Dallas CMSA	330.7-750.6	418.8-929.2	396.5-945.3	434.3-869.9
Davenport-Rock Island, IA-IL*	0.0	0.0	0.0	0.0
Dayton-Springfield, OH	26.7	65.6	35.4	41.6
Denver CMSA	38.4	74.4	54.8	61.3
Des Moines, IA*	0.0	0.0	0.0	0.0
Detroit CMSA	243.1	347.4	282.3	299.1
Dubuque, IA*	0.0	0.0	0.0	0.0
El Paso, TX	21.1-28.2	31.8-48.3	29.5-53.1	33.3-45.7
Erie, PA	4.4	16.5	13.9	8.6
Fort Collins, CO*	0.9	1.1	0.9	1.0

Table IX.5

Ozone and CO Nonattainment Control Cost Summary by CMSA

CMSA	2000 Cost (million$) EPA Policy	Mitchell Bill	Waxman Bill	Group of Nine Proposal
Fresno, CA	60.9-125.1	72.0-146.0	69.0-147.3	72.9-141.2
Gadsden, AL	3.3	8.1	4.1	4.1
Grand Rapids, MI	38.8-50.6	64.1	42.8	58.3-91.4
Greater Connecticut CMSA	68.2-155.5	273.4-371.7	224.2-347.8	102.7
Greeley, CO*	2.8	3.0	2.9	2.9
Greensborough, NC*	0.1	0.4	0.1	0.1
Harrisburg-Lebanon, PA	4.9	27.9	23.8	11.2
Houston CMSA	1,095.1-2,403.2	2,117.5-3,475.1	1,373.0-2,892.9	1,108.9-1,909.9
Huntington-Ashland, WV-KY-OH	45.8	60.7	48.2	57.0
Indianapolis, IN	105.1	155.4	115.5	119.4
Jacksonville, FL	16.7-36.3	47.8	19.7-25.6	39.2
Janesville-Beloit, WI	36.0	42.2	37.3	38.2
Kansas City, MO-KS	96.4	157.8	141.0	175.3
Lake Charles, LA	19.4	24.7	20.7	22.0
Las Vegas, NV*	2.8	3.9	3.5	3.2
Lexington, KY*	0.0	0.1	0.0	0.0
Longview, TX	32.4	39.7	34.2-35.3	34.6
Los Angeles CMSA	824.7-2,806.7	1,708.1-3,374.0	1,677.3-4,871.8	1,040.3-2,620.3
Louisville, KY-IN	50.0	69.2	58.8-59.1	61.2
Manchester, NH*	1.5	0.3	0.0	1.8
Massachusetts	513.5-1,179.7	660.3-1,431.5	641.6-1,466.8	681.2-1,311.2
Medford, OR*	0.8	1.1	0.8	0.9
Memphis, TN	26.8-28.5	42.5-45.2	35.6-38.6	48.2-91.9
Miami CMSA	41.9	156.5	65.6	141.4
Milwaukee CMSA	82.3-213.2	123.5-275.4	110.5-282.8	122.2-246.9
Minneapolis-St. Paul, MN-WI	124.1	169.5	152.2	208.6
Modesto, CA	16.5-33.8	22.5-45.2	21.0-45.9	23.8-41.5
Muskegon, MI	9.6	18.4	10.9	15.3
Nashville, TN	48.8	78.4	56.7	72.1
New York CMSA	467.2-555.0	1,931.9-2,057.4	1,440.1-1,574.3	1,161.5-2,305.3

Table IX.5

Ozone and CO Nonattainment Control Cost Summary by CMSA

CMSA	2000 Cost (million$) EPA Policy	Mitchell Bill	Waxman Bill	Group of Nine Proposal
Norfolk, VA	38.6	88.3	79.2	81.1
Oklahoma City, OK*	0.0	5.3	5.1	0.0
Peoria, IL*	0.0	0.4	7.9	6.0
Philadelphia CMSA	318.9-332.3	879.7-895.4	700.5-721.3	465.6
Phoenix, AZ	96.5-301.2	138.4-388.9	128.1-391.7	147.7-362.6
Pittsburgh CMSA	40.7	93.5	78.2	59.2
Portland CMSA	23.1	55.8	41.1	45.3-71.0
Providence, RI	34.6-64.9	53.3-96.0	48.3-98.3	49.6-82.9
Provo, UT*	1.2	1.8	1.9	1.4
Raleigh-Durham, NC*	3.2	3.8	3.2	3.6
Reading, PA	8.6	22.1	19.6	13.7
Reno, NV*	1.1	1.3	1.1	1.3
Richmond-Petersburg, VA	115.7	150.3	141.8	123.7
Rockford, IL*	0.0	0.0	0.0	0.0
Sacramento, CA	67.4-189.4	92.8-237.2	86.4-244.5	96.7-229.9
Salem, OR*	0.0	0.1	0.0	0.0
Salt Lake City, UT	27.1	49.5-70.8	44.6-77.3	46.3-73.7
San Diego, CA	147.4-492.3	262.2-618.4	217.2-603.4	156.7-336.4
San Francisco CMSA	385.2-1,173.8	875.9-1,708.8	684.5-1,598.3	404.6-742.0
Santa Barbara, CA	24.1-57.0	32.1-74.0	30.2-75.5	33.2-70.1
Seattle, WA*	0.2	23.9	20.1	8.5
Sheboygan, WI	7.4-21.9	10.2-25.4	9.5-27.3	10.5-23.6
Spokane, WA*	0.0	33.6	1.9	0.0
Steubenville, OH-WV*	0.0	25.0	3.4	2.6
Stockton, CA	13.9	20.1	17.2	17.7
St. Cloud, MN*	0.0	4.0	3.7	2.8
St. Louis, MO-IL	152.8	198.3	175.4-178.2	210.9
Tampa-St. Petersburg, FL	23.9	102.3	39.3	48.7-72.6
Toledo, OH*	0.0	0.1	0.0	0.0
Tucson, AZ*	0.0	3.1	3.0	0.0

Table IX.5

Ozone and CO Nonattainment Control Cost Summary by CMSA

CMSA	2000 Cost (million$) EPA Policy	Mitchell Bill	Waxman Bill	Group of Nine Proposal
Tulsa, OK	33.0	44.4	39.4	41.2
Visalia-Tulare-Porterville, CA	3.1	13.3	5.2	5.4
Washington, DC	76.1	123.9-133.0	106.8-119.3	147.2-163.3
West Palm Beach, FL	21.9-80.0	45.2-73.0	24.3-68.7	37.8-62.1
Yakima, WA*	3.9	4.2	3.9	4.0
York, PA	3.6	22.1	10.7	10.4
Yuba City, CA	1.2	5.3	2.0	1.9-2.1

Note: Costs include both ozone precursor (VOC and NOx) and CO control costs unless otherwise noted. Control of residual tons necessary to meet attainment/progress requirements at $2,000 to $10,000 per ton produces a cost range for some areas.

* Indicates CO nonattainment area which is in attainment of the ozone standard. Costs reported for these areas include only the CO control costs.

Table IX.6

Ozone and CO Nonattainment Control Cost Summary by State

State	1995 Cost (million$)			
	EPA Policy	Mitchell Bill	Waxman Bill	Group of Nine Proposal
Alabama	176.6	241.1	207.3	212.8
Alaska	5.5	9.3	8.8	9.6
Arizona	74.6-203.9	120.8-273.0	111.6-276.7	106.3-169.4
Arkansas	27.2-27.3	48.0-48.7	46.6-47.6	53.9-54.9
California	1,013.3-2,603.7	1,754.2-4,699.7	1,631.8-3,071.7	1,207.3-1,773.0
Colorado	41.6	86.7	69.0	68.9
Connecticut	70.9-141.4	143.7-270.8	247.8-277.8	118.9
Delaware	52.4-59.2	68.7-78.1	107.8	62.1
Washington, D.C	11.6	15.3	19.2	20.2
Florida	91.0-112.3	364.3	173.1-183.9	290.1-387.8
Georgia	170.0	236.7	218.7	254.8-257.5
Hawaii	1.9	8.9	8.9	10.5
Idaho	3.7	11.4	10.8	12.9
Illinois	523.3-831.9	856.6-1,492.6	899.9	736.2-976.3
Indiana	295.8-323.1	546.4-602.8	506.9-507.4	368.9-390.1
Iowa	9.3	31.2	31.1	37.7
Kansas	43.6	79.8	74.3	87.9
Kentucky	101.1	145.8-146.5	130.1-133.5	138.5
Louisiana	209.4	253.1	240.8	254.2
Maine	5.9	42.7	46.8	17.8
Maryland	123.3-124.3	207.6-209.1	190.1	196.5
Massachusetts	378.9-803.9	506.2-982.8	514.3-1,043.9	458.6-673.6
Michigan	268.0	527.5	344.3	364.8-380.0
Minnesota	140.2	202.5	185.0	232.7
Mississippi	24.4-24.5	45.3-46.1	44.5-45.6	50.8-51.9
Missouri	198.2	288.9	259.5	301.0
Montana	3.3	9.3	8.8	10.0
Nebraska	4.2	16.0	15.9	19.3

Table IX.6

Ozone and CO Nonattainment Control Cost Summary by State

State	1995 Cost (million$)			
	EPA Policy	Mitchell Bill	Waxman Bill	Group of Nine Proposal
Nevada	8.8	17.0	16.3	18.1
New Hampshire	21.3	47.3	50.5	34.6
New Jersey	341.7-579.6	555.8-1,101.9	610.2-826.0	452.0-452.7
New Mexico	14.8	25.2	24.3	26.6
New York	380.7-786.2	787.7-1,793.4	1,170.8-1,579.1	537.9
North Carolina	149.5	221.3	208.0	219.7
North Dakota	1.5	6.0	6.0	6.8
Ohio	217.9	407.7-411.0	316.6-334.0	377.2-388.3
Oklahoma	56.7	90.9	85.9	84.6
Oregon	76.2	111.8	103.2	99.2
Pennsylvania	220.1-283.0	534.0-620.8	630.6	355.2
Rhode Island	25.6-35.6	43.1-58.1	42.5-64.6	38.8-59.9
South Carolina	38.1	69.0	67.1	76.0
South Dakota	2.7	7.6	7.5	8.6
Tennessee	219.7-221.9	299.4-311.2	262.3-279.1	283.0-308.0
Texas	2,223.1-3,285.6	2,538.3-3,646.6	2,436.5-3,255.7	2,277.1-2,385.1
Utah	32.2	53.2	46.0	45.5
Vermont	1.1	18.5	20.3	7.2
Virginia	166.1	318.9	365.1	251.4
Washington	87.0	184.2	141.3	137.3
West Virginia	122.3	178.9	137.2	142.8
Wisconsin	123.0-221.5	277.1-411.9	241.8-387.9	177.1-206.6
Wyoming	2.5	5.9	5.8	6.2

Note: Costs include both ozone precursor (VOC and NOx) and CO control costs. Control of residual tons necessary to meet attainment/progress requirements at $2,000 to $10,000 per ton produces a cost range for some areas.

Table IX.7

Ozone and CO Nonattainment Control Cost Summary by State

State	2000 Cost (million$)			
	EPA Policy	Mitchell Bill	Waxman Bill	Group of Nine Proposal
Alabama	244.3	313.1	276.1	296.5
Alaska	6.0	9.9	9.4	11.6
Arizona	103.0-307.7	158.2-408.7	147.6-411.2	133.9-197.1
Arkansas	37.9-39.6	59.7-62.4	58.2-61.2	76.2-77.2
California	1,582.1-4,934.1	3,214.1-6,356.5	2,867.9-7,683.3	1,475.1-2,040.8
Colorado	50.6	99.6	79.4	91.7
Connecticut	109.9-285.1	418.4-642.3	343.8-601.6	153.1
Delaware	61.2-74.6	136.1-151.8	123.7-144.5	72.3
Washington, D.C	14.0	20.3-29.3	22.3-34.9	24.9
Florida	122.9-204.9	413.2-441.0	204.2-255.6	364.0-461.7
Georgia	204.4-215.2	278.1-300.0	263.9-309.0	317.4-320.0
Hawaii	2.0	9.3	9.3	13.9
Idaho	4.2	12.2	11.6	17.1
Illinois	702.0-1,487.5	1,620.9-2,474.9	1,290.6-2,229.6	851.2-1,091.3
Indiana	380.2-450.1	837.5-913.9	611.6-696.0	471.1-492.3
Iowa	11.1	33.6	33.4	50.3
Kansas	47.8	86.4	79.1	103.4
Kentucky	123.5-126.6	170.9-177.7	154.6-165.6	173.8
Louisiana	262.2	307.4	295.8-301.3	321.5
Maine	7.5	47.9	47.2	24.4
Maryland	151.4-153.5	248.1-272.9	215.1-260.7	242.7
Massachusetts	513.8-1,180.0	662.3-1,433.6	642.7-1,467.9	577.7-792.7
Michigan	313.1-324.8	589.3	388.6	448.3-463.5
Minnesota	167.5	232.3	213.9	279.1
Mississippi	33.1-35.0	54.8-57.9	54.0-57.4	69.9-71.0
Missouri	237.4	333.4	302.4-311.1	365.8
Montana	4.1	10.2	9.8	13.2
Nebraska	4.8	17.1	17.0	25.9

Table IX.7

Ozone and CO Nonattainment Control Cost Summary by State

State	2000 Cost (million$)			
	EPA Policy	Mitchell Bill	Waxman Bill	Group of Nine Proposal
Nevada	10.7	19.2	18.5	24.0
New Hampshire	26.5	54.8	54.1	46.5
New Jersey	524.4-1,184.1	1,188.3-2,114.6	948.8-1,954.7	572.4-573.1
New Mexico	16.3	27.0	26.1	32.4
New York	644.4-1,838.2	1,835.2-3,542.5	1,685.3-3,510.7	680.6
North Carolina	204.2-227.7	273.5	259.0	300.5
North Dakota	1.7	6.3	6.3	8.8
Ohio	253.8-269.9	458.6-493.4	359.4-408.6	463.7-474.8
Oklahoma	68.2	104.2	98.3	107.7
Oregon	107.8	145.9	135.8	141.9
Pennsylvania	276.5-399.6	897.5-1,041.6	736.7-927.5	445.2
Rhode Island	35.9-66.3	56.2-99.0	51.3-101.2	49.1-70.2
South Carolina	49.1-52.0	80.7	78.5	102.5
South Dakota	3.5	8.5	8.4	11.5
Tennessee	285.1-346.5	366.2-425.3	329.8-407.6	356.1-381.0
Texas	3,117.5-4,852.7	4,366.9-6,251.3	3,533.6-5,627.0	3,078.8-3,186.9
Utah	39.8	67.5-88.8	62.5-95.2	60.0
Vermont	1.2	20.4	20.1	10.0
Virginia	217.1	383.6-401.8	412.8-438.1	327.8
Washington	107.0	206.1	162.5	174.9
West Virginia	151.8	210.1	167.0	178.0
Wisconsin	153.4-311.8	390.9-572.2	277.7-483.3	217.3-246.7
Wyoming	3.4	6.9	6.7	8.4

Note: Costs include both ozone precursor (VOC and NOx) and CO control costs. Control of residual tons necessary to meet attainment/progress requirements at $2,000 to $10,000 per ton produces a cost range for some areas.

B. CARBON MONOXIDE NONATTAINMENT

Costs of measures to help MSAs (and non-MSAs) attain the CO ambient standard that are presented in this chapter are those in addition to what is estimated to be spent to comply with the ozone related provisions of the policy or bill. This effort to avoid double counting control costs affects I/M costs. Thus, the bill with the most stringent I/M requirements for CO may not have the highest costs, because similarly stringent ozone requirements have probably already accounted for most of the cost increase.

Table IX.8 summarizes estimated CO costs by control measure for the EPA policy and the three legislative approaches. CO costs of the EPA policy are much lower than the costs of the three legislative approaches. The only CO control measure modeled as if it were mandated by the EPA policy is enhanced I/M. While the proposed EPA policy mentions 17 ppm as a possible cutoff for requiring enhanced I/M, a lower cutoff was used in this analysis because preliminary simulations showed that many areas with design values below 17 ppm would not be able to demonstrate short-term attainment without new measures. Thus, enhanced I/M is modeled as if it would be the preferred "discretionary control measure" adopted by urban areas to attain the standard under the EPA policy.

Total CO costs for the Mitchell bill, the Waxman bill, and the Group of Nine Proposal are similar in magnitude. The cost burden is distributed differently for each legislative approach, however. The Mitchell bill places more of the cost burden on stationary sources. Group of Nine Proposal costs affect only motor vehicles.

All of the policies/bills have additional I/M costs. These costs can include improving the effectiveness of existing I/M programs and establishing new I/M programs in areas where they currently do not exist. Both the Mitchell bill and the Group of Nine Proposal have alternative fuel programs in severe CO nonattainment areas. These programs are estimated to cost $27 million. The alternative fuels case modeled is a CO season

Table IX.8

Additional Carbon Monoxide Control Costs*
1995 Projection Year
(millions)

Control Measures	EPA Policy	Mitchell Bill	Waxman Bill	Group of Nine Proposal
	Policies/Bills			
Motor Vehicle Measures				
Enhanced I/M	$38	$67	$128	$132
Alternative Fuels**	--	27	--	27
Stationary Source Controls	0	40	0	0
Emission Fee	0	34	13	0
Totals	$38	$168	$141	$159

* Costs are those in addition to what is estimated to be spent to comply with ozone provisions.

** The alternative fuels case modeled is a CO season (winter) switch from straight gasoline to an ethanol blend.

Note: Effects of cold start certification testing for motor vehicles have not been included in this analysis.

(winter) switch from straight gasoline to an ethanol blend. This program is similar to the one currently being used in the Front Range of Colorado.

The CO stationary source controls called for by the Mitchell bill are estimated to cost $40 million. These are the costs of applying the control techniques listed in Table III.1 to serious and severe CO nonattainment areas.

Stationary source emission fees of $100 per ton are applied in both the Mitchell and Waxman bills. Costs are higher for the Mitchell bill because the fee is applied in both serious and severe nonattainment areas. The Waxman bill only has an emission fee for sources in severe nonattainment areas.

Estimates of expected attainment dates depend on which source types are assumed to be contributing to observed CO standard exceedances. With the assumption that mobile sources and a percentage of stationary area sources (20 percent) affect the design value monitor, there are three residual CO nonattainment areas in 1995 in the simulations for the proposed EPA policy and the Waxman bill. The Mitchell bill and Group of Nine Proposal simulations showed one remaining CO nonattainment area in 1995. If all sources within an MSA are assumed to contribute equally to CO standard exceedances, many more areas are projected to fail to attain the standard by 1995.

Note also that MOBILE3 CO I/M credits are higher than what has been observed in recent surveys (Sierra Research, 1988). If I/M programs are less successful than indicated by MOBILE3, the number of remaining CO nonattainment areas in 1995 will increase.

The weighting procedure employed in this study to estimate whether areas are expected to attain the CO NAAQS by 1995 is one that has historically been used by the EPA (U.S. EPA, 1980; 1985). As it says in the "Cost and Economic Assessment of Alternative NAAQSs for Carbon Monoxide":

> Because of the different nature of mobile source and stationary source emission problems and the location of the existing monitoring network, it is believed that recorded violations in nonattainment areas are a result of mobile sources and localized area sources. As part of this study, an analysis of the stationary source problem was conducted

which indicates that stationary source emissions had negligible effects on CO monitor readings in most counties.

X SENSITIVITY ANALYSIS

The emission projections and cost results for future years are dependent on the growth rates used in the analysis. As an alternative to the baseline growth used (MSA-level BEA growth rates and national average VMT growth from the motor fuel consumption model), projections were made using a set of SIC national average growth rates (U.S. EPA, 1980). The MOBILE3 Fuel Consumption Model was used as an alternate source of national VMT growth projections. This alternative case is referred to as the national growth case while the baseline growth is referred to as the MSA growth case (although national VMT growth rates are used in both cases). Table X.1 provides the national average growth rates by ERCAM industrial category derived from the SIC annual growth rates. National average VMT projections used for the national growth case are shown in Table X.2. VMT by vehicle type used in the MSA growth case was shown earlier in Table II.7.

Average annual VMT growth for all vehicle types between 1985 and 1995 is 3.1 percent per year for the MSA growth case. In contrast, the national growth case shows an average VMT growth of 1.9 percent per year for the same period. (When compared with historic evidence and alternative forecasts, EPA's MOBILE 3 Fuel Consumption Model projections are on the order of 10 to 30 percent lower than forecasts prepared by other organizations.) On the stationary source side, average annual growth from 1985 to 1995 for chemical manufacturing pods is 2.5 percent per year for the MSA growth case compared with 3.1 percent per year for the national growth case. The largest difference in annual growth is for sources classified as "other" under ERCAM's industrial classifications. The national growth case uses population based growth of 0.8 percent per year. The MSA growth case uses total earnings as the basis for growth projections in the "other" classification. The average growth varies by pod since the growth rates are MSA dependent. Consumer solvents, classified as "other," show an average growth between 1985 and 1995 of 3.1

Table X.1

National Average Growth Rates by Industrial Category
Used in Sensitivity Analysis

ERCAM Industrial Category	Average Annual Growth (1977-2000)
Food and Agriculture	0.6
Mining Operations	1.3
Wood Products	2.3
Printing and Publishing	2.3
Chemicals	3.1
Petroleum Refining	1.9
Mineral Products	1.3
Metals	2.4
Machinery & Equipment Mfg.	2.6
Crude Oil Production, Storage, and Transfer	2.2
Electric Utilities	3.5
Other Fuel Combustion	3.5
Petroleum Product Production, Storage, and Transfer	1.9
Other Transportation	2.9
Dry Cleaning	0.8
Other	0.8

Source: U.S. EPA, 1980

Table X.2

Annual VMT by Vehicle Class and Year

VMT (billions)

	1985	1995	2000	2010
LDGV	1,075.5	1,298.8	1,410.0	1,632.4
LDGT	357.2	438.6	479.3	560.2
HDGV	55.3	55.9	58.7	68.2
HDDV	104.0	137.8	154.3	182.8
Totals	1,592.0	1,931.1	2,102.3	2,443.6

Equivalent Annual Growth Rates

	1985-1995	1995-2000	2000-2010
LDGV	1.9%	1.7%	1.4%
LDGT	2.2	1.8	1.5
HDGV	0.1	1.0	1.5
HDDV	2.8	2.3	1.7
Average	2.0%	1.7%	1.5%

Source: U.S. EPA, 1984

percent per year while TSDFs show an average of 3.5 percent per year.

Nonattainment area emission projection results for the two alternative growth cases are compared in Table X.3. The national growth case projects lower emissions in all analyses. The 1995 difference (MSA growth-national growth) ranges from 767 thousand tons for the Mitchell Bill to 837 thousand tons for the EPA Policy. Approximately 70 percent of the difference can be accounted for by four or five categories as shown in Figure X.1. The categories accounting for this difference are the same for both the EPA Policy and the Mitchell Bill with the exception of TSDFs. TSDFs are not as important an emissions difference in the EPA policy analysis because this source is well controlled in all areas. The Mitchell Bill does not mandate TSDF controls in attainment areas.

The national total cost differences by alternative and year are shown in Figure X.2. The MSA growth case total costs are higher than the national growth case costs in all cases. The cost difference in 1995 ranges from $711 million for the EPA policy to $1,058 million for the Group of Nine Proposal. For the 2000 results, the difference ranges from $304 million for the EPA policy to $961 million for the Group of Nine Proposal. The cost difference decreases from 1995 to 2000 for two reasons. Many new source costs are negative, denoting a cost savings (savings on solvent usage) for the control. Also, many of the organic chemical manufacturing industry sources show higher growth in the national growth case than in the MSA growth case.

With growth rates for key manufacturing industry categories, such as the chemical industry, not being appreciably different between the two alternatives used in this sensitivity analysis, the choice between MSA-level growth rates versus national averages will only lead to significant differences in results if nonattainment area growth rates (especially those for serious and severe nonattainment areas) are much higher than those elsewhere in the country. Analysis results for chemical industry sources indicate that this is not the case. Serious nonattainment area

Table X.3

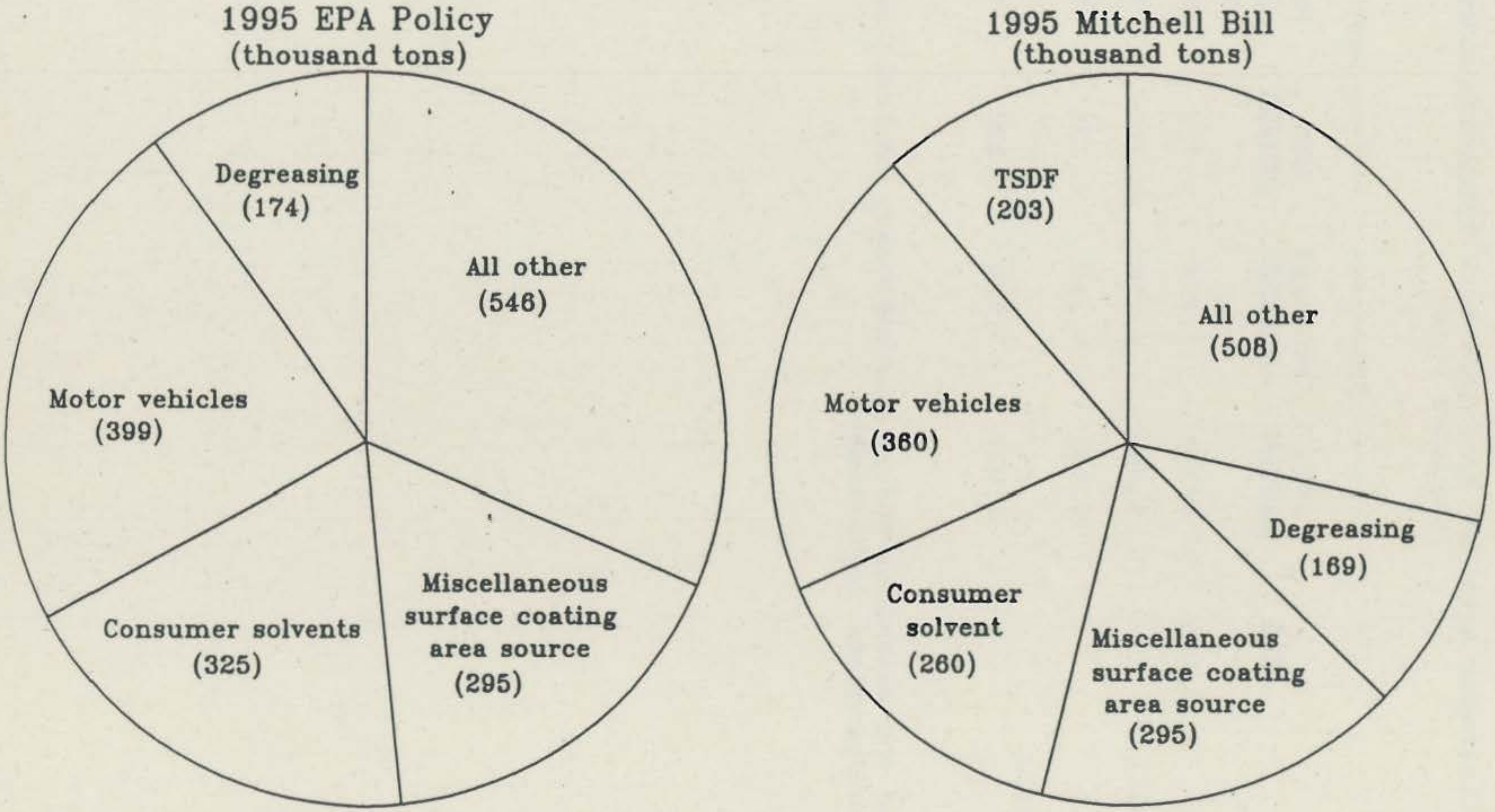
Nonattainment Area VOC Emissions by Alternative Growth
(thousand tons)

		1995		2000	
	1985	MSA Growth	National Growth	MSA Growth	National Growth
EPA Policy	8,626	6,173	5,336	6,774	5,748
Mitchell Bill		5,685	4,918	6,147	5,230
Waxman Bill		5,892	5,112	6,396	5,454
Group of Nine Proposal		5,921	5,120	6,252	5,328

* Projected VOC emissions before discretionary controls and attainment/progress requirements

Figure X.1

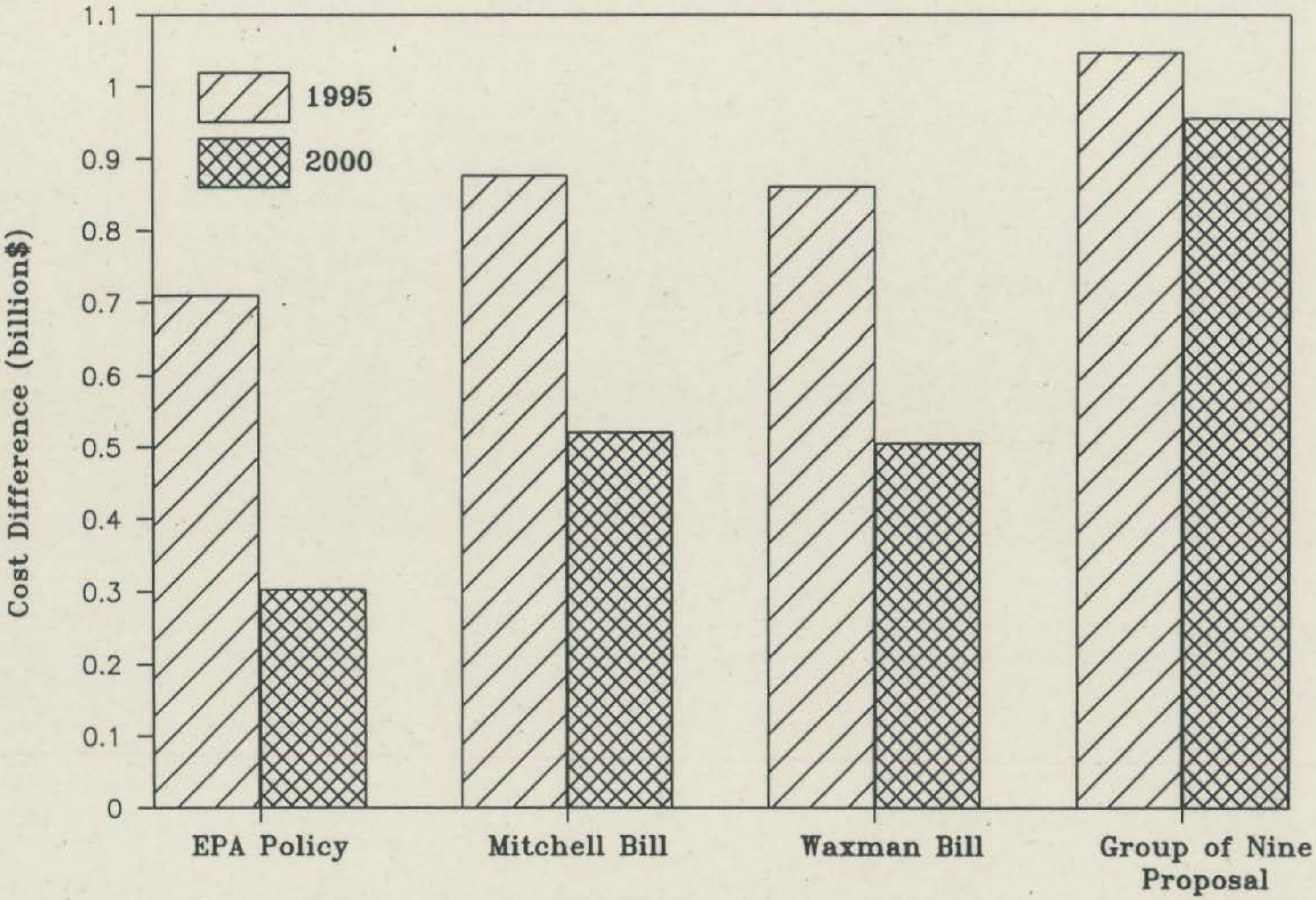
VOC Emission Differences for Alternative Growth



Notes: Emission difference = base case − national growth.
Emission difference is for all areas, attainment and nonattainment.
All other includes sources with less than 5% absolute of total emission difference and includes some negative values.

Figure X.2

National Cost Differences for Growth Analysis
(MSA Growth Cost - National Growth Cost)



VOC emissions as a whole in 1995 are estimated to be higher in 1995 using national average growth rates than they are estimated to be using the MSA specific rates. The reverse is true for severe nonattainment areas.

XI CAVEATS

Any analysis that attempts to estimate how future laws or regulations will affect the behavior of individuals, firms, and state and local regulatory agencies must incorporate simplifying assumptions. In addition, data bases are employed which may not be perfectly designed for the analysis being performed. The most important caveats and assumptions associated with this analysis are listed below. As a general rule, the model results presented in this study are more useful for comparing the relative impacts of alternative policies and bills than they are in estimating absolute values.

- Growth in motor vehicle travel is estimated using national averages for all areas. These national average growth rates are different for each of the four vehicle types modeled. Area specific growth rates are typically available, but they do not permit separate rates to be specified for the four vehicle types modeled, so they were not used. In any case, motor vehicle projections in this analysis will not capture city-by-city differences in travel.

- New stationary source growth is estimated using Bureau of Economic Analysis values published in 1985. These rates may overestimate growth in areas with petroleum-based economies.

- New source costs include all the costs of going from zero to the indicated level of control. Some controls may be undertaken for economic, process, or non-ozone related, non-pollution control reasons. The costs of control designed at the outset for newly constructed plants may well be lower than the simple product of a cost per ton add-on control times potential uncontrolled emissions based on present day systems. Therefore, total cost estimates probably overestimate the costs of the policies/bills for new sources.

- The modeling approach used in this study may also be biased toward estimating higher costs to existing sources than might actually occur. Whenever a controlled existing source is forced to increase its control level, ERCAM-VOC estimates the cost of the new control equipment without taking into account the salvage value or reduction in operating cost associated with the previous control technique. Less costly upgrades to current control systems are also not considered.

- The 1985 NEDS VOC emission estimates for some area source categories were adjusted downward to account for likely control levels in nonattainment areas. This change affected emission estimates for the following area source categories: paper surface coating, degreasing, rubber and plastics manufacturing, and stage I gasoline marketing. This change makes 1985 VOC emission estimates lower and provides less opportunity for future emission reductions. No adjustments were made to base year motor vehicle VOC emission estimates to try to include excess evaporative and running loss emissions because quantitative estimates of these values were not available during the study period.

. Rule effectiveness is almost always less than originally predicted. The proposed EPA policy states that areas can only take 80 percent emission reduction credit for various measures. This 80 percent rule effectiveness provision in the policy is not modeled in this analysis.

. Where bills and policies call for control measures which have not been previously demonstrated or studied there is considerable uncertainty in control costs. To avoid omitting important source types from the analysis, default cost per ton values have been adopted for a number of different control options, including controls for miscellaneous point sources, consumer solvent controls, and discretionary controls beyond those for which there are some data.

. Ozone and CO design values from 1983 to 1985 data have been used in this study. Estimated control requirements by MSA would change if more recent data were used. Note also that these control requirements have been estimated with a simplified ozone trajectory model with considerable uncertainty.

. Not all of the policy and bill provisions could be explicitly included in this analysis. For instance, no attempt was made to quantify the effects of changing new source review procedures. Future effects of cold start certification testing for motor vehicles were also not included in this analysis.

. The point source data file used in this analysis has incomplete data for plants that emit less than 100 tons per year of VOC. Therefore, this study may underestimate emission reductions associated with regulatory approaches that make smaller VOC emitters subject to controls.

. Control of emissions in ozone transport regions as defined in the bills is not assumed to assist in reaching [illegible] attainment. Thus, while costs are estimated for [illegible] these regions, any benefits are not included. The overall effect of regional transport is [illegible] in assessing control strategies. Thus, estimates of [illegible] needed in areas influenced by transport, e.g. [illegible] Boston, are based solely on a default [illegible] for the particular MSA, with assumed background ozone and precursors. This may over or under estimate controls needed to attain the standards, depending on the MSA involved.

- The modeling approach does not incorporate market adjustments for existing sources as they respond differently than anticipated to a new policy initiative. If this occurs, the model probably overstates costs because efficiencies associated with technological innovations, economies of scale, process and product substitution, and geographical migration are ignored.

- NO_x costs have only been estimated for the explicit provisions of the Waxman and Mitchell bills that require NO_x controls. Additional NO_x controls may be undertaken in some areas under the proposed EPA policy or the Group of Nine proposal, but no attempt has been made to capture these costs. The effects of NO_x control on ozone concentrations (plus or minus) have been ignored in all cases. These assumptions could lead to overestimating or underestimating NO_x control costs and benefits, depending on the area involved.

ABBREVIATIONS AND ACRONYMS

ARB	Air Resources Board
BACT	Best Available Control Technology
BEA	Bureau of Economic Analysis
CCWI	Cost Components of Water Injection System
CCWT	Cost Components of Water Treatment
CMSA	Consolidated Metropolitan Statistical Area
CNG	compressed natural gas
CO	carbon monoxide
CTGs	Control Technique Guidelines
EAB	Economic Analysis Branch
ERCAM	Emission Reduction and Cost Analysis Model
FIP	Federal Implementation Plan
FMVCP	Federal Motor Vehicle Control Program
HC	hydrocarbon
HDDVs	heavy-duty diesel-powered vehicles
HDGVs	heavy-duty gasoline-powered vehicles
I/M	inspection and maintenance
LDGTs	light-duty gasoline-powered trucks
LDGVs	light-duty gasoline-powered vehicles
LEA	low excess air
LNB	low NO_x burners
MSA	Metropolitan Statistical Area
MTBE	Methyl Tertiary Butyl Ether
NAAQS	National Ambient Air Quality Standards
NEDS	National Emissions Data System
NESHAP	National Emissions Standards for Hazardous Air Pollutants
NH_3	ammonia
NMOC	nonmethane organic compounds
NO_x	oxides of nitrogen
NSPSs	New Source Performance Standards
O&M	operation and maintenance
POTWs	Publicly Owned Treatment Works

PPM	parts per million
RACT	Reasonably Available Control Technology
RVP	Reid Vapor Pressure
SCCs	Source Classification Codes
SCR	Selective Catalytic Reduction
SIC	Standard Industrial Classification
SIP	State Implementation Plan
SO_2	sulfur dioxide
SOCMI	Synthetic Organic Chemicals Manufacturing Industry
TSDFs	treatment, storage, and disposal facilities
VMT	vehicle miles traveled
VOC	volatile organic compound
VOCM	VOC Model
WCAP	Water Flow Capacity

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APPENDIX A

NO_x CONTROL COST EQUATION DEVELOPMENT

A. RACT LEVEL CONTROL EQUATIONS

1. Industrial and Utility Boilers

The cost equations for the RACT level control of NO_x from industrial boilers were derived from cost data given in an industrial boiler cost report (Bowen and Jennings, 1982). For each type of fuel and control method, at least three different boiler sizes were costed. When more than one control method was listed for a given type of boiler, the control technique yielding the highest NO_x control efficiency was chosen.

The cost equations for stokers and oil and gas-fired industrial boilers were also applied to the same types of utility boilers for lack of any better data for these utility boilers. The validity of applying the cost equations developed for industrial boilers to utility boilers is uncertain. Considering that the same types of modifications would be made in applying the same types of control techniques to either utility or industrial boilers, it is expected that this assumption is reasonable. The greatest difference between utility and industrial boilers is size. (Utility boilers are generally larger than industrial boilers.) In many instances, though, no real distinction exists between the two types. Therefore, it is expected that the application of the industrial boiler cost equations to utility boilers should not cause a large degree of error. The equations used are all listed in Tables A.1 and A.2. The SCC categories to which the cost equations were applied are listed in Table A.3.

The low excess air (LEA) control technique, used for distillate oil boilers and stokers, results in a net savings. This results from an increase in the boiler efficiency when implementing LEA. The capital costs for this technology are relatively low and so the savings in O&M expenses produce an overall cost savings. The high savings per ton achieved by distillate oil industrial boilers is somewhat misleading.

Table A.1

NOx Control Cost Equations for Utility and Industrial Boilers

Source Type	Control Device	Capital Cost Equations Coefficient	Capital Cost Equations Exponent	Operating & Maintenance Cost Equations Coefficient	Operating & Maintenance Cost Equations Exponent	Control Eff. %	Default Cost Per Ton
Utility Boilers							
PC - Wall/Opposed	LNB	7,860	0.72	393	0.72	50	87
PC - Tangential	LNB	232,400	0.40	11,620	0.40	50	232
Residual Oil	SCA	10,480	0.62	600	0.84	42	353
Gas	FGR	6,610	0.43	450	1.00	31	983
Stoker	LEA	3,730	0.44	-67	1.11	21	-525
Coal	SCR	292,400	0.60	4,500	1.00	80	2911
Oil/Gas	SCR	265,800	0.50	2,370	1.00	80	3120
Industrial Boilers							
Pulverized Coal	SCA	1,910	0.70	186	0.96	36	2198
Stoker	LEA	3,730	0.44	-67	1.11	21	-337
Residual Oil	SCA	10,480	0.62	600	0.84	42	827
Distillate Oil	LEA	3,960	0.36	-690	1.00	36	-4592
Gas	FGR	6,610	0.43	450	1.00	31	1025
Coal	SCR	147,900	0.70	4,600	0.95	80	3278
Oil/Gas	SCR	134,450	0.60	2,425	0.95	80	3667

NOTES: All equations are of the form COST = COEFFICIENT*(BOILER DESIGN CAPACITY)^EXPONENT
Units for BOILER DESIGN CAPACITY are in MMBtu/hr
All costs are in 1985 dollars

Table A.2

NOx Control Cost Equations for IC Engines, Gas Turbines, and Process Heaters

SOURCE	CONTROL METHOD	CAPITAL COST EQUATIONS	O&M COST EQUATIONS	CONTROL EFF(%)	DEFAULT COST PER TON
IC Engines					
Gas	Change A/F Ratio	0	574*(OPRATE)	30	1126
Oil	Change A/F Ratio	0	65.8*(OPRATE)	30	935
Gas	SCR	8,802,000*(DESRATE)^0.86	131*(OPRATE)+5,355,000*(DESRATE)	80	964
Oil	SCR	1,556,000*(DESRATE)^0.86	18.1*(OPRATE) + 714,000*(DESRATE)	80	936
Gas Turbines					
Gas	Water Injection	1,393,000*(DESRATE)^0.52	174*(OPRATE)	70	1560
Oil	Water Injection	508,000*(DESRATE)^0.52	22.1*(OPRATE)	70	1020
Gas	SCR+Water Injection	10,031,000*(DESRATE)^0.74	179*(OPRATE)+1,700,000*(DESRATE)	94	3730
Oil	SCR+Water Injection	2,283,000*(DESRATE)^0.74	23.1*(OPRATE) + 227,000*(DESRATE)	94	2480
Process Heater					
Gas	SCA	47,260*(DESRATE)^0.67	-65,100*(DESRATE)	45	-306
Oil	SCA	12,830*(DESRATE)^0.67	-9,300*(DESRATE)	45	-110
Gas	SCR	5,774,000*(DESRATE)^0.60	221*(OPRATE)	90	7810
Oil	SCR	1,780,000*(DESRATE)^0.60	29.8*(OPRATE)	90	2760

NOTES: DESRATE is the maximum design rate in SCC units per hour
OPRATE is the operating rate in SCC units per year
All costs are in 1985 dollars

Table A.3

SCC Codes Corresponding to NOx Control Cost Equations

Source Category	Control Type	Applicable SCCs
Utility Boilers		
Pulverized Coal		
Wall/Opposed	LNB	10100101
		10100201
		10100202
		10100221
		10100222
		10100301
Pulverized Coal		
Tangentially	LNB	10100212
		10100226
		10100302
Residual Oil	SCA	10100401
		10100404
		10100405
		10100406
Gas	FGR	10100601
		10100602
		10100604
		10100701
		10100702
Stoker	LEA	10100102
		10100204
		10100205
		10100224
		10100225
		10100304
		10100306

Table A.3

SCC Codes Corresponding to NOx Control Cost Equations

Source Category	Control Type	Applicable SCCs
Coal	SCR	10100101
		10100201
		10100202
		10100221
		10100222
		10100301
		10100212
		10100226
		10100302
		10100102
		10100204
		10100205
		10100224
		10100225
		10100304
		10100306
Oil/Gas	SCR	10100401
		10100404
		10100405
		10100406
		10100501
		10100504
		10100505
		10100601
		10100602
		10100604
		10100701
		10100702

Table A.3

SCC Codes Corresponding to NOx Control Cost Equations

Source Category	Control Type	Applicable SCCs
Industrial Boilers		
Pulverized Coal		
	SCA	10200201
		10200202
		10200212
		10200221
		10200222
		10200226
		10200301
		10200302
		10300101
		10300102
		10300205
		10300206
		10300216
		10300221
		10300222
		10300226
		10300305
		10300306
Stoker	LEA	10200204
		10200205
		10200206
		10200224
		10200225
		10200304
		10200306
		10300207
		10300208
		10300209
		10300224
		10300225
		10300307
		10300309

Table A.3

SCC Codes Corresponding to NOx Control Cost Equations

Source Category	Control Type	Applicable SCCs
Residual Oil	SCA	10200401 10200402 10200403 10200404 10300401 10300404
Distillate Oil	LEA	10200501 10200502 10200504 10300501 10300504
Gas	FGR	10200601 10200602 10200603 10200701 10200704 10200707 10300601 10300602

Table A.3

SCC Codes Corresponding to NOx Control Cost Equations

Source Category	Control Type	Applicable SCCs
Coal	SCR	10200201
		10200202
		10200212
		10200221
		10200222
		10200226
		10200301
		10200302
		10300101
		10300102
		10300205
		10300206
		10300216
		10300221
		10300222
		10300226
		10300305
		10300306
		10200204
		10200205
		10200206
		10200224
		10200225
		10200304
		10200306
		10300207
		10300208
		10300209
		10300224
		10300225
		10300307
		10300309

Table A.3

SCC Codes Corresponding to NOx Control Cost Equations

Source Category	Control Type	Applicable SCCs
Oil/Gas	SCR	10200401
		10200402
		10200403
		10200404
		10300401
		10300404
		10200501
		10200502
		10200504
		10300501
		10300504
		10200601
		10200602
		10200603
		10200701
		10200704
		10200707
		10300601
		10300602
IC Engines		
Gas	Change AFR	20100202
		20100702
		20200202
		20200204
		20300201
Oil	Change AFR	20100102
		20100902
		20200102
		20200104
		20200301
		20200401
		20200501
		20200902
		20300101
		20300301

Table A.3

SCC Codes Corresponding to NOx Control Cost Equations

Source Category	Control Type	Applicable SCCs
Gas	SCR	20100202
		20100702
		20200202
		20200204
		20300201
Oil	SCR	20100102
		20100902
		20200102
		20200104
		20200301
		20200401
		20200501
		20200902
		20300101
		20300301
Gas Turbines		
Gas	Water Inj.	20100201
		20200201
		20200203
		20300202
Oil	Water Inj.	20100101
		20200101
		20200103
		20300102
Gas	Water Inj. & SCR	20100201
		20200201
		20200203
		20300202

Table A.3

SCC Codes Corresponding to NOx Control Cost Equations

Source Category	Control Type	Applicable SCCs
Oil	Water Inj. & SCR	20100101 20200101 20200103 20300102
Process Heaters		
Gas	SCA	30600104 30600105 30600106
Oil	SCA	30600103
Gas	SCR	30600104 30600105 30600106
Oil	SCR	30600103

Distillate oil-fired boilers have a much lower emission rate than coal-fired boilers. Thus, any reduction in NO_x emissions will also be relatively small. Dividing the negative annual cost by a small number leads to this large savings per ton, making LEA appear to be very cost effective for distillate boilers. In actuality, if the emission rate had been greater, leading to a larger reduction in emissions, while maintaining the same annual cost savings, the cost effectiveness would actually decrease. This contradiction is due entirely to the negative cost.

The remaining two RACT level control cost equations, for LNB applied to pulverized coal-fired utility boilers, were based on equations given for this control technique in a (Pechan, 1987) report. These retrofit equations were based on the size of the boiler in MW and were simply converted to accept the boiler size in MMBtu/hr. The use of LNB is expected to decrease NO_x emissions from wall-fired and opposed-fired utility boilers and tangentially fired utility boilers by 50 percent. Tangentially fired boilers are much more difficult to retrofit with LNB than either wall-fired or opposed-fired units, and they emit only about one half as much NO_x in the uncontrolled state as the wall-fired and opposed-fired boilers. As a result, the cost per ton to control the tangentially fired units is much higher than that of the other types of pulverized coal-fired utility boilers.

2. Internal Combustion Engines

Cost equations for reciprocating internal combustion engines (EEA, 1982) were updated and revised for this analysis. The RACT level method of control used is a combustion modification of fine tuning the engine controls and changing the air/fuel ratio of the engine. This technique is expected to give a 30 percent reduction in NO_x emissions. No capital costs are incurred by making these adjustments. These process modifications do incur O&M expenses, however, including a fuel penalty for the additional fuel consumed. The retrofit equations for O&M costs and the fuel penalty were combined since the other NO_x cost equations incorporate fuel costs or savings into the O&M

equations. The fuel costs used are the expected long-term fuel prices (Pechan, 1986). The natural gas price used was \$5.08/MMBtu, and \$4.54/MMBtu was used as the oil price. The cost equations are listed in Table A.2.

3. Gas Turbines

The set of cost equations for water injection applied to gas turbines was derived from data in Radian (1988b). These equations apply to a NO_x removal efficiency of 70 percent, using a water to fuel ratio of 1:1. Using water injection with gas turbines leads to approximately a 1 percent reduction in engine efficiency. Therefore, before calculating any costs, the actual fuel consumption rate with the water injection system in place was calculated.

The total capital cost of applying a water injection control system to a gas turbine is composed of capital cost components for the water injection system and for water treatment. Both of these components are based on the water flow capacity (WCAP), in gallons per minute, of the water injection system. The capital cost components of water treatment (CCWT) and of the water injection system (CCWI) are given by the following equations:

$$CCWT = 59{,}200 * (WCAP)^{0.53}$$
$$CCWI = 45{,}300 * (WCAP)^{0.5}$$

The total capital cost of water injection is the sum of these two cost components multiplied by an assumed retrofit factor of 1.2. The resulting capital cost equations for applying water injection to gas turbines are listed in Table A.2.

The annual O&M costs associated with controlling gas turbines by water injection include the cost of water consumption as well as the cost of increased fuel consumption due to the reduction in engine efficiency. The cost of water is a function of the operating rate since the amount of water used is directly proportional to the amount of fuel consumed.

Using a unit cost of water in 1985 of \$0.60/1,000 gal (Radian, 1988b) and with the operating rate in SCC units per year, the component for the annual cost of water is given by the following expressions:

$$ACW_{OIL} = 534 * (OPRATE)$$
$$ACW_{GAS} = 3.63 * (OPRATE)$$

The other cost component which must be included in the final O&M cost equations is the annual cost for the increase in fuel use due to the decrease in turbine efficiency. The following expressions were derived for the increase in the annual cost of fuel:

$$ACF_{OIL} = 21.6 * (OPRATE)$$
$$ACF_{GAS} = 171 * (OPRATE)$$

The final O&M equations for applying water injection to control NO_x emissions from gas turbines were obtained by adding the annual cost of fuel and water. These equations are listed in Table A.[illegible]

4. Process Heaters

[illegible]

reduction in NO_x emissions. The actual capital costs involved in retrofitting a specific boiler with SCR depend on the site requirements of the unit. Therefore, capital costs could be as much as two times greater or two times less than those predicted by the cost equations. The O&M equations are based on an operating capacity factor of 1.0. Units operating at less than 100 percent capacity will incur O&M costs proportional to their operating capacity. The cost equations for retrofitting oil-fired industrial boilers with SCR are based on data reported by the California Air Resources Board (CARB, 1987).

Because there were no relatively current data available for SCR costs applied to pulverized coal industrial boilers, the 1979 Technology Assessment Report (Jones and Johnson, 1979) was used to determine the relationship between SCR costs for coal-fired and oil-fired industrial boilers. Data for parallel flow SCR for both types of boilers were compared and the following relationship for capital costs was obtained, with the size in MMBtu/hr:

$$\frac{CAP_{Coal}}{CAP_{Oil}} = 1.1 * (SIZE)^{0.1}$$

This ratio was applied to the capital cost equation for oil-fired boilers to derive the equation for SCR capital costs for pulverized coal-fired boilers.

The same procedure was followed in deriving the O&M cost equation. The O&M cost of SCR for a coal-fired boiler is 1.9 times greater than the O&M cost of applying SCR to an oil-fired industrial boiler.

The cost equations for applying SCR to coal-fired utility boilers are based on EPRI (1985) studies. EPRI provides cost estimates for applying SCR, yielding 80 percent NO_x removal, to four plants of the same size but with different retrofit difficulties. The average of these four cases, $73/kW, was taken as the base case for capital costs. To derive a capital cost equation, it was assumed that cost varies with size to the 0.6

power, a frequently used assumption when data are unavailable. The average O&M cost of the four cases was 8 mills/kWh. The resultant O&M equation assumes that the O&M costs vary linearly with size.

To determine the costs of SCR retrofitted to oil-fired utility boilers, it was assumed that the same relationship existed between coal-fired and oil-fired utility boilers as was found to exist between coal-fired and oil-fired industrial boilers. The resultant equations are listed in Table A.1.

2. <u>Internal Combustion Engines</u>

Information on the cost of SCR applied to internal combustion engines, as well as the cost information on SCR for all the nonboiler sources, was obtained from Radian (1988). Items included in the calculation of the capital costs for SCR are the catalyst, the reaction vessel, the ammonia injection system, and the ammonia injection control system. The final capital cost equations for applying SCR to oil-fired and gas-fired internal combustion engines are listed in Table A.2.

The annual O&M cost consists mainly of the cost of catalyst replacement and ammonia. It was conservatively assumed that the catalyst would need to be replaced every 2 years. Thus, the O&M catalyst replacement cost will be approximately one-half of the installed SCR equipment cost, excluding the cost of the ammonia control system. With the design rate in SCC units/hr, the O&M catalyst replacement cost in 1985 dollars is given by the following equations:

GAS-FIRED: $O\&M_{CAT} = 5{,}355{,}000 * (DESRATE)$

OIL-FIRED: $O\&M_{CAT} = 714{,}000 * (DESRATE)$

The amount of ammonia required is dependent on the inlet rate of NO_x to the SCR reactor. In determining the annual cost of ammonia, it was assumed that the molar ratio of ammonia (NH_3) to NO_x would be 0.93:1 (Radian, 1988). A value of $150/ton NH_3 was used as the unit cost of ammonia in accordance with the EPRI

Technical Assessment Guide (1986). The equations used to calculate the annual cost of ammonia are provided below:

GAS-FIRED: $O\&M_{NH_3} = 131 * (OPRATE)$

OIL-FIRED: $O\&M_{NH_3} = 18.1 * (OPRATE)$

The total annual O&M costs for internal combustion engines were obtained by adding the catalyst replacement cost and the annual cost of ammonia. Because the amount of catalyst needed is dependent on the size of the engine, while the amount of ammonia needed is dependent on the actual system operating rate, both the design rate and the operating rate are included in the final O&M cost equations which are listed in Table A.2.

It is assumed that applying SCR to IC engines will result in an 80 percent reduction in NO_x emissions. This reduction will actually vary somewhat, depending on the catalyst. When the catalyst is new, it is likely to remove approximately 90 percent of the NO_x emissions, but the ability of the catalyst to reduce NO_x emissions will diminish as it ages. For this reason, it is important that the catalyst be replaced on a regular basis to insure high reduction potential.

3. Gas Turbines

At the BACT level of NO_x control, a combination of water injection and SCR can produce an overall reduction in NO_x emissions of 94 percent. The water injection removes the first 70 percent of the NO_x emissions and the SCR can remove an additional 80 percent of the NO_x emissions entering the SCR reactor. The cost, size, and performance of the water injection system are unaffected by the presence of SCR. The capital cost of SCR is not affected by the presence of water injection, but the O&M costs for the SCR will be reduced over those of an SCR system alone. The amount of ammonia required will be decreased since the amount of NO_x entering the SCR reactor has already been reduced by 70 percent. The derivation of the water injection cost equations has already been described in a previous section. Therefore, only the costs relating to the SCR system and the combined water injection and SCR cost equations are discussed here.

The capital cost of the SCR system is broken down into two components -- the capital cost of the catalyst and the capital cost of the remaining equipment. The remaining equipment includes the reactor housing, the ammonia injection system, and the ammonia control system plus the cost of installation of the SCR system.

The capital cost of the catalyst is expected to be directly proportional to the size of the turbine with no economies of scale. This is because the catalyst is sized in direct proportion with the gas flow rate entering the system to achieve a given removal efficiency. Since the gas flow rate determines the amount of catalyst needed and because the catalyst is made from an expensive metal oxide, any economy of scale which might exist would be minimal.

As opposed to the capital cost of the catalyst, the capital cost of the remaining equipment is expected to have an economy of scale. The cost should vary with size to the 0.6 power. The total capital cost of the SCR system is given by the following equations:

GAS-FIRED: $CAP_{SCR} = 8{,}641{,}000 * (DESRATE)^{0.78}$

OIL-FIRED: $CAP_{SCR} = 1{,}801{,}000 * (DESRATE)^{0.78}$

The final capital cost equations for water injection combined with SCR applied to gas turbines are listed in Table A.2.

The O&M costs for water injection plus SCR are the sum of the water injection O&M costs plus the O&M cost of SCR using the reduced gas flow rate entering the SCR reactor. The O&M costs included for the SCR system are the catalyst replacement cost and the ammonia cost. Assuming that the catalyst must be replaced every 2 years to maintain the desired catalyst activity, the O&M catalyst cost is one-half of the capital catalyst cost. The following equations give the O&M catalyst costs with the design rate in SCC units/hr:

GAS-FIRED: $O\&M_{CAT}$ = 1,700,000 * (DESRATE)

OIL-FIRED: $O\&M_{CAT}$ = 227,000 * (DESRATE)

The SCR ammonia costs are affected by the use of water injection since the amount of ammonia required for the SCR system is dependent on the amount of NO_x in the gas stream. The SCR will remove 80 percent of the NO_x emissions remaining after water injection. The ammonia O&M cost equations for the SCR system are given below, with OPRATE being the turbine operating rate in SCC units/year:

GAS-FIRED: ACA = 5.01 * OPRATE

OIL-FIRED: ACA = 1.001 * OPRATE

To obtain the final O&M cost equations for a combined water injection and SCR control system applied to gas turbines, the O&M component for the water injection costs, the SCR catalyst replacement costs, and the ammonia costs were summed. These final O&M equations, listed in Table A.2, are functions of both the design rate and the operating rate.

4. Process Heaters

The cost equations for SCR applied to process heaters were based on Radian (1988) data. It was assumed that the capital cost would vary to the 0.6 power with size. A retrofit factor of 1.2 was applied to account for the difficulties of applying SCR to site specific conditions as opposed to applying SCR to a new unit. The resulting capital cost equations are listed in Table A.2.

The O&M costs were assumed to vary linearly with the operating rate of the unit. Radian's base case cost estimates were converted to 1985 dollars in SCC units. As the Radian estimate was based on a 100 percent capacity utilization, the equation was divided by 8,760 hours per year to allow the annual operating rate to be used as the equation variable. The final O&M cost equations for SCR applied to process heaters are listed in Table A.2.