Chapter 7

New Opportunities for Controlling Ozone

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Chapter *7*

New **Opportunities for Controlling Ozone**

INTRODUCTION

In the previous chapter, we examined progress that could be made towards attaining the current ozone standard by applying currently available control measures. We predicted that most of the cities with design values of 0.16 parts per million (ppm) or higher and some of the cities with design values of 0.14 and 0.15 ppm would still fall short of attainment after implementing all of the measures we could identify.

As shown in figure 6-10, after all controls have been applied, two categories of sources—organic solvent evaporation, and highway vehicles (and associated gasoline marketing)—acount for over two-thirds of the volatile organic compound (VOC) emissions remaining in nonattainment cities in 1994. This chapter addresses the possibility of further controlling emissions from these source categories, using new regulatory approaches or technology that is not yet ready for application.

As discussed in chapter 5, NO_x reductions in addition to VOC controls would be counterproductive for some cities, actually increasing ozone concentrations compared to levels that would have resulted if just VOC emissions had been reduced. However, other cities may need to control NO, emissions in addition to VOCs in order to meet the ozone standard. Although we assume that the primary strategy for reducing urban ozone will continue to be controlling VOCs, in this chapter we also discuss measures that are currently available for reducing NO_x emissions.

The first section of this chapter examines opportunities for controlling nitrogen oxides. Of the 20 million tons of NO_x emitted per year, nationwide, approximately 35 percent were generated in ozone nonattainment areas. Without additional controls, NO_x emissions are projected to increase by almost 30 percent by 2004, with most of the increase coming from stationary sources. We analyzed potential NO_x emissions reductions from highway vehicles and stationary sources including electric utility boilers, industrial boilers, stationary engines, gas turbines, and process heaters. We estimate that by 2004, application of controls to all of these categories would result in reductions in nonattainment areas of about 28 percent, compared to 1985 levels, and would cost about $3.7 to $6.2 billion per year in nonattainment cities, and about $5.4 to $7.9 billion per year, nationwide.

The second section focuses on emissions from organic solvent evaporation. We first describe categories of organic solvent use, and identify which categories provide opportunities for further control. We estimate that only about one-fourth of total solvent use is covered by existing regulations, and that an additional one-fourth could be covered by broader application of these rules. Of the remaining, ‘‘unregulated” solvent uses, the majority of emissions come from very small sources such as consumer and commercial products and miscellaneous surface coating uses. To suggest approaches for reducing emissions from these sources, we present examples of innovative State programs, and discuss the alternative of market-based controls.

Addressing motor vehicles, the third section looks at transportation control measures (TCMs)----such as encouraging use of mass transit or carpooling-that attempt to reduce vehicle use. TCMs have to be tailored to individual cities, and the emissions reductions that could be obtained from them will vary significantly from one city to another. However, to suggest the magnitude of reductions that could be achieved from an aggressive program, we review the assessment of TCMs that was recently completed for the Los Angeles area. With full funding and authority, it is hoped that the proposed measures will reduce highway-vehicle VOC emissions by a total of 30 percent by 2010, compared to projected baseline emissions for that year. Growth management measures aimed at matching new jobs with nearby housing account for almost 50 percent of the reductions.

In the final section on alternative fuels, we first discuss their effect on motor vehicle emission rates and other aspects of vehicle operation and performance. We then present estimates of total emissions impacts of using alternative fuels, and the costs per ton of VOC emissions effectively eliminated. We conclude that in the near term, effective VOC emission rates with alternative-fueled vehicles will be only moderately lower than rates that could be obtained with gasoline vehicles meeting current standards. Using either methanol blends or dual-fueled compressed natural gas (CNG) vehicles would be an extremely costly means of reducing ozone. With **significant** advances in vehicle technology, greater and more cost-effective reductions may eventually be possible.

OPPORTUNITIES FOR LOWERING EMISSIONS OF NITROGEN OXIDES

Ozone is produced in the atmosphere from reactions involving **two** "precursor" pollutants: volatile organic compounds **and** nitrogen oxides. The focus of efforts to reduce ozone has historically been on controlling local VOC emissions. This focus is expected to continue. In some cities, controlling NO_x emissions in addition to VOCs would be counterproductive, increasing ozone concentrations compared to levels that would have resulted if just VOC emissions had been reduced. In other cities, however, controlling NO_x emissions in addition to VOCs might help reduce ozone.

At present, our ability to make reliable predictions about whether or not NO_x controls will be helpful is limited. For most cities, the data gathering and modeling needed to assess the impact of NO_x emissions reductions have not been done. In the best-studied area, Los Angeles, the issue is clouded by the fact that reducing NO_x emissions would apparently lower peak ozone concentrations at some locations but increase them at others, compared to VOC controls alone. Such mixed outcomes might occur in other cities, as well.

The effect of reducing NO_x emissions in the Northeastern United States has been studied using EPA's Regional Oxidant Model. The analysis should be considered preliminary, and consideration of different meteorological conditions or levels of control might change the conclusions. The results suggest that totalled over all of the urban areas in the region, reducing NO_x emissions by 27 percent and VOC emissions by 42 percent below estimated 1980 levels would improve air quality more than reducing VOC emissions alone. However, for a few individual cities, the NO_x reductions were predicted to be counterproductive. In all of the northeastern States, the NO_x reductions were predicted to be beneficial for **nonurban** areas, supporting the theoretically based expectation that NO_x control would help reduce ozone in most rural areas.

Modeling calculations comparable to those performed for the Northeast have not been done for the South. However, measurements of VOCs and NO_x in urban air, and estimates of VOC emissions from vegetation, give a very preliminary suggestion that cities in the South are even more likely to benefit from NO_x control than cities in the Midwest or Northeast.

This next section describes **the** sources of NO_x emissions and presents our estimates of the changes in emissions over the next 15 years due to the offsetting influences of economic growth and State and Federal regulations in place as of 1987. These estimates serve as a baseline for considering the effects of regulatory changes that could be required to attain the ozone standard. We analyze potential NO_x emissions reductions and control costs for highway vehicles, and stationary sources including electric utility boilers, industrial boilers, stationary engines, gas turbines, and process heaters.

Sources of Nitrogen Oxides

Table 7-1 displays estimates of 1985 NO_x emissions, number of cities, and population within each of five ozone design value categories. The EPA 1985 National Emissions Data System (NEDS) inventory is the source of our emissions data and serves as the base inventory for all future year projections presented in this report. Residential fuel combustion sources have been excluded from our analysis since these emissions occur primarily during the wintertime when ozone is not a problem. Of the 20 million tons of NO_x emitted per year, approximately 35 percent were generated in cities that exceeded the ozone standard during the 1983-85 period.[1]

[1] For our analysis, an area is considered in nonattainment if its design value is greater than 0.12 ppm ozone according to EPA-published 1983-85 ozone monitoring data. EPA's actual determination of nonattainment is based on a slightly different method, but the resulting number of nonattainment cities are essentially the same. Our number of nonattainment areas differs from EPA's count of 61 because, in several cases, EPA has used Consolidated Metropolitan Statistical Areas (CMSAs), rather than cities. Several of these CMSAS include two or more cities that we have considered separately.

Table 7-l-Summary of 1985 NO_x Emissions in Nonattainment Cities and Attainment Regions

	NO_x emissions (1,000 tons)[a]	Percent stationary (%)	Percent mobile (%)	No. of cities	1985 population (millions)
Nonattainment cities by design value category (in ppm O_3)					
0.13-0.14	2,300	5a	42	37	30.2
0.15-0.17	3,300	49	51	40	55.3
0.18-0.26	970	51	49	14	20.2
>0.26	490	25	75	3	11.9
Total (nonattainment)	7,100	50	50	94	117.7
Attainment regions	13,000	60	40		118.8
Total	20,000	56	44		236.5

[a]Totals are rounded.

SOURCE: EPA 1985 National Emissions Data System emissions inventory, January 1988 printout: population data from Bureau of Census. Residential fuel combustion sources are excluded.

Figure 7-1 displays the percent contribution of various source categories to total 1985 NO_x emissions. About three-quarters of the emissions are generated from two main categories: mobile sources and electric utility boilers. About a third of the 1985 emissions inventory is composed of highway-vehicle emissions. A further breakdown of the data, shown in figure 7-2, reveals that passenger cars are the largest contributors within the highway-vehicle category, with about 17 percent of the total 1985 NO_x emissions, followed by heavy-duty diesel trucks with 9 percent. It is interesting to note that in cities with ozone design values greater than 0.26 ppm (southern California), mobile sources account for almost three-quarters of the total NO_x emissions. In other nonattainment cities, mobile sources contribute between about 42 and 49 percent of total NO_x emissions.

Tables 7-2 through 7-4 display our projections of NO_x emissions in 1994, 1999, and 2004, assuming that existing State and EPA regulations do not change. Under current regulations, total NO_x emissions increase steadily between 1985 and 2004, showing an increase of about 7 percent between 1985 and 1994, and 27 percent between 1985 and 2004.

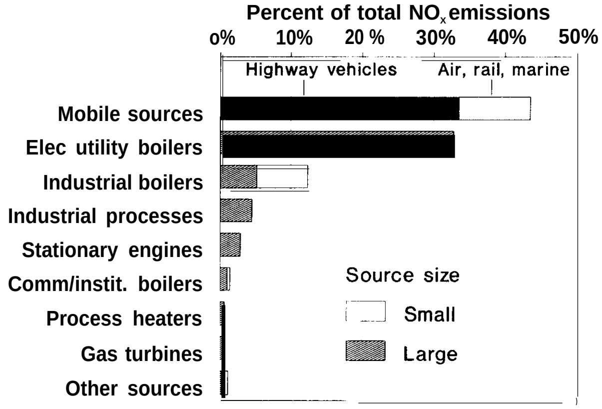
Although the number of vehicle-miles traveled is forecast to increase in many areas through 2004, the gradual replacement of current vehicles with newer, cleaner ones will result in an overall decline in highway-vehicle emissions by 1994. However after 1994, total highway-vehicle emissions will begin to increase because of the dominant influence of increasing vehicle-miles traveled. Stationary source emissions, on the other hand, are forecast to increase continuously between 1985 and 2004, showing an 18-percent increase by 1994 and a 45-percent increase by 2004, over 1985 levels.[2] About 60 percent of the stationary source *growth* between 1985 and 1994 is contributed by electric utility boilers. These sources are estimated to increase about 18 percent by 1994, and 38 percent by 2004, from 1985 levels. Figure 7-3 shows mobile and stationary source NO_x emissions through time. The net increase in total emissions from 1985 to 1994 would be much greater were it not for the 12-percent decline in highway-vehicle emissions by 1994.[3]

Our emissions projections for large stationary sources other than utility boilers may be somewhat high because we do not model the effect of New Source Performance Standards (NSPS), control requirements that apply to new and modified large

[2]Future emissions from electric utility boilers were estimated based on growth in electricity demand per capita. We assume that between 1985 and 1994 expansion of *existing sources* will account for all the growth in utility boiler emissions; after 1994, growth is assumed to come from new sources (which have lower NO_x emission rates). For industrial boilers, gas turbines, process heaters, and stationary engines, estimates were based on growth in Gross National Product per capita. Population growth rates were used for all other stationary source categories.

[3]Future highway vehicle emissions were projected using EPA estimates of future highway vehicle VOC emission rates, combined with estimates of average yearly miles-travelled per person, and Census Bureau population projections.

Figure 7-1—NO_x Emissions in 1985, by Source Category

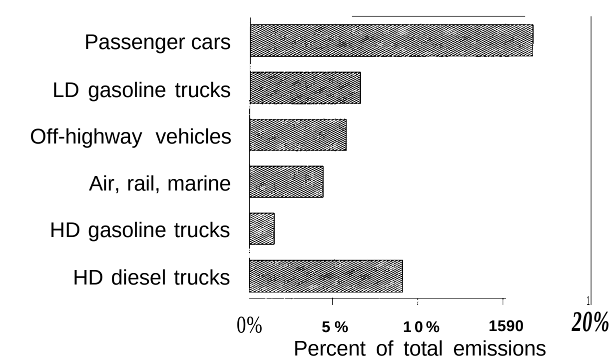


Total emissions = **20.3 million tons/year**

Stationary sources that emit more than **50** tons per year of NO, are included in the "Large" categories.

SOURCE: OTA, from EPA's National Emissions Data System (NEDS) and National Acid Precipitation Assessment Program emissions inventories.

Figure 7-2—NO_x Emissions from Mobile Sources in 1985 as a Percentage of Total (Mobile plus Stationary) Emissions



LD = light-duty; HD = heavy-duty
Total NO_x emissions = 20.3 MM tons/year

SOURCE: Office of Technology Assessment, 1989.

NO, emission sources.[4] However, the effect on our overall emissions estimates is small because, as illustrated in figure 7-3, utility boiler emissions (which do factor in NSPS requirements) will have a much more significant impact on future estimates of total NO_x emissions than other large stationary sources.

Potential NO_x Emissions Reductions From Control Strategies Analyzed by OTA

In this section we analyze the NO_x emissions reductions from, and costs of, the following source-specific control strategies:

- controls on major existing stationary sources;
- inspection and maintenance (1/M) programs for highway vehicles; and
- more stringent exhaust emission standards for gasoline highway vehicles.

Throughout the analysis, emissions reductions reported apply to the change occurring between 1985 and the relevant future year. The emissions reductions reported in our analysis result from currently available control methods that we know can be applied in the near-term. We were able to analyze the emissions reduction potential and associated control costs for strategies applicable to about 86 percent of current NO, emissions. Source categories for which we had emission control information include electric utility and large industrial boilers, gas turbines, stationary engines, process heaters, and highway vehicles. The remaining 14 percent of NO_x emissions for which we did not have control information include commercial and institutional boilers, industrial processes, and miscellaneous small sources.

All control strategies listed above can be restricted to ozone nonattainment cities if desired, except for more stringent tailpipe standards which would apply nationwide. Tables 7-5 through 7-7 present estimates of emissions reductions achieved in 1994, 1999, and 2004, respectively, if the various control strategies listed above are applied. We estimate that NO_x emissions in nonattainment cities can be reduced by 1.2 million tons per year in 1994, about 17 percent below 1985 levels. By 2004, total

[4] These regulations require that new stationary sources with the potential to emit more than 100 tons per year install stringent emission controls. These same control requirements apply to major modifications of existing sources that result in a NO_x emissions increase of more than 40 tons per year. More stringent controls are required in nitrogen dioxide nonattainment areas; as of 1986, the Los Angeles metropolitan area was the only region in the Nation that exceeded this standard,

Table 7-2--Summary of 1994 NO_x Emissions in Nonattainment Cities and Attainment Regions (emissions in 1,000 tons per year)[a]

	NO_x emissions			Change from 1985 emissions		
	Total	Stationary	Mobile	Total	Stationary	Mobile
Nonattainment cities by design value category (in ppm O_3)						
0.13-0.14	2,400	1,500	880	5%	16%	–lo%
0.15-0.17	3,500	1,900	1,600	4%	18%	–870
0.18-0.26	1,100	620	450	1 0%0	250/.	–6%.
>0.26	490	150	340	l %	21%	–6%
Total (nonattainment)	7,400	4,200	3,200	5%	18%	–8%
Attainment regions	14,000	9,400	5,000	80/0	180/0	–6%
Total	22,000	14,000	8,200	7%	180/0	–7%

[a]Totals are rounded.

SOURCE: Office of Technology Assessment, 1989.

Table 7-3-Summary of 1999 NO_x Emissions in Nonattainment Cities and Attainment Regions (emissions in 1,000 tons per year)[a]

	NO, emissions			Change from 1985 emissions		
	Total	Stationary	Mobile	Total	Stationary	Mobile
Nonattainment cities by design value category (in ppm O_3)						
0.13-0.14	**2,600**	**1,700**	**900**	**1 1%**	**260/.**	**–8°7&**
0.15-0.17	**3,700**	**2,100**	**1,600**	**1 20/0**	**290/o**	**–50/0**
0.18-0.26	**1,200**	**700**	**460**	**20%**	**43%**	**–3%**
>0.26	**510**	**170**	**340**	**5 %**	**3 8 %**	**– 6 %**
Total (nonattainment)	**7,900**	**4,600**	**3,300**	**12%**	30%0	–60/0
Attainment regions	16,000	**10,000**	**5,200**	**170/'**	**31%**	**–2%0**
Total	**23,000**	**15,000**	**8,500**	**16%**	**30%**	**–3%**

[a]Totals are roundad.

SOURCE: Office of Technology Assessment, 1989.

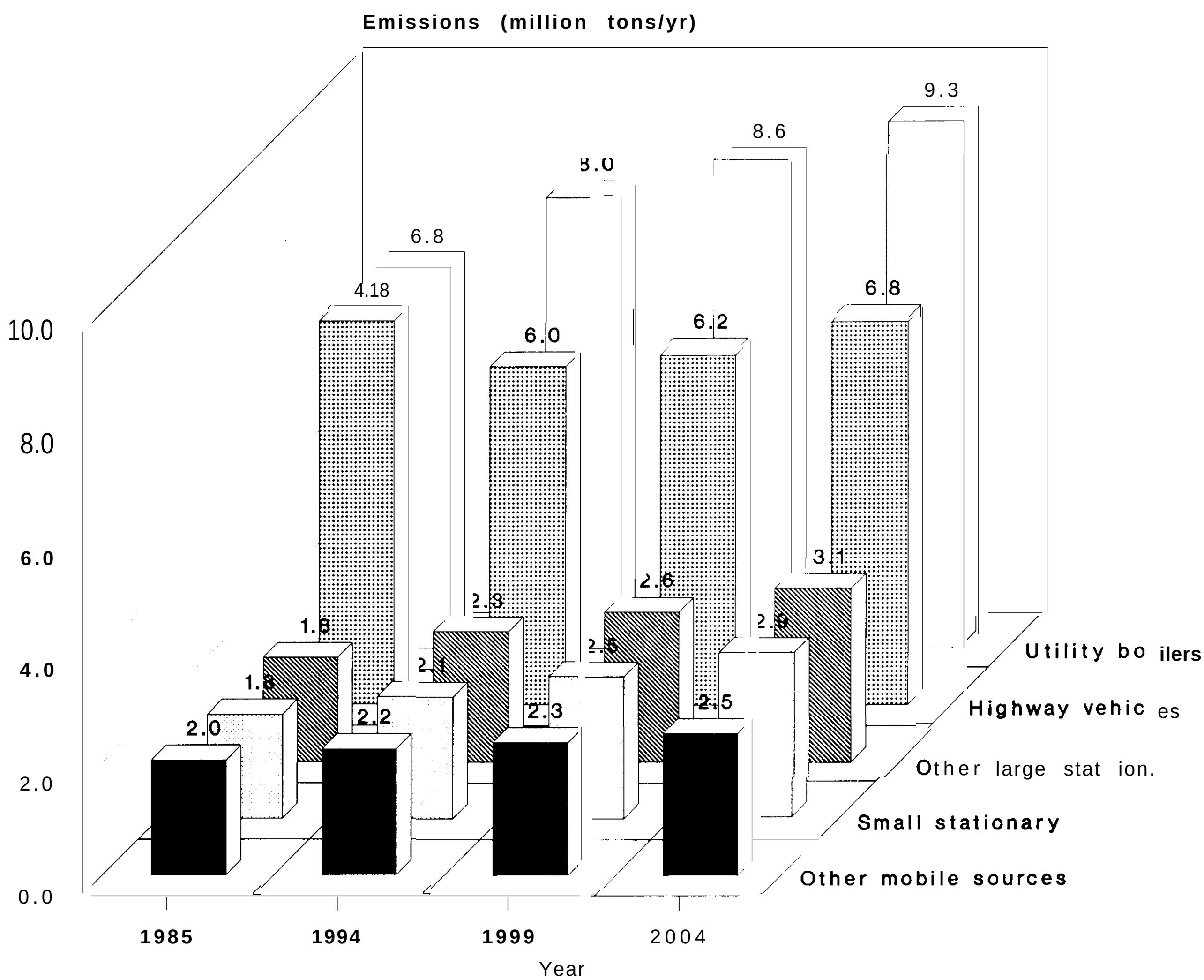
Table 7—Summary of 2004 NO_x Emissions in Nonattainment Cities and Attainment Regions (emissions in 1,000 tons per year)[a]

	NO_x emissions			Change from 1985 emissions		
	Total	Stationary	Mobile	Total	Stationary	Mobile
Nonattainment cities by design value category (in ppm O_3						
0.13-0.14	**2,800**	**1,800**	**960**	**21%**	**37%**	**–1%**
0.15-0.17	**4,000**	**2,300**	**1,700**	**22%**	**42%**	**2%**
0.18-0.26	**1,300**	**810**	**500**	**350/0**	**640/.**	**50/0**
>0.26	**550**	**190**	**360**	**13%**	**56%**	**–1%**
Total (nonattainment)	**8,700**	**5,100**	**3,600**	**230/.**	**44%**	**1%**
Attainment regions	**17,000**	**11,000**	**5,700**	**300/o**	**45%**	**80/0**
Total	**26,000**	**17,000**	**9,300**	**27%**	**45%**	**5%**

[a]Totals are rounded.

SOURCE: Office of Technology Assessment, 1989.

Figure 7—Summary of Estimated Nationwide NO_x by Source Category, by Year



The numbers directly above the boxes are the total emissions within the source category. For example, emissions from highway vehicles in 1994 are 6.0 million tons per year, nationwide. Assumes no regulations other than those in place in 1987.

SOURCE: Office of Technology Assessment, 1989.

emissions reductions from these control measures in nonattainment areas increase to about 2 million tons per year, about 28 percent below 1985 levels. An additional 810,000 tons per year would be eliminated in attainment areas by 2004 due to new highway-vehicle emission standards.

Figure 7-4 displays our estimates of emissions reductions resulting from each control strategy in 1994 and 2004, as a percentage reduction below total 1985 emissions in nonattainment cities. The largest reductions come from instituting controls[5] on electric utility boilers. The percentage reductions are

[5] For these estimates we assume the use of moderately stringent control techniques which we consider to be reasonably available control technologies (RACY). Controls include boiler combustion modifications such as the installation of low NO_X-emitting fuel burners, reducing air flow through the boiler, and other techniques.

Table 7-5-Potential NO_x Emissions Reductions in 1994 Compared to 1985 Emissions From Source-Specific Control Strategies (emissions reductions in 1,000 tons par year)[a]

	Stationary source controls				
	Utility boilers	Industrial boilers, gas turbines, stationary engines process heaters	Enhanced I/M	New highway-vehicle emission standards	Total reductions
Nonattainment cities by design value category (in ppm O_3)					
0.13-0.14	440	83	54	0	570
0.15-0.17	290	110	86	0	480
0.18-0.26	63	48	27	0	140
>0.26	5	12	19	0	37
Total (nonattainment)	790	250	190	0	1,200
Attainment areas	0	0	0	0	0
Total	**790**	**250**	**190**	**0**	**1,200**

[a]Totals are roundad.

Strategy descriptions;

Stationary source controls = moderately stringent controls on all existing stationary sources that emit more than 100 tons par year of NO,. considered to be "reasonably available control technologies."

Enhanced inspection and **maintenance (I/M)** programs for cars and light-duty trucks.

New highway-vehkfa **emission standards** for passenger cars and light-duty gasoline trucks.

SOURCE: Office of Technology Assessment, 1969.

Table 7-6—Potential NO_x Emissions Reductions in 1999 Compared to 1985 Emissions From source-specific Control Strategies (emissions reductions in 1,000 tons per year)[a]

	Stationary source controls				
	Utility boilers	Industrial boilers, gas turbines, stationary engines process heaters	Enhanced I/M	New highway-vehicle emission standards	Total reductions
Nonattainment cities by design value category (in ppm O_3)					
0.13-0.14	460	97	55	100	710
0.15-0.17	300	120	88	170	680
0.18-0.26	69	57	27	43	200
>0.26	6	14	19	0	38
Total (nonattainment)	840	290	190	310	1,600
Attainment areas	0	0	0	470	490
Total	840	290	190	780	2,100

[a]Totals are rounded.

Strategy descriptions:

Stationary source controls = moderately stringent controls on all existing stationary sources that emit more than 100 tons par year of NO,. considered to be "reasonably available control technologies."

Enhanced inspection and maintenance (I/M) programs for cars and light-duty mucks.

New highway.vehkfe **emission standards** for passenger cars and light-duty gasoline trucks,

SOURCE: Office of Technology Assessment, 1989.

about the same for each category between 1994 and 2004, except for new highway vehicle standards, which increase over time due to the gradual replacement of older cars with newer ones equipped with additional controls,

Figure 7-5 displays potential emissions reductions and the percentage of emissions that remain after all of the reductions have been accounted for by 1994 and 2004. In 1994, after all controls are applied, emissions are approximately 83 percent of

Table 7-7-Potential NO_x Emissions Reductions in 2004 Compared to 1985 Emissions From Source-Specific Control Sttategies (emissions reductions in 1,000 tons per year)[a]

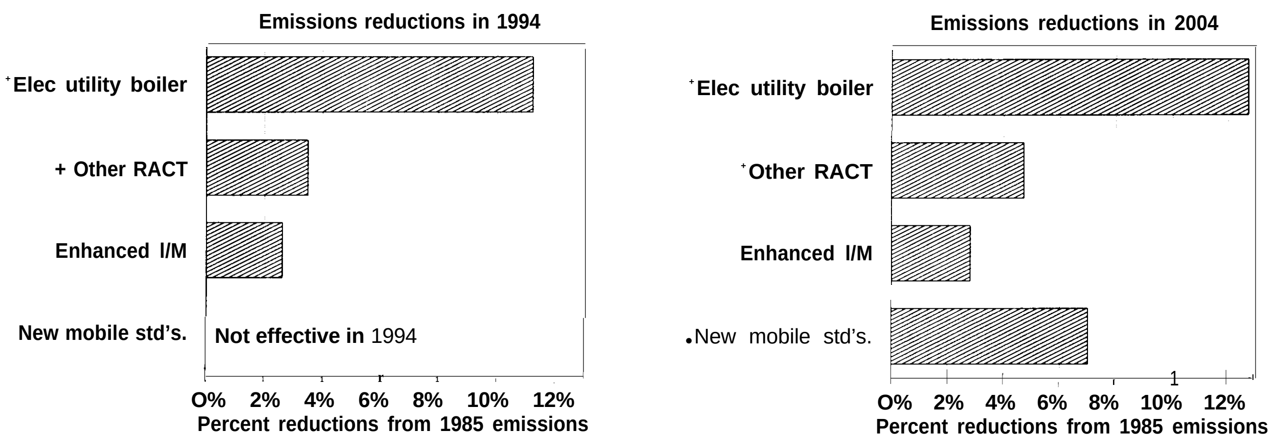
	Stationary source controls				
	Utility boilers	Industrial boilers, gas turbines, stationary engines process heaters	Enhanced I/M	New highway-vehicle emission standards	Total reductions
Nonattainment cities by design value oategory (in ppm O_3)					
0.13-0.14	490	110	58	170	830
0.15-0.17	320	130	94	290	840
0.18-0.26	75	67	29	74	240
>0.26	6	16	19	0	41
Total (nonattainment)	900	330	200	530	2,000
Attainment areas	0	0	0	810	810
Total	900	330	200	1,300	2,800

[a]Totals am rounded.

Strategy descriptions:
Stationary source controls = moderately stringent controls on all existing stationary sources that emit more than 100 tons per year of NO_x. Considered to be "reasonably available control technologies."
Enhanced inspection and maintenance (I/N) programs for cars and light-duty trucks.
New highway-vohkle emission standards for passenger cars and light-duty gasoline trucks.

SOURCE: Office of Technology Assessment, 19S9.

Figure 7-4—NO_x Emissions Reductions in 1994 and 2004 Compared to 1985 Emissions, by Control Method



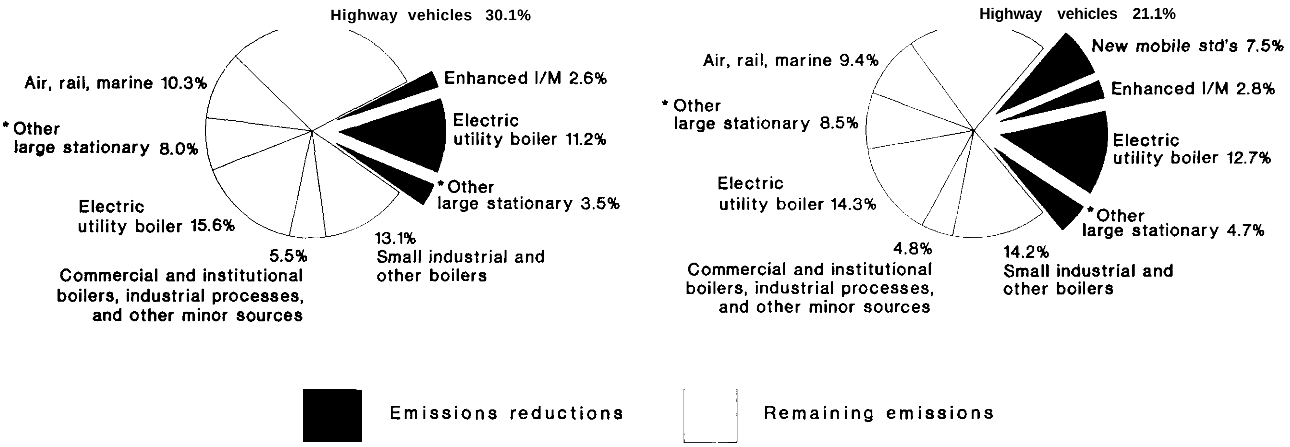
+ Controls on sources emitting more than 100 tons per year.
•Reductions are also achieved in attainment areas.

See text for description of control methods.

SOURCE: Office of Technology Assessment, 1989.

the 1985 total. By 2004, the emissions that remain after all controls are applied declines to about 72 percent of 1985 levels. The drop in remaining emissions between 1994 and 2004 is due to the increased effectiveness of more stringent highway-vehicle emission standards.

Figure 7-5-Potential NO_x Emissions Reductions and Remaining Emissions in 1994 and 2004 as a Percentage of 1085 Emissions in Nonattainment Cities



•Other large stationary includes: industrial boilers, stationary engines, gas turbines, and process heaters.

The pulled-out slices represent emissions that can be eliminated by each control method. The six connected slices represent emissions that remain after all control methods are applied. "Large" emission sources are defined **as those** which emit more than **50 tons per year** NO_x. See text for description of control methods.

SOURCE: Office of Technology Assessment, 1989.

Approximately 22 percent of the remaining emissions in 1994 comes from two categories (shown in figure 7-5): 1) commercial and institutional boilers, and industrial processes, and 2) small industrial and other boilers. The 14 percent of the inventory for which we were unable to identify control methods is composed entirely of these two categories. Although controls were applied to utility boilers, this category still accounts for about 16 percent of the inventory after control in 1994 (based on 1985 emissions). As we will discuss later, these estimates do not reflect the most stringent level of control possible for existing stationary sources.

The following subsections summarize the emissions reduction potential of each individual control strategy.

Controls on All Major Stationary Sources

The following subsection presents estimates of emissions reduction potential after applying NO_x controls at two levels of stringency. The first level represents control techniques of *moderate* stringency, or what we may consider *reasonably available control technologies* (RACT). This is the control level used in the estimates discussed in the previous section. The second level represents the *most* stringent level of control achievable given current technology.

In our analysis, we have applied controls on five source categories: electric utility boilers, industrial boilers, stationary engines, gas turbines, and process heaters.[6] Data on the emissions reduction potential

[6]For example, NO_x emissions from utility and industrial boilers can be reduced by installing devices which alter the way fuel is combusted inside the boiler.

and associated costs of the control technologies used in our analysis were supplied by E.H. Pechan & Associates, Inc., and were used in a recent report to EPA [34].

Moderately Stringent Controls. We estimate emissions reductions achievable through RACT-level regulations by simulating controls on all existing stationary sources that emit more than 100 tons of NO_x per year in those cities that did *not* have an existing regulation for a particular source category as of 1985.[7] For this analysis, additional RACT controls are applied only in nonattainment cities.

We estimate that applying RACT to all sources would lower NO_x emissions by approximately 1 million tons per year in 1994, representing a 15-percent decline based on 1985 levels. Electric utility boilers, alone, account for about three-quarters of this total reduction. By 2004, RACT reductions are estimated to increase to about 1.2 million tons per year, from 1985 levels.

Most Stringent Controls. If the most stringent control technologies are required on sources that emit more than 100 tons of NO_x per year, about 2.1 million tons per year could be eliminated from nonattainment cities in 1994, more than double the amount achieved through RACT-level control. Lowering the source size cutoff from 100 to 25 tons per year while requiring the most stringent controls adds about an additional 100,000 tons per year of emissions reductions to this total.

Enhanced Motor Vehicle Inspection and Maintenance (I/M) Programs

The definition and scope of our analysis of an enhanced I/M program were outlined in chapter 6. Emissions reduction benefit assumptions were taken from Sierra Research, Inc. [37]. We assume that the NO_x emissions reduction potential from existing I/M programs is about 4 percent. The full benefit from enhanced programs is about 14 percent, while the incremental benefit gained by switching from an existing to an enhanced program is about 10 percent.

We estimate that enhanced I/M programs in nonattainment cities will reduce NO_x emissions by about 190,000 tons per year in 1994 and by 200,000 tons in 2004.[9] This represents about a 3-percent reduction in both 1994 and 2004, based on 1985 emissions.

More Stringent Highway-Vehicle Emission Standards

This analysis includes the NO_x emissions reduction potential of instituting more stringent tailpipe controls on new passenger cars and light-duty gasoline-fueled trucks. The standards we analyzed were determined to be the most stringent technologically feasible, given currently "available" control technology, according to Sierra Research, Inc. [37].[10] Sierra Research, Inc., assumes that these standards can be met after 50,000 miles of *controlled test* driving for passenger cars, and 120,000 miles for light-duty trucks.[11] These standards are discussed in more detail in chapter 6. We assume that new standards go into effect in 1994 for both passenger cars and light-duty trucks.

We estimate that new highway-vehicle standards will reduce NO_x emissions in 1999 by about 4 percent, both nationwide and in nonattainment cities. By 2004, reductions increase to about 7 percent in both nonattainment and attainment areas, based on 1985 emissions. Again, the increase in emissions reductions over time is due to the gradual

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[7] If a source already had a control device that resulted in an emissions reduction of more than 10 percent, a regulation was assumed to exist for that source and no further controls were applied.

[8] We assume the highest level of NO_x control could& achieved through a process called *selective catalytic reduction* which eliminates nitrogen oxides from fuel combustion exhaust gases.

[9] Volatile organic compound emissions reductions from enhanced I/M programs are discussed in chapter 6. Carbon monoxide and particulate emissions reduction benefits are also gained, but are not calculated in this *analysis.*

[10] According to Sierra Research, Inc., more stringent NO_x standards for heavy-duty diesel-fueled trucks were not considered to be technologically feasible given current technology and, thus, were not analyzed.

[11] The new NO_x emission standards used in our analysis are as follows: (in "grams of NO_x emitted per mile traveled," g/mile)
Passenger cars: 0.4 g/mile
Light-duty gasoline trucks (by weight)
(less than 3,750 pounds): 0.46 g/mile
(3,75 1 to 6,000 pounds): 0.80 g/mile
(6,001 to 8,000 pounds): 1.15 g/mile

replacement of older vehicles with newer, cleaner ones. Since California has already adopted standards to those we analyze here, further emissions reduction credits due to this control strategy are not assigned to cities in this State.[12]

Costs *of* No_x *Contol* **Strategies** *Analyzed by OTA*

This section summarizes the costs of the three NO_x control strategies discussed previously. Of the three, only one—RACT-level controls on stationary sources emitting more than 100 ton per year-was **not** included in the cost of more "traditional" controls presented in chapter 6. Thus, the costs of the NO_x controls that we considered, over and above the VOC control costs presented earlier, are about $550 million per year in 1994 and about $670 million per year in 2004. We have assumed that stationary source controls are applied in all nonattainment areas, regardless of their effectiveness for lowering ozone concentrations.

The costs for all three programs, of course, is quite a bit higher. We estimate that, in 1994, the total cost of all controls is about $2.0 to $4.0 billion per year in nonattainment cities, and about $2.8 to $4.8 billion per year, nationwide. By 2004, costs will increase to about $3.7 to $6.2 billion per year in nonattainment cities, and to about $5.4 to $7.9 billion per year, nationwide. This increase is primarily because of the higher percentage of highway vehicles equipped with more stringent controls. Again, two of the programs will provide multiple emissions reduction benefits. In addition to reducing NO_x emissions, enhanced I/M programs and more stringent highway-vehicle standards also reduce VOC emissions. Furthermore, I/M programs also reduce emissions of carbon monoxide. Table 7-8 displays the ranges of costs in nonattainment in 1994 and 2004 by source category. Figure 7-6 displays the ranges of costs in nonattainment cities in 1994 and 2004.

Table 7-9 presents the "cost-effectiveness" of specific control measures for 1994 and 2004. Figure 7-7 illustrates the cost-effectiveness of control measures in nonattainment in 1994. The solid bars represent the average cost-effectiveness in all nonattainment cities. Uncertainty in cost-effectiveness estimates is denoted by the thin horizontal lines. The average cost-effectiveness for control strategies varies between $400 per ton of NO_x reduced (for electric utility boilers) to about $2,200 per ton (enhanced I/M programs). Note that for cities with ozone design values greater than 0.26 ppm (southern California), the cost of controls on electric utility boilers is much higher than the average nonattainment city estimate. Since this region has already adopted measures to control NO_x emissions from these, and other, sources (e.g., use cleaner burning fuels), each dollar spent on further NO_x controls yields relatively less emissions reductions.

Table 7-8--Estimated Costs of Selected NO_x Control Methods in Nonattainment Cities in 1994 and 2004 (In million dollars per year)[a]

	Nonattainment cities	
	1994	2004
Stationary source controls		
Electric utility boilers	320	360
Industrial boilers, stationary engines, gas turbines, process heaters	230	310
	550	670
Enhanced I/M (for NO_x, VOC, and CO)[b]	2,500	3,100
New highway-vehicle emission ***standards*** (for NO_x, and VOC)[c]	—	1,200
Total (low estimate)[d]	2,000	3,700
Total (high estimate)[e]	4,000	6,200

[a] Totals are rounded.
[b] These estimates are also presented in ch. 6. Enhanced I/M costs range between $1.5 billion and $3.5 billion per year in 1994. NO, costs are approximately one-sixth of this total.
[c] These estimates are also presented in ch. 6. Costs in attainment areas are about $1.7 billion in 2004. On average, about two-thirds of the cost is attributable to NO_x control.
[d] About $1.5 billion and $3.1 billion per year in 1994 and 2004, respectively, are also presented in ch. 6.
[e] About $3,5 billion and $5.5 billion par year in 1994 and 2004, respectively, are also presented in ch. 6.

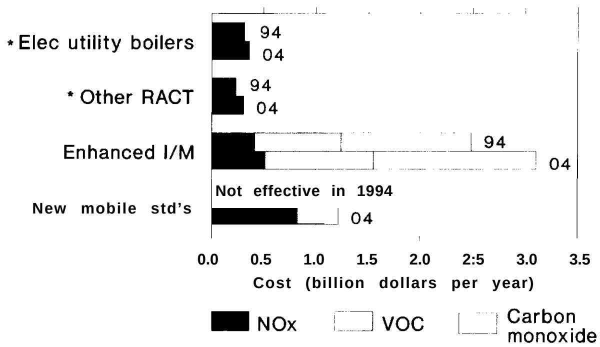
Strategy descriptions
Stationary **source controls** = moderately stringent controls on all existing stationary sources that emit more than 100 tons par year of NO,. Considerad to be "reasonably available control technologies."
Enhanced inspection • d **maintenance** (t/M) programs for cars and light-duty trucks.
New **highway-vehicle emission standards** for passenger cars and light-duty gasoline trucks.

SOURCE Office of Technology Assessment, 1969.

A brief discussion of the costs and cost-effectiveness of each of the control strategies,

[12] California's adoption of similar highway-vehicle emission standards is reflected in our estimates of future emissions that will occur with existing controls as presented in tables 7-2 through 7-4.

Figure 7-6-Estimated Cost of NO_x Emission Control Methods in 1994 and 2004 in Nonattainment Cities



•Assumes sources emitting greater than 100 tons/year are subject to RACT controls.

Of the four control methods shown above, only two—controls on electric utility boilers and RACT-level controls on other stationary sources emitting more than 100 ton per year-were not included in the cost of more "traditional" controls presented in Chapter 6. Thus, the costs of the NO_x controls that we considered, over and above the VOC control costs presented earlier, are about $550 million per year in 1994 and about $670 million per year in 2004. See text for description of control methods.

SOURCE: Office of Technology Assessment, 1989.

Table 7-9-Estimated Cost-Effectiveness of Selected NO_x Control Methods in Nonattainment Cities in 1994 and 2004 (in dollars per ton of NO_x reduced)[a]

	Cost-effectiveness	
	1994	2004
Stationary sources controls		
Electric utility boilers	240-5,50@	240-5,500[b]
Industrial boilers, stationary engines, gas turbines, process heaters	690-1,400	670-1,400
	370-2,700	390-2,500
Enhanced I/M[c]	1,200-3,300	1,400-4,400
Nswhighwsy-vehicle emission standanrds[c]	—	1,600

[a]Totals are rounded.
[b]Excluding the southern California cities, the upper-bound estimate is about $1,000 per ton of NO_x reduced.
[c]Includes costs of NO, only.

Strategy descriptions
Stationary source controls = moderately stringent controls on all existing stationery sources that emit more than 100 tons per year of NO_x. Considered to be "reasonably available control technologies."
Enhanced inspection and **maintenance (I/M)** programs for cars and light-duty trucks.
New highway-v.hlctoomt8slon atandardsfor passenger csrsand light-duty gasoline trucks.

SOURCE: Office of Technology Assessment, 1989.

including the data sources from which the estimates are calculated, follows.

Controls on All Major Stationary Sources

If moderately stringent controls[13] are required, total costs in nonattainment cities for this category are estimated to be about $550 million per year in 1994, averaging about $240 to $1,100 per ton of NO_x removed.[14] Controls on electric utility boilers account for about 58 percent of this total ($320 million per year).

If the most stringent level of control[15] is required, the total cost for this category increases dramatically to about $8.3 billion per year in 1994. As mentioned earlier, these controls buy about an extra 15 percent more emissions reductions than RACT-level controls. While lowering the source-size cutoff from 100 to 25 tons per year adds an additional 2 percent onto the reductions achieved using the most stringent level of control, it does so at an additional cost of $1.7 billion per year.

Enhanced Motor Vehicle Inspection and Maintenance (I/M) Programs

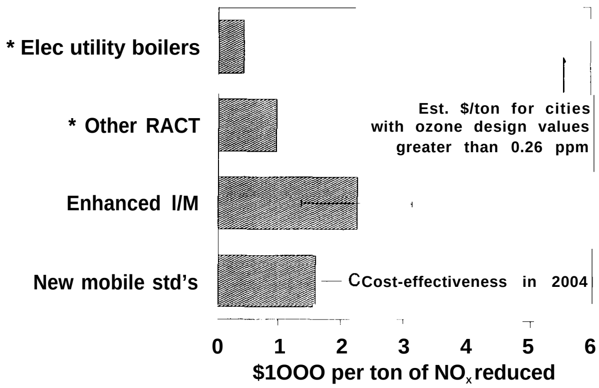
We estimate that enhanced I/M programs in nonattainment cities cost between about $1.5 billion and $3.5 billion per year in 1994. In 2004, costs are expected to rise to between about $1.9 billion and $4.3 billion per year. We assume that about half of the costs are attributable to carbon monoxide control and the other half to ozone control. Of the ozone fraction, we assign about one-third of the cost to NO, and the other two-thirds to VOC. Assuming that one-sixth of the *total* cost of I/M programs is for NO_x reductions, the cost-effectiveness in 1994 is estimated to be between $1,200 and $3,300 per ton of NO_x, eliminated.

[13]We define moderately stringent control techniques to include boiler combustion modifications such as the installation of low NO_x-emitting fuel burners, reducing air flow through the boiler, and other techniques.

[14]Average cost-effectiveness excludes estimates for the three southern &Ii fornia cities with ozone design values greater than 0.26 ppm. The average cost-effectiveness for electric utility boiler controls in these areas is about $5,500 per ton. The cost-effectiveness is higher in these regions because measures to control NO_x emissions have already been adopted, so that each dollar spent buys leas emissions reductions.

[15]We define most stringent control techniques to include selective catalytic reduction which eliminate NO_x from fuel combustion exhaust gases.

Figure 7-7—Estimated Cost-Effecttveness of NO_x Emission Control Methods in 1994 in Nonattainment cities



*** 100-ton/year RACT source-size cutoff**

The cost-effectiveness of enhanced inspection and maintenance (I/M) programs and new mobile standards include only the cost of NO_x control. The thick horizontal bars represent the average cost-effectiveness in nonattainment cities. The thin horizontal line for I/M programs represents the range of uncertainty associated with assumptions we used to estimate total annual costs. We were unable to estimate cost-effectiveness uncertainty for other control methods. See text for a description of control methods.

SOURCE: Office of Technology Assessment, 19S9.

Our estimates of enhanced I/M program costs are based on an analysis of the California I/M program, prepared for the California Air Resources Board by Sierra Research, Inc. [37]. We use Sierra Research's finding that an enhanced I/M program costs about $34 to $55 per vehicle per year. About $20 of this cost is for the inspection fee and program administration. The remainder is for repair costs, which we assume to range between $70 and $100 per vehicle. We also assume that 20 and 35 percent of the vehicles tested will fail.[16]

More Stringent Highway-Vehicle Emission Standards

We estimate that the total cost of more stringent VOC and NO_x exhaust standards for highway vehicles in 1999 will be about $1.6 billion per year, nationwide, of which about $0.66 billion per year will be incurred in nonattainment cities. By 2004, costs increase to about $2.9 billion per year, nationwide, because a higher percentage of vehicles on the road will be equipped with new controls. About 70 percent of the costs are for controlling NO_x.

The cost-effectiveness of these controls in 2004 is about $1,600 per ton of NO_x reduced. As discussed in an earlier section, our cost estimates are based on a Sierra Research, Inc. report which concluded that more stringent emission standards would cost about $140 per vehicle (combined cost for NO_x and VOC emissions control) [37].

OPPORTUNITIES FOR LOWERING EMISSIONS FROM SOLVENT USE

To find the additional VOC emissions reductions needed to meet the ozone standard, many nonattainment cities may want to consider new ways of controlling emissions from organic solvent use. Although some State and Federal regulations controlling organic solvent emissions already exist, most have traditionally focused on larger sources. Much of the emissions from organic solvent use, however, originate from smaller sources (which vastly outnumber their larger counterparts). Because controls on *some* of the smaller organic solvent emission sources have been considered to be either technically, economically, or administratively infeasible, many of these sources are exempt from current regulations.

This section characterizes several aspects of organic solvent use in nonattainment areas that may be of interest when developing new control strategies. The first part describes: a) the relative contribution of various solvent end uses to total VOC emissions in nonattainment areas, b) the distribution of solvent emissions by source size, c) the fraction of solvent emissions that are currently covered by existing Federal and State regulations, and d) source categories where future significant emissions reductions may be possible. The section continues with a description of how various States are planning to capture uncontrolled organic solvent emissions. The section concludes with a discussion of market-based approaches to controlling solvent emissions.

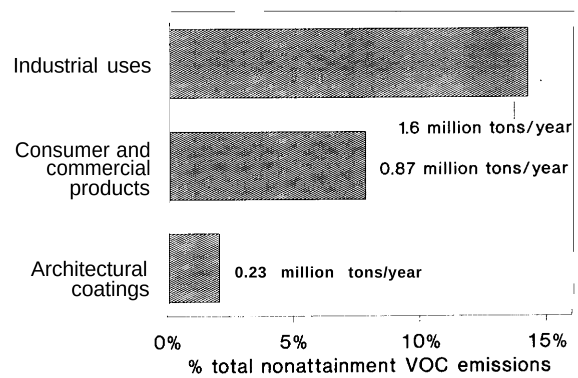
[16] The low I/M cost estimate assumes that a repair cost of $7o per vehicle will be levied on the 20 percent of the vehicles which fail; the hi@ estimate assumes $100 repair cost on 35 percent of the vehicles.

Sources of Organic Solvent Use

Solvents are used in such diverse applications as surface coatings, cleaning agents, decreasing, and drycleaning, and in many other industrial applications. Solvents are also used in a wide variety of commercial and consumer products such as insecticides, various household cleaners, nail polish and remover, underarm deodorants, hair spray, window cleaners, spot removers, automotive products, adhesives and sealants, pesticides, and many others. In 1985, VOC emissions from organic solvent evaporation in nonattainment areas were about 2.7 million tons per year, or about 27 percent of total emissions.[17]

The above estimate assumes that 100 percent of the solvent purchased in 1985 is eventually emitted to the atmosphere. However, in response to existing regulations, some sources may recycle or destroy excess solvent emitted from their operations. Therefore we may have overestimated actual emissions. Figure 7-8 displays organic solvent emissions as a percentage of total emissions in nonattainment areas. We use the same end use categories, and solvent purchased therein, as EPA used in the 1985 National Acid Precipitation Assessment Program (NAPAP) inventory. Industrial solvent use[18] accounts for about 14 percent of total nonattainment area VOC emissions, followed by commercial and consumer solvents, and architectural coatings at 8 and 2 percent, respectively.

Figure 7-8—Total Solvent Use as a Percentage of 1985 Total VOC Emissions in Nonattainment Areas



Total VOC emissions in nonattainment areas = 11 MM tons/year

See text for description of sources included in the "industrial uses" category.

SOURCE: OTA, from EPA's National Acid Precipitation Assessment Program emission inventory.

Organic Solvent Use by Source Size

The Clean Air Act currently requires existing stationary sources in nonattainment areas that emit more than 100 tons per year of VOC to adopt "reasonably available" control technologies. Since bills from the l00th Congress have proposed lowering the 100-ton-per-year cutoff, it is useful to see what fraction of total solvent use in nonattainment areas originates from sources of various sizes.

Because the 1985 NAPAP emissions inventory does not contain source-by-source emissions data for sources that emit less than 50 tons per year, we had to estimate the breakdown of emissions by type of application and by source size using a method developed by EPA [18] based on the relationship between solvent use and employment. By using the number of employees[19] as surrogates for solvent use we were able to apportion EPA estimates of solvent use [19] to three source sizes: greater than 100, 50, and 25 tons per year.[20] Since we had no employment data for architectural coating, consumer and commercial products, and miscellaneous surface coating, we assumed that these sources all individually emit less than 25 tons per year.

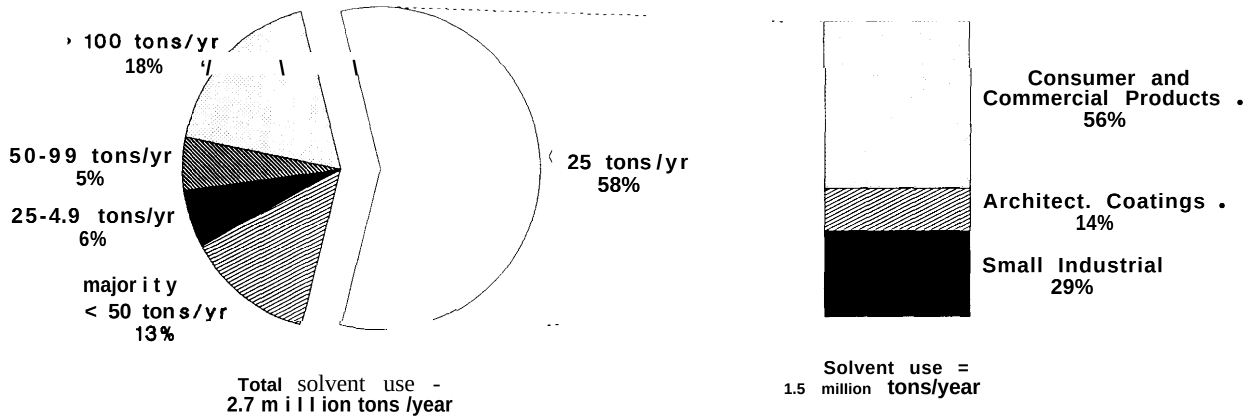
[17] Solvent use data used throughout this section was calculated based on the 1985 National Acid Precipitation Assessment Program emissions inventory [59].

[18] The *industrial solvent use* category includes the following 15 subcategories as defined by EPA for the 1985 NAPAP emissions inventory: automobile refinishing, new motor vehicle manufacturing, furniture and fixtures, fabricated metal products, machinery and equipment, paper coating, factory-finished wood products, non-automobile transportation equipment, electrical insulation, shipbuilding, metal cleaning (decreasing), dry cleaning, printing, rubber and plastics production and other miscellaneous surface coatings.

[19] Data on the number of employees and firms are from U.S. Department of Commerce, Bureau of the Census [44].

[20] We assume that the ratio of solvent use to the number of employees in a particular solvent category is the same (i.e., each employee uses the same amount of solvent) for all three source size categories. The ratio of emissions (rather than solvent use) to employment will be smaller if individual sources choose to comply with existing State or Federal regulations by incinerating or recycling excess solvent.

Figure 7-9-Total 1085 Solvent Use In Nonattainment Areas, by Source Size



•**These sources emit much less tha. 25 tons per year.**

Solvent use in the **"less-than-25-tons-per-year"** category is probably understated since an unknown fraction in the "majority less-than-50-tone-per-year" category may actually originate from sources using lees than 25 tons per year. The latter category contains solvent use that EPA has identified as miscellaneous surface coatings. Because of the way EPA constructs this category, we were **unable to disaggregate solvent use below 50 tons per year.**

SOURCE: **Office of Technology Assessment, 1989.**

Figure 7-9 displays the contribution of different source sizes to total solvent use in nonattainment areas. Note that about three-quarters of the total solvent use (2.1 million tons per year) originates from sources that emit less than 50 tons per year. Sources less than 25 tons per year account for about 1.5 million tons per year, or about 60 percent of the total.[21] About one-quarter of the solvent used came from sources greater than 50 tons per year.

Figure 7-10 displays a more detailed breakdown of 1.6 million tons per year of *industrial* solvent use in nonattainment areas presented in figure 7-8. About 480,000 tons originate from sources greater than 100 tons per year. As mentioned earlier, this is the size category that existing State and Federal VOC regulations have traditionally targeted.[22] As we will discuss later, not all sources in this size class have been subject to regulations.

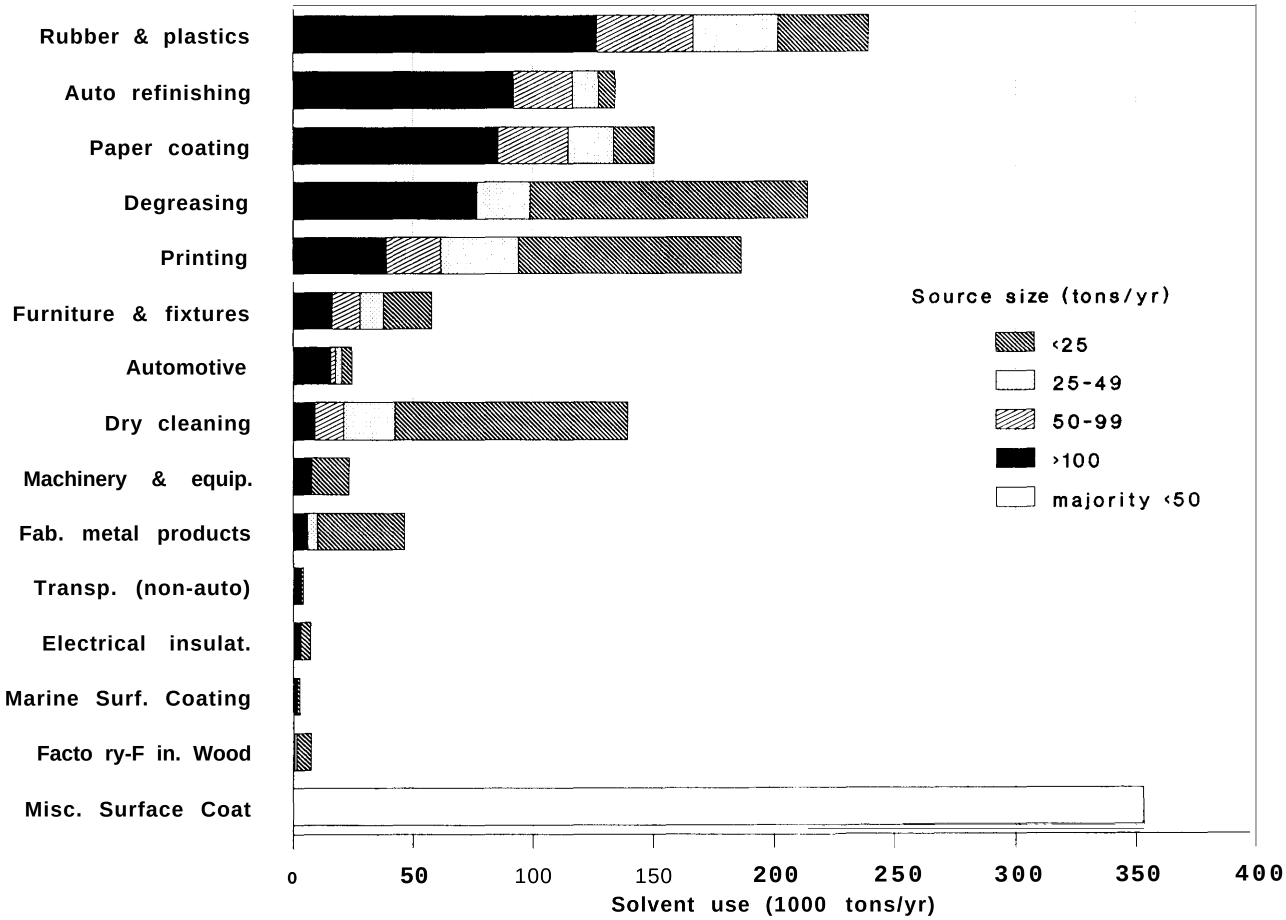
Figure 7-10 also shows that ***at least* 30** percent of the industrial solvent use, or nearly 450,000 tons, originate from sources emitting less than 25 tons per year, mostly in the decreasing, printing, and drycleaning categories. This estimate should be considered a lower bound since an unknown fraction of use *from miscellaneous surface coatings* may also come from less-than-25-ton sources. Therefore, if we include all miscellaneous surface coatings in our estimates, sources less than 25 tons per year may contribute *as much as 810,000* tons per year, or about 50 percent of total nonattainment industrial solvent use.

Figure 7-11 displays the breakdown of total solvent use, by source size, that is covered by State and Federal regulations as of 1985. Information on the regulatory status of various source categories was obtained from EPA summaries of State VOC regulations [57,58]. We estimate that approximately

[21] **This percentage** is probably underestimated since some of the solvent **use** in the ***majority-less-than-50-tons*** slice shown in the figure may belong in& ***less-than-25-ton category. The*** former category contains solvent use that **EPA has identified as** ***miscellaneous surface coatings,*** and could include sources that are both less than **and greater than 50 tons** per year. Since we were unable to determine employee **fractions** associated with this category, we chose not to disaggregate the solvent use below 50 tons per year.

[22] **Some State regulations,** however, **require controls on sources in nonattainment areas that emit less than 100 tons per year.**

Figure 7-10-industrial Solvent Use in 1985 by Four Source-Size Cutoffs in Nonattainment Cities



Because of the way EPA constructs the miscellanous surface coating category, we were unable to disaggregate solvent use below 50 tons per year.

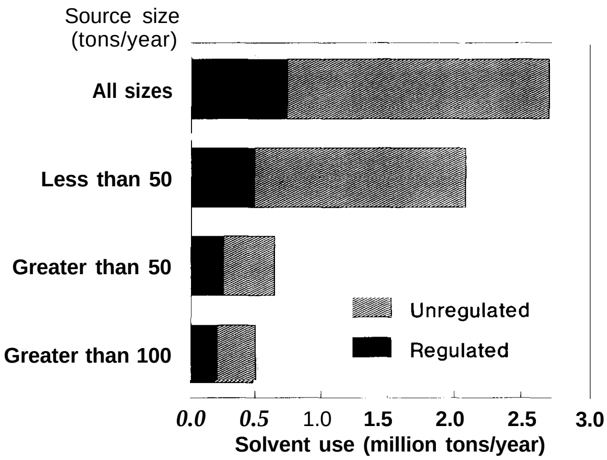
SOURCE: Office of Technology Assessment, 1989.

one-quarter of all the solvent used in nonattainment areas in 1985 was subject to VOC emission regulations. About 45 percent of the solvent used by sources greater than 50 tons per year was covered by regulations, while 20 percent of the solvent used by sources emitting less than 50 tons per year was covered. Overall, there is about four times as much unregulated solvent use from less-than-50-ton sources than by sources emitting more than 50 tons per year.

Our estimates of solvent use may overestimate actual solvent emissions since many sources which are subject to solvent regulations (especially those emitting more than 50 tons per year) may use control devices which capture or destroy excess solvent emissions. Hence, solvent use is not always synonymous with solvent emissions.

Because many State VOC regulations are applied on the basis of the amount of solvent used by a source (e.g., gallons of solvent used, pounds of clothes cleaned, etc.) rather than on the amount of VOC emitted to the atmosphere during a year, it is difficult to know the precise source-size cutoff for which a particular regulation applies. Therefore, the estimates presented here should be considered only rough approximations.

Figure 7-11—Total Solvent Use Covered by Existing Regulations in 1985 in Nonattainment Cities



Determinations of the regulatory status of solvent use categories in nonattainment cities were made using EPA summaries of State and local VOC regulations in place as of 1985 [57,58]. The estimates presented here should be considered only rough approximations. See text for explanation.

SOURCE: Office of Technology Assesment, 1989,

Opportunities for Additional Emissions Reductions

Figure 7-12 displays a detailed breakdown of solvent use, by end-use and source size, that is covered by existing regulations. We show solvent use that is: 1) covered by existing regulations, 2) not covered, but for which applicable regulations exist, and 3) not covered and for which *no* regulations exist. The "Regs-Not-Applied" category refers to solvent use that could be covered: a) if existing regulations for larger sources were applied to smaller sources in the same end-use category, orb) if existing regulations in some nonattainment areas were applied to the same end-use categories in all *other* nonattainment areas. The "No-Regs-Exist" category contains solvent use for which no regulations exist anywhere in the Nation.

Figure 7-12 shows that an additional 550,000 tons of solvent use in nonattainment cities, or about 20 percent, *could* be covered if regulations currently applied in some areas are adopted in all other areas. This category is important because it highlights solvent use that has the most immediate potential for additional emissions reductions.

Of the 2.7 million tons per year of total solvent use shown in figure 7-12, about 1.2 million tons of solvent were used by identifiable industrial sources[23] in nonattainment cities. Figure 7-13 presents a slightly different breakdown of this category together with the number of firms that contain sources of various sizes.[24] We estimate that about 650,000 tons per year of solvent is used by about 150,000 identifiable industrial sources that are already covered by control requirements. About 580,000 tons per year of solvent is used by about 90,000 sources in nonattainment areas that are *not* covered by control requirements.

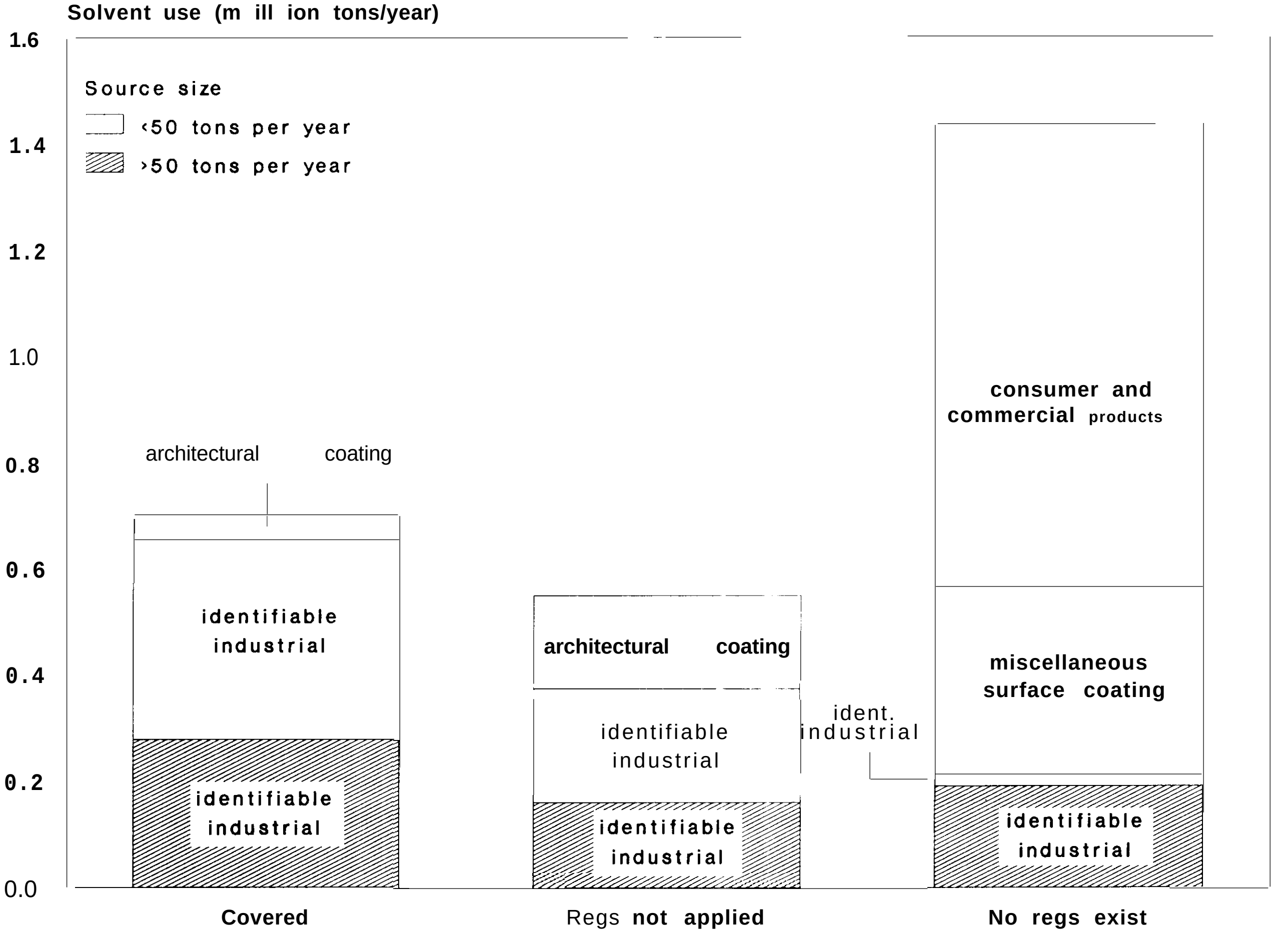
About 270,000 tons of unregulated solvent use in this category, or about 45 percent, could be covered by targeting the small number of unregulated firms that contain sources emitting more than 100 tons per year. The emissions reductions achieved will be lower than our estimated solvent use and will depend on the type of control technique required by new regulations.[25] If unregulated sources emitting 50 tons per year or more are targeted, we estimate that about 60 percent of the total unregulated solvent use among identifiable industrial sources could be covered. At this source-size cutoff, roughly 3,000 firms in nonattainment cities would need to be identified. If the source-size cutoff is lowered from 50 to 25 tons per year, about 10 percent more solvent use—about 410,000 tons per year-could be covered, but about two-thirds more firms would then have to be identified. Finally, we estimate that the addition of sources emitting less than 25 tons per year would require the identification of about 86,000 more firms. Although including these smaller sources would allow about 40 percent more solvent use to be covered, about 20 times as many firms

[23] See footnote 18 for a list of the 14 sources included in the identifiable industrial category.

[24] In this figure we do not show solvent use from other less-than-50-ton sources including consumer products, architectural coatings and other miscellaneous coatings because we were unable to determine the number of firms associated with their use.

[25] For example, control devices such as incinerators can reduce emissions from organic solvent use by about 90 percent. Therefore the emissions reductions achieved by targeting unregulated IOO-ton-per-year sources would be about 240,000 tons per years.

Figure 7-12—Total Solvent Use Covered by Existing Regulations in 1985, by Source Category in Nonattainment Cities



The **Identifiable industrial category includes the same sources as those in figure 7-10, except** for **miscellaneous surfacecoatings which is a seperate** category in the figure shown above. **We** show solvent use that is (1) covered by existing regulations **in place as of 1985, (2) not covered in a particular nonattainment area, but for** which regulations do exist in other areas, and (3) not covered and for which no regulations exist as of 1985. See text for further explanation.

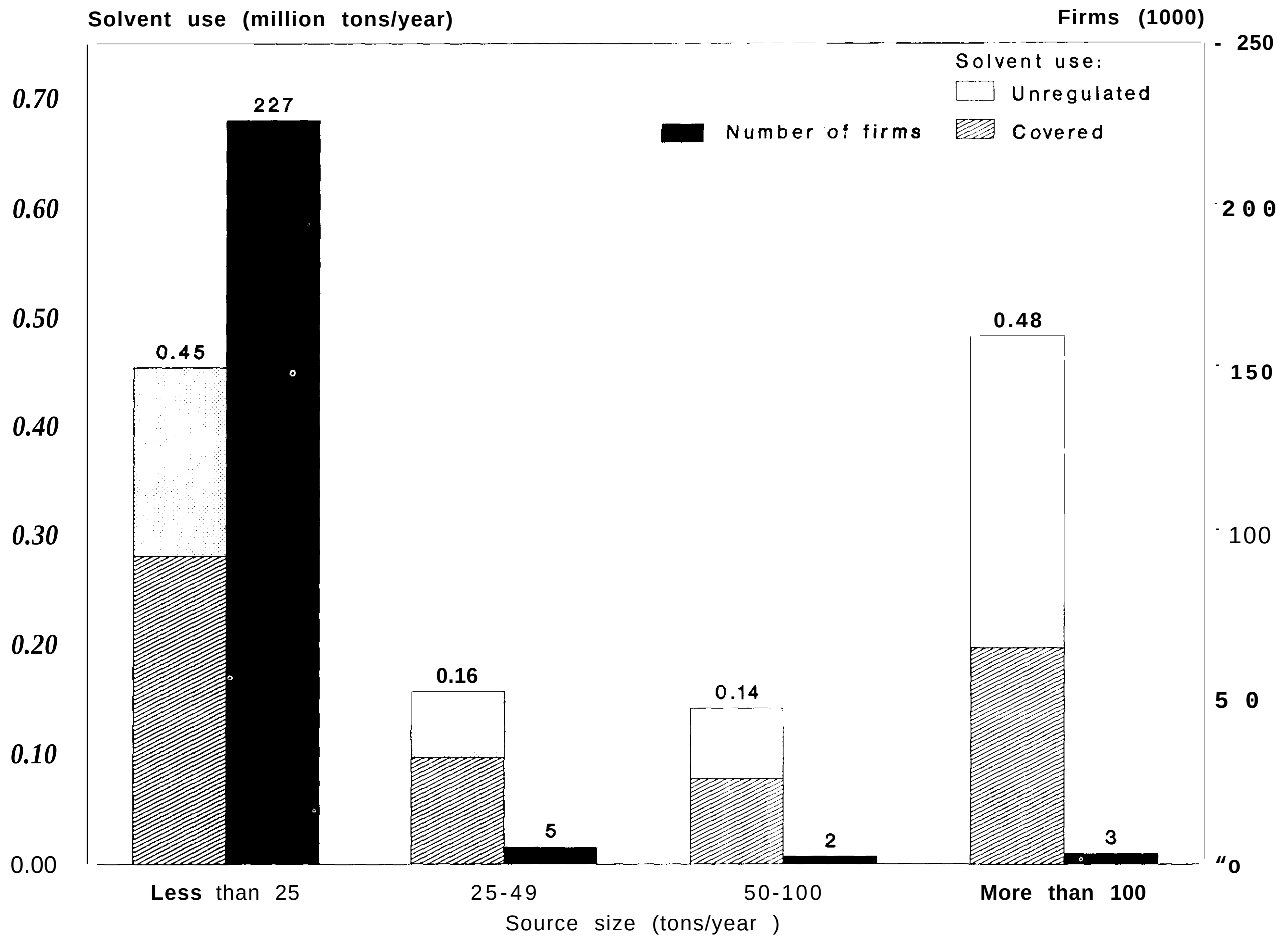
SOURCE: Office of Technology Assessment, 1989.

would have to be identified compared to a strategy which targeted sources emitting more than 25 tons per year.

Figure 7-13 shows that solvent use from sources greater than either 25 or 50 tons per year offers regulators a relatively attractive target for future emissions reductions. While including sources that emit less than 25 tons per year would offer a somewhat greater potential for emissions reductions, regulators would be faced with the difficult task of locating and keeping track of a much larger number of fins.

While some identifiable industrial sources present a good opportunity for capturing unregulated VOC emissions (at least from an administrative efficiency standpoint), figure 7-12 shows that consumer and commercial products and miscellaneous surface coatings accounted for about 1.2 million tons, or about 60 percent, of total unregulated solvent use in

Figure 7-13—Identifiable Industrial Solvent Use Covered by Existing Regulations; and the Number of Firms by Source Size



The identifiable Industrial category includes the same sources as those in figure 7-10, except for miscellaneous surface coatings which is excluded.

SOURCE: Office of Technology Assessment, 1989

nonattainment cities.[26] A large fraction of this solvent use originates from sources emitting less than 50 tons of VOC per year; and in some cases, these sources emit very much less than 25 tons per year per source (e.g., consumer products). Because these solvent uses originate both in the home and from a large number of small commercial, institutional, and industrial establishments, traditional forms of "command-and-control" regulations may be difficult to administer and enforce. In the next section, we review how some States are planning to control this fraction of solvent use.

Further Regulation of Solvents

As the preceding analysis indicates, only about one-quarter of total solvent use *is covered* by

[26] Some States and localities have *general* solvent use regulations that may apply to some uses contained in the miscellaneous surface coating category, however we were unable to identify these particular uses.

existing regulations. Most of this is from industrial solvent use by both large and small sources. At most, we believe that another one-quarter of total solvent use could be controlled (to some extent) given more widespread application of current regulations. Much of these additional reductions would come from use of industrial solvents and architectural coatings by predominantly small sources, although some emissions reductions could be realized from controlling selected large sources. Of the remaining ' 'unregulated" solvent use, we believe that small sources offer the greatest opportunity for additional emissions reductions. These sources are mainly consumer and commercial products, miscellaneous surface coating uses, and some industrial solvent use.

While it is conceivable that a "command-and-control" approach could be devised to reduce part of the remaining uncontrolled emissions, the large number, small size, and diversity of sources might make this approach costly and difficult to administer. For these reasons, some have proposed alternative, market-based strategies to controlling emissions. In the following section, we will present some examples of innovative State programs designed to capture uncontrolled solvent emissions and will discuss some market-based alternatives to the traditional "engineering" approach.

State Efforts To Capture Uncontrolled Solvent Emissions

The solvent end uses that are currently subject to some form of regulation are listed in appendix A. Here we see that most industrial solvent use categories have some form of regulatory requirements. However, regulation of some surface coating uses, as well as architectural surface coatings and consumer and commercial products, is limited. A recent national ozone control strategy proposed by STAPPA-ALAPCO also identified these three solvent end use categories as being the least well-regulated at this time and as having significant emissions reduction potential [43].

Although very few Federal controls have been issued for these uses of solvents, a few States have begun to devise ways to control their emissions, as well as ways to get further reductions from end uses already subject to some control. The following policy options represent the major approaches that States have either already taken or are proposing at this time:

1. lowering source-size exemption cutoffs of existing regulations to capture smaller sources within particular end use categories;
2. developing new regulations directed towards specific end uses, in some cases bringing in all sources in the category irrespective of size (e.g., lithographic printing, consumer solvents, architectural coatings);
3. placing limits on the VOC content of certain products or processes to encourage reformulation of solvents or use of non-solvent-based alternatives; imposing bans on the sale of products that fail to meet these control requirements by a specified date; and
4. establishing emissions fees or marketable permit systems to discourage the use of products with high VOC content.

Generally, States have been inconsistent in their degree of VOC emissions control requirements for solvent uses. While some have stringent regulations applicable to a broad range of end uses, others are less far-reaching in their requirements. For example, Massachusetts allows very few exemptions from its requirements for surface coating sources, whereas Rhode Island has no regulations for many of the same types of sources. In some cases, States are developing their own "allowable limits" on VOC emissions from source categories for which EPA has not yet issued any Control Technique Guidelines (CTGs) (e.g., New York is developing regulations for wood furniture coating). Most States follow EPA's lead in applying RACT requirements mostly to greater than 100-ton" sources, although some have begun to lower control requirements to apply to smaller sources. A few States are eliminating applicability limits altogether, so as to capture all VOC sources within an end use category. Others are issuing exemptions from certain regulatory requirements for using alternative, 1ow-VOC products in place of traditional solvents (e.g., North Carolina exempts waterborne inks with low VOC content for use in graphic arts).

One reason many States give for having resisted lowering the source-size cutoffs in their regulations is a lack of resources. Because States already have resource limitations in trying to enforce existing regulations, they are wary about their ability to account for and monitor additional sources. Some States or nonattainment areas, such as Illinois, Philadelphia, and the San Francisco Bay area, have used their source permitting systems to improve their inventories. These areas have been able to maintain inventory data on sources as small as 10 tons per year for many categories. However, most areas do not keep records on such small sources.

With regard to consumer and commercial product regulation, many of the regulators from States that have attempted or proposed some form of this regulation stated that such efforts would perhaps best be done on a *national* basis. Because most of these products are being sold across State lines, they believe it will be a very difficult strategy to enforce on a State-by-State basis. Inconsistencies in the stringency of such regulations from State to State may cause manufacturers to abandon some markets and relocate to other regions of the country.

Two nonattainment areas in particular have been at the forefront in developing innovative or stringent approaches to controlling VOC emissions: the South Coast Air Quality Management District (AQMD) of California and the New York City metropolitan area. Many of their requirements apply to solvent-related activities and cover the range of the four policy options presented above. The control approaches designed by these two areas provide examples of some of the options available to policy makers for reducing VOC emissions from solvents.

The South Coast AQMD has proposed a three-tiered approach to controlling VOC emissions from solvent uses that would make its regulations the most stringent in the country. More rigorous requirements are phased-in with each new tier. The first two tiers consist mainly of limiting the reactive solvent content of products and establishing a minimum transfer efficiency requirement for several coating categories. Tier I requires application of existing technologies. Tier 11 aims to cut in half the remaining emissions by improving and refining the applicability of these technologies. The third tier aims to almost eliminate VOC emissions from solvents in the Basin, by fostering "technological breakthroughs" to process changes that do not rely on solvents, new product formulations, and substitute products. The proposed third tier would culminate with a Basin-wide ban on noncompliant products and processes.

Tier I of the South Coast's strategy requires the application of all currently known technologies to existing sources. State regulators have listed 22 control measures directed at controlling VOC emissions from various categories of solvent use, including selected surface coating uses, architectural coatings, graphic arts operations, metal cleaning and decreasing, plastics manufacturing operations, dry-cleaning operations, and underarm and other domestic products. The AQMD estimates that VOC emissions from solvents could be reduced by approximately 45 percent of projected levels for the year 2000 by implementing Tier I controls. The greatest reductions are expected to come from regulations on domestic products (33 percent of total reductions in solvent emissions expected from Tier I controls), automobile refinishing (19 percent) and wood furniture coating (14 percent). Tier I is to be implemented over the next 5 years. Most of the measures included are expected to be "reasonably available" at the time the regulations take effect. However, at least for the domestic products category, the efforts necessary to bring about the anticipated reductions (e.g., total phaseout of aerosol propellants) seem more extraordinary than 'reasonably available. "

Three forcing mechanisms are set up to ensure that the objectives established under Tier I are met: 1) compliance schedules with interim dates for progressively reducing the VOC content of products and limiting process emissions; 2) emissions charges for architectural coatings to discourage purchase of coatings with high VOC content; and 3) the threat of a ban on the sale or limitations on the use of a product if its manufacturer fails to comply with regulations.

The goal of Tier II is to obtain a reduction of 50 percent of the emissions remaining from solvent evaporation after Tier I has been implemented, for cumulative reductions with Tiers I and II of about 70 percent compared to projected emissions levels in the year 2000. While categories for reduction are only generally described, controls on surface coating and consumer products are targeted. The South Coast hopes to reduce VOC emissions from coating operations by one-half through the use of alternative coating technologies, more efficient application of coatings, and the use of low- or non-solvent-based coating products and processes. They hope to cut, in half, emissions from consumer products through further development and widespread application of such controls as product reformulation and alternative propellant or dispensing mechanisms. The time frame for implementing Tier II is within the next 10 years. In addition to broader application of technology-forcing compliance schedules and emissions charges, the following actions have been proposed by the AQMD to facilitate achieving Tier II goals: 1) a cooperative effort with the State, product manufacturers and end users, to fully assess obstacles to and options for reducing solvent evaporation; 2) a Basin-wide program to disseminate information and educate business owners or operators about alternative products and processes; and 3) a program to increase public awareness, to enhance the marketability of newly formulated or packaged products.

Tier 111 sets forth the ambitious goal of "near-total phase-out" of VOC emissions from solvents by the year 2007. At present, no detailed strategy for achieving this goal has been proposed. However, Tier III does appear to rely on more full application of efforts begun in the earlier two tiers, such as adoption of alternative, non-solvent products or processes. The underlying assumption is that Tiers I and 11 will pave the way. As proposed, Tier 111 culminates with a ban on products that cannot comply with restrictions on solvent content, and processes that cannot meet emissions limitations.

A variety of impacts could result from the South Coast's three-tiered strategy. Sources may be moved out of the area or forced out of business because of the regulatory burden. In some cases, greater **use** of exempt solvents such as chlorinated solvents, would increase air toxic emissions. In other cases, as with controls on solvents used in drycleaning, emissions of potentially toxic air contaminants would be reduced. Also, additional liquid or solid waste could be produced from some add-on control devices. There would also be some administrative burden due to increased source permitting and additional enforcement needs.

While New York's approach is perhaps less ambitious and far-reaching than the South Coast's, it also aims to significantly reduce VOC emissions from solvents. Rather than exempting sources that emit VOCs below a certain level, all users of VOC-based solvents in some end use categories (e.g., all lithographic printers) will be required to meet limitations on the use of products with certain VOC contents. This approach is also designed to bring the supplier of such products into the regulatory loop, so that both the user and supplier are held accountable.

Two types of new regulations are being issued by the State: 1) regulations that bring in all sources in categories that are already regulated, and 2) regulations that apply to ***new,*** previously unregulated end use categories. By removing exemptions from RACT for selected categories-e.g., EPA's 100-ton source exemption for graphic arts facilities, and the exemption for surface coating sources using less than 5 gallons per day—the State is making all sources in a particular end use category subject to control requirements. And, because EPA has issued little or no technical guidance to States for regulating some categories, New York is developing its own control requirements independent of the Agency. For example, the State has recently issued final regulations for the following previously unregulated categories: graphic arts, surface coating uses (wood, plastic, glass and leather coating, auto refinishing), architectural coatings, and consumer and commercial products.

With the eventual goal of controlling all *emissions* from selected solvent categories, many of New York's regulations place strict limits on the VOC content in paints, inks, and other surface coatings. By 1990, new regulations are expected to reduce emissions from these three categories by about 40 percent compared to 1987 levels. This will constitute a 20-percent reduction in VOC emissions from all solvent uses. Eighty percent of these emissions reductions are expected to be from graphic arts facilities. The remainder of the anticipated reductions would come from limits on the VOC content of eight surface coating categories, autobody refinishing shops, and architectural paints. Regulations prohibit the sale (in the New York City metropolitan area) of architectural coatings that exceed a specified VOC content after July 1, 1989. Manufacturers of some consumer products (air fresheners, disinfectants, and insecticides) are required to study ways of reducing VOC emissions from these products. There is an accompanying ban on the sale of these products if the manufacturer has not registered them with the New York Department of Environmental Protection (DEP) and if a study protocol has not been submitted and approved by specified dates. While actual emissions reductions are not specified, projected schedules for implementation of measures proposed in the study are not to go beyond January 1, 1997.

In implementing these new regulations, the major issue as far the DEP is concerned seems to be how previously unregulated sources are going to be notified of the new regulatory requirements. The State plans to notify major manufacturers that their products are now subject to regulations, and let them tell their distributors, who in turn can notify the end users. Both users and manufacturers will be considered liable if users are found to be using non-approved products.

Alternatives to Traditional Methods of Controlling Solvent Emissions

Solvent emissions can be lowered in many ways. In some instances it is possible to switch to alternative products that use no solvent (e.g., using water-based rather than oil-based paints). Products can be reformulated using low-solvent technologies or using solvents which are not involved in ozone formation. Manufacturing methods can be changed so that less solvent is emitted per unit manufactured. And finally, emissions can be captured or destroyed through control methods such as incineration so that VOCs are not released to the atmosphere.

Most regulation under the Clean Air Act follows a traditional "engineering control" approach. Pollution control engineers within EPA or the States define "reasonably available control technology" (RACT) or the "lowest achievable emission rate" (LAER) for many different types of sources, and then source-specific regulations are issued. However, for many products and processes, this traditional approach may not produce the desired emissions reductions. Low- or non-solvent alternatives may not be available, and alternative manufacturing methods may not deliver the desired quality end product. Congress, EPA, and the States must find new ways to force the development of new products, manufacturing processes, and control methods.

The California Air Resources Board (CARB) is currently looking at alternatives to the traditional engineering approach to help reduce VOC emissions from solvent use in cases where new products or processes are needed. CARB has examined three basic options: 1) setting limits on solvent content or VOC emissions, together with deadlines for compliance and penalties for failure to meet the deadlines; 2) setting fees or taxing products that contain solvents or are manufactured using solvents; and 3) allocating permits to emit VOCs, and gradually phasing out allowable emissions by reducing the number or value of permits. CARB has not completed its evaluation of these options, and we have not analyzed them in detail. However, we attempt to provide a broad description of each, in this section, along with examples of how they might apply to solvents.

Compliance Schedules and Penalties**-When** Congress directed EPA in 1970 to develop regulations to lower motor vehicle emission rates by 90 percent, the technology to achieve this target was not available. Congress decided to force development of technology by choosing a percentage reduction target and a date by which it was to be reached, and by adopting penalties to give manufacturers incentives to develop the technologies needed to comply. Deadlines slipped many times, and several have yet to be reached, but tailpipe emissions of VOCs, nitrogen oxides, and carbon monoxide have been lowered considerably.

A similar framework could conceivably be developed for solvents. For domestic products, for example, increasingly stringent limits on solvent content could be set, along with compliance schedules and penalties for noncompliant products. Emissions reduction targets and deadlines could also be established for specific categories of sources, and flexibility provided for meeting them through process changes that eliminate or reduce solvent use, or add-on devices to control emissions.

Although it might work for large manufacturers of solvent-containing products or large businesses that use solvents, a potential problem with this approach is that numerous small businesses that one would like to cover through such regulations lack the resources to develop new products, processes, or control methods needed to comply. Furthermore, State or local regulatory agencies may lack the resources needed to enforce such an approach on the large number of small end users. Market-based strategies, that allow sources to "trade" emissions reductions, might help to ease this problem.

Marketable Emissions Permits—EPA'S proposed regulations for chlorofluorocarbons (CFCs and Halons—two chemicals that deplete stratospheric ozone[27]—combine technology forcing with a market-based approach to minimize the costs of cutting back production of these chemicals [52]. After considering the traditional engineering approach to control, EPA opted for a regulatory scheme that allocates production rights to CFC manufacturers based on their production in a historical year (1986), and gradually cuts back production rights from that level over a 12-year period.

In EPA's proposal, manufacturers are given the rights to produce 100 percent of their baseline levels each year through 1993. Manufacturers that produce less can sell their extra rights to produce CFCs to other firms. Any firm wishing to produce more than the amount they produced in 1986 must purchase rights from another manufacturer. In 1993, firms will be allowed to either produce--or sell the rights to produce—80 percent of their baseline levels. Each firm must return 20 percent of their rights to produce CFCs to EPA. In 1998, firms will be allowed to produce, or sell the rights to produce, 50 percent of the amount they produced in 1986. Theoretically, allowing trades should minimize the costs of cutting back production, as those firms for which reductions are most economical reduce more than necessary, and sell their unused production rights to other firms for whom reductions are more expensive.

Regulating CFC use and VOC emissions has one striking similarity: engineers cannot at this moment sit down and list all the control methods that one would need to achieve the desired reductions. A market-based approach has the advantage of actively involving industry in the search for new control methods. There are enough differences between the characteristics of the two control problems, however, so that one cannot just substitute the word "VOC" for "CFC" throughout the EPA regulations and expect a market-based program to work. (For example, CFC control applies nationwide, while VOCs are controlled primarily in nonattainment areas.)

In the case of CFCs, EPA preferred to regulate producers because there are far fewer of them than users, thus lowering EPA's record keeping burden. For solvents, there are reasons why it might be preferable to regulate users. First, VOCs are of concern primarily in nonattainment areas, and it might not be desirable to limit solvent production and hence restrict their availability everywhere. Second, it might be desirable to allow solvent users the option of destroying or capturing VOCs before they are released to the atmosphere. Because some record of emissions by end users is required for States' emission inventories anyway, EPA might choose to allocate solvent emission rights directly to users in nonattainment areas. The phase-out and trading provisions of the CFC proposal would still apply.

One controversial issue associated with a marketable permit system is how the permits will be initially allocated. In the case of emissions permits, allocation based on a historical year could be considered to place sources that have controlled stringently in the past at an unfair disadvantage. An alternative approach would be to require initial controls on some source types and then allocate production rights from this new, "post-control" baseline. While rejected for CFCs, this approach might be useful for regulating solvent use. Unlike CFCs, emissions from solvent use are already regulated, to some extent. Some States stringently regulate some types of solvent use, some do not. Defining a "fair baseline" for allocation of permits would be an important, if difficult frost step in implementing a market-based strategy.

Emission Fees or Taxes— In addition to marketable permits, EPA also considered placing fees on production of CFCs, with the intent that a high enough fee would discourage production. Agency staff rejected this approach because they felt they could not ensure that the required control levels would be reached by specified date. Manufacturers could opt to continue producing CFCs and pay the fees rather than lower production. Through trial and error the agency would eventually determine the

[27] Ozone in the stratosphere, 6 to 30 miles above the Earth's surface, shields plants and animals from harmfully high levels of ultraviolet radiation.

level of the fee necessary to achieve the required production limit, but it would be difficult to meet a target date. In considering the approach for solvents, the California Air Resources Board similarly notes that political difficulties associated with setting and subsequently adjusting emissions fees could be a major drawback.

One place where a fee or tax system seems particularly useful is in giving consumers incentives to purchase products with low solvent content. While it would be difficult to project how much emissions would be reduced by taxing spray deodorants to make them more expensive than stick deodorants, it might be one way to significantly reduce VOC emissions from consumer products that are sold on the national market, without banning them from nonattainment areas altogether.

A final problem with fees is that it is unclear whether the Clean Air Act gives EPA the authority to set fees for purposes other than recovering the cost of regulation. Congress needs to clarify its intent on this matter if market-based approaches are to be given full consideration.

LOWERING EMISSIONS FROM HIGHWAY VEHICLES: TRANSPORTATION CONTROL MEASURES

Of the VOC emissions remaining in nonattainment cities in 1994 after all of the controls we analyzed in chapter 6 are applied, highway vehicles account for about 28 percent, and gasoline marketing contributes 6 percent. Especially in fast-growing areas, efforts to further reduce emissions associated with highway vehicles involve a race between tighter controls that reduce emissions per vehicle mile, and increases in the number of vehicles on the road. Averaged nationwide, motor vehicle exhaust emissions are projected to decline through the late 1990s as an increasing percentage of vehicles on the road meet new standards, but rise after that due to growth in vehicle use.

Based on current trends in population and travel, and trends in age and income distributions, the number of vehicle-miles traveled (VMT) nationwide is projected to increase by 2 to 3 percent per year from now through 2005, resulting in a cumulative increase of about 40 to 60 percent [23]. The national average projections understate the increase expected in some cities: for example, 3.5 and 4 percent per year increases are projected for Houston and Phoenix, respectively, compared to increases of 1.5 and 2 percent per year in Detroit and Philadelphia.

Obviously, VMT growth could have a major impact on traffic flow in urban areas, as well as on air pollution. According to the Federal Highway Administration [23], traffic volumes in 1985 equalled or exceeded 80 percent of capacity on over 40 percent of the Interstate highways in the Nation's 45 largest metropolitan areas, indicating "extensive congestion during peak-traffic periods." Coping with, or *limiting* future growth in motor vehicle use presents major challenges to both air quality and transportation planners, who face the twin problems of congestion and air pollution.

To address motor vehicle use, the 1977 Amendments to the Clean Air Act required some urban areas to implement transportation control measures.[28] TCMs are a set of interrelated measures that have the general objective of reducing emissions by reducing driving or improving traffic flow.[29] Examples include improved public transit, exclusive highway lanes for buses and carpools, bicycle lanes, modified schedules for work, parking management, and road use charges or tolls. Because they try to change the behavior of large segments of the public (e.g., getting people to use mass transit or share rides to work), public awareness of congestion and air quality problems is a key to the success of TCMs. In most cases in which these measures have been used, they have been justified on broad grounds of improving urban mobility as well as air quality.

In this section, we first review the TCM requirements in the 1977 Amendments, including requirements for integrating air quality and transportation

[28] Sec. 110(c)(5)(B) of the Clean *Air* Act, *as* amended.

[29] VOC emission rates decline as "chic.e speeds increase, especially up to about 35 to 40 mph. Also, emission rates are lower when speeds are held constant, than under stop/start conditions,

Photo credit: South Coast Air Quality Management District, El Monte, CA

The number of miles traveled on our Nation's highways is projected to increase by about 40 to 60 percent by 2005. The adoption of transportation control measures, such as ridesharing, carpool lanes, alternative work schedules, and transit improvements could help reduce congestion and the accompanying increased highway vehicle emissions by improving traffic flow.

planning. We then provide estimates of the magnitude of reductions that can be expected from TCMs, based on the 1988 Air Quality Maintenance Plan for the Los Angeles area. In addition to "traditional" measures that focus on the transportation system of roads and mass transit facilities, measures that seek to reduce driving by managing land-use are also considered. Finally, we discuss key implementation issues, including transportation and land-use planning and policy, and strategies to ensure participation.

Requirements in the 1977 Clean Air Act Amendments

The 1977 Amendments to the Clean Air Act required urban areas that would not be able to meet the ozone or carbon monoxide standards by 1982 to implement transportation control measures (TCMs) as necessary to attain the ozone and carbon monoxide standards.[30] The Act specified that development of TCM programs had to be coordinated with the transportation planning process that the Department of Transportation requires as a condition for receipt

[30] Secs. 110(a)(3)(D) and 110(c)(5)(B) of the Clean Air Act, as amended.

of Federal highway and mass transit assistance.[31] One-time-only grants to Metropolitan Planning Organizations (MPOs) for integrated air quality and transportation planning were authorized.[32] About $50 million was awarded. The Amendments also tried to provide a check on the air quality impacts of all projects supported by Federal highway and mass transit finds, by requiring the Secretary of Transportation to ensure that federally funded projects "conform" to State Implementation Plans (SIPs) .33

Some transportation control measures were included in most States' 1979 and 1982 SIP revisions. In most cases the TCM programs were not very aggressive, and accordingly, expectations of VOC emissions reductions from TCM programs were generally modest. Many of the TCMs included in the 1979 and 1982 SIPS were adopted primarily to help reduce carbon monoxide emissions, or even to ease congestion or meet other transportation or development-related goals [51]. For example, a review of a few 1982 SIP submittals found that in the two from Louisville and St. Louis, TCMs such as transit improvements, ridesharing programs, parking controls and traffic flow improvements were expected to yield 6 to 7 percent of the VOC reductions anticipated through 1987. In SIPs from two other areas—Baltimore and Chicago-expected reductions from transportation control measures amounted to 1 percent or less of the anticipated VOC reductions [22].

Unfortunately, we cannot evaluate whether previous SIP projections generally overestimated or underestimated the effect of transportation control measures, because the impact of the measures that have been implemented has not been systematically monitored by EPA or the States. EPA's Office of Transportation and Land Use Policy was eliminated in 1982 due to budget constraints and shifted priorities, and the Agency has not subsequently required detailed program evaluations and reports from the States. Moreover, it is generally difficult to evaluate the impact of individual TCMs on air quality, due to errors and uncertainty in baseline estimates of vehicle use, and confounding factors such as local economic conditions, fuel prices, and unrelated changes in the local transportation system (e.g., freeway construction).

Several key generalizations about TCMs can be drawn from interviews and reports on programs in various cities [27,1 1]:

- **TCM programs have to be tailored to each individual area. Critical** local characteristics that need to be considered in developing TCM programs include population and employment distributions and densities, city layout and transportation routes, highway system capacity and level of congestion; access to mass transit; and parking availability and costs.
- **The success of many transportation control measures depends to a large degree on public acceptance and participation.** In the absence of widespread public concern about air pollution and/or traffic congestion problems, past experience indicates that political resistance to involuntary restrictions on people's modes or amount of travel will be insurmountable. From a political standpoint, it is apt to be much easier to initiate voluntary TCM programs than mandatory ones. However, the ultimate success of voluntary programs can also depend critically on public awareness. And, due to turnover in participation, promotional efforts for strictly voluntary programs have to be sustained over time. For example, carpools typically have turnover rates of 1 to 2 years. Two approaches other than promotional campaigns that attempt to give people incentives to participate in TCM programs are discussed below: "trip reduction ordinances" directed at employers, and financial incentives and disincentives.
- **Long leadtimes and sustained efforts are required to implement TCMs.** Major capital projects such as development of mass transit obviously require long lead times. Other measures may be directed at new employers or

[31] Federal aid for highways and mass transit totals about $16 billion, annually, most of which is supported through Federal motor fuels taxes. To be eligible for Federal highway and mass transit assistance, metropolitan areas are required to coordinate transportation plans and transportation improvement programs across local jurisdictions within the area. Metropolitan Planning Organizations (MPOs) with elected representatives from each local jurisdiction, perform this function. MPOs typically do not have authority to implement or enforce transportation plans.

[32] Sec. 175 of the Clean Air Act.

[33] Sec. 176(c) of the Clean Air Act.

commercial developments, and thus take effect only gradually. Ordinances requiring new employers to encourage employees to share rides, use transit, or otherwise collectively reduce their driving are one example. Ridesharing programs and parking restrictions could help reduce emissions within a very short time, although their continuing impact may depend on long-term land use and transportation policies.

- The effectiveness of one transportation control measure may depend substantially on concurrent implementation of another. For example, ridesharing programs and mass transit are likely to be more successful if some highway lanes are restricted to buses and carpools, or if parking in business districts is restricted or expensive. A recent comparison of the business districts of San Francisco, Portland, Seattle and Denver found that transit shares were highest in the cities with the highest parking prices and most limited parking [28]. In general, larger reductions in emissions are likely to be achieved if TCM programs are coordinated throughout an area and over an extended time horizon, than if measures are developed on a piecemeal or sporadic basis.
- For TCMs to be effective, air quality has to **be considered a priority in urban transportation and land-use planning.** Because TCMs involve highway and transit facilities and operations, it is obvious that State and local organizations with responsibility for transportation system operations, maintenance and improvements have to be involved in their development and implementation. Since TCMs can also involve zoning laws and requirements for new developments, the participation of local organizations with authority over land-use policies is also needed. Land-use policies that affect VMT are discussed further in the next section,

The planning grants made under the 1977 Amendments were judged to have been effective in getting MPOs to examine transportation control measures (many of them for the first time). The grants also enabled areas to obtain local data on mobile sources that were needed to evaluate potential TCM impacts. However, the one-time-only grants apparently fell short of convincing transportation planners in most areas to give continuing priority to improving air quality [51].

The requirement that federally funded projects conform to SIPS also failed to institute improvement or maintenance of air quality as a goal in urban transportation planning. The U.S. Department of Transportation (DoT), which distributes Federal highway and mass transit assistance, has sought to equate "conformance" with a narrow finding that a transportation plan or project does not interfere with transportation control measures included in SIPS [50]. EPA has suggested a broader requirement that transportation plans and projects "should not cause or contribute to existing or new standard violations, or delay attainment" [12]. While DoT and EPA have debated the meaning of 'conformance," transportation plans, projects and programs have not generally been required to address air quality concerns proactively.

Potential Reductions From Transposition Control Measures

One of the most up-to-date and comprehensive assessments of transportation control measures is the review that the South Coast Air Quality Management District (AQMD) and the Southern California Association of Governments recently completed for the Los Angeles area [38,40]. For each of the transportation control measures listed below, the AQMD estimated the VOC reductions that would be possible using existing authority and funds (the low end of the range) as well as reductions dependent upon additional funding or new legislative initiatives (the upper end of the range). Reductions are estimated for the period 2000-10.

Without the measures listed below, VMT in the Los Angeles area is projected to increase by almost 70 percent by the year 2010, as the population living in the area increases by 35 percent, to 18.3 million. Due to congestion, the average vehicle speed on area freeways is predicted to fall from 47 to 24 mph [41]. In 2010 total VOC emissions from highway vehicles are projected to be reduced by about 40 percent from 1985 levels, to about 320 tons per day, despite increased VMT and without the measures listed below [40].

With full funding and authority, the proposed measures are expected to reduce highway-vehicle VOC emissions by a total of 30 percent, by 2010, compared to levels projected without them. Note that under these circumstances, growth management measures that are aimed at matching new jobs with nearby housing account for over 40 percent of these reductions. (Total reductions in highway vehicle emissions of NO_x, sulfur oxides, carbon monoxide, and particulate matter from the set of measures listed below are also expected to be about 30 percent, compared to emissions levels projected for 2010 without the TCMs listed below.)

- strategies to reduce the number of single-occupancy car trips, including: employer ride share and mass transit incentives, parking management (increase parking meter fees, eliminate peak-period on-street parking, eliminate employer-subsidized parking, etc.), vanpool purchase incentives, auto use restrictions, and high-occupancy vehicle (HOV) lanes. Businesses in the Los Angeles area with more than 100 employees are already required to encourage ride sharing and transit use; requirements for employers would be strengthened and expanded. New laws would regulate commercial parking and eliminate parking subsidies. New funding is sought for transit improvements and HOV lanes. Federal legislation is called for to restore tax credits for vanpool purchases. The South Coast AQMD estimates that all such measures will reduce highway vehicle emissions by about 0.2 to 3 percent, compared to levels projected without TCMs.
- **traffic flow improvements,** including: metering on highway ramps, synchronized traffic signals, and intersection improvements. Making these improvements is primarily a matter of obtaining funds for roadway modifications and installation and maintenance of metering and synchronization technology. The South Coast AQMD estimates that these measures will reduce highway vehicle emissions by about 0.5 to 1.5 percent.
- **rescheduling and rerouting of truck deliveries away from congested areas during peak commute hours.** Truck delivery routes and schedules were altered voluntarily during the 1984 Olympic Games. To implement these measures on a wider scale, local ordinances such as those that restrict night deliveries might have to be modified. The AQMD estimates reductions of about 0.3 to 3 percent from this measure.
- alternative work schedules (e.g., work weeks consisting of 10-hour days), and telecommuting. As examples, businesses would be required to adopt alternative work scheduling as a condition for permit renewal, and new employment developments in business or industrial districts with more jobs than available housing would be required to establish satellite work centers in predominantly residential areas. Employers in the Los Angeles area have some experience with alternative work schedules, which were adopted voluntarily to help reduce traffic congestion and air pollution during the 1984 Olympic Games. Although the State of California is currently conducting a pilot project on telecommuting, the idea of requiring new businesses to have satellite work centers is unprecedented, and would require changes in zoning, licensing, tax and possibly labor laws to implement. Highway-vehicle emission reductions of about 0.5 to 7 percent are estimated to be available from these measures.
- **freeway capacity enhancements. The AQMD** estimates that by building an additional 880 lane miles, highway vehicle emissions can be reduced by about 1.5 to 4 percent. This step constitutes an extremely ambitious highway construction program, and AQMD acknowledges that obtaining sufficient funding will be a major challenge. The projection that net reductions in emissions would result from freeway expansion means that in the Los Angeles area, lower emissions due to reduced congestion are expected to offset increased travel that might be encouraged by new roads.
- growth management. The population in the South Coast is projected to grow to 18.3 million by the year 2010, almost a 50-percent increase since 1984. This measure proposes to use land-use management measures to help match new jobs with nearby housing, and vice versa. Specific measures include assessing development fees, modifying zoning rules, and strategically locating new public facilities and infrastructure. Though growth management is likely

to be politically contentious, it is becoming more common for fast-growing municipalities to use zoning laws, development fees, etc. to try to do so. However, the scale of the AQMD proposal, which entails coordination over dozens of municipalities, is unprecedented. The AQMD estimates that shifting 10 percent of new jobs to housing-rich areas, and 4 percent of new housing to job-rich areas, would reduce highway vehicle emissions by 0.6 to 14 percent.

Role of Transportation and Land-Use Planning

Land-use patterns play an important role in either tying people to their cars or facilitating other modes of transportation. As an illustration, people who live within a few miles of work might choose to walk or bike. But where urban areas consist of sprawling residential suburbs and separate business districts or industrial parks, few people have these options. A recent comparison of ten U.S. cities found that per capita gasoline consumption (which we assume to be a reasonable surrogate for VMT) is relatively low in cities with high population and job density, and relatively high in cities with abundant roads and parking. Per capita gasoline consumption is 10 times higher for residents of suburbs outside of Denver than for residents of Manhattan [32].

Between 1980 and 1986, about 85 percent of the population growth in the United States was in metropolitan areas. About three-fourths of that growth occurred in the suburbs of those areas. According to a task force formed to advise the Federal Highway Administration (FHWA), this pattern of growth is expected to continue [23]. However, growth in the suburbs does not necessarily have to mean more and longer commutes in private cars. The FHWA's task force anticipates that the density of residential development in the suburbs will increase as rising housing costs and declining household sizes necessitate construction of apartments and compact townhouses rather than expansive subdivisions [23]. This increase in density could facilitate transit service. And, some analysts have suggested, land-use policies could guide development to limit reliance on driving,

Land-use planning and regulation are traditionally activities carried out by local governments, whereas transportation planning is more apt to be a State or regional responsibility. Land-use policies are implemented through local zoning laws and permit requirements for subdivision and commercial site development. Permit reviews typically ensure that public works (e.g., water, sewers, roads, interchanges, and parking) are adequate to support the development. Interaction between transportation and land-use planning agencies usually takes the form of assessing the impacts of new developments. The number of trips that would be generated by a proposed development is estimated and compared with the capacity of nearby roads and intersections.

If a transportation system is inadequate to support new development, it maybe expanded, sometimes at a developer's expense. Increasingly, where funds are limited or congestion is already an issue, developers are being required to take steps such as providing convenience stores on site, or providing transit shelters or bike paths, in order to reduce potential transportation impacts. Downtown developers in several cities have been faced with caps on the number of parking spaces they can provide. As mentioned above for Los Angeles, area-wide land-use regulations can also be modified to help reduce traffic congestion and air pollution. The guiding principles include: promoting development in areas with existing mass transit services; encouraging development within developed areas to increase population density and thus make transit services easier to provide; and promoting housing construction in job-rich areas or employment opportunities in residential areas. Due to the links between land-use policies, jobs, and tax revenues, local political resistance is apt to be the major problem in trying to modify land-use regulations [15].

Trip Reduction Ordinances

To circumvent problems in getting people to accept and participate in transportation control measures, some areas have passed ''trip reduction ordinances" requiring companies to provide services, facilities, or incentives to encourage their employees not to drive to work alone. Companies are required to promote transportation alternatives, but the participation of individuals is voluntary. Some companies have increased the proportion of their employees who do not drive alone to more than 80 percent [11]. Services and incentives provided include preferential parking, shuttle services, on-site sale and subsidies of mass transit passes, and subsidized vanpools.

Examples of trip reduction ordinances include a regulation passed in 1987 in the Los Angeles area that is designed to increase average ridership from the current level of 1.13 to 1.5 people per vehicle during peak periods. The ordinance applies to all employers of 100 or more people and thus affects more than 8,000 businesses. Employers are required to prepare comprehensive trip reduction plans for their companies. Failure to submit a plan or annual update, or offer any incentive included in the plan is a violation of the ordinance; failure to meet ridership goals is not. The regulation is expected to reduce the number of private motor vehicle trips made each day by about 10 percent, resulting in VOC emissions reductions of about 4 percent of current highway vehicle emissions [25].

An ordinance passed in Pleasanton, CA in 1984 set a goal of reducing peak hour commuting traffic by 55 percent, from a baseline that assumes everyone drives alone. Employers are expected to achieve a 15-percent reduction in the first year, and additional reductions of 10 percent each of the next 4 years. In the second year of the program, only three companies failed to achieve the targeted 25 percent reductions, and twelve companies had already exceeded the fourth year target of 45 percent. Companies are fined for failing to provide required survey data, but not for failing to meet goals [24].

Financial Incentives for Reducing Vehicle Use

Because the cost of driving influences the number of miles per year that people travel, another approach to reducing VMT involves the use of fees to make driving more expensive, and subsidies to encourage use of alternative modes of transportation. Financial incentives have the potential to affect a greater fraction of urban travel than trip reduction ordinances, because less than 30 percent of local travel is work-related [49]. Targets that have been proposed for fees or taxes include gasoline, parking, and road-use (i.e., tolls).

Ironically, Federal income tax policy currently provides a financial incentive that encourages driving to work alone over using mass transit or ride sharing. Employers' provision of free or subsidized parking is a tax free benefit, worth up to $300 per month if valued at commercial rates charged in the business districts of some cities. In contrast, provision of more than $15 per month worth of mass transit passes is a taxable benefit. The amount by which the market value of vanpool trips exceeds what employees are charged to participate is also taxable under current law [31].

Although many studies have looked at the relationship between the price of and demand for gasoline, only a few have explicitly estimated the effect of gasoline price on automobile travel.[34] Of these, most have concentrated on the effect over the first few years of a price change, not on changes that might persist over many years. When estimating the effect of gasoline price on travel from historical data, several factors must be considered simultaneously. Income, average fuel economy, and the cost of more fuel-efficient cars must all be taken into account as factors that influence how a consumer will respond to changing gasoline prices. Data from different time periods and countries indicate that the likely response to a $0,50 per gallon tax is a reduction in automobile travel of between 5 and 25 percent, for the first few years the tax is imposed.[35] Thus a reasonable assumption is that a 15-percent reduction in automobile travel would result from a $0.50 per gallon tax. Similarly, one would expect about an 8-percent reduction in automobile travel from a **$0.25** per gallon tax.

The effect of a gasoline tax over the long term is quite a bit more uncertain. *Some* studies have found that the effectiveness of a gas tax increased through time. Others found that it dropped. In many cases, the latter trend seems most likely. Rather than reducing travel, consumers will respond by purchasing more fuel-efficient cars when it is time to replace their old ones. However, this is not the only response

[34] Two recent reviews of the relationship between gasoline price and automobile travel are Dahl, 1986 [14] and Bohi and *Zimmerman,* 1984 [6].

[35] These studies estimate the "elasticity" of miles traveled to changes in the price of gasoline, that is the ratio of the change in miles traveled to the change in the price of gasoline, Short-term elasticities of -0.1 to –0.5 have been reported in the literature and summarized by Dahl [14],

possible. If a gasoline taxis combined with improvements in mass transit, for example, consumers may permanently shift their mode of transportation.

If the only benefit from a gasoline tax that is considered is the reduction in VOC emissions, the cost-effectiveness of a gasoline taxis quite high. We estimate that emissions reductions from a gasoline tax would cost about $35,000 to $75,000 per ton of VOCs over the first few years. Over the long term, costs might rise to about $100,000 to $200,000 per ton. Of course, other benefits would also result, including lower emissions of carbon monoxide, nitrogen oxides, and carbon dioxide, reduced highway congestion, and less reliance on imported oil.

Photo credit: South Coast Air Quality Management District, El Monte, CA

Methanol-fueled vehicles emit less ozone-forming pollutants than traditional gasoline-fueled vehicles. The use of compressed natural gas also represents a promising alternative to gasoline.

LOWERING EMISSIONS FROM HIGHWAY VEHICLES: ALTERNATIVE FUELS

Two motor vehicle fuels, methanol and compressed natural gas (CNG),[36] are currently being considered as alternatives to gasoline, to help reduce urban ozone. Roughly 1,000 vehicles in the United States, mostly in demonstration fleets in California, are currently operated on methanol blended with a small amount of gasoline [47,1]. About 30,000 vehicles in the United States have been retrofit to run on either CNG or gasoline [47].

Based on experience in the United States and elsewhere, it appears feasible to modify or design light-duty vehicles (i.e., cars and light trucks) to operate on either CNG or methanol, and give performance that is generally comparable to that of vehicles running on gasoline. The limited distance that can be driven on CNG before refueling is currently a disadvantage for it, compared to gasoline. Problems that still need to be addressed with methanol vehicles include starting them on straight (100 percent) methanol in cold weather, and safety concerns related to the fuel's acute toxicity and invisible flame. Partly because of these limitations, methanol vehicles used within the next 10 years will probably operate on blends of methanol and gasoline. CNG vehicles will most likely be dual-fueled, operating on CNG part of the time, and gasoline part of the time.

The potential for reducing ozone when methanol or CNG are substituted for gasoline stems from the fact that methanol and natural gas (methane) are VOCs that react more slowly in the atmosphere and consequently lead to less ozone production than the complex mixture of VOCs emitted from the combustion and evaporation of gasoline. In the near term, "effective" VOC emission rates with alternatively fueled vehicles will be only moderately lower than rates that could be obtained with gasoline vehicles meeting current standards.[37] In the short term, using either methanol blends or dual-fueled CNG vehicles is likely to be an extremely costly means of reducing ozone. With major advances in vehicle technology over the next 10 years, and use of straight methanol (rather than a blend) or exclusive use of CNG (rather than dual-fuel operation) greater and more cost-effective reductions may be possible.

36111 ti,~tion,4'me~ao]" refers to fuels that are 100 percent or 'neat" methanol, or gasoline-methanol blends that are at least 85 percent methanol, by volume. "Compressed natural gas" is natural gas that is stored on a vehicle under high pressure-typically at 2,400 psi or higher.

37We use the phrase "effective VOC emissions" throughout this section to indicate relative ozone-forming potential, as opposed to the actual amount of VOCs (i.e., tons of carbon) emitted. Because different organic compounds are emitted from methanol or CNG versus gasoline-fueled vehicles, alternative fuel use can "effectively" lower emissions in terms of how much ozone is produced when various compounds react, even if the total amount of VOCs emitted is unchanged.

In the sections that follow, we first discuss estimates of the effect of alternative fuel use on emission rates and other aspects of motor vehicle operation and performance. We then present estimates of total emissions impacts of using alternative fuels in: 1) fleets of 10 or more light-duty vehicles, and 2) light-duty vehicles in general use. Finally, we present a range of estimates of the costs per ton of VOC emissions effectively eliminated by using methanol or CNG. Throughout the analysis, we adopt estimates of effective emissions reductions attainable with methanol blends or dual-fueled CNG vehicles as our best estimates. We use projections of reductions that might be obtainable with advanced technology and use of straight methanol or exclusive use of CNG, to get upper bound estimates of the potential benefits of alternative fuels.

Emissions From Alternatively Fueled Motor Vehicles

Estimates of emissions rates for methanol-fueled vehicles are speculative because the vehicles tested to date have been versions of vehicles originally designed to operate on gasoline, which were retrofit or modified in limited production runs. Mass-produced vehicles could have different emissions characteristics. Moreover, most methanol vehicles tested had not accumulated much mileage, and it is not known how much emissions rates would deteriorate in use. Our best estimate is that vehicles likely to be available in the next 10 years, which would be operated on blends of 85 percent methanol mixed with 15 percent gasoline (by volume), would have total rates of evaporative and exhaust VOC emissions that are effectively 30 percent lower (in terms of ozone-forming potential) than those of light-duty vehicles meeting current standards and operating on low volatility gasoline (9.0 psi Reid Vapor Pressure (RVP)) [3,47].

Estimates of emission rates that might eventually be obtainable with technological advances and with operation on straight methanol are very speculative. As an upper bound, we adopt EPA's assumption that effective reductions of up to 90 percent may be possible, compared to gasoline vehicles meeting current standards [56]. A major advance needed before such large reductions could be obtained is to improve engine and catalyst designs to control emissions of formaldehyde, a highly reactive, toxic VOC produced when methanol is burned. Some engineers and analysts are skeptical that formaldehyde emissions can be controlled well enough to reduce overall ozone-forming potential by 90 percent [33,4].

Emissions reductions that could be achieved using CNG are even more speculative than those for methanol vehicles, because emissions have only been measured for a few dual-fuel CNG vehicles, and the results have varied significantly from one test to another [3,7]. EPA has preliminarily estimated that while operated on CNG, dual-fuel vehicle exhaust emissions would effectively be 40 percent lower, and evaporative emissions 100 percent lower, than emissions from vehicles meeting current emission standards and operating on low volatility gasoline [56]. Adding up the exhaust and evaporative impacts, total emissions would be reduced by about 75 percent.[38] As an upper bound for CNG, we assume that if vehicles are designed and adjusted for minimal emissions with exclusive operation on CNG, total effective reductions of up to 90 percent might be realized.

It is important to emphasize that the relative ozone-producing potential of vehicles operated on gasoline versus alternative fuels will depend on future regulations, including volatility limits set for gasoline, and exhaust and evaporative emissions limits imposed on both gasoline and alternative-fueled vehicles. With any fuel, considerable leeway exists in trading off emission rates for engine performance, starting and warm-up characteristics, and vehicle costs. EPA has promulgated emissions standards for methanol-fueled vehicles that allow the same levels of exhaust and evaporative VOC emissions for methanol as for current gasoline-

[38] Based on EPA's model of motor vehicle emissions, MOBILE 4, for a vehicle meeting current exhaust standards and operating on 9.0 psi RVP gasoline, and for atypical hot summer day, we assume in-use exhaust, evaporative and 'running loss" emissions are 42,21, and 37 percent, respectively, of total emissions.

fueled vehicles.[39] Under the proposed regulations, the improvement in air quality anticipated with methanol would be due solely to the reduced ozone-forming character of the emissions, rather than reduced emissions, per se. To date, EPA has not proposed standards for CNG vehicles.

Switching to alternative fuels could affect levels of several air pollutants besides ozone. In addition to VOCs, gasoline vehicles also emit nitrogen oxides, benzene and other toxic organic compounds, carbon monoxide, and particulate. In theory, methanol and CNG have the potential to reduce emissions of all of these pollutants, although the reductions that actually occur will depend on regulations, and on vehicle design and operation. Replacing diesel with methanol or CNG might be especially helpful in allowing heavy-duty buses and trucks to obtain concurrent reductions in emissions of both particulate and nitrogen oxides.[40] For light-duty vehicles, EPA applies the same carbon monoxide and nitrogen oxides emissions standards for methanol as for gasoline **[52], so** potential reductions in these pollutants would probably not be realized. A critical problem that needs to be addressed with methanol vehicles is emissions of formaldehyde. With catalyst designs tested to date, methanol vehicles cannot meet the in-use standards California has proposed for formaldehyde emissions [33].

One final air quality consideration associated with the use of motor vehicle fuels other than gasoline is their comparative emissions of "greenhouse" gases that trap heat in the atmosphere, such as carbon dioxide (Co_2) and natural gas (methane). Considering production of the fuels as well as combustion in motor vehicles, and assuming that on an energy equivalent basis the fuel economy is the same, use of CNG would be expected to reduce greenhouse gas emissions by about 20 percent, compared to gasoline [16]. Greenhouse gas emissions from methanol produced from natural gas would be about the same as emissions from gasoline [16]. However, use of methanol produced from coal could increase emissions of greenhouse gases by 50 to 100 percent, depending on the efficiency of the process of producing methanol [16,25]. At present, methanol is produced almost exclusively from natural gas, because production from coal is not economically viable [46].

Vehicle Operation and Performance

Because methanol is incompatible with some metals and polymers currently used in automotive fuel systems, straight methanol cannot be used in vehicles designed to run on gasoline. However, in California tests, vehicles that were built to run on methanol have given comparable performance and maintenance records and equal or improved fuel economy (on an energy equivalent basis[41]) compared to gasoline-fueled vehicles of the same model [1]. Gasoline was generally added to the methanol used in these demonstration programs for safety, so that in case of an accident the fuel would burn with a visible flame, and because cars run on straight methanol are difficult to start in cold weather [1]. Theory suggests that if these two problems can be overcome, vehicles that are modified to operate on straight methanol could get 10 to 15 percent higher fuel economy (energy equivalent basis) and give improved performance (due to methanol's high octane rating) than gasoline-fueled vehicles [1]. Finally, methanol is much more toxic than gasoline.

[39] U.S. EPA's standards for light-duty-methanol-fueled vehicles are exhaust emissions of 0.41 g/mi hydrocarbon (HC), and evaporative emissions of 2.0 g/test HC [52]. The State of California's standards for methanol-fueled passenger vehicles are similarly equivalent to their proposed gasoline-fueled vehicle standards (California has proposed a new exhaust emissions limit for 1992 and subsequent model year passenger vehicles of 0,25 g/mi) except that limits on formaldehyde in exhaust are specified explicitly (0.015 g/mi at certification and 0.023 g/mi in-use for the 1993 to 1995 period, and 0.015 g/mi at certification and in-use after 1995) [9].

[40] In 1990, the NO_X emissions standard for all heavy duty vehicles will be reduced from the current Standard of 10.7 g/bhp-hr to 6.0 g/bhp-hr and to 5.0 g/bhp-hr in 1991. in 1991 the particulate standard for urban transit buses will be reduced from 0.6 g/bhp-hr to 0.1 g/bhp-hr and for other heavy duty vehicles to 0.25 g/bhp-hr. In 1994, all heavy duty vehicles will be required to meet a 0.1 g/bhp-hr particulate emissions standard, The particulate and NO_X standards may be difficult to meet concurrently with the add-on control technology anticipated to be available for heavy-duty diesel vehicles. In a demonstration program in California, transit buses with either spark or compression ignition engines that were designed or significantly modified to run on methanol emitted lower levels of NO_X and particulate than diesel-fueled buses. However, methanol buses have had problems with limited durability of parts and restricted range between refueling [1]. Several heavy-duty engine manufacturers have research underway to develop spark ignition engines to operate on CNG [35].

[41] The energy content of a gallon of gasoline is approximately 2.0 times greater than that of a gallon of methanol.

Ingestion can cause permanent blindness or death.[42] Widespread use of methanol would require safety precautions that have not been taken with gasoline.

The advantages of CNG include its very high octane rating, high combustion efficiency, and good characteristics for starting in cold weather. The main disadvantages of the fuel are related to its low volumetric energy content. The distance that current CNG vehicles can be driven without refueling is currently limited to about 200 miles, whereas a typical light-duty vehicle has a range of up to 350 miles on 15 gallons of gasoline. In providing a 200-mile range, current CNG-fueled vehicles carry extra weight and displace about five times the space that gasoline tanks providing the same range would require. The most commonly used steel tanks weigh up to 400 pounds, while more recently developed fiberglass-wrapped aluminum tanks weigh about 200 pounds [17]. For comparison, the average weight of current passenger cars is about 3,000 pounds, including a 25-pound gasoline tank.

Most of the CNG vehicles that are currently in operation in the United States have been retrofitted for dual CNG or gasoline use. Adjustments made to allow dual fuel operation affect performance and fuel efficiency. Dual-fuel vehicles have generally given poorer performance and had worse fuel economy on both gasoline and CNG than comparable gasoline vehicles [46,7]. Some experience with CNG vehicles that operate exclusively on CNG has been gained with 27 light-duty trucks built by the Ford Motor Company. The truck tested by U.S. EPA gave performance and fuel efficiency comparable to an equivalent gasoline-fueled truck [3].

Potential Emissions Reductions from Alternative Fuel Use

In the following sections, we consider the total emissions impacts of alternative fuel use in the year **2004,** in: 1) fleets of 10 or more light-duty vehicles (e.g., vehicles owned by corporations or police departments), and 2) light-duty vehicles in general use. We also estimate the costs per ton of VOC emissions effectively eliminated.[43] Emissions impacts are calculated assuming that refueling emissions and gasoline volatility have already been controlled, and that light-duty vehicles are subject to current standards. Because of the potentially high cost of using methanol and natural gas, it may be desirable to limit their use to those areas with the most severe ozone problems. Therefore we only consider alternative fuel use in areas with design values of 0.15 ppm or higher. The other control measures OTA has identified are projected to be insufficient to bring most of these areas into attainment by the year 2004 (see chapter 6).

In the sections that follow, as our best estimates, we assume that emission rates with methanol blends would effectively be 30 percent lower than those of gasoline vehicles; and that emissions from dual-fuel vehicles operated on CNG would effectively be 75 percent lower. We assume full-time use of methanol blends, but that dual-fuel vehicles are only operated on CNG 75 percent of the time.[44] As an upper bound for exclusive use of either CNG or methanol in vehicles incorporating technological advances, we use an effective reduction in emission rates of 90 percent, compared to gasoline.

In addition to motor vehicle exhaust and evaporative emissions, refueling emissions would also be reduced if gasoline were displaced by straight methanol or by CNG. Negligible reductions in refueling emissions would be anticipated if gasoline were displaced by a methanol/gasoline blend. With straight methanol or CNG use, we assume that refueling controls would have been in place anyway, and that reductions in VOC emissions from refueling are proportional to the amount of gasoline displaced.[45]

[42] Just over 2 ounces of methanol could potentially be lethal if swallowed by a 150-pound adult. This amount could readily be ingested accidentally by someone siphoning fuel. Swallowing less than half an ounce of methanol could be lethal to a young child [30].

[43] Note that in estimating VOC control cost-effectiveness, we have used the full cost differential between gasoline and the alternatives. If, compared to gasoline, use of alternative fuels also reduced emissions of other pollutants such as carbon monoxide, the costs associated with fuel substitution should be distributed across pollutant control programs.

[44] We assume that some operation on gasoline would be necessary for dual-fuel CNG vehicles, because the distance they can be driven on CNG without refueling is limited, and because CNG would not be available everywhere. Nationwide, about 15 percent of vehicle males are driven on trips that cover more than 75 miles in distance, one-way [48].

[45] VOC emissions from petroleum refining could also be reduced, assuming that they are tied to gasoline ales. However, we cannot be sure where such reductions would occur, so we do not count them in the totals for the areas where alternative fuels are used.

Light-Duty Fleet Vehicles

In 1986,6 million cars and 2 million light trucks in centrally owned fleets of 10 or more vehicles accounted for about 13 percent of light-duty vehicle miles traveled (VMT) nationwide [5]. Centrally owned fleets account for such a large fraction of VMT because on average, fleet vehicles are driven over two times as many miles in a year as vehicles in general use. Use of alternative fuels in centrally fueled fleets is expected to be easier to promote or require than general use, because the latter would have to be preceded by development of a much more extensive network of refueling stations than the former.[46]

In 2004, in areas with design values of 0.15 ppm or higher, about 4.5 million light-duty vehicles are expected to be operating in centrally owned fleets of 10 or more. About 7.9 billion gallons of methanol per year would be required to operate these 4.5 million vehicles.[47] This amount is about equal to the worldwide capacity for production projected for 1990 [21].[48] About 520 billion cubic feet of natural gas (approximately 3 percent of current U.S. production) would be required annually to operate 4.5 million light-duty vehicles exclusively on CNG.

Table 7-10 summarizes the effective VOC reductions that could be obtained with CNG or methanol use in areas with design values of 0.15 ppm or higher. Our best estimate is that by 2004, use of methanol in fleets would be equivalent to reducing emissions by 0.7 percent of total 1985 levels. Using CNG in fleets (75 percent of the time) is estimated to be equivalent to reducing VOC emissions by 1.3 percent of 1985 levels. As an upper bound, with technological advances and exclusive use of either CNG or straight methanol, we estimate that emissions might be reduced by 2.1 percent.

Vehicles in General Use

By 2004, it might be possible to expand the supply and distribution of alternative motor vehicle fuels to satisfy a large portion of the general market. To illustrate the magnitude of potential VOC emissions reductions and fuel consumption involved, we consider the impacts of using alternative fuels in 25 percent of the light-duty vehicles in general use in 2004, in nonattainment areas with current design values of 0.15 ppm or higher.

About 15 billion gallons of methanol are estimated to be needed to fuel 25 percent of the general population of light-duty vehicles in nonattainment areas with design values of 0.15 ppm or higher. About 1 trillion cubic feet of natural gas (5 percent of U.S. production in 1987) is estimated to be needed if CNG is used.

As shown in table 7-10, our best estimate is that if 25 percent of the light-duty vehicles in areas with design values of 0.15 ppm or higher used methanol or CNG, emissions would be effectively reduced by 1.3 or 2.5 percent, respectively, compared to 1985 levels. Our upper bound estimate is that emissions might be effectively reduced by up to 4.1 percent, again with technological advances and exclusive use of either CNG or straight methanol.

Cost-Effectiveness of Alternative Fuel Use in Light-Duty Vehicles

Methanol

One automobile manufacturer has estimated that in production runs of fewer than about 100,000 vehicles, cars and light-duty trucks designed to operate on methanol would cost $500 to $1,000 more than gasoline-fueled vehicles; whereas in larger runs, methanol and gasoline-fueled vehicle production costs could be comparable [53]. For centrally owned fleets, assuming a vehicle life of 6 years (150,000 miles) and an 8-percent discount rate, the annualized cost differential for a methanol vehicle could thus range from $0 to about $215. For a vehicle in general use, with a 10-year (100,000 mile) life and again assuming an 8-percent discount rate, the annualized added cost could range from $0 to $150.

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[46]Because of data limitations, we focus our analysis on centrally owned fleet vehicles, rather than on centrally fueled fleet vehicles.

[47]This assumes that cars average 27.5 miles per gasoline gallon equivalent fuel, and that light duty trucks average 20 miles per gallon. About 690 billion cubic feet of natural gas would be required to produce 7.9 billion gallons of methanol.

[48]U.S. production capacity in 1990 is projected to be about 2 billion gallons. The principal use of methanol is currently as a chemical feedstock.

Table 7-10-Effective VOC Reductions in 2004, From Use of CNG and Methanol as Light-Duty Motor Vehicle Fuels in Areas with Design Value of 0.15 ppm or Higher[a]

	New vehicle reduction (percent)	Area-wide total fleets[c]		Area-wide total general[d]	
		(tons)	(percent)	(tons)	(percent)
Methanol blends (best estimate)	**30**	**54,000**	**0.7**	**102,000**	**1.3**
Straight methanol (upper bound)	90	173,000	2.1	328,000	4.1
Dual-fuel CNG[e] (best estimate)	75	108,000	1.3	205,000	2.5
Exclusive CNG (upper bound)	90	173,000	2.1	328,000	4.1

[a]The reduction totals for straight methanol and exclusive CNG use include refueling emissions reductions of 11,000 tons for fleets, and 21,000 tons for general-use vehicles. For dual-fuel CNG vehicles, 75 percent of those reductions are counted. Reductions in refueling emissions are expected to be negligible, with methanol blends.
[b]Compared to vehicles me&g current standards on 9.0 psi gasoline.
[c]Alternative fuel use in centrally owned fleets of 10 or more light-duty vehicles.
[d]Alternative fuel use in 25 percent of all light-duty vehicles.
[e]Assumes 75 percent operation on CNG, 25 percent operation on gasoline.

SOURCE: Office of Technology Assessment, 1989.

Based on a range of 40 to 60 cents per gallon as the wholesale price of methano1[49] we estimate that methanol would be sold to consumers at $0.64 to $0.84 per gallon, or $1.15 to $1.51 per gasoline-gallon equivalent, adjusting for the difference in the energy content of the two fuels.[50] These estimates can be compared to national average prices for regular and premium unleaded gasoline of $0.95 and $1.10 per gallon, respectively [47]. Assuming that fleet vehicles average 26,000 miles per year and get the energy equivalent of 26.5 miles per gallon of gasoline, straight methanol use would increase annual fuel costs by about$130 to $480 per vehicle. Annual fuel costs would be about $50to$180 higher for a vehicle in the general population averaging 10,000 miles per year and 26.2 miles per gallon.

Table 7-11 summarizes our cost-effectiveness estimates for methanol-fueled vehicles. In the near term, assuming that methanol is blended with 15 percent gasoline and yields effective VOC emissions rates that are only 30 percent lower than gasoline-fueled vehicles, we estimate that using methanol would cost $9,000 to $66,000 per ton of VOCs eliminated. If the equivalent of 90-percent reductions in VOC emissions can be achieved through advanced technology, we estimate that using straight methanol would cost $3,000 to $22,000 per ton. In each case, the low estimate assumes both vehicle and fuel costs that are most favorable to methanol, and the high estimate assumes costs that are least favorable.

Compressed Natural Gas

Retrofitting a gasoline vehicle to operate on both CNG and gasoline costs about $1,000to $1,500 [53]. Because a special fuel tank is required, a cost differential of about $500 is expected between CNG and gasoline-fueled vehicles even in large production runs. The annualized added cost of a vehicle that would be run on CNG is expected to fall between $110 and $325, for a fleet vehicle, and between $75 and $218, for a vehicle in general use.

Based on 1987 national average commercial natural gas prices of $4.76 per thousand cubic feet [47], or $0.56 per gasoline-gallon equivalent, and $0.20 to $0.30 per gasoline-gallon equivalent com-

49Wholesale methanol prices in summer, 1988, were $0.60 per gallon, delivered to the Gulf Coast [29]. Methanol used in demonstration fleets in California is supplied at $0.59 *per* gallon, but tbe State has new commitments for delivery of 9 million gallons at $0.45 per gallon [10]. With new plants and sufficient demand to ship methanol by tanker, various analysts estimate long-run costs for methanol ranging from less than $0.35 to more than $0.70 per @on [13,21,20,10,42,2]. Relatively cheap methanol is expected to come from countries such as Trinidad or Saudi Arabia, where it could be retie from natural gas that is recovered in the process of oil production and would otherwise be vented or flared. U.S. methanol production costs would be relatively high due to the high cost of U.S. natural gas. Because of the dominance of feedstock costs, the cost of producing methanol domestically would increase with demand.

50We have added $0.24 per gallon for taxes, distribution to refueling stations, and retail markup. The gasoline-gallon equivalent price is estimated by assuming that a gallon of methanol is equivalent to 1.8 gallons of gasoline, based on the 2:1 ratio of gasoline to methanol energy content and a 10-percent improvement in energy efficiency with methanol.

Table 7-ll+Xet-Effectiveness of Alternative Fuel Use

	Fuel price ($/gas. gal. equiv.)	New vehicle differential ($)	Fleet cost-effectiveness ($/ton)	General cost-effectiveness ($/ton)
Methanol blends			8,700-51,000	8,700-66,000
Straight methanol	1.15-1.51	0-1,000	3,200-18,000	3,200-22,000
Dual-fuel CNG[a]			400-12,000	3,900-22,000
Exclusive CNG	0.85-0.95	500-1,500	0-7,400	1,600-14,000

[a]Assumes 75 percent operation on CNG, 25 percent operation on gasoline.

NOTE: A retail gasoline price of $1.025 per gallon is used to calculate fuel cost differentials.

SOURCE: Office of Techology Assessment, 1989.

pression costs [46,17,36], we estimate that CNG would be sold to consumers at about $0.89 to $0.99 per gasoline-gallon equivalent.[51] At these prices, use of CNG in fleet vehicles could save from $35 to $130 per vehicle per year. In general, light-duty vehicles' use of CNG could save $10 to $50 annually per vehicle.

As shown in table 7-11, if three-quarter time use of CNG in dual-fuel vehicles resulted in 56-percent reductions in VOC emissions overall (averaged over operation on gasoline and CNG), the cost of using CNG would be $400 to $22,000 per ton of VOCs removed, depending on vehicle and fuel costs, and distance traveled (which determines how much fuel cost savings offset vehicle purchase costs). If 90-percent reductions could be realized with advanced vehicles operated exclusively on CNG, use of CNG in fleets could result in a net savings, compared to gasoline, or cost up to $7,000 per ton of VOCs removed; in the general population, costs would be $1,600 to $14,000 per ton.

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