

The Cost Effectiveness of VOC and NO_x Emission Control Measures

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The Cost Effectiveness of VOC and NO_x Emission Control Measures

Health and Environmental Affairs Department

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**RADIAN CORPORATION
AUSTIN, TEXAS 78720-1088**

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ABSTRACT

The Clean Air Act Amendments of 1990 require that ozone nonattainment areas reduce total volatile organic compound (VOC) emissions by specified amounts, for certain milestone years. In addition, EPA may require similar reductions of nitrogen oxides (NO_x) in the future. For most nonattainment areas, the controls required to meet these Reasonable Further Progress (RFP) milestones may be very costly. Therefore air pollution control plans must evaluate all available emission control options in order to develop the most cost-effective strategy for meeting their RFP reduction targets. Because of local variations in the types of sources and emission rates, these strategies must be developed on an area-specific basis. An RFP analysis was performed for five different ozone nonattainment areas: Baltimore; Chicago; Houston; Philadelphia; and, Washington, D.C.. The first step in this effort entailed collecting VOC and NO_x emission inventory information from the various state agencies. Next, potential control measures were identified from an extensive literature review, considering both technical and economic constraints. In addition, emissions modeling was performed to estimate the effect of mobile source controls for each area. Cost-effectiveness rankings were developed and total progress toward RFP targets were estimated. Available controls range in cost-effectiveness from a net savings up to \$500,000 per ton of pollutant. Controls of the currently unregulated non-road mobile source category are essential to meeting these long-run targets. Additional study of the feasibility of applying NO_x controls to major point sources is crucial to assess total reduction potentials accurately.

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EXECUTIVE SUMMARY

Under the requirements of Title I of the 1990 Clean Air Act Amendments (CAAA), all moderate and above ozone nonattainment areas must reduce their volatile organic compound (VOC) emissions by 15 percent by 1996. Depending on the severity of the nonattainment status, a city may have to decrease emissions further, by three percent per year, until attainment is demonstrated. Once attainment is achieved, the city must implement a control plan designed to maintain those standards. In addition to the VOC requirements, specific NO_x reduction requirements may be specified by EPA and the states in the future, based on the results of air quality modeling studies. These emission reduction targets are known as the Reasonable Further Progress, or RFP, requirements, and they present significant technical and economic challenges to state agencies and emission sources.

The main purpose of this study is to provide air pollution control planners and other interested parties with a "menu" of possible control options, using the most up-to-date information and accurate analyses, for all significant sources of VOCs and NO_x. This menu provides a preliminary demonstration of how cost-effective packages of attainment strategies and control measures can be developed to meet RFP targets and achieve attainment, as well as maintain standards after attainment. State agencies may be able to incorporate portions of this study's findings into their 1994 SIP revisions. Final determination of appropriate strategies should be based on the air quality modeling studies required by the CAAA.

One set of control strategies alone cannot be identified that will allow all nonattainment areas to meet their RFP targets and achieve attainment in the most cost-effective manner. Site-specific variations in source distribution and emissions mean that different cities must be analyzed on a case-by-case basis. For this reason, API contracted Radian Corporation to evaluate five different cities: Baltimore, Chicago, Houston, Philadelphia,

and Washington, D.C. These cities are all severe ozone nonattainment areas (with the exception of Washington, D.C., which is serious), and all must develop a broad range of control measures. Various sections of this report may apply to other cities not included in the analysis.

In order to develop site-specific control packages for VOC and NO_x, Radian performed the following tasks:

- Identified major source categories from state inventories;
- Identified feasible control options from literature;
- Model emissions reductions for mobile source controls for each site;
- Conducted technical and economic assessment of options and determined cost-effectiveness rankings; and
- Developed site-specific cost-effective control approaches.

This report provides the initial results of Radian's study. The body of the report discusses the potential control options in a general manner, while the appendices provide a more detailed analysis of costs, effectiveness, and application limitations.

FINDINGS OF RFP ANALYSES

Based upon Radian's analysis, the cities of Chicago and D.C. should be able to meet their 1996 RFP milestones. In addition, Chicago and D.C. can do so in using controls with relatively low cost-effectiveness values (typically \$1,000 to \$2,000 per ton of VOCs). However, based upon the preliminary emissions inventories provided by the states, the Houston, Baltimore, and Philadelphia areas may not reach their reduction targets, even after applying all available controls, regardless of cost. These shortfalls may be the result of these cities' relatively low emissions from mobile sources (a source category that experiences large percentage reductions by 1996). The shortfalls may also be the result

of errors in the emissions inventories received from the states. Figure ES-1 provides a summary of the progress made toward the 1996 RFP milestones, based upon the control strategy packages developed by Radian.¹

Radian also estimated the potential NO_x reductions available from on and non-road mobile source controls, as well as utility boiler controls, for each city in 1996, 1999, and 2010. Radian adopted a three-tiered control approach for utility boilers, applying low-efficiency controls first, then increasingly more stringent, and costly, controls thereafter. Potential NO_x emission reductions were not estimated for other source categories due to a lack of information on technical feasibility. Nevertheless, Radian found that significant emission reductions could be achieved by applying controls to just these three source categories. Also, potential reductions become greater with time as controls begin to penetrate the non-road source category. Figures ES-2 through ES-4 depict the NO_x reductions that may be obtained in each city, for 1996, 1999, and 2010.

CONCLUSIONS

Based on the findings of this study, the available controls for VOC and NO_x emissions have a wide range of cost-effectiveness values – anywhere from a cost savings to almost \$500,000 per ton of pollutant. Even costs for a given type of control applied to a specific source category can be highly variable, dependant upon site-specific factors such as retrofit feasibility, local conditions, fuel cost, and a host of other factors. Nevertheless, a few general observations can still be made:

- For those cities with relatively high emissions from their vehicle fleet, RFP targets for 1996 may be met without resorting to extremely high cost-effectiveness controls. For those cities with large point source and non-

¹ Since the completion of this study in December of 1993, the state agencies in Pennsylvania and Texas have revised their inventories significantly. Based upon these revisions the agencies anticipate meeting their 1996 RFP targets. However, no speculation was provided regarding the likelihood of meeting later year milestones.

road inventories, 1996 RFP target attainment may require more stringent and expensive measures.

- By and large the mandated mobile source controls, Stage II, RFG, and enhanced I/M provided the greatest boost toward meeting the 1996 RFP targets. Other mobile source controls, such as Clean Fleets and LEVs, cannot generate significant reductions until after 2000.
- Without a downturn in economic growth, and barring major technological breakthroughs, most cities will not be able to meet their RFP targets for 1999 and thereafter relying solely on VOC controls. It is likely that some form of NO_x-for-VOC substitution will be needed to facilitate the process.
- As of this time, non-road mobile sources are one of the last significant uncontrolled sources of VOC emissions. Therefore these sources must be addressed in the future in order to attain and maintain target emission levels.
- With the probable establishment of NO_x emission reduction targets in the near future, it is crucial to assess the feasibility of applying controls beyond the utility and on-road mobile categories. While Radian did find studies in the literature on controls for process heaters, IC engines, and other unregulated NO_x sources, Radian found little to no assessment of the potential application rates of these new controls (i.e., the percentage of sources that can be retrofit with controls considering technical and economic feasibility). A comprehensive technological assessment of retrofit potentials should be undertaken in this regard.

1996 Rate-of-Progress Plans

VOC Controls

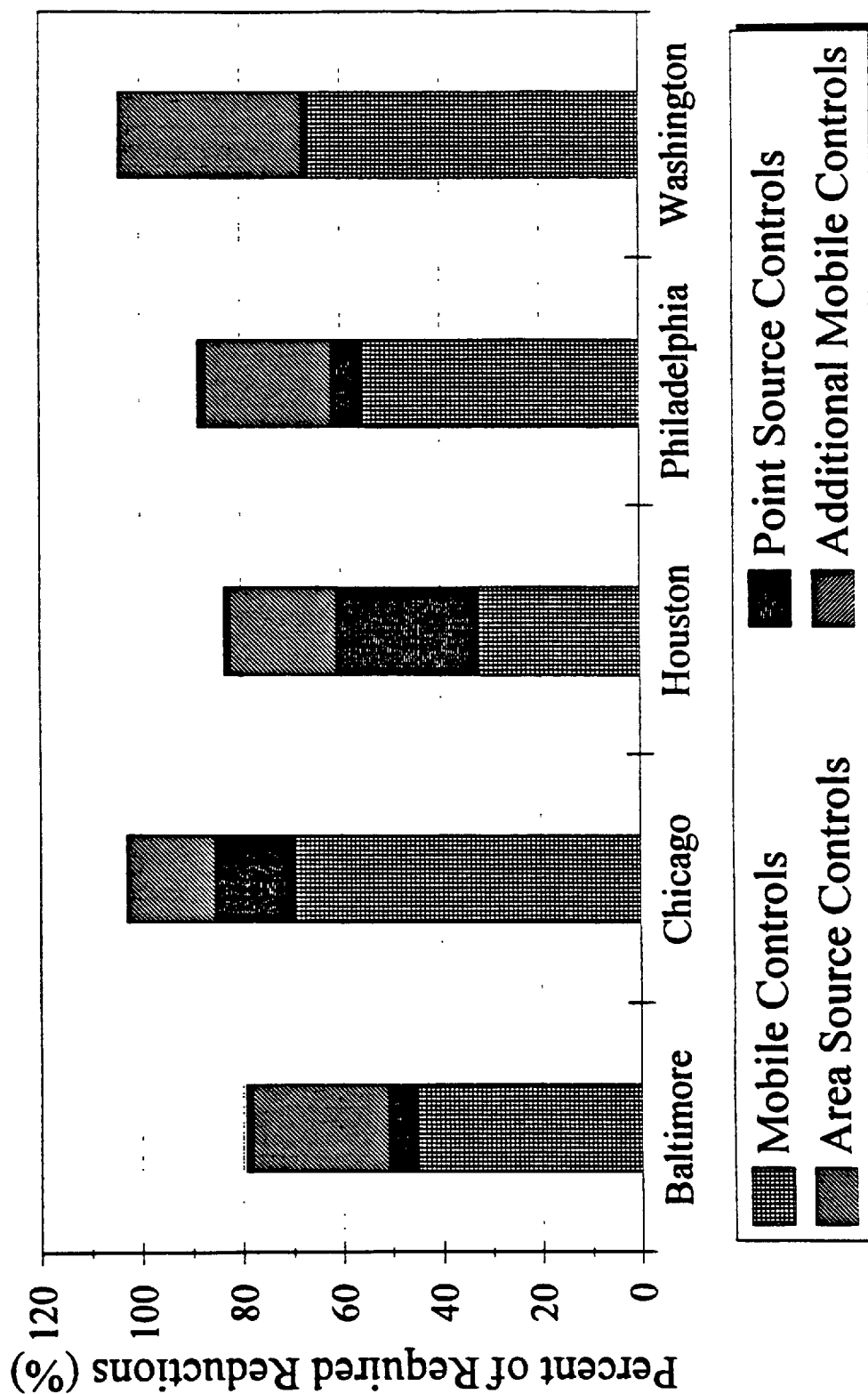


Figure ES-1. Rate-of-Progress Plans by City.

NOx Emissions Reductions Baltimore Nonattainment Area

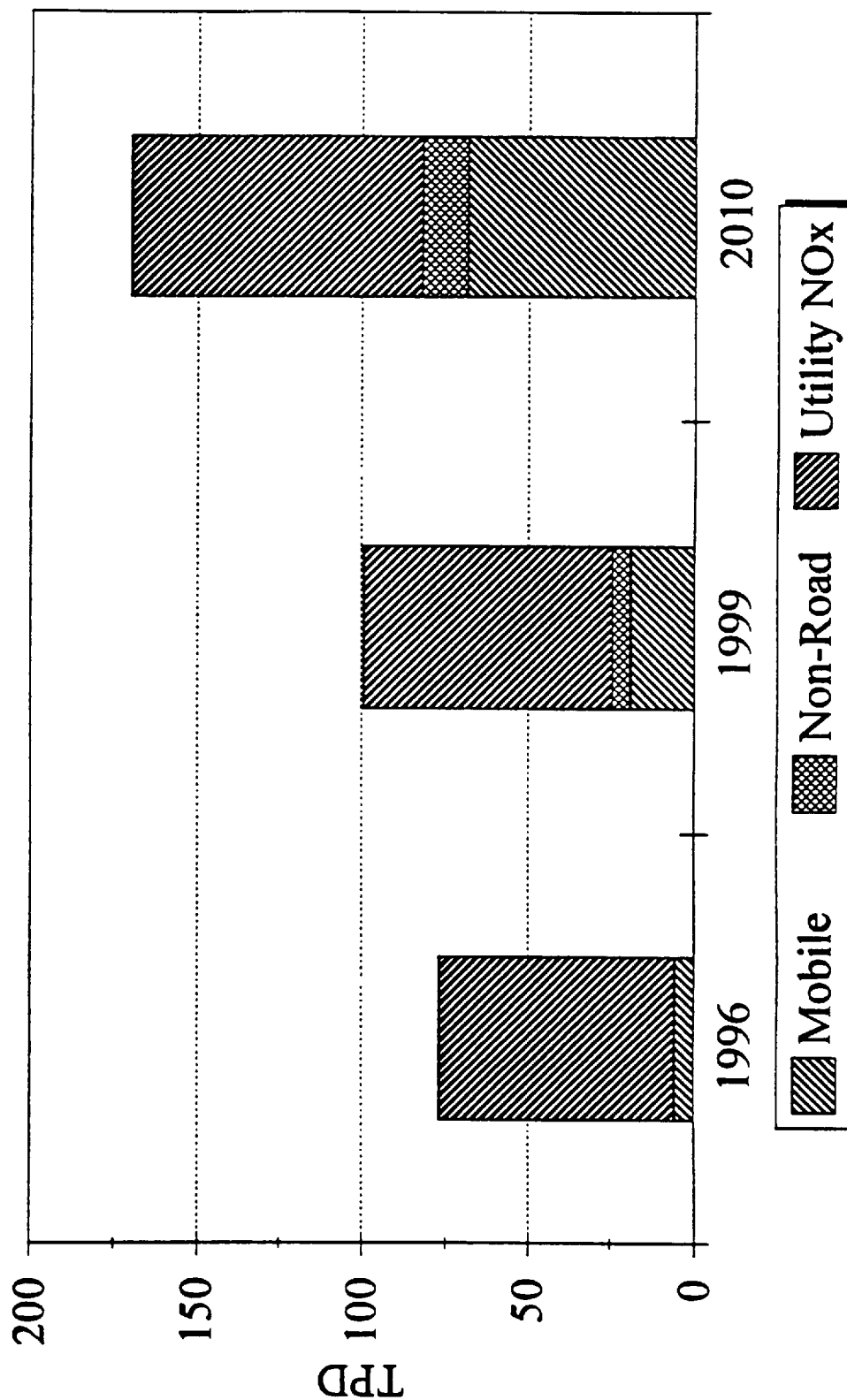


Figure ES-2. NOx Emissions Reductions in Baltimore.

NOx Emissions Reductions Chicago Nonattainment Area

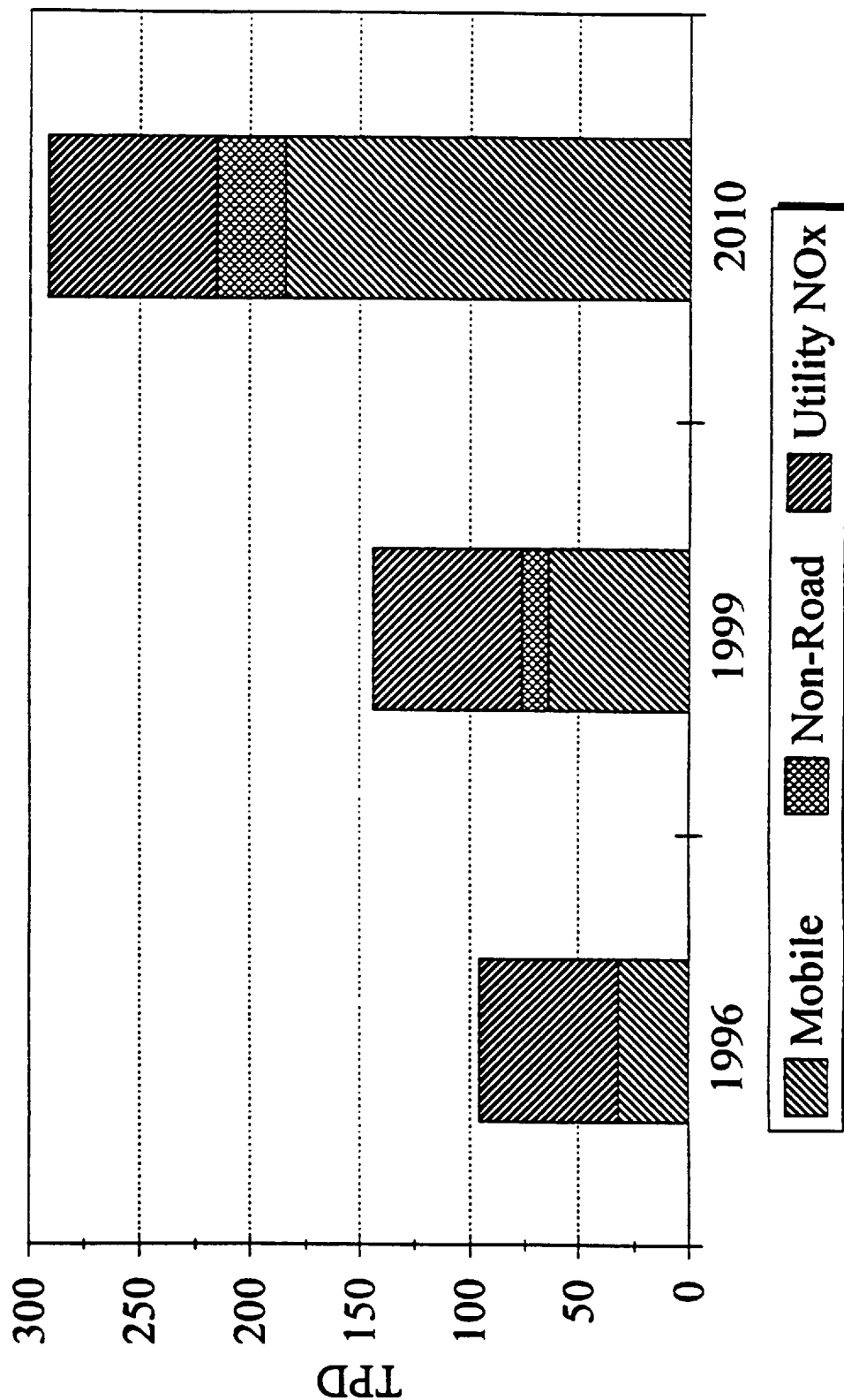


Figure ES-3. NOx Emissions Reductions in Chicago.

NOx Emissions Reductions

Houston Nonattainment Area

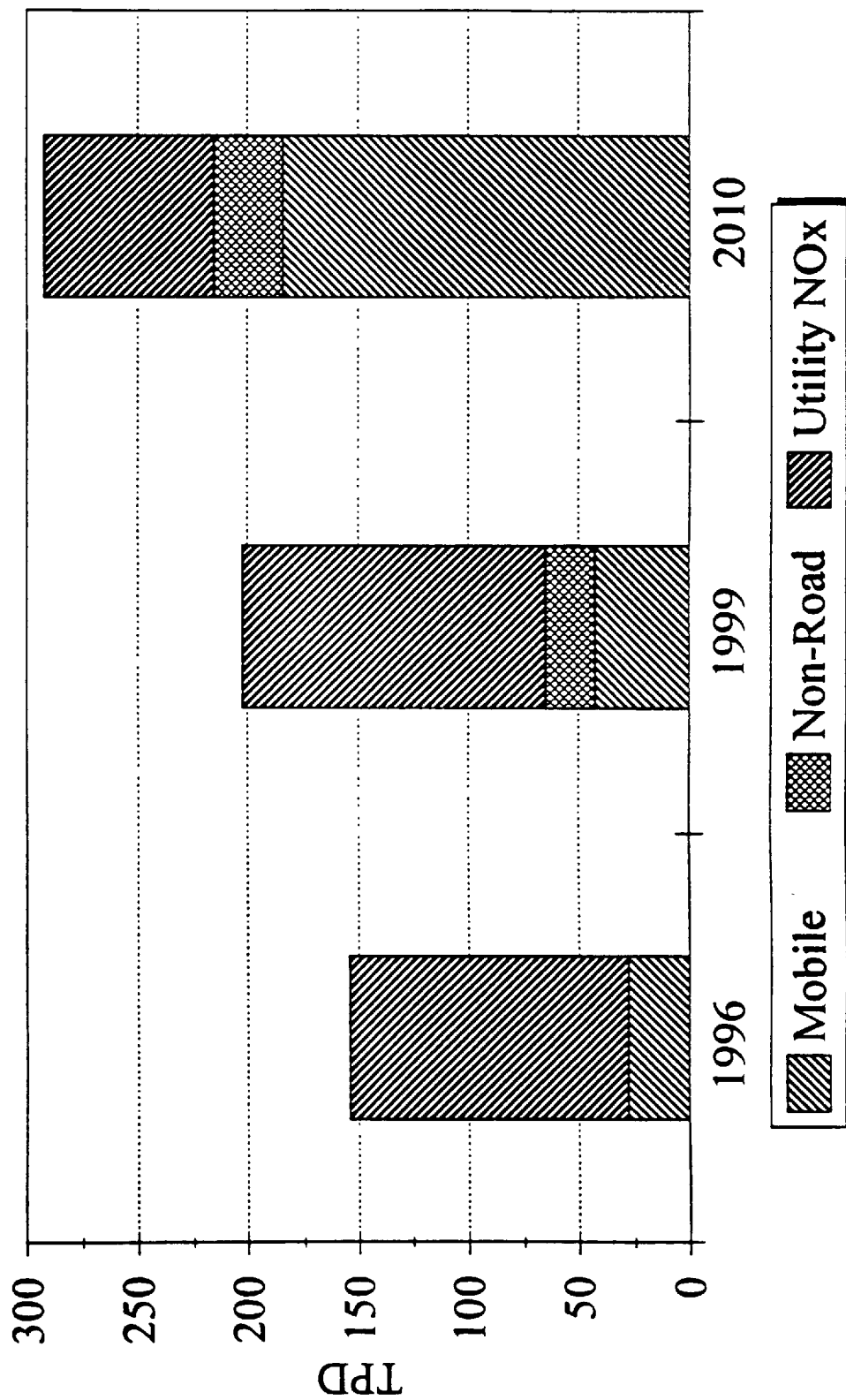


Figure ES-4. NOx Emissions Reductions in Houston.

ES-8



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NOx Emissions Reductions Philadelphia Nonattainment Area

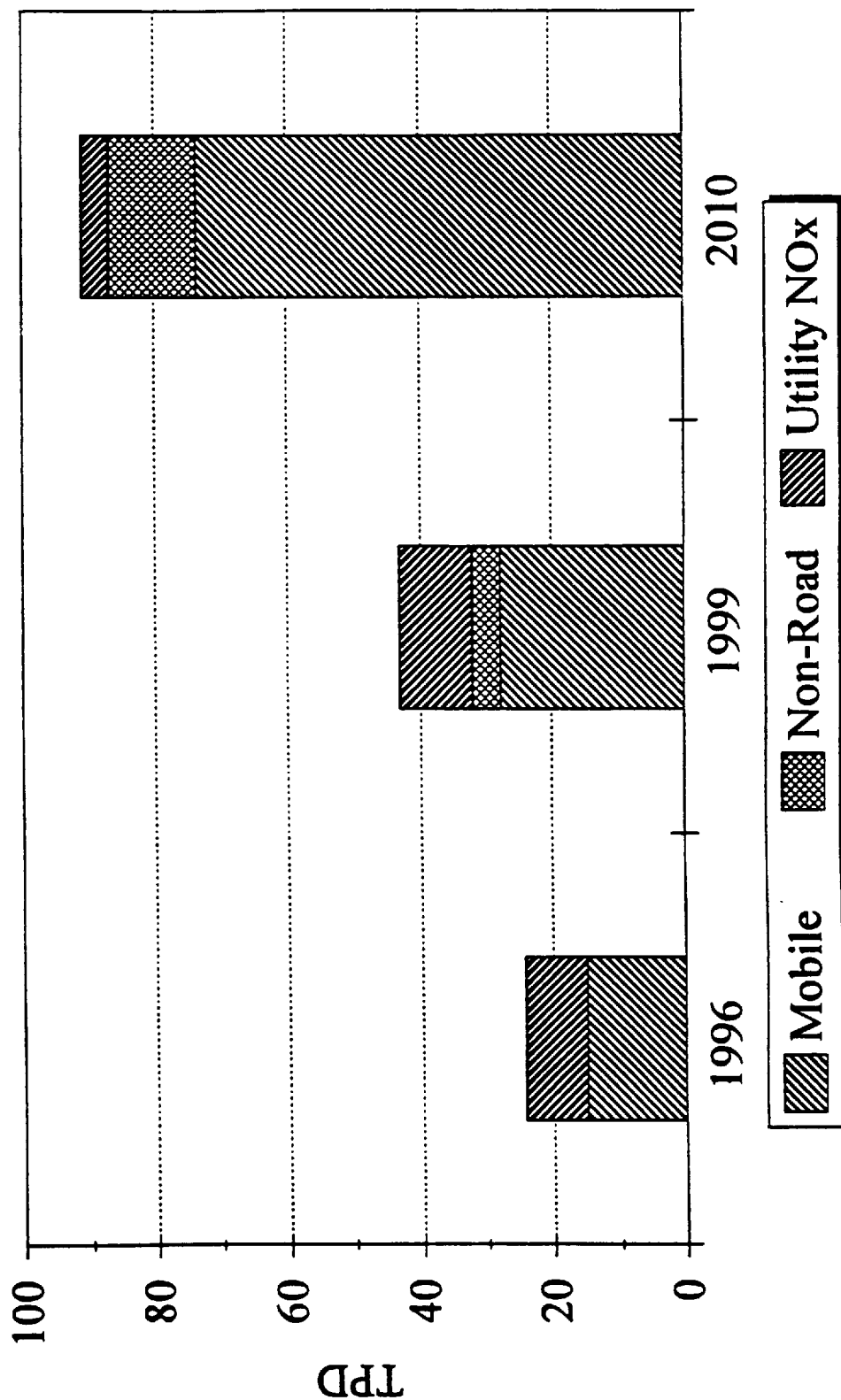


Figure ES-5. NOx Emissions Reductions in Philadelphia.

NOx Emissions Reductions Washington D.C. Nonattainment Area

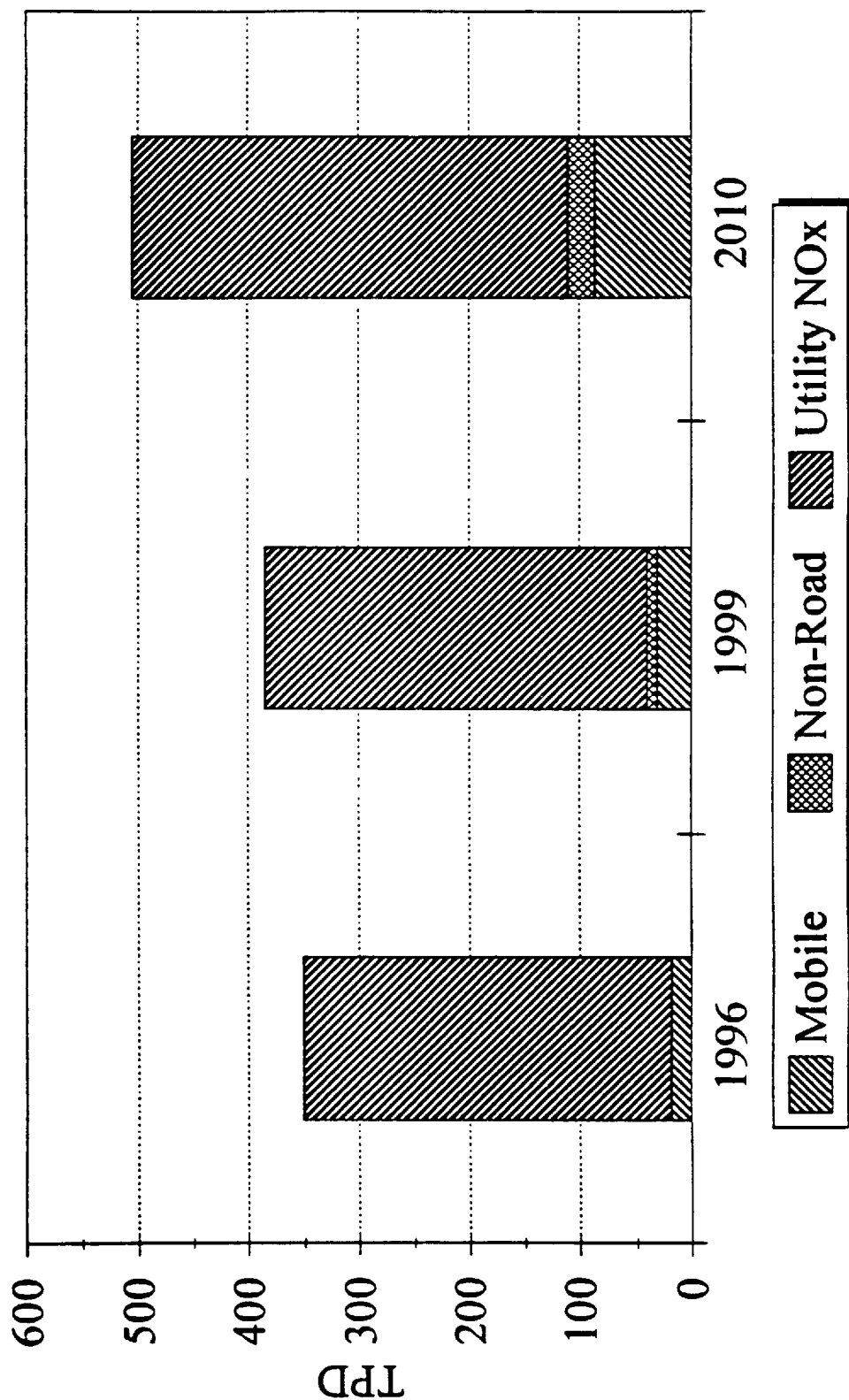


Figure ES-6. NOx Emissions Reductions in Washington D.C.

Section 1

INTRODUCTION

BACKGROUND

Since the initial passage of the Clean Air Act over two decades ago, emissions controls have become increasingly more stringent, and costly, for the largest sources of pollution. These sources include large point sources (e.g., petroleum refineries), and highway vehicles. The first controls applied were very cost-effective by today's standards, often reducing emissions for little or no cost. However, as time progressed and the National Ambient Air Quality Standards (NAAQS) for ozone still were not achieved, more and more stringent and expensive controls had to be adopted in order to continue reducing emissions.

Today, additional air quality regulations may mandate quite costly controls in order to meet new federal requirements. Under the requirements of Title I of the 1990 Clean Air Act Amendments (CAAA), all moderate and above ozone nonattainment areas must reduce their volatile organic compound (VOC) emissions by 15 percent by 1996 from adjusted 1990 levels. Depending on the severity of the nonattainment status, a city may have to decrease emissions further, by three percent per year, until attainment is reached. Once attainment is achieved, the city must implement a control plan designed to maintain those standards. In addition to the VOC requirements, specific NO_x reduction requirements may be adopted by EPA and the states in the future, based on the results of air quality modeling studies. These emission reduction targets are known as the Reasonable Further Progress, or RFP, requirements, and they present significant technical and economic challenges to state agencies and emission sources.

In order to comply with the requirements of the CAA, state air quality agencies must submit a State Implementation Plan, or SIP, demonstrating exactly how they intend to achieve the necessary emissions reductions. States must submit the SIPs to EPA by November of 1993. Revisions to the SIP for the serious and severe nonattainment areas

must be submitted one year later to demonstrate attainment based on air quality modeling. To develop these plans, the states can select from a broad "menu" of control strategies and options, covering the entire range of emissions sources, from point and area to on- and non-road mobile sources. Ideally, the state would evaluate all possible controls on the basis of contribution toward meeting the RFP and attainment targets, and choose to implement those that are the most cost-effective first. However, there are large uncertainties associated with both control efficiency and cost estimates. This point is particularly true for sources such as non-road mobile and large NO_x sources, that have not been regulated up to this time.

PURPOSE OF STUDY

The main purpose of this study is to provide SIP planners and other interested parties with a "menu" of possible control options, using the most up-to-date information and accurate analyses available, for all significant sources of VOCs and NO_x. In addition, the study also demonstrates how cost-effective packages of attainment strategies and control measures can be developed to meet RFP targets, as well as maintain standards after attainment. State agencies may be able to incorporate portions of this study's findings into their 1994 SIP revisions.

APPROACH

One set of control strategies alone cannot be identified that will allow all nonattainment areas to meet their RFP targets and achieve attainment in the most cost-effective manner. Site-specific variations in source distribution and other factors mean that different areas must be analyzed on a case-by-case basis. For example, factors such as temperature and average roadway speed have a significant impact on automobile emissions. Therefore mobile source control strategies also will have different impacts, depending on the area. For these reasons, Radian was asked to evaluate controls for five different cities: Baltimore, Chicago, Houston, Philadelphia, and Washington, D.C. These cities are all designated "severe" ozone nonattainment areas (with the exception of Washington, D.C., which is designated "serious"), and all must implement a broad range

of control measures. The cities provide a representative cross section of many of the ozone nonattainment areas in the U.S. Therefore, various sections of this report will be applicable to other cities not included in our analysis.

In order to develop site-specific control packages for VOC and NO_x, Radian performed the following tasks:

- Identified major source categories from state inventories;
- Identified feasible control options from literature;
- Modeled mobile source control effectiveness for all five areas;
- Conducted technical and economic assessments of options and determined cost-effectiveness rankings; and
- Developed site-specific cost-effective control approaches.

This report provides the results of Radian's study. The body of the report discusses the potential control options in a general manner, while the appendices provide a more detailed analysis of costs, effectiveness, and application limitations.

Section 2

KEY SOURCE CATEGORIES WITHIN SELECTED OZONE NONATTAINMENT AREAS

INTRODUCTION

Detailed, accurate inventory estimates are critical to the development of effective control strategies and recommendations for meeting RFP requirements. State-generated emission inventories are the basis of all further analysis in our study. The inventories received by Radian from the individual states varied in the level of detail. Quality control checks were done throughout the analysis to determine inconsistencies in the inventories, but resources did not allow us to quantify all the possible discrepancies. Radian therefore acknowledges there are uncertainties with the emissions estimates used in the analysis.

The methods used by the states to generate values in the emission inventories varied with the type of source. Point source estimates were determined using one or more of the following methods: direct measurement from source testing or monitoring data; permits specifying allowable emission rates; and EPA-approved emission factors. Area source emissions were determined using similar methods. The EPA MOBILE (release 5, 5a, or 4.1, depending on the location) emissions model was used to estimate mobile sources emission levels. Non-road mobile source emissions were estimated, primarily using emission factors.

Developing an accurate control strategy analysis also requires a detailed source category breakdown. Therefore the accuracy of this analysis is limited by the degree of detail found in the inventories. For example, if an entry in an emission inventory aggregates chemical manufacturing and petroleum refining activities, it becomes difficult to estimate what specific types of controls are applicable, and their relative contribution to total reduction potentials. Radian found varying levels of source category aggregation in the state inventories.

Uncertainties persist for many source categories, due to differences in the reporting formats among the states. For example, Chicago reported the Storage of Volatile Organic Liquids (VOLs) from all industries as a single source entry, whereas Houston included VOL storage within the Petroleum Refineries and Organic Chemical Manufacturing categories, separately. Another example of differing reporting practices is evident in the Graphic Arts and Printing and Publishing categories. For some of the inventories, emissions from all printing operations were reported within the Graphic Arts category, whereas for other inventories, a distinction was made between the two industries. (Graphic arts consists of flexography and rotogravure printing whereas printing and publishing includes lithography printing.) Similar differences were found with the Gasoline and Crude Oil Storage, Organic Chemical Manufacturing, Industrial Wastewater, Coke Ovens and Coke By-products, Degreasing, and Fuel Combustion categories.

DATA GATHERING

Five nonattainment areas were studied for this project: Baltimore, Chicago, Houston, Philadelphia, and Washington D.C. For each of these areas, Radian contacted the state agency responsible of generating the SIP emission inventory for that area. The main contacts in each city are given in Table 2-1.

Radian asked each agency for the final (or most recent) version of their 1990 SIP inventory, listing point, area and mobile source VOC and NO_x emissions. Most agencies responded promptly to our request providing the necessary information to develop our data base.

However, in some instances the inventories received were not the final inventories used in the November 1993 SIP submittals -- the Houston and Philadelphia data sent to Radian in September and October of 1993 have been revised significantly since that time. In these instances Radian's analysis may not cover all of the pertinent source categories, and there may be some errors in the projection of future emissions levels. (Nevertheless, Radian believes that the cost-effectiveness values and long-term ROP analysis contained in this report are accurate and dependable.)

The first step in analyzing the data was to obtain a list of all the emission sources in all five areas. In order to do this, Radian chose the list which had the most detailed breakdown of emission sources, and proceeded to complete it with a few missing source categories. The most detailed list was the one developed by the Illinois EPA for the Chicago nonattainment area, which was then entered into a spreadsheet. We reviewed the list of point sources in other cities to find the SIC code corresponding to the Chicago source categories, as several of these inventories were in database form, sorted by SIC code rather than by source category description.

This procedure is not without its drawbacks. In some cases, the classification by SIC Code was done on such a broad basis that all the point sources in a category such as Chemicals and Allied Products were aggregated into one emission number. Given the purpose of this project, a more detailed breakdown was necessary in such cases because it was difficult to identify appropriate control processes without knowing which manufacturing processes were involved. In such cases, we attempted to disaggregate emissions estimates by consulting with industry experts.

Table 2-1. Sources of Inventory Information

City	Agency
Baltimore	Air and Radiation Management Administration
Chicago	Illinois EPA
Houston	TNRCC
Philadelphia	PennDOT, Department of Environmental Resources, City of Philadelphia Department of Public Health
Washington D.C.	Metropolitan Washington Council of Governments

By and large, all area source categories were the same for all cities (e.g. coating sources, solvent use, etc.). Radian completed the inventory compilation by entering on-road

mobile source emissions based on the state's MOBILE model runs, as well as non-road mobile emissions.

The completed 1990 emission inventories used in our study can be found in Appendix A.

SOURCE CATEGORIZATION

Due to the size of the emission inventories and the large number of source categories, Radian had to limit the number of categories for detailed review. This selection was done by calculating emission level "cutpoints," and evaluating controls for those sources above this level, specified in tons per year. This level was chosen so as to include approximately 95 percent of the total emissions inventory. Controls for all source categories with total emissions above this cutpoint were evaluated. The cutpoints used to determine these "major" emission sources are provided in Table 2-2.

Table 2-2. Emission Cutpoints

Location	Total 1990 VOC Inventory (tons/day)	VOC Cutpoint (tons/day)	Total 1990 NO _x Inventory (tons/day)	NO _x Cutpoint (tons/day)
Chicago, Illinois	1248.5	3.8	1008.9	10
Washington, D.C.	556.1	8	863.7	20
Baltimore, Maryland	323.5	2.6	430.5	5.9
Philadelphia, Pennsylvania	577.9	6	381.9	7
Houston, Texas	1103.1	10	1347.2	20

Once the cutpoints were established for each city and the major sources were identified, Radian reviewed the available literature to determine possible control strategies. We found that not every source category emitting above the cutpoint level has the potential for further control. Open burning operations, for example, fell within our cutpoints for several areas, but no control can be explicitly applied to this source, with the possible exception of a burning ban. Also, the Chicago inventory has an entry for Other Industri-

al Processes which is included within the 95 percent level, for which we were unable to assess controls because of its non-descript characterization. Similar situations were found for Plastic Parts Manufacturing and Stage I systems, which were also above the cutpoint levels. Radian did not apply control estimates to these categories for lack of further information.

Perchloroethylene dry cleaning also fell within the 95 percent level. However, perchloroethylene was removed recently from the list of photochemically reactive chemicals and is therefore no longer considered a VOC. Therefore, Radian did not evaluate controls for this source since it is no longer classified as a photochemically reactive emission.

Figures 2-1 through 2-10, presented on the following pages, illustrate the VOC and NO_x inventory breakdowns and provide a visual representation of the relative source contributions for each city.

Although there are some sources within the inventories that account for a large percentage of total emissions, no one source can supply all the emissions reductions needed to meet the RFP targets. It is important to understand that most nonattainment areas have already adopted regulations to limit VOC emissions from stationary sources to a great extent. Therefore, a broad-based, comprehensive control strategy package, including all four source areas (point, area, on-road, and off-road) must be developed.

MAJOR SOURCE CATEGORIES

Table 2-3 provides a summary of the major VOC emission sources by site and Table 2-4 illustrates the distribution of major NO_x sources. Major sources were defined as any category emitting above a region's cutpoint level. If a source was considered major, an "X" is shown in the table to illustrate the distribution of sources within each inventory. Sources denoted by an "○" are sources that were not documented in the emission inventory as major sources but for which, due to the industrial make-up of the region, seem to have been omitted from the inventory.

Baltimore Inventory VOC

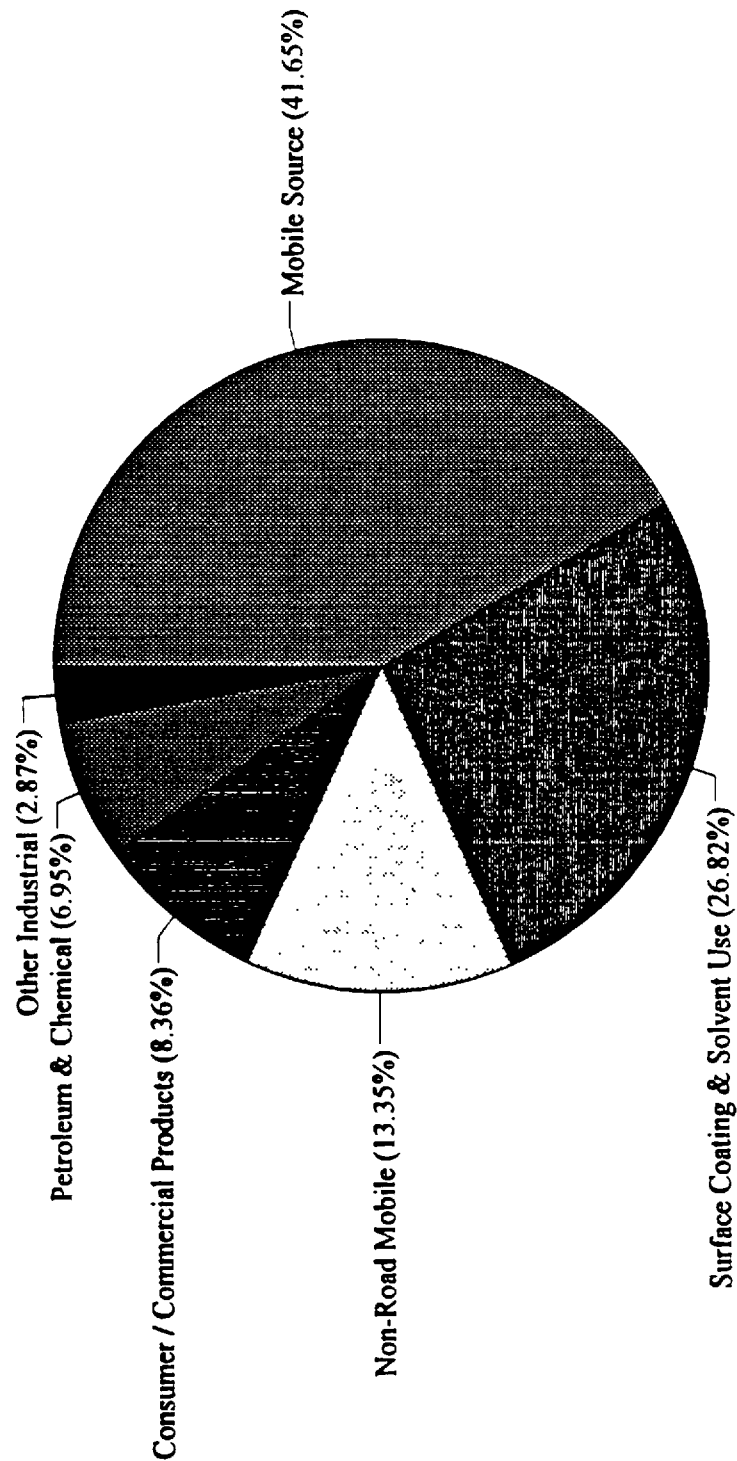


Figure 2-1. 1990 VOC Emissions in the Baltimore Nonattainment Area.

Chicago Inventory VOC

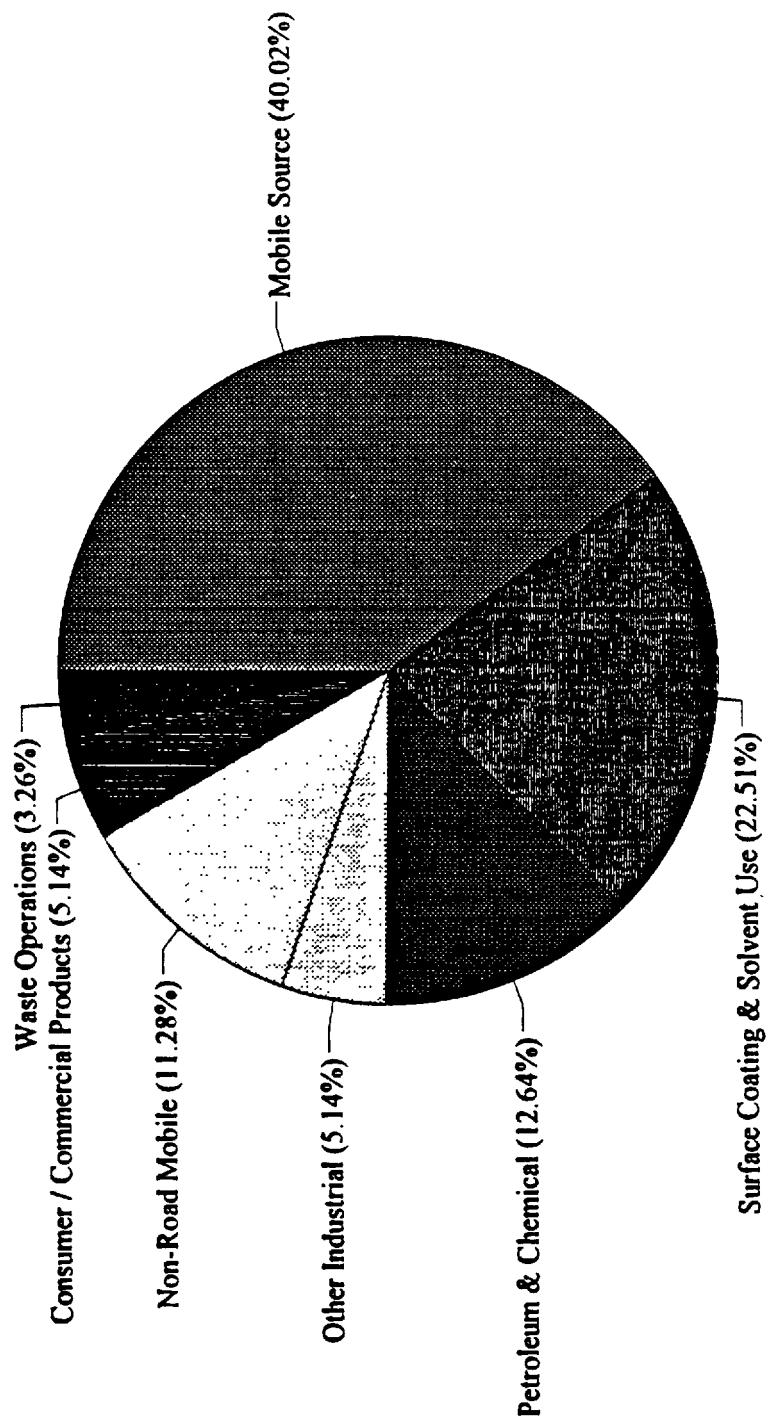


Figure 2-2. 1990 VOC Emissions in the Chicago Nonattainment Area.

Houston Inventory VOC

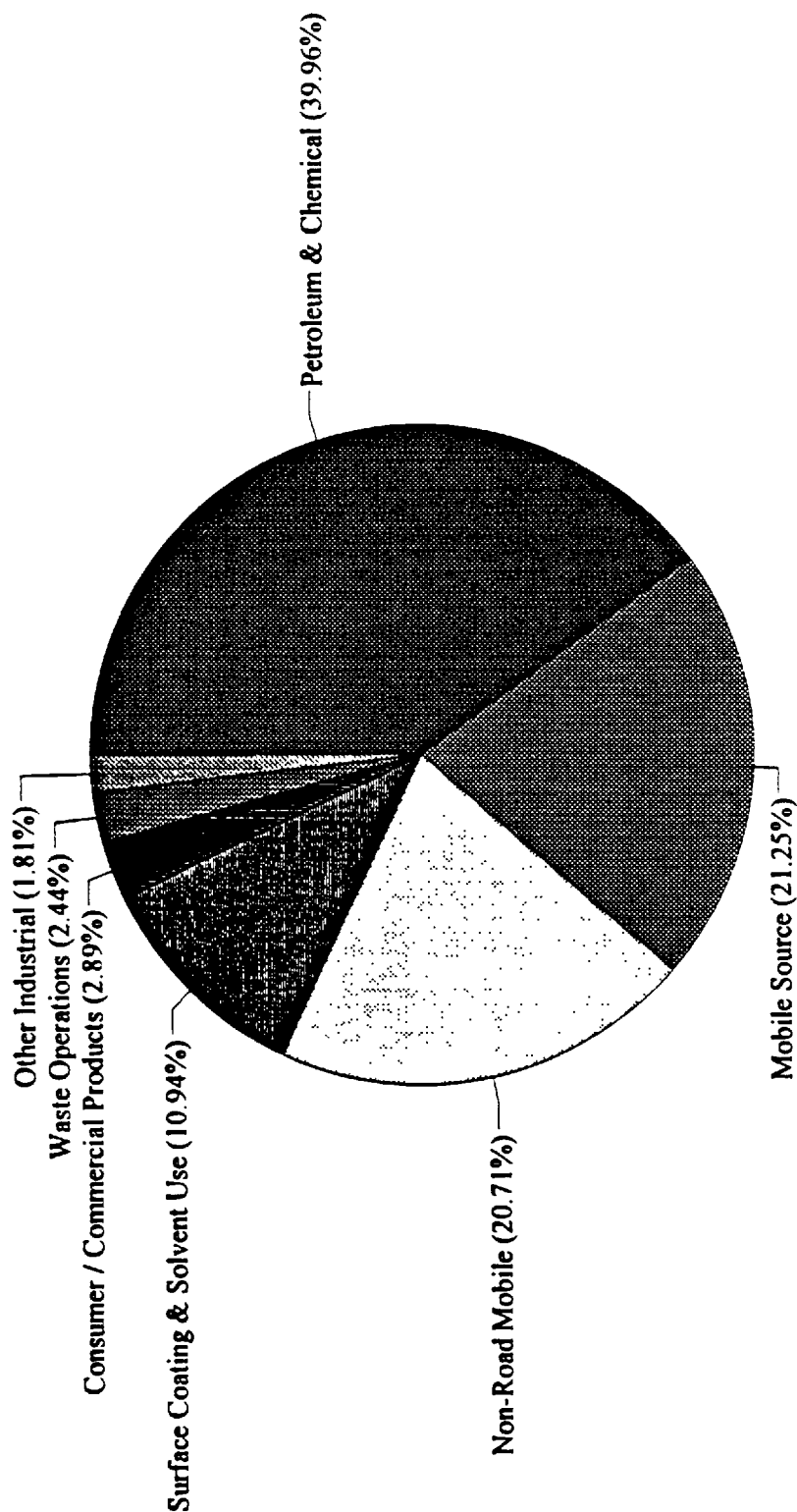


Figure 2-3. 1990 VOC Emissions in the Houston Nonattainment Area.

Philadelphia Inventory VOC

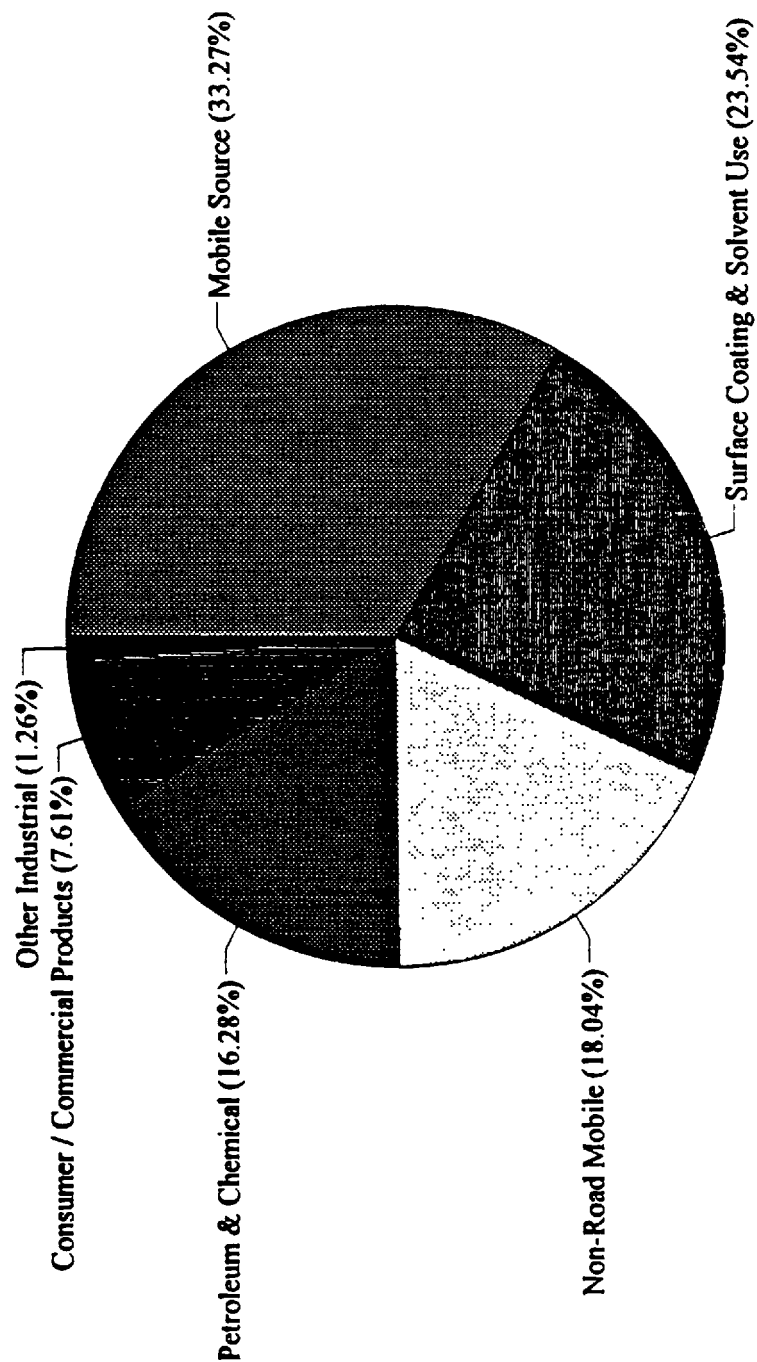


Figure 2-4. 1990 VOC Emissions in the Philadelphia Nonattainment Area.

Washington D.C. Inventory VOC

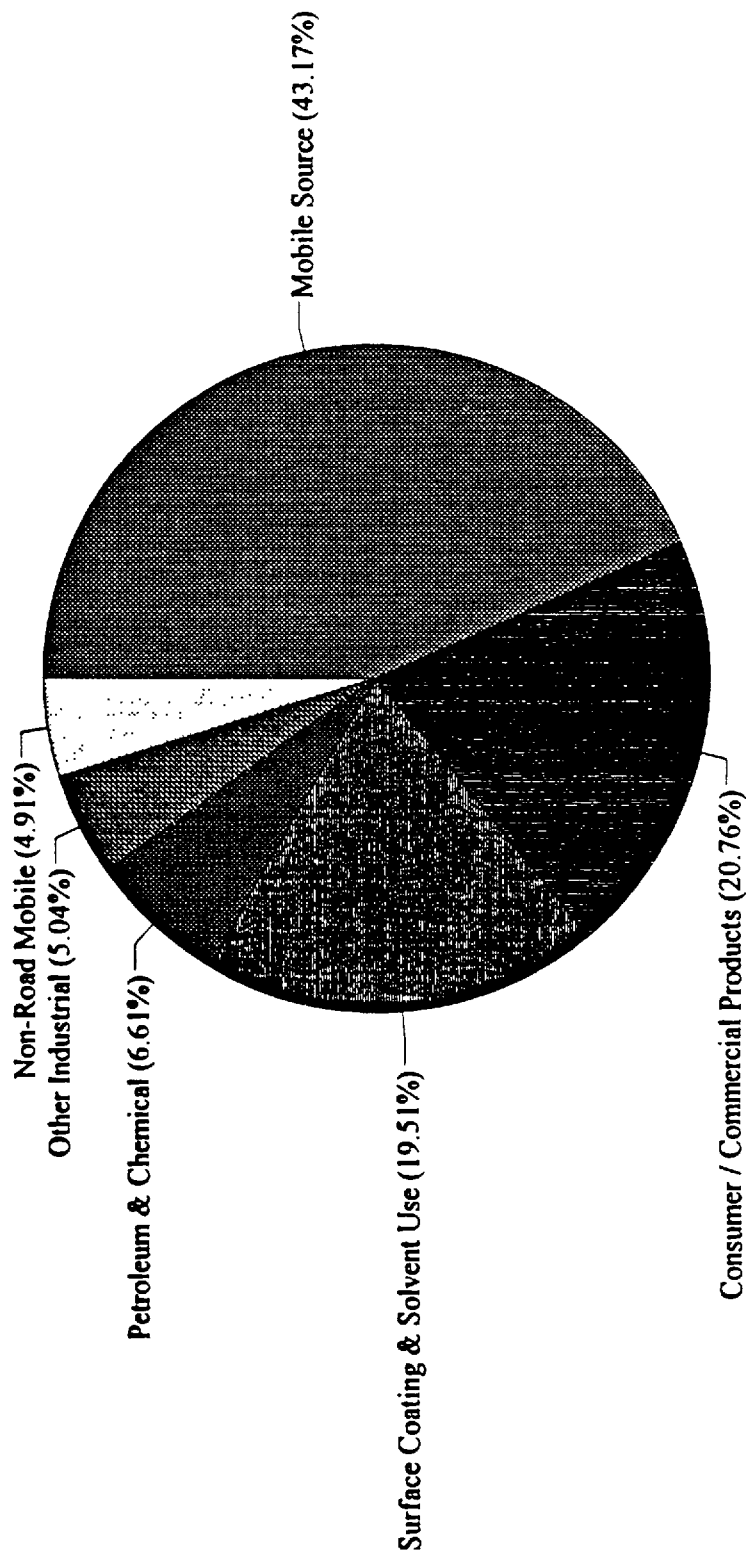


Figure 2-5. 1990 VOC Emission in the Washington D.C. Nonattainment Area.

Baltimore Inventory NOx

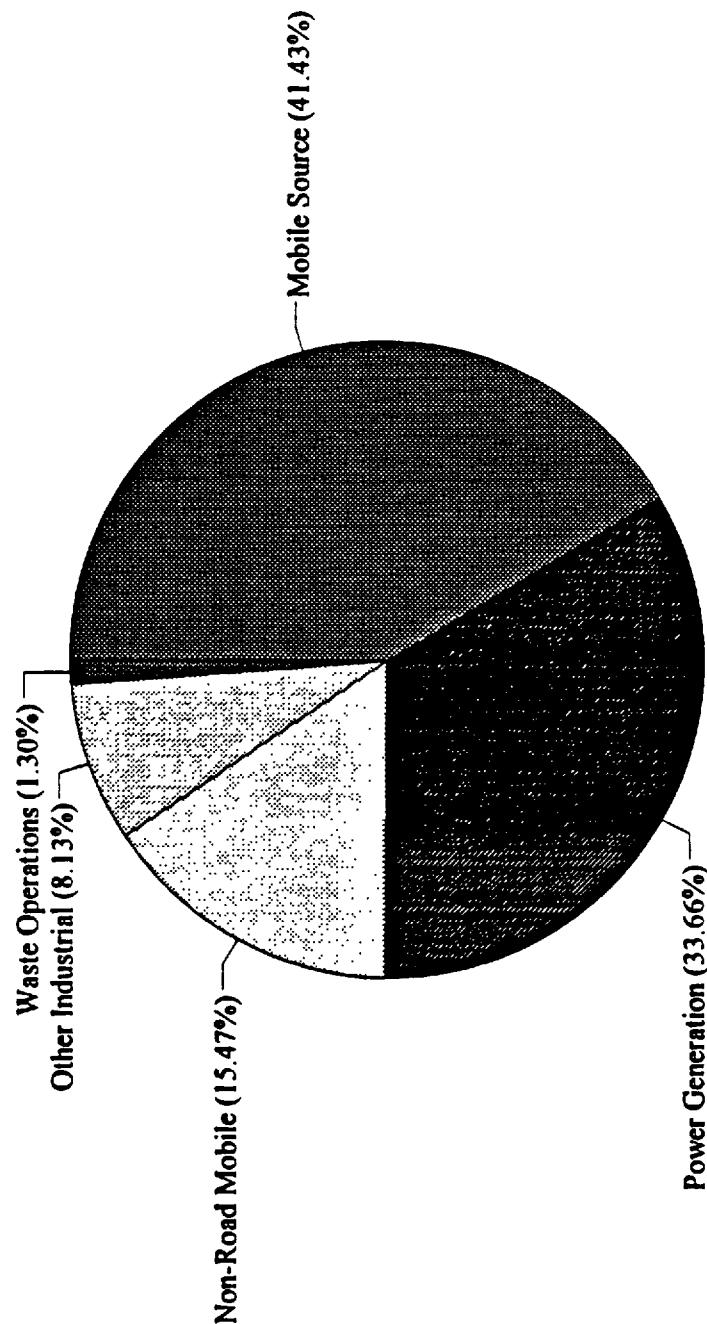


Figure 2-6. 1990 NOx Emissions in the Baltimore Nonattainment Area.

Chicago Inventory NOx

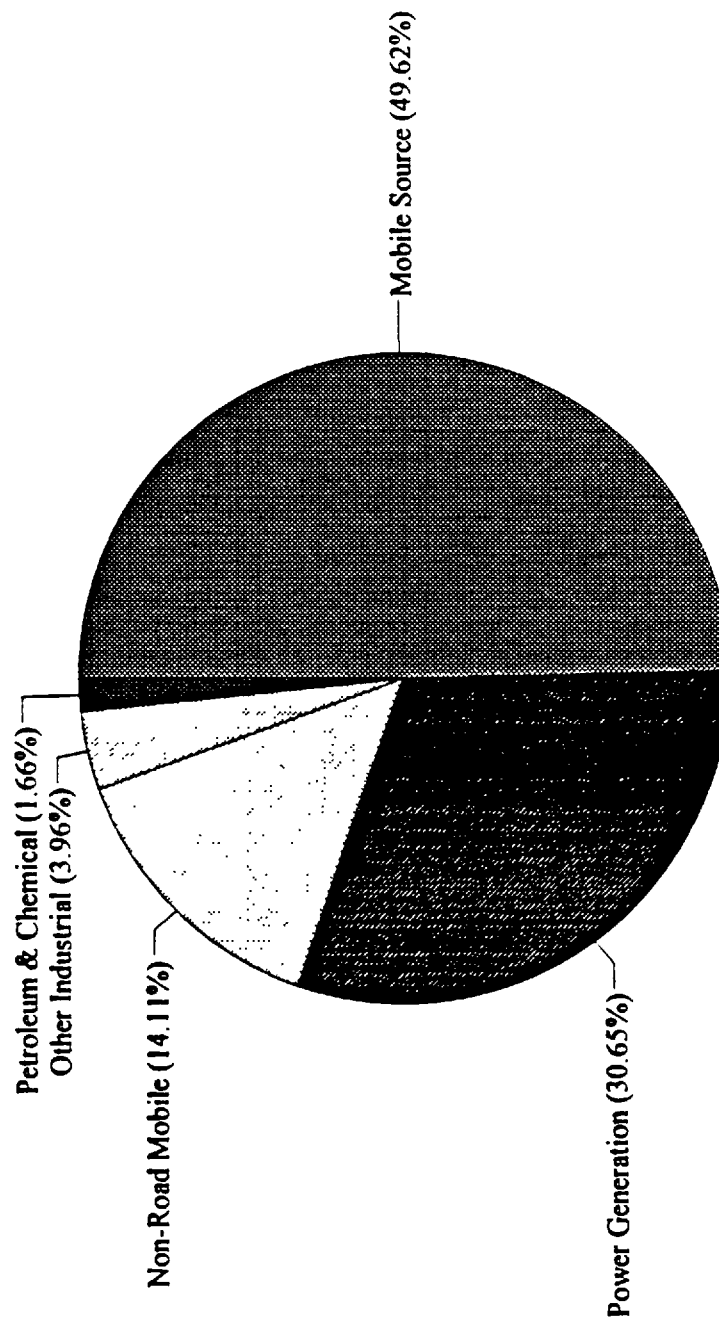


Figure 2-7. 1990 NOx Emissions in the Chicago Nonattainment Area.

Houston Inventory NO_x

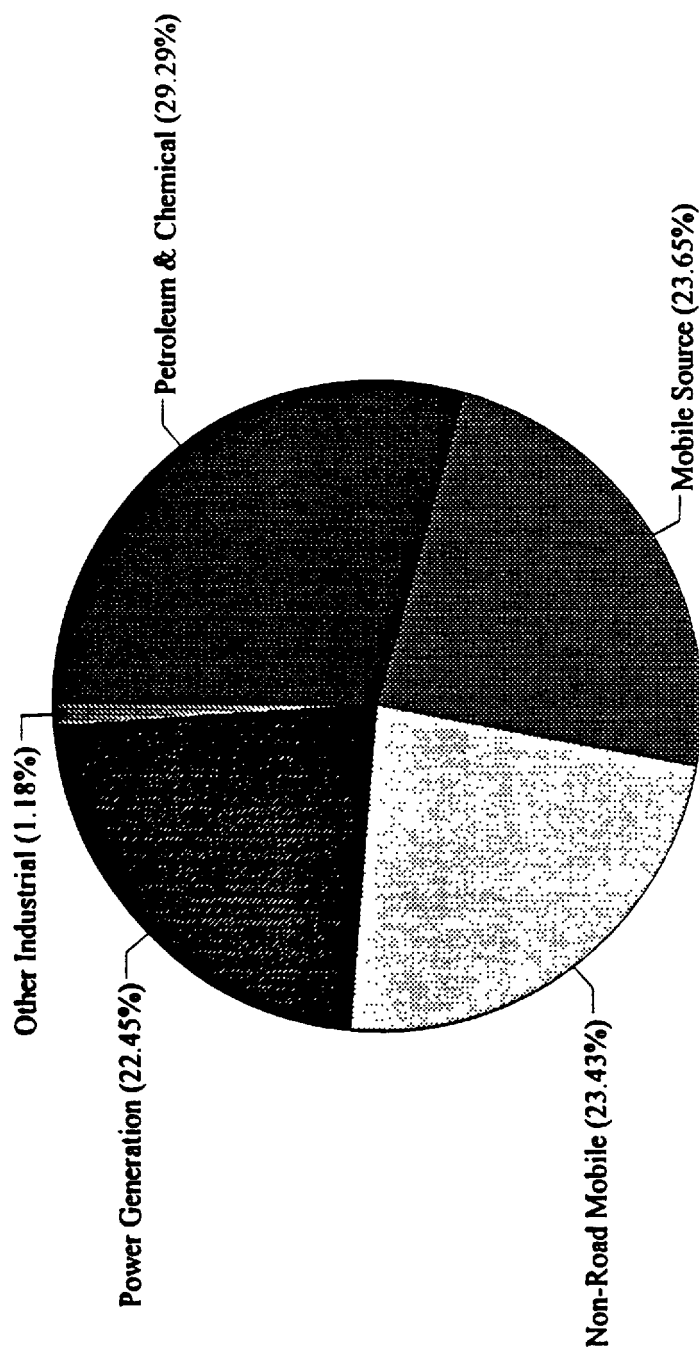


Figure 2-8. 1990 NO_x Emission in the Houston Nonattainment Area.

Philadelphia Inventory NO_x

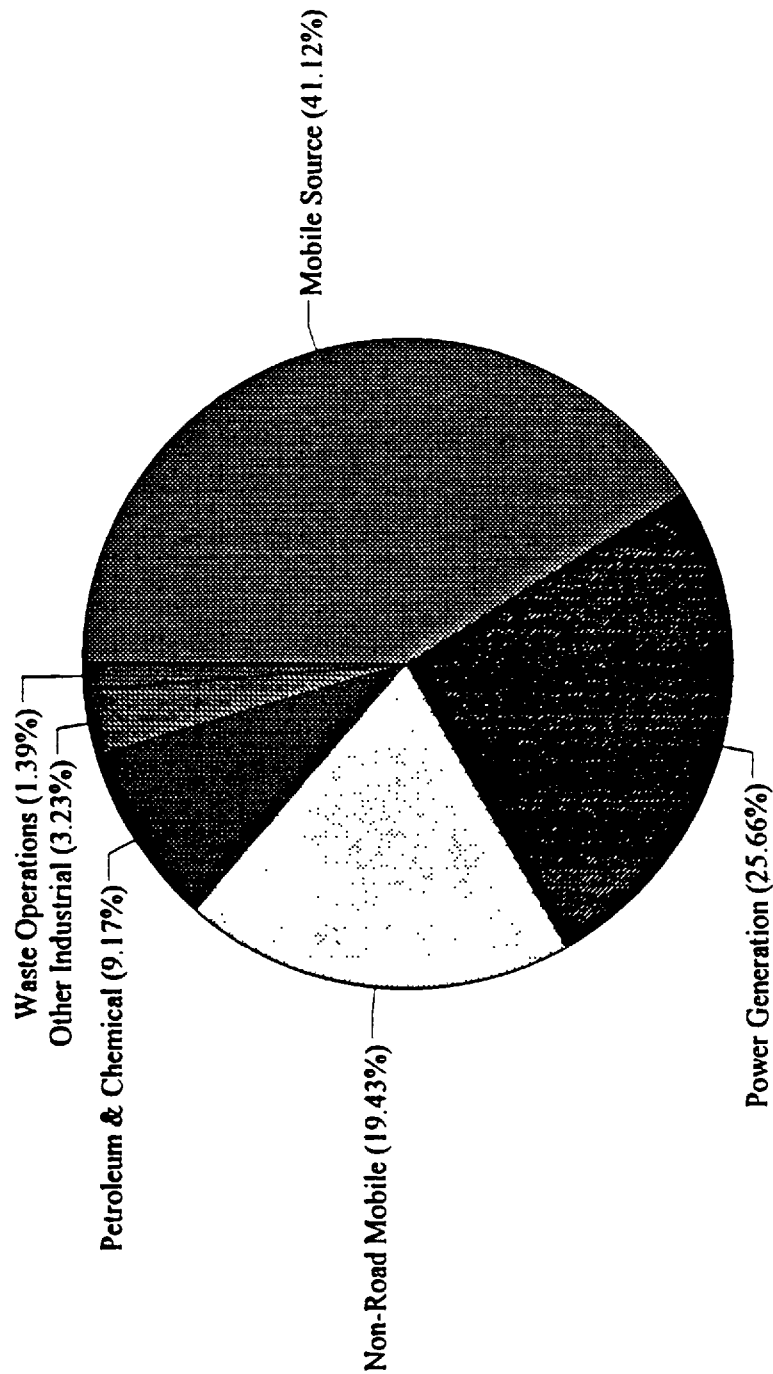


Figure 2-9. 1990 NO_x Emission in the Philadelphia Nonattainment Area.

Washington D.C. Inventory NOx

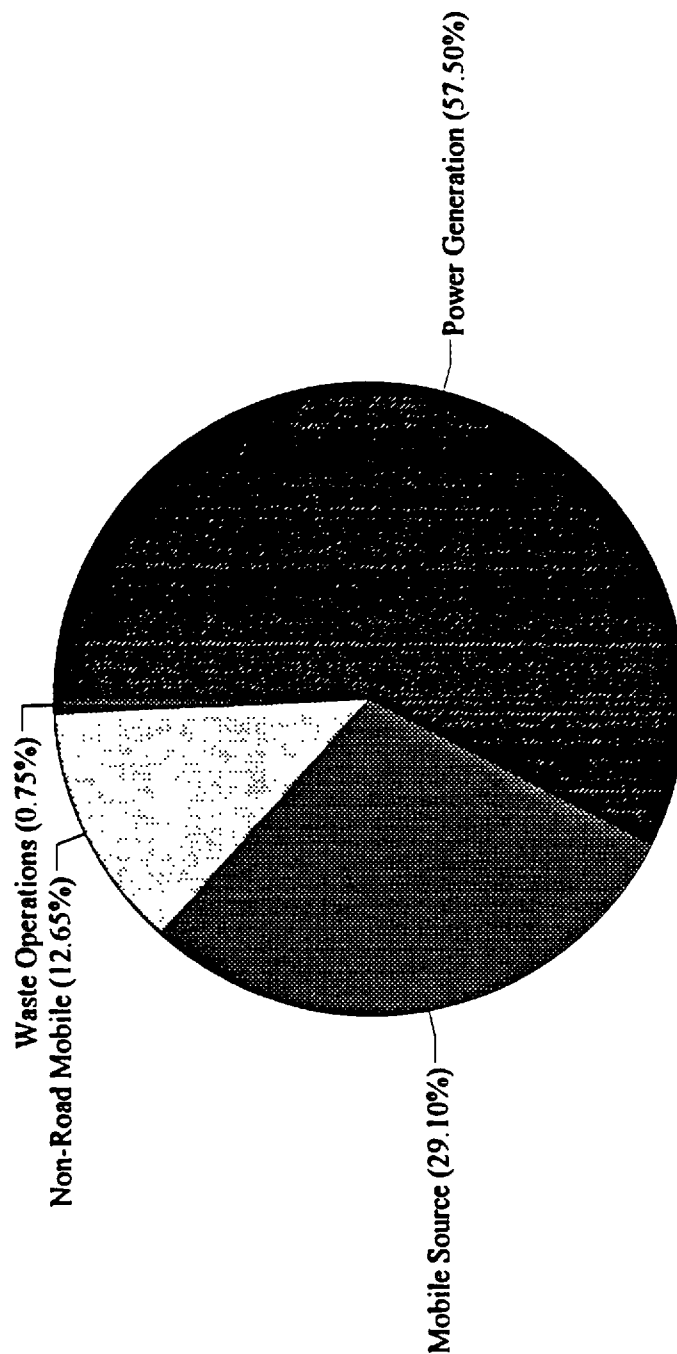


Figure 2-10. 1990 NOx Emissions in the Washington D.C. Nonattainment Area.

Table 2-3. Major VOC Source Distribution

Source Category	Chicago Illinois	Houston Texas	Philadelphia Pennsylvania	Washington D.C.	Baltimore Maryland
Point Sources:					
Bulk Gasoline Terminals	X	X	○		X
Coke Production	X	○			
Degreasing	X	○	X		○
Graphic Arts	X		X		X
Industrial WWTFs	X	X			○
Iron and Steel Mfg.	X				○
Landfills	X				○
Oil and Gas Production		X			
Petroleum Refineries	X	X	X		
Pharmaceutical Mfg.	X				○
Plastic Parts Mfg.	X	X			
POTWs	X				○
SOCMI	X	X	○		
Surface Coating	X	X	X	X	X
Textile, Polymer, and Resin Mfg.	X	○	○		
VOL Storage	X	X	X		○
Waste Operations	X				○
Area Sources:					
AIM Coatings	X	X	X	X	X
Asphalt Paving	X			X	
Consumer and Commercial Products	X	X	X	X	X
Degreasing	X	X	X	X	X
Marine Vessel Loading		X	○		○
Service Station Loading	X	○	X		○
Underground Tank Breathing	X		X		○
On-Road Mobile:	X	X	X	X	X
Off-Road Mobile:	X	X	X	X	X

Table 2-4. Major NO_x Source Distribution

Source Category	Chicago Illinois	Houston Texas	Philadelphia Pennsylvania	Washington D.C.	Baltimore Maryland
Point Sources:					
Glass Production	X				
Industrial Power Generation	X				
Iron and Steel Mfg.	○				X
Oil and Gas Production		X			
Petroleum Refineries	X	X	X		
Stationary IC Engines	X	○	○		X
SOCMI	○	X	○		
Utility Power Generation	X	X	X	X	X
Area Sources:					
Residential	X		X		
On-Road Mobile:	X	X	X	X	X
Off-Road Mobile:	X	X	X	X	X

As illustrated in Tables 2-3 and 2-4, the relative impact of each category on the total emission inventory varies by location. Much of this difference is explained by looking at the industrial and demographic make-up within each nonattainment area. For example, because Washington D.C. has little industrial activity within its boundaries, there is no significant chemical or petroleum refining, manufacturing or production emissions. However, due to its large population, emission sources such as graphic arts, consumer products, and vehicle emissions have more of an effect on the inventory. Conversely, the industrial sectors in the Houston and Chicago areas account for a significant portion of their total emissions inventories. Similar observations can be made for other categories and nonattainment areas of study. It should be noted that if an "X" doesn't appear, it may be a result of Radian's inability to characterize or disaggregate the data.

Several source categories are common throughout all the inventories. Common categories include Degreasing Operations, Consumer and Commercial Solvents, Utility Power

Generation, and On- and Off-Road Mobile sources. These categories are generic, and are essential to urban activity, independent of geographic location.

There were also several sources that were unique to each area. For instance, Chicago was the only area that had Coke Production, Iron and Steel Manufacturing, and Textile, Polymer, and Resin Manufacturing as major sources of VOC emissions. Likewise, Oil and Gas Production is only significant in the Houston inventory.

Section 3

VOC AND NO_x CONTROLS FOR POINT AND AREA SOURCES

Once the major source categories for each nonattainment area were identified, Radian looked for possible technologies for controlling VOC and NO_x emissions. Determination of the baseline level of controls for each area of study was the first step in identifying further control alternatives. Next, numerous documents and reports were reviewed and experts were consulted to determine feasible control measures. Finally, stationary source control options were reviewed to provide estimates for control efficiencies and cost-effectiveness.

CONTROLS IN PLACE IN 1990

The first step in developing accurate and comprehensive control strategies for point and area sources was to determine the baseline level of controls for each of the five nonattainment areas included in the study. This information was gathered from a variety of sources, including: EPA's Control Technology Guideline (CTG) documents that provide possible technologies for meeting the reasonably available control technology (RACT) levels being adopted in nonattainment areas; the Bureau of National Affairs (BNA) reference guide, used to determine the individual states' regulations; the STAPPA report, which provided a detailed description of both current state and federal as well as proposed regulations; and personal contacts with industry representatives, EPA officials, and Radian experts.

For the development of emission reductions estimates, it was assumed, unless explicitly noted, that the baseline controls already adopted in the various regions had a 100% rule penetration. We are aware that in practice this would not be the case, but this assumption provides a conservative baseline and ensures that the study will not overestimate the potential reductions from further controls. Rule effectiveness is another factor that states use to account for uncertainty in the ability of the rule to control the targeted source. The EPA guidelines employ an 80% rule effectiveness value for sources that are

currently regulated. States may show an increase in the rule effectiveness value, representing increased compliance or application rates, as a method of increasing emission reductions.

INFORMATION SOURCES

Much of the information gathered for our analysis of further controls came from the following sources:

- U.S. EPA control techniques guideline (CTG) documents describing regulatory alternatives and reasonably available control technology (RACT) alternatives for ozone nonattainment areas;
- Background information document (BIDs) for proposed/promulgated new source performance standards (NSPS) and National Emission Standards for Hazardous Air Pollutants (NESHAP), defining control techniques above CTG-RACT level;
- The South Coast Air Quality Management District (SCAQMD) Final Air Quality Management Plan providing model regulations applicable throughout the five areas of study;
- The Bay Area Air Quality Management District (BAAQMD) Clean Air Plan providing additional regional regulatory alternatives;
- The State and Territorial Air Pollution Program Administrators (STAPPA) list of control measures for meeting the RFP requirements of the Clean Air Act;
- Lake Michigan Ozone Control Program (LMOP) document providing an evaluation of possible VOC and NO_x control measures; and
- Studies performed by Radian for government or private industry.

Each of these documents provided valuable information for determining the 1990 baseline level of control, regulatory activities, impending legislation, incremental control options, and cost-effectiveness estimates.

POINT AND AREA SOURCE VOC CONTROLS

After establishing baseline control estimates for many of the VOC emission sources, it became evident that a majority of the large point source categories were already regulated to varying degrees. These regulations ranged from RACT-level controls to the more rigorous National Emission Standards for Hazardous Air Pollutants (NESHAP) control requirements. Petroleum refining is an example of a large point source currently under multiple regulations. Within this industry, regulated activities include RACT-level standards for storage, transfer, and shipping of petroleum products, process vents throughout facilities, wastewater treatment facilities, and leaks from valves, flanges, and compressors. In addition, the industry is also subject to the Benzene NESHAP and the Benzene Waste Operations NESHAP regulations which provide even more stringent control requirements for toxins and VOCs as a whole. Similar levels of control and regulations were found for the SOCFI industry. Additional controls for the SOCFI industry through the Hazardous Organic NESHAP (HON), and refineries and petroleum marketing terminals through MACT requirements will result in additional VOC reductions. Finally, federal New Source Performance Standards and varying degrees of state regulations affect the baseline level of VOC control for numerous source categories.

Industries for which regulations are not currently in effect provide the greatest potential for further control. The Clean Air Act Amendments of 1990 required the development of thirteen new CTGs by November 1993. The sources targeted by these new control documents are widely available for further control since little or no regulation has been developed in the past for them. The 13 new CTGs cover:

- SOCFI Distillation
- SOCFI Reactors
- Wood Furniture Coating
- Plastic Parts: Business Machines
- Plastic Parts: Other
- Offset Lithography
- Autobody Refinishing
- Batch Processing
- VOL Storage Tanks
- Cleanup Solvents
- Aerospace Coatings
- Ship Building and Repair

- **Industrial Wastewater**

In addition to the thirteen new CTG documents, other Federal control programs have been, or are being, developed to control VOC emissions at a national level. These measures cover:

- **Marine Vessel Loading;**
- **Consumer and Commercial Products;**
- **Architectural and Industrial Coatings; and**
- **Adhesives.**

The EPA has also produced alternative control documents (ACTs) for the following sources providing possible control alternatives, including:

- **Halogenated Solvent Cleaners;**
- **Traffic Markings;**
- **Automobile Refinishing;**
- **Organic Waste Process Vents; and**
- **Pesticide Application and Bakeries.**

This information was used to develop incremental control options above and beyond those already in place, and to determine the applicability of available VOC controls. Radian compiled detailed descriptions of control methods, control efficiencies, and cost-effectiveness estimates for the VOC categories listed in Table 3-1. Detailed analysis of each source category can be found in the supplemental documentation.

Table 3-1. Ranking of Stationary Source VOC Control Categories

Stationary Source VOC Controls Categories	Effectiveness of Control	Cost of Control (\$/ton) (1993\$)
Traffic/Maintenance Paints • Reformulation	40-53%	\$(1,462)
Emulsified Asphalt • Reduce oil distillate content	50%	\$100
Underground Storage Tank Breathing • Pressure/vacuum valves	80-100%	\$10-230
Degreasing • Alternative solution/operating requirements	20-40%	\$2-368
Landfills • Gas collection systems	79%	\$500-930
Oil and Gas Production • Tanks, dehydrators, fugitive, and pneumatic	69-100% (process dependent)	\$1,300 (Tanks) \$750 (Pneumatic)
Organic Chemical Manufacturing - Others • Add-on controls	20%	\$800-2,000
Pesticide Application • Change formulation and application	30-45%	\$1,600
Consumer and Commercial Products • Reformulation	28%	(100)-3,400
Industrial Wastewater Treatment • Steam stripping	83-92%	\$400-3,000
Graphic Arts • Offset lithography	43-60%	\$0-3,700
Architectural and Industrial Maintenance Coatings • Reformulation	20%	\$(8,600)-12,800
Can Coating • Control technologies	5-10%	\$2,200
Industrial Machinery and Equipment Coating • Improved transfer efficiency and reformulation	25-30%	\$2,200
Miscellaneous Metal Parts Coating • Improved transfer efficiency and reformulation	25-30%	\$2,200

Stationary Source VOC Controls Categories	Effectiveness of Control	Cost of Control (\$/ton) (1993\$)
Bulk Gasoline Terminals • Improved vapor recovery units	70%	\$2,600
Vessel Loading - Marine • Vapor control devices	80-98%	\$500-8,000
Petroleum Refineries • Control tank and fugitive emissions	27-34%	\$42-6,067
Paper Coating • Low-solvent coatings	1%	\$5,000
Automobile Refinishing • Control preparation, coating operation and gun cleaning	43%	\$478-7,000
Organic Chemical Manufacturing - Synthetic • WWT, process vents, equipment leaks, and tanks	77-85%	\$210-10,032
Storage and Warehousing • Vapor recovery units, internal/-external roofs, and seals	60-95%	\$120-12,320
Volatile Organic Liquid Storage • Vapor recovery units, internal/-external roofs, and seals	60-95%	\$120-12,320
Auto and Light Truck Surface Coating • Add-on controls	20-30%	\$17,400-19,000
Coke Oven Batteries	12%	\$37,120

Table 3-1 presents a list of the VOC control options' cost-effectiveness. For those options with a range of dollars per ton values, the average of the range was used for ranking purposes. The "average" cost-effectiveness values given above assume that retrofit costs are evenly distributed between the high and low ends of the cost range. In actuality, the distribution of costs across all sources within a category may be weighted near either end, and may have a "clumpy" distribution, reflecting a variety of unit configurations, fuel types, waste stream flow rates and concentrations, etc. Thus each source category would require detailed model plant breakdowns to precisely estimate

cost-effectiveness values, a task beyond the scope of this study. Therefore, because of the large uncertainties associated with the above figures, the reader should consider these rankings a rough approximation of their true order. In addition, due to site-specific factors these rankings will change somewhat from city to city.

Summary of Selected VOC Control Measures

Brief source descriptions with accompanying control strategies are provided in this section for a representative number of source categories. Although a description is not given for every major source category, complete control descriptions are provided in the supplementary document for further review.

Architectural and Industrial Maintenance (AIM) Coatings. AIM coatings are a substantial source of VOC emissions in all five inventories providing a prime candidate for reductions. AIM coatings are used for both commercial and residential applications as surface coatings for homes, buildings, and other structures. The AIM coating category contains more than 35 types of specialty coatings as well as flat and non-flat paints. VOC emissions occur primarily from the evaporation of organic solvents from the coating during application and drying.

The EPA is currently conducting negotiations providing for the development of a national rule. This rule will determine VOC limits for AIM coatings at a federal level. In the interim, adoption of the 1989 California model rule limiting the VOC content of the coatings can serve as an estimate of the magnitude of reductions which can be expected for this category.

Bulk Gasoline Terminals. Bulk gasoline terminals are major sources of VOC emission in the inventories of Chicago, Houston, and Baltimore. These terminals serve as the major distribution points for gasoline produced at refineries. The majority of VOC emissions occur during loading of delivery tank trucks, as the entering gasoline displaces

the vapors into a collection system. The collected vapors are then routed to a vapor processing system.

VOC emissions from gasoline bulk terminals can be controlled through the use of available control technologies such as vapor balancing, carbon adsorption, thermal oxidation, or other vapor recovery systems (SCAQMD, 1991a).

Surface Coating Operations. Surface coating operations are major source contributors to all five nonattainment areas. Several industries have significant VOC emissions from surface coating operations, including Auto & Light Truck Coating, Can Coating, Furniture Coating, Paper Coating, and Misc. Products Coatings. VOC emissions occur during both the application processes and drying operations.

Emission reductions are possible through three primary methods: reformulation to water-borne coatings, higher solids coatings, radiation curable coatings, or powder coatings; alternative application methods like high transfer efficiency application methods, high-volume low-pressure (HVLP) sprayers, or further use of electrodeposition; and add-on controls including adsorption, absorption, or incineration (technology depend on factors like exhaust concentration, flow rate, and other factors) (EPA, 1978c). Most of these technologies are applicable to surface coating operations independent of the industry.

Consumer and Commercial Products. Consumer and commercial products are large contributors in all five emission inventories providing a prime candidate for additional controls. They consist of those items sold to retail customers for household, personal or automotive use, along with the products marketed by wholesale distributors for use in commercial or institutional settings.

California has led the way in regulating these industries. CARB has developed the Phase I, Phase II, and Deodorants and Antiperspirants regulations to reduce emissions