Chapter 6

Controlling Emissions of Volatile Organic Compounds

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Chapter 6
Controlling Emissions of Volatile Organic Compounds

INTRODUCTION

Controlling emissions of volatile organic compounds (VOC) is the primary strategy used by the Environmental Protection Agency (EPA) and most States for reducing urban ozone. In this chapter, we discuss the sources of VOC emissions, our ability to control them, and the costs of control.

The first section describes the sources of VOC emissions and presents our estimates of the changes in emissions over the next several years. The next section analyzes the VOC emissions reductions from source-specific control methods that are currently available. We also compare these potential emissions reductions with estimates of the overall emissions reductions needed to attain the ozone standard in each nonattainment city. In the final section, we summarize the costs of each control method.

CHARACTERIZATION OF CURRENT AND FUTURE EMISSIONS

This section describes the man-made sources of VOC 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 needed to attain the ozone standard. The focus of this section is on manmade emissions, since they are subject to control. VOC emissions from vegetation are discussed in chapter 5.

Sources of Volatile Organic Compounds

Table 6-1 displays estimates of 1985 VOC emissions, number of cities, and population within each of five ozone design value categories. The EPA 1985 National Emissions Data System (NEDS) and the 1985 National Acid Precipitation Assessment Program (NAPAP) inventories are the sources of our emissions data and serve as the base inventory for all future year projections presented in this report. Three adjustments have been made to these data. First, highway-vehicle emissions contained in the 1985 NEDS inventory have been updated using EPA's most recent estimates of exhaust and evaporative emission rates. [1] Vehicle emission rates were also adjusted to reflect a higher rate of gasoline evaporation during vehicle use.[2] Highway vehicle emission rates were estimated for hot summer temperatures typical of days when the ozone standard is violated. Finally, VOC emissions from residential fuel combustion (primarily from wood burning) have been excluded from our analysis since these emissions occur primarily during the wintertime when ozone is not a problem. Thus, the estimates that we present are representative of the emissions on a typical nonattainment day, multiplied by 365 days per year, rather than estimates of true annual emissions. For convenience, throughout the report, we refer to these estimates as annual emissions rather than as ''nonattainment-day-equivalent-annual-emissions."

Of the 25 million tons of VOCs emitted in 1985, nationwide, about 45 percent (11 million tons) were generated in 94 cities that exceeded the ozone standard during the 1983-85 period. For our analy -

[1] We use EPA's MOBILE 4 model to estimate highway vehicle emission rates. In a recent effort using MOBILE 4, EPA grouped nonattainment cities into five categories based on the Reid vapor pressure (RVP) of gasoline and ambient temperatures. These categories included:

	% of total VMT in 61 selected cities	RVP (psi)	Ambient temperature, OF (min.)	(max.)
Group 1:	0.18	11.6	62	85
Group 2:	0.23	10.5	69	95
Group 3:	0.21	11.2	72	90
Group 4:	0.16	11.7	61	96
Group 5:	0.22	11.1	81	96

We used the vehicle-miles-traveled (VMT)-weighted average exhaust and evaporative emission rates of these five groups, assuming an average vehicle speed of 28 miles per hour.

[2] Preliminary EPA tests have shown that gasoline evaporation during vehicle operation on warm days (called ''running loss") is significantly higher than previously thought. Details of this adjustment are discussed later.

Table 6-l-Summary of 1985 VOC Emissions in Nonattainment Cities and Attainment Regions

	VOC emissions (1 ,000 tons)[a]	Percent stationary (%)	Percent mobile (%)	Number of cities	1985 population (millions)
Nonattainment cities by design value category (in ppm O_3)					
0.13-0.14	**3,200**	**53**	**47**	**37**	**30.2**
0.15-0.17	**5,400**	51	**49**	**40**	**55.3**
0.18-0.26	**1,600**	**53**	**47**	**14**	**20.2**
>0.26	**970**	**53**	**47**	**3**	**11.9**
Total (nonattainment)	**11,000**	**52**	**48**	**94**	**117.7**
Attainment regions	14,000	49	51		118.8
Total	25,000	50	50		236.5

[a]Totals are rounded. The estimates that we present are representative of the emissions on a typical nonattainment day. multiplied by 365 days per year, rather than estimates of true annual emissions. For convenience, throughout the report, we refer to these estimates as annual *emissions* rather than as "nonattainment-day-equivalent-annual-emissions."

SOURCE: EPA 1985 National Emissions Data System emissions Inventory, January 1988 printout; 1985 National Acid Precipitation Assessment Program area source emissions inventory; population data from Bureau of Census. Mobile source inventory is adjusted to reflect increased emissions from gasoline evaporation. Residential fuel combustion sources are excluded.

sis, an area is considered nonattainment if its design value is greater than 0.12 parts per million (ppm) ozone according to EPA-published 1983-85 ozone monitoring data.[3] 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 Ii-em 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. These regions contain about half of the Nation's population.

Our estimates of emissions throughout this analysis are subject to potentially significant uncertainty. We estimate that VOC emissions in nonattainment cities could be as low as 8 million or as high as 14 million tons per year in 1985 depending on several important mobile and stationary source assumptions. Uncertainties in the emissions inventory are discussed in more detail in a later section.

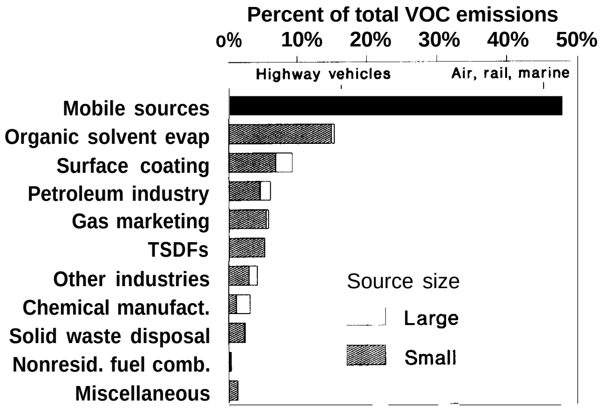
Figure 6-1 displays the percent contribution of various source categories to the total 1985 VOC emissions in nonattainment cities. About three-quarters of the emissions are generated from three main categories: mobile sources, surface coating, and other organic solvent evaporation from stationary sources, About 43 percent of the 1985 emissions inventory is composed of highway vehicle emissions. A further breakdown of the data, shown in figure 6-2, reveals that passenger cars are the largest contributors within the highway vehicle category, with about one-third of the total 1985 nonattainment area VOC emissions, followed by light-duty gasoline trucks with 7 percent.

Surface coatings contributed about 9 percent of the total VOC emissions in 1985. Surface coatings are used in the manufacture of a wide variety of products including automobiles, furniture, large appliances, and other metal and plastic products; printing inks and many other applications are also included. Organic solvent evaporation from stationary sources other than from surface coatings contributed about 15 percent of the total VOC emissions in 1985. The sources within this category are extremely varied and include such activities as decreasing of metal parts and products, drycleaning, consumer and commercial products, and cutback asphalt paving.

The range of individual source sizes (as defined by their individual annual VOC emission rates) can also be quite wide, ranging from a small gas station

[3]The list of cities exceeding the standard during the 19116-88 period had not been released by EPA at the time of this analysis. We used the 1983-85 period in our analysis, rather than the most recent list available because we felt it is more representative of current nonattainment status.

Figure 6-l-Volatile Organic Compound (VOC) Emissions in Nonattainment Cities, by Source Category, in 1985

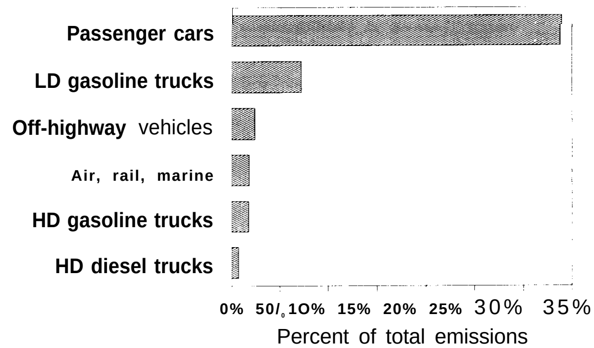


Total emissions = 11 million tons/year

Stationary sources that emit more than 50 tons per year of VOC 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 6-2-Volatile Organic Compound Emissions From Mobile Sources in 1985 as a Percentage of Total (mobile plus stationary) Emissions in Nonattainment Cities



LD = light-duty; HD = heavy-duty
Total emissions = 11 million tons/year

SOURCE: OTA, from EPA's National Emissions Data System (NEDS), National Acid Precipitation Assessment Program emission inventory, and MOBILE-4 modal.

decreasing tank that emits less than a ton per year, to large industrial operations that contain evaporation sources emitting several hundred tons per year. Figure 6-1 shows that solvent evaporation (including surface coatings) from small stationary sources emitting less than 50 tons per year contributes about 20 percent of total VOC emissions.

Figure 6-3 displays the breakdown of stationary source emissions by source size. About 45 percent of the total 1985 VOC emissions originated from stationary sources that emit less than 50 tons per year. Because of the way EPA constructs the NEDS emissions inventory, it is not possible to show, with much certainty, a more detailed breakdown of the "less-than-50-tons-per-year" size class.[4] However, we do know that *at least 1* percent of the inventory comes from sources emitting between 25 and 50 tons per year, and that this contribution *could* be as high as 30 to 35 percent. We have chosen 15 percent as a "rough guess," *assuming* that about a third of the small aggregated VOC stationary sources in the inventory (for which no source size can be identified) may, individually, emit more than 25 tons per years The uncertainty in actual sizes of the less-than-50-ton sources does not diminish the significant contribution they make to total VOC emissions.

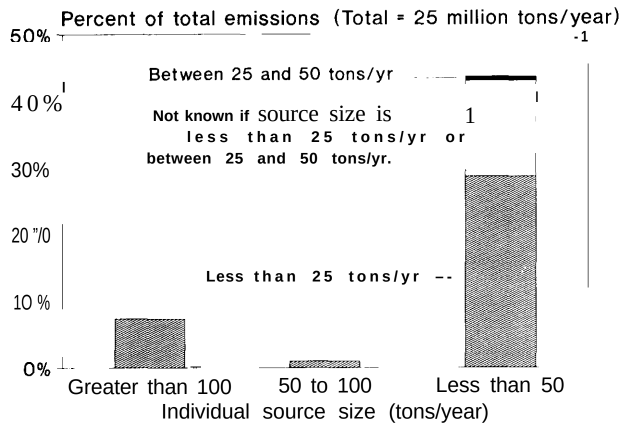
Future VOC Emissions

Tables 6-2 through 6-4 display our projections of VOC emissions in 5, 10, and 15 years-1994, 1999, and 2004-assuming that existing State and EPA regulations do not change. These projections serve as a baseline from which to gauge the effectiveness of future regulations; for example, the changes proposed in recent congressional bills or EPA's proposed post-1987 ozone policy. Under regulations in place as of 1987, total VOC emissions would decline approximately 6 percent by 1994 compared

[4]EPA requires States to report VOC emissions from individual sources that emit more than 50 tons per year. If a large "facility" (that contains more than one source) emits more than 100 tons per year of VOCs, each individual source emitting more than 25 tons per year *within* that facility must also be reported, EPA uses a "market-balance" approach to indirectly estimate the aggregate remaining emissions from small sources that are not required to report their emissions. Determination of individual source sizes is, therefore, not possible for these small size categories.

[5]The 25-ton-per-year size cutoff was chosen so that we could analyze (in a later section) the emissions reduction potential frOm stationary sources greater than 25 tons per year. The Clean Air Act currently requires that, at a minimum, all stationary VOC sources that emit more than 100 tons per year in nonattainment areas must adopt "reasonably available" control methods, though this cutoff is lower for some categories.

Figure 6-3—Stationary Source Emissions of Volatile Organic Compounds (VOCs) in 1985 as a Percentage of the Total Emissions inventory, by Size of the individual Source



Each bar displays the percentage of total VOC emissions that are contributed by each source-size class. For example, about 45 percent of total emissions come from sources that emit less than 50 tons per year. Because of the way the 1985 emissions inventory is constructed, we are unable to give a more precise detailed breakdown within the "Less-than-50 tons-per-year" category. We have assumed that sources that emit between 25 and 100 tons per year account for about 15 percent of the total VOC emissions; this percentage could be as high as 30 to 35 percent.

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

to 1985 levels. Note that the baseline does not include reductions due to the recently promulgated limit on gasoline volatility of 10.5 psi Reid vapor pressure (RVP).

Total emissions are expected to start increasing again sometime after 1999, showing a net increase of 1 percent in 2004 compared to 1985 levels. Our estimates of future emissions depend on several key assumptions regarding stationary and mobile sources and are subject to potentially significant uncertainty. These assumptions, and their effects on total future emissions estimates, are discussed in more detail in a later section.

Total VOC emissions drop between 1985 and 1994 due to lower emission rates from cars and trucks.[6] Although the number of vehicle-miles-traveled is forecast to increase in many areas over this period, the gradual replacement of current vehicles with newer, cleaner ones will result in an overall decline in highway vehicle emissions. Figure 6-4 shows mobile and stationary source VOC emissions through time. VOC emissions from highway vehicles are projected to decline by about 25 percent between 1985 and 1999. Stationary source emissions, on the other hand, are forecast to increase steadily between 1985 and 2004, showing a 10-percent increase by 1994 and a 23-percent increase by 2004, over 1985 levels.[7] Growth of small (less than 50 ton-per-year) stationary VOC source emissions is one of the most important reasons why overall VOC emissions are not expected to decline more rapidly in the earlier years and why total emissions may show a net *increase* after 1999. This source category effectively offsets much of the emissions reductions realized from highway vehicles.

Analysis of Important Assumptions Used in VOC Emissions Estimates

In this section, we address some of the assumptions used in our emissions estimates presented above. The assumptions we tested include: 1) the rate of gasoline evaporation from in-use highway vehicles ("running losses"), 2) average highway-vehicle speeds, 3) exhaust emission rates from passenger cars after 50,000 miles of use, 4) level of compliance with existing stationary source VOC regulations, 5) emissions from organic solvent evaporation sources, and 6) emissions from hazardous waste treatment, storage, and disposal facilities (TSDFs). Figures 6-5 and 6-6 and table 6-5 display our estimates of uncertainty for these categories.

We estimate total VOC emissions in nonattainment cities would be about 10 million tons per year

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

[7] Future large stationary source (greater than 50 tons per year) emissions were estimated using projections of industrial employment growth within various industrial categories, while small source growth was based either on industrial employment, estimates of population growth, or growth in the gross national product per capita [17] [22] [23].

Table 6-2-Summary of 1994 VOC Emissions in Nonattainment Cities and Attainment Regions (emissions in 1,000 tons per year)[a]

	VOC 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	3,000	1,800	1,100	–7%	8%	–24%
0.15-0 .17	5,100	3,000	2,000	–770	90/0	–23%
0.18-0 .26	1,500	940	590	–6%	8%	–22%
> 0.26	890	570	320	–90/0	10%	–30%
Total (nonattainment)	10,000	6,400	4,100	–770	90/0	–24%
Attainment regions	13,000	7,500	5,600	–5%	1 1%	–20%
Total	24,000	14,000	9,700	–6°A	1 0“/’	–22%

[a]Totals are rounded. Assumes no regulations other than those in place in 1987. The estimates that we present are representative of the emissions on a typical nonattainment day, multiplied by 365 days per year, rather than estimates of true annual emissions. For convenience, throughout the report, we refer to these estimates as annual emissions rather than as "nonattainment-day -equivalent-annual-emissions." Note that the baseline does not include reductions due to the recently promulgated limit on gasoline volatility of 10.5 psi Reid vapor pressure (RVP).

SOURCE: Office of Technology Assessment, 1989.

Table 6-3-Summary of 1999 VOC Emissions in Nonattainment Cities and Attainment Regions (emissions in 1,000 tons per year)[a]

	VOC 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	3,000	1,900	1,100	–6%	13%	–29%
0.15-0 .17	5,100	3,200	1,900	–60/0	15%	–28%
0.18-0 .26	1,500	980	560	–5%	13%	–27%
> 0.26	890	600	280	–9%	160/0	–38%
Total (nonattainment)	10,000	6,700	3,800	-6%	14%	–29%
Attainment regions	13,000	8,000	5,400	–3%	18%	–23%
Total	24,000	15,000	9,200	–5%	16%	–260/o

[a]Totals are rounded. Assumes no regulations other than those In place in 1887. The estimates that we present are representative of the emissions on a typical nonattainment day, multiplied by 365 days per year, rather than estimates of true annual emissions. For convenience, throughout the report, we referto these estimates as annual emissions rather than as "nonattainment-day-equivalent-annual emissions." Note that the baseline does not include reductions due to the recently promulgated limit on gasoline volatility of 10.5 psi Reid vapor pressure (RVP).

SOURCE: Office of Technology Assessment, 1989.

in 1994, again assuming the regulations in place as of 1987.[8] This total could be as low as 7 million or as high as 13 million tons per year given a range of variability in all the assumptions listed above. Of all the assumptions we tested, running losses appear to have the most significant effect on total VOC emissions in nonattainment cities. The following discussion presents a more detailed account of our analysis of the five categories of uncertainty which we were able to analyze.

[8]This estimate assumes running losses equal to 1.5 grams per mile, average highway vehicle speeds equal to 28 miles per hour, 100 percent compliance with all existing stationary source VOC regulations, EPA's 1985 estimate of organic solvent use and TSDF emissions, and unadjusted in-use vehicle tailpipe emission rates.

Table 6-4-Summary of 2004 VOC Emissions in Nonattainment Cities and Attainment Regions (emissions in 1,000 tons per year)[a]

	VOC 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....., ...	**3,100**	**2,000**	**1,100**	**–20/0**	**20%**	**–26%**
0.15-0 .17	**5,400**	**3,400**	**2,000**	**–10/0**	**210/0**	**–240/o**
0.18-0 .26	**1,600**	**1,000**	**590**	**0%**	**19%**	**–22%**
> 0.26	930	640	2	9–4°/0	240%	-36%
Total **(nonattainment) . . . .**	**11,000**	**7,100**	**4,000**	**– 1 %**	21 ”/0	–250/’
Attainment regions .’.	14,000	8,500	5,700	3%	26%	–18?40
Total	25,000	16,000	9,700	1%	23%	–21%

[a]Totals are rounded. Assumes no regulations other than those in place in 1967. The estimates that we present are representative of the emissions on a typical nonattainment day, multiplied by 365 days per year, rather than estimates of true annual emissions. For convenience, throughout thereport, wereferto these estimates as annual emissions rather than as “nonattainmentday-equivalent-annual-emissions.” Note that the baseline does not include reductions due to the recently promulgated limit on gasoline volatility of 10.5 psi Reid vapor pressure (RVP).

SOURCE: Office of Technology Assessment, 1989.

Rate of Gasoline Evaporation From In-Use Highway Vehicles

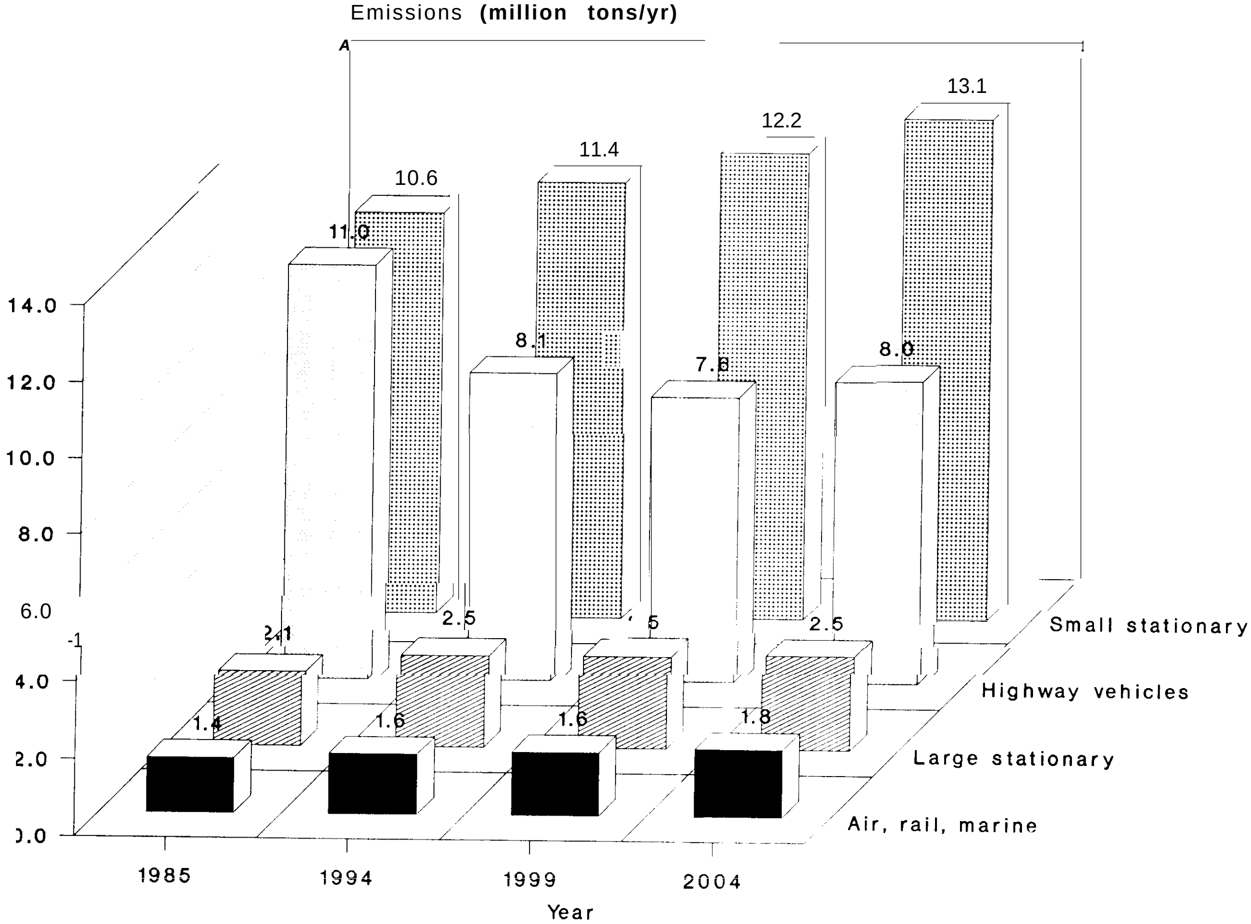
Preliminary results from EPA tests on 34 passenger cars and light-duty trucks [31] have shown that on hot summer days gasoline evaporation from the fuel system (“running losses”) may significantly increase total vehicle emissions. The magnitude of additional emissions from running losses will vary from city to city depending factors such as ambient temperature and gasoline volatility. For example, in nonattainment cities with relatively moderate ambient summertime temperatures (e.g., 79 ‘F) and gasoline volatilities of around 11.5 pounds per square inch (psi) (e.g., Washington, DC), EPA’s MOBILE-4 model estimates that fleet average running losses are about 1.5 grams of VOC emitted per mile driven in 1985. In cities with higher ambient temperatures (87 ‘F) and gasoline volatilities (1 1.7 psi), such as New York City, fleet average running losses are estimated to be about 2.9 grams per mile.

Figure 6-7 shows how varying running losses affects individual vehicle emission rates in nonattainment cities.[9] A running loss of 1.5 grams per mile increases passenger car emission rates by about 34 percent; at 2.5 grams per mile, emission rates are about 58 percent higher than those which do not account for running losses. For passenger cars, gasoline evaporation contributes about 60 percent of the total in-use VOC emissions at a running loss of 1.5 grams per mile. Running losses represent a potentially large source of VOC emissions which are not included in EPA’s 1985 NEDS mobile source inventory.

MOBILE-4 assumes that fleet average running losses will decline in the future as newer, cleaner vehicles replace older ones. However, because of the limited number of vehicles tested thus far, we believe it would be premature to predict future trends in running loss emission rates due solely to vehicle changes made for other reasons. Our estimates of current and future highway vehicle emissions presented above, and throughout our analysis, have been adjusted to reflect an additional 1.5 grams per mile emission rate due to running

[9]Exhaust emission rates shown in the figure do not include the effects of current motor vehicle inspection and maintenance (I/M) programs. We estimate that current I/M programs reduce exhaust emissions by about 12 percent. Estimates of exhaust emission rates assume average vehicle speeds of 28 miles per hour, Emission rates for vehicles in California will be lower since the State maintains a summertime gasoline volatility limit of 9 pounds per square inch.

Figure 6-4—Summary of Estimated Nationwide Voiltile Organic Compound Emissions by Source Category, by Year



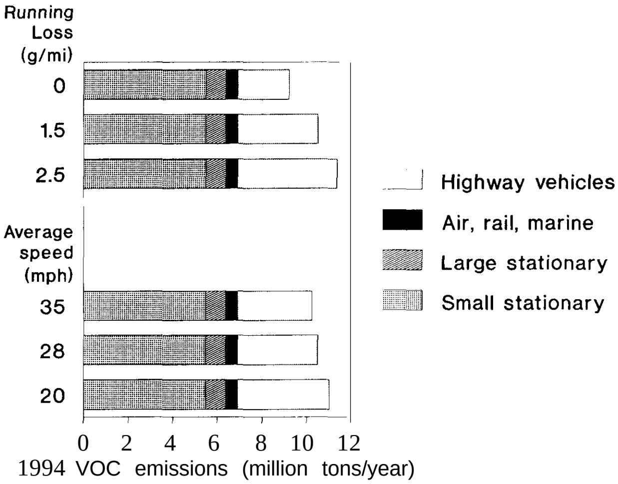
The numbers directly above the boxes are the total emissions within the source category. For example, emissions from highway vehicles in 1994 are 8.1 million tons per year, nationwide. "Small stationary" sources emit less than 50 **tons per year. Assumes no regulations other than those in place in 1987.** The estimates that we present are representative of the emissions on a typical nonattainment day, multiplied by 365 days per year, rather than estimates of true annual emissions. For convenience, throughout the report, we refer to these estimates as annual emissions rather than as "nonattainment-day-equivalent-annual-emissions ." Note that the baseline does **not include reductions due to the recently promulgated limit on** gasoline **volatility of 10.5** psi Reid vapor pressure (RVP).

SOURCE: Office of Technology Assessment, 1989.

losses (0.5 gram per mile in California).[10] If running losses are omitted from current highway vehicle emission rates (i.e., assumed to be zero grams per mile), we estimate that total VOC emissions in nonattainment cities decrease by about 10 percent in 1985. At 2.5 grams per mile, total emissions increase by about 6 percent in 1985. Although running losses add a potentially signifi-

[10] The VMT-weighted fleetwide average running loss for the five regional areas in 1985 (see footnote 1), as derived from EPA's MOBILE-4 model, is about 2 grams per mile, while after 20 to 25 years it is predicted to be about 1 gram per mile. For our analysis, we chose a fleetwide average estimate in the middle of this range-1.5 grams per mile—which, based on MOBILE-4 data, would be expected to occur sometime in the 1990s. In regions with relatively higher ambient summertime temperatures and gasoline volatilities, MOBILE-4 estimates that fleetwide average running losses are between about 2 and 3 grams per mile in 1985. Therefore, we chose 2.5 grams per mile as a high estimate. MOBILE-4 data estimates that lowering gasoline volatility from 11.5 to 9.0 psi will reduce running losses by about two-thirds, In general, light-duty gasoline trucks probably have lower running losses than passenger cars. California emission rates are estimated assuming a gasoline volatility of 9.0 psi.

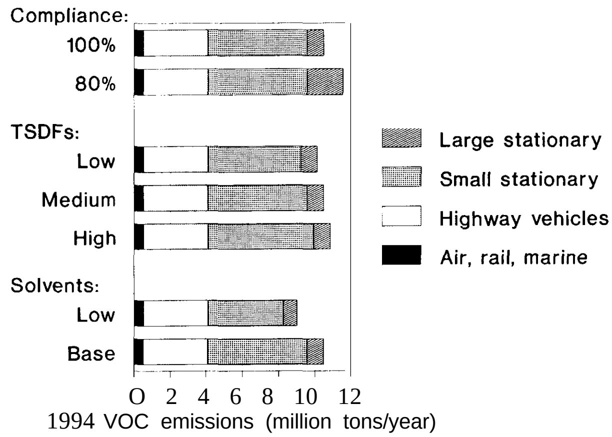
Figure 6-5—Uncertainty in Highway-Vehicle VOC Emissions in Nonattainment Areas in 1904



Throughout our **analysis, we** assume a 1.5 grams-per-mile running loss and average vehicle speeds of 28 miles per hour.

SOURCE: Office of Technology Assessment, 1989.

Figure 6-6-Uncertainty in Stationary-Source VOC Emissions in Nonattainment Areas in 1994



Throughout our analysis, we assume that: 1) stationary sources are in 100 percent compliance with existing VOC regulations, and 2) emissions from hazardous waste treatment, storage, and disposal facilities (TSDFs) (shown in the "medium" category) and organic solvent evaporation sources (shown in the "base") are the same as what is reported in the 1985 NAPAP inventory.

SOURCE: Office of Technology Assessment, 1989.

cant amount of emissions to existing inventones, these additional emissions, as we will show later, can be largely controlled by lowering current gasoline volatility limits.

Average Highway-Vehicle Speeds

Vehicle speed affects the rate at which pollutants are emitted from the tailpipe. VOC exhaust emissions generally increase with decreasing vehicle speed. A recent study found that the average automobile speed in 10 principal U.S. cities was about 27 miles per hour in 1980 [14]. In southern California, highway vehicle speeds are expected to decrease to about 19 miles per hour by 2010 if no further regional transportation improvements are adopted [16].

Our estimates of current and future highway vehicle emissions throughout our analysis are calculated assuming average speeds of 28 miles per hour for all cities [12,14]. If average speeds are reduced from 28 to 20 miles per hour, we estimate that total VOC emissions in nonattainment areas increase by about 7 percent, from about 11.2 million tons to about 12.1 million tons per year in 1985. If speeds increase from 28 to 35 miles per hour, nonattainment area total VOC emissions decrease by about 4 percent, to about 10.8 million tons per year in 1985.

Lower Passenger Car Tailpipe Emission Rates

We have also analyzed one automobile manufacturer's assertion that cars built over the past several years emit at lower rates than EPA estimates. The manufacturer claims that improvements in passenger car emission control systems since 1981 were not reflected in the data used by EPA to estimate emissions from this vehicle class [10]. Test results on several hundred 1982-through-1986 model-year cars showed lower tailpipe VOC emissions after 50,000 miles of vehicle use compared to estimates used by EPA in compiling the 1985 mobile source inventory.[11] If these new passenger car estimates are

[11] EPA assumes that in-use exhaust emission rates for cars manufactured after 1982 are about 1 gram per mile. The test results showed emission rates about 0.6 gram per mile lower than EPA's estimate which would mean that these vehicles now meet the current 0.41-gram-per-mile hydrocarbon standard after 50,000 miles of use.

Table 6-5-Estimate of Uncertainty in Volatile Organic Compound Emissions in Nonattainment Cities

	Emissions (million tons/year)[a]			
Source category	Highway vehicles only	Total mobile	Stationary	Total
Mobile ***sources***				
Running losses (grams/mile):				
1985:				
0	**3.8**	4.3	5.9	**10.2**
1.5[b]	4.9	5.4	5.9	**11.2**
2.5	5.6	6.1	5.9	**12.0**
1994:				
0	2.3	2.8	6.4	9.2
I . 5[b]	3 . 6	4.1	6.4	10.5
2.5	4.4	**5.0**	6.4	11.3
Average highway-vehicle speeds (miles/hour):[c]				
1985:				
20	5.7	6.2	5.9	12.1
28[b]	4.9	5.4	5.9	11.2
35	4.5	4.9	5.9	10.8
1994:				
20	**4.1**	4.6	6.4	11.0
28[b]	**3.6**	4.1	6.4	10.5
35	**3.3**	3.8	6.4	10.2
Lower in-use emission rates After 50,000 miles(in1994):[c]	**3.4**	3.9	6.4	10.3
Stationary sources				
Level of compliance with existing stationary source regulations (in 1994)$				
100 percent		4.1[c]	**6.4**[b]	**10.5**
80 percent		4.1[c]	**7.4**	11.5
Hazardous waste treatment, storage and disposal facility emissions uncertainty (in 1994)?				
Low		4.1[c]	6.0	10.1
Medium		4.1	6,4	10.5
High		4.1	6.7	10.8
Organic solvent emissions uncertainty (in 1994)!				
Base		4.1[c]	6.4	10.5
Low		4.1	4.9	9.0
Combination of mobile and stationary source emissions uncertainty (in:1994)				
	1.9	**2.4**	**4.5**	**6.9**
Medium[b]	**3.6**	**4.1**	**6.4**	**10.5**
High.	**5.0**	**5.5**	**7.8**	**13.3**

[a]Estimatas areroundad.

[b]This estimate was used as a "base case" throughout our analysis.

[c]This estimate includes running losses of 15 grams per mile.

[d]throughout our analysis, we have assumed that stationary source compliance with existing regulations has been 100 percent. The estimate presentedhera represents emissions if compliance was acually 80 percent.

[e]The low, medium, and high estimates for treatment, storage, and disposal tactilities represent 50, 100, and 150 percent of reported emissions, respectively, from the NAPAP inventory.

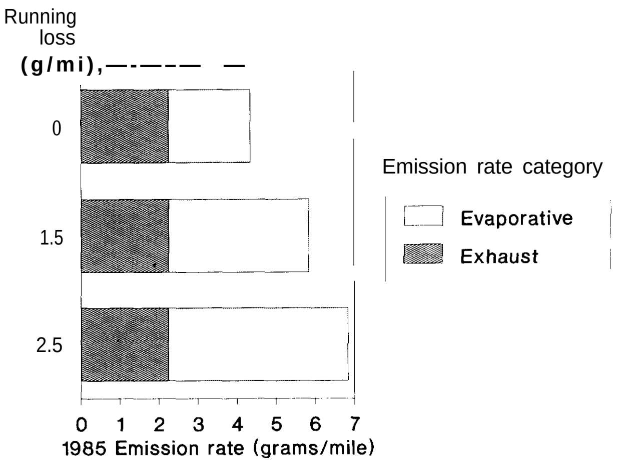
[f]"Base" is the estimate contained in the NAPAP inventory;low estmate.50 percent of the organic solvent emissions contained in the NAPAP inventory (TSDF emissions are unchanged),

[g]Combination includes: 1) no running losses, 2) average vehicle speeds of 35 miles per hour, 3) lower passanger vehicle in-use emission rates, 4) 100 percent stationary source regulatory compliance, 5) low estimate of reported TSDF emissions, and 6) low estimate of reportad organic solvent emissions.

[h]Combination includes: 1) running losses equal to 2.5 grams par mile, 2) average vehicle speeds of 20 miles per hour, 3) increased stationary source emissions due to lower compliance with existing regulations, 4) high estimate of reported TSDF emissions, and 5) organic solvent emissions as reported in the NAPAP Inventory

SOURCE: Office of Technology Assessment, 1989.

Figure 6-7-Effect of Running Losses on Passenger-Car Emission Rates in Nonattainment Cities in 1985



Exhaust emission rates do not include the effects of current motor vehicle inspection and maintenance (I/M) programs. We estimate that current I/M programs reduce exhaust emissions by about 12 percent. Estimates of exhaust emission rates assume average vehicle speeds of 28 miles per hour. Emission rates for vehicles in California will be lower since the State maintains a summertime gasoline volatility limit of 9.0 pounds per square inch.

SOURCE: Office of Technology Assessment, 1989.

substituted into the current emissions inventory, we estimate that total VOC emissions in nonattainment cities will be reduced by about 2 percent in 1994.

Level of Compliance With Existing Stationary Source VOC Regulations

Each year, the States submit emissions data to EPA for inclusion in the NEDS inventory. Most States assume that all affected sources have complied fully with existing emission control rules and regulations. However, EPA no longer believes that rules are fully effective across all sources, all source categories, and over time. In fact, EPA recently proposed that States estimate their emissions based on an assumed compliance of no more than 80 percent [7]. Therefore, VOC emissions for some source categories in the 1985 NEDS inventory may be much higher than reported.[12]

We estimate that *at least* 1 million tons could be missing from 1985 stationary source totals for nonattainment cities, assuming that existing controls on selected stationary sources are only 80 percent as effective as reported. *3 Therefore, total nonattainment area emissions reported in 1985 may be 10 percent too low.

Uncertainty in Hazardous Waste Treatment, Storage, and Disposal Facility Emissions

VOC emissions data from hazardous waste TSDFs in the 1985 NAPAP inventory were derived from two EPA reports [30,34]. Because of discrepancies in total TSDF emissions between these two sources and local air pollution control agency emission inventories, we believe that the 1.4 million tons per year of emissions in the 1985 NAPAP inventory could be subject to significant uncertainty. If we assume that TSDF emissions are 50 percent higher than what is reported in the NAPAP inventory, our estimate of total VOC emissions in 1994 in nonattainment cities would increase by about 3 percent. Similarly, if we assume that TSDF emissions are 50 percent lower than what is currently reported, total emissions would decrease by about 3 percent.

Uncertainty in Organic Solvent Emissions

As figure 6-1 shows, organic solvent evaporation sources, including surface coatings, account for about one-quarter of total 1985 emissions in nonattainment cities. The majority of these emissions originate from sources that emit less than 50 tons per year. The uncertainty associated with the method that EPA uses to estimate emissions from these small sources (see footnote 4) may be quite significant. In particular, since many State and local regulations requiring emission controls on these

[12] For example, if the State reported that a control technology on a particular source was 75 percent effective at reducing uncontrolled emissions, ‘e may assume that the actual control efficiency was SO percent of this value. The resulting controlled emission would then be 60 percent higher than previously reported.

[13] This estimate includes only large stationary sources that reported using control equipment designed to trap or destroy excess emissions (e.g., carbon adsorber, incinerator).

[14] EPA's method assumes that all the organic solvent produced and consumed nationwide is emitted to the atmosphere. In fact, some Of the solvent used in various processes may be captured by control devices mandated by State or local regulations. Therefore, in some cases, solvent emissions may be less than solvent consumption.

sources may not be factored into the estimates contained in the inventory, these emissions may be overestimated.[14]

If we assume, as a lower bound estimate, that organic solvent emissions are 50 percent lower than what is reported in the inventory, total VOC emissions in nonattainment cities in 1994 would decline about 14 percent from 10.5 million to about 9 million tons per year.

Our projections for large stationary source emissions in *all* source categories (including organic solvents) could be somewhat high because we are unable to explicitly model all of the control requirements in the Clean Air Act pertaining to new and modified large VOC emission sources in nonattainment areas.[15] However, the effect on our overall emissions estimates is small because, as illustrated in figure 6-4, small stationary source growth will have a much more significant impact on future estimates of total VOC emissions than large stationary sources. Inmost States, these more stringent new source regulations do not apply to small sources.

Finally, it is important to recognize that *all* emission inventories have an inherent, unquantified, level of uncertainty. Given this drawback, any interpretation of emissions inventory data, including those presented in this report, must be made with caution.

POTENTIAL EMISSIONS REDUCTIONS FROM VOC CONTROL STRATEGIES ANALYZED BY OTA

In this section we analyze the VOC emissions reductions from source-specific control strategies currently being considered by the Congress and EPA. We also show how these potential emissions reductions compare with estimates of the overall emissions reductions needed to attain the ozone standard in each nonattainment city. Discussion of the costs of these control strategies appears in the section *Costs of Control Strategies.*

We are able to analyze the following source-specific control strategies:

- adoption of 'reasonably available control technologies" (RACT) on all existing stationary sources for which a regulation already exists in any State Implementation Plan;
- adoption of new Control Technique Guidelines (CTGs)—RACT-level controls for several existing stationary sources of VOC for which EPA has not issued control guidelines and not previously subject to regulation in any State Implementation Plan;
- emission controls on hazardous waste TSDFs;
- establishment of new federally regulated controls on architectural surface coatings;
- "Onboard" technology on motor vehicles to capture gasoline vapor during refueling;
- "Stage II" control devices on gas pumps to capture gasoline vapor during motor vehicle refueling;
- inspection and maintenance (I/M) programs for highway vehicles;
- more stringent exhaust emission standards for gasoline highway vehicles;
- new Federal restrictions on gasoline volatility; and
- the use of methanol instead of gasoline as a fuel for vehicles in centrally owned fleets in the worst nonattainment cities.

Transportation control measures that limit motor vehicle use are potentially important control strategies that we are unable to analyze. These measures are discussed in more detail in chapter 7.

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 technologies that we believe can be applied in the near-term. We were able to analyze the emissions reduction potential and associated control costs for methods applicable to about 85 percent of current VOC emissions. The remaining 15 percent of VOC emissions come primarily from stationary sources for which we

[15] These regulations require that new stationary sources with the potential to emit more than 100 tons per year install the most stringent emission controls possible ***and*** that VOC emissions from other existing sources in the area be reduced so that there will be a net ***decline*** in emissions after new operations commence. These same control requirements apply to major modifications of existing sources that result in a VOC emissions increase of more than 40 tons per year.

either could not find applicable control technologies or that we could not analyze because of a lack of suitable information. We believe that the large majority of emission reductions possible with currently available control technologies are accounted for in our analysis. This does not imply that additional VOC reductions beyond those analyzed here are not possible, but that they should not be counted on within the next 5 to 10 years.

All control methods listed above apply to nonattainment cities. Several control methods apply nationwide, not just in nonattainment cities, including: Federal controls on architectural surface coatings, Onboard controls, more stringent highway-vehicle emission standards and gasoline volatility limitations.

Figure 6-8 displays our estimates of emissions reductions resulting from each control category in 1994 and 2004, as a percentage reduction below total 1985 emissions in nonattainment cities. By 1994, total reductions average about 34 percent in nonattainment cities. The largest reductions come from limiting gasoline volatility and controls on hazardous waste TSDFs.[16] The percentage reductions for most categories are about the same in 1994 and 2004, except for Onboard controls and new highway-vehicle standards which increase because more of the older vehicles will have been replaced by newer ones equipped with additional controls.

Tables 6-6 through 6-8 present estimates of emissions reductions achieved in 1994, 1999, and 2004, respectively, if the various control strategies listed above are applied. We estimate that VOC emissions in nonattainment cities can be reduced by 3.8 million tons per year in 1994, about 34 percent below 1985 levels.[17] Due to uncertainty in the emissions inventory and the degree to which future emissions can be controlled, total emissions reductions from all the control measures we analyzed in 1994 may range between 1.5 million to 5.0 million tons per year in nonattainment cities, or about 18 to 37 percent of 1985 levels. (Emissions reduction uncertainties are discussed in more detail in a later section.) Because some measures are not restricted to nonattainment areas, about 6.5 million tons per year would be eliminated nationwide. Total emissions reductions in 2004 in nonattainment areas are about the same as those in 1994.[18]

Again, we must stress that these estimates are for emissions reductions from the additional controls that we are able to analyze. Higher percentages may be possible, but they should not be counted on in the near term. In addition, the remaining 15 percent of the inventory for which we were unable to identify *any* controls may, in fact, be controllable to some extent. Therefore, actual emissions reduction potential available from these additional controls may be greater than represented here. Other potential control strategies, such as transportation control measures, are not included in our analysis.

Figure 6-9 displays potential emissions reductions and the percentage of emissions that remain after all of the reductions have been accounted for in 1994 and 2004. In 1994 and 2004, after all controls are applied, nonattainment area emissions are approximately two-thirds of the 1985 total. Most of the remaining emissions are from small stationary sources that emit less than 25 tons of VOCs per year. Figure 6-10 displays a more detailed breakdown of the nonattainment emissions inventory in 1994 after all controls have been applied. About 35 percent of the remaining emissions in 1994 are from surface coatings and other organic solvent evaporation sources. As stated earlier, we are unable to identify controls for approximately 15 percent of the emissions inventory. Over one-third of this (about 6 percent of the entire inventory) is emissions from small stationary sources.

Uncertainty Surrounding Estimates of Emissions Reduction Potential

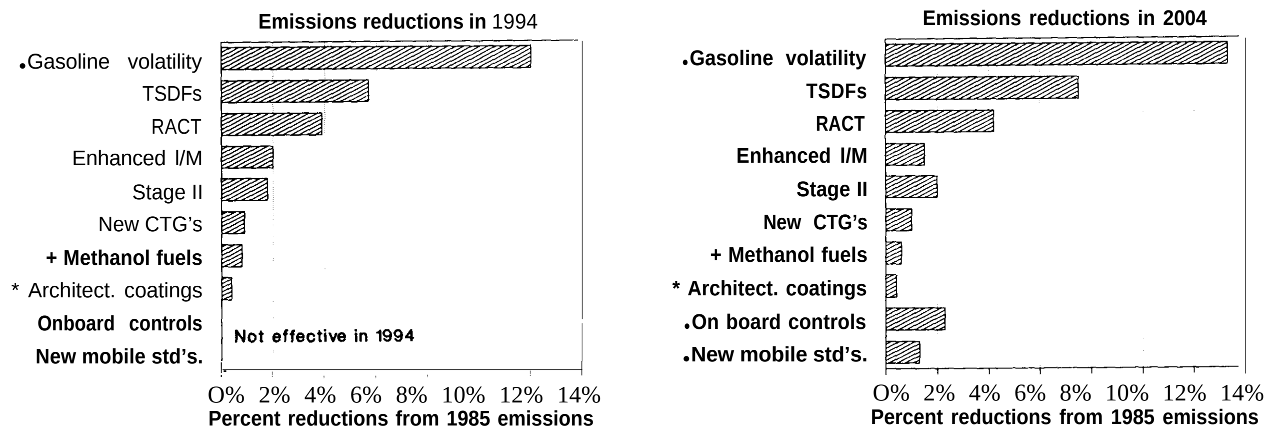
In an earlier section, we analyzed the effects of various assumptions on our estimates of future VOC emissions before additional controls are applied. In

[16] As we discuss in a later section, due to uncertainty in TSDF emissions reported in the 1985 NEDS inventory and the degree to which they can be controlled, the percentage reduction for this source category may range between 3 and 8 percent of total 1985 emissions.

[17] This estimate includes the 760,000 tons that would be eliminated as a result of the current Federal Motor Vehicle Control Program, which is equivalent to a 7-percent reduction based on 1985 emissions.

[18] Note that the total reductions are slightly lower than the sum of the component categories. This is because the emissions reductions achieved by: a) lowering gasoline volatility in combination with an I/M program, and b) combining a Stage 11 and Onboard control program, are slightly less than instituting each one alone.

Figure 6-8-Volatile Organic Compound (VOC) Emissions Reductions in 1994 and 2004 Compared to 1985 Emissions, by Control Method



•Emissions redutions also achieved in attainment areas.
+ Percent reductions only in those cities in which it is adopted.

See text for description of control methods.

SOURCE: Office of Technology Assessment, 1989.

this section, we analyze how some of these same assumptions combined with the uncertainty associated with selected VOC control strategies affect our estimates of potential emissions reductions presented above. The assumptions we tested include: 1) the rate of gasoline evaporation from in-use highway vehicles ("running losses"), 2) average highway-vehicle speeds, 3) level of compliance with *current* and *future* stationary source VOC regulations, 4) emissions from organic solvent evaporation sources, and 5) emissions from hazardous waste TSDFs and the degree to which they can be controlled. Table 6-9 and figure 6-11 display our estimates of uncertainty for these particular categories.

We estimate that by applying currently available control methods, VOC emissions in nonattainment cities can be lowered by about 3.8 million tons per year in 1994, or about 34 percent of 1985 emissions.[19] This total could be as low as 1.5 million or as high as 5.0 million tons per year given the variability in all the assumptions listed above.[20] As figure 6-11 shows, as running losses increase, total emissions reductions also increase. Although baseline highway vehicle emissions increase with increasing estimates of running losses (see figure 6-5), most of the additional emissions are controllable by lowering gasoline volatility. Also, as average highway vehicle speeds decrease, some of the resulting additional exhaust emissions are controllable through enhanced inspection and maintenance programs. If we assume that organic solvent emissions are 50 percent lower than what is reported in the 1985 inventory, total emissions reductions in 1994 are also slightly lowered. However, the total percent reductions compared to 1985 emissions after all controls are applied *increase* from **34** to 37 percent

[19] This estimate assumes running losses equal to 1.5 grams per mile, average vehicle speeds of 28 miles per hour, and 100 percent compliance with all current and future stationary source VOC regulations.

[20] Low estimate is calculated assuming: 1) no running losses from highway vehicles, 2) average vehicle speeds of 35 miles per hour, 3) the level of compliance with current and future stationary source regulations is 80 percent, and 4) emissions from organic solvent evaporation and TSDFs are 50 percent lower than totals reported in the 1985 NAPAPinventory, and that compliance with new TSDF regulations is only 80 percent. The high estimate assumes: 1) running losses of 2.5 grams per mile, 2) average vehicle speeds of 20 miles per hour, 3) both current and future regulatory compliance equals 100 percent, and 4) emissions from organic solvent evaporation and TSDFs are 50 percent higher than reported totals.

Table 6-6-Potential Emissions Reductions in 1994 Compared to 1985 Emissions From Source-Specific Control Strategies

(emissions reductions in 1,000 tons per year)[a]

	RACT	New CTGs	TSDFs	Architectural coatings	Onboard	Stage II	Combined Stage II & Onboard	Gasoline volatility control[b]	Enhanced I/M	New highway vehicle emission standards	Methanol fuels[c]	(Existing controls)[d]	All controls[e]
Nonattainment cities by design value category (in ppm O_3)													
0.13-0.14	120	29	280	15	0	64	64	430	68	0	0	220	1,200
0,15-0.17	230	46	330	23	0	100	IOO	730	100	0	0	360	1,900
0.18-0.26	73	11	31	8	0	31	31	190	31	0	8	99	480
>0.26	15	15	3	0	0	0	0	0	22	0	6	85	150
Total (nonattainment)	440	100	640	47	0	200	200	1,300	220	0	14	760	3,800
Attainment areas .	0	0	0	61	0	0	0	1,900	0	0	0	680	2,700
Total	440	100	640	110	0	200	200	3,300	220	0	14	1,400	6,500

[a]Totals are rounded.
[b]Estimates are equivalent annual reductions, Actual reductions are required only 5 months out of the year.
[c]These estimates assume the use of fuel that is 85 percent methanol and 15 percent gasoline in light-duty cars and trucks in fleets of 10 or more.
[d]Emissions reductions from the existing Federal Motor Vehicle Control Program.
[e]"All controls" includes RACT, new CTGs, TSDFs, architectural coatings, combined Stage II and Onboard, gasoline volatility controls, enhanced I/M, new highway-vehicle emission standards, methanol fuels, and existing controls. Note that total reductions are slightly lower than the sum of each component category This is because the reductions achieved by lowering gasoline volatility in combination with an enhanced I/M program, a combined Staga II and Onboard program, and methanol fuels, are slightly lower than instituting each one alone

Strategy Descriptions

RACT = "Reasonable Available Control Technology" on all existing stationary sources that emit more than 25 tons per year of VOC.
New **CTGs** = new Control Technique Guidelines for existing stationary sources that emit more than 25 tons per year of VOC.
TSDFs = controls on hazardous waste treatment, storage, and disposal facilities.
Federal controls on architectural coatings.
Onboard controls on motor vehicles to capture gasoline vapor during refueling.
Stage II control devices on gas pumps to capture gasoline vapor during motor vehicle refueling.
Gasoline volatility controls which limit the rate of gasoline evaporation,
Enhanced inspection and **maintenance (I/M)** programs for cars and light-duty trucks.
New **highway-vehicle emission standards** for passenger cars and light-duty gasoline trucks
Methanol **fuels** as a substitute for gasoline as a motor vehicle fuel.

SOURCE: Office of Technology Assessment, 1989.

Table 6-7—Potential Emissions Reductions in 1999 Compared to 1985 Emissions From Source-Specific Control Strategies

(emissions reductions in 1,000 tons per year)[a]

	RACT	New CTGs	TSDFs	Architectural coatings	Onboard	Stage II	Combined Stage II & Onboard	Gasoline volatility control[b]	Enhanced I/M	New highway vehicle emission standards	Methanol fuels[c]	(Existing cortrols)[d]	All controls
Nonattainment cities by design value category (in ppm o̧)													
0.13-0.14	120	29	320	16	48	65	69	450	54	20	0	210	1,300
0.15-0.17	240	48	380	24	85	110	120	770	80	36	0	320	2,000
0,18-0.26	75	12	36	9	28	33	38	200	25	12	8	90	510
>0.26	17	15	4	0	19	0	19	0	17	9	7	88	180
Total (nonattainment)	**450**	100	730	49	180	210	240	1,400	180	77	15	710	4,000
Attainment areas	0	0	0	65	190	0	190	2,000	0	100	0	450	2,900
Total	450	100	730	110	370	210	440	3,400	180	180	15	1,200	6,900

[a]Totals are rounded.
[b]Estimates are equivalent annual reductions Actual reductions are required only 5 months out of the year.
[c]These estimates assume the use of fuel that is 85 percent methanol and 15 percent gasoline in light-duty cars and trucks m fleets of 10 or more.
[d]Emissions reductions from the existing Federal Motor Vehicle Control program.
[e]"All controls" includes RACT, new CTGs, TSDFs, Federal controls on architectural coatings, combined Stage II and Onboard, gasoline volatility controls, enhanced I/M, new high standards, methanol fuels, and existing controls. Note that total reductions are slightly lower than the sum of each component category. This is because the reductions achieved by lowering gasoline volatility in combination with an enhanced I/M program, a combined Staga II and Onboard program, and methanol fuels, are sightly lower than instituting each one alone.

Strategy Descriptions

RACT = "Reasonable Available Control Technology" on all existing stationary sources that emit more than 25 tons per year of VOC.
New **CTGs** = new Control Technique Guidelines for existing stationary sources that emit more than 25 tons per year of VOC.
TSDFs = controls on hazardous waste treatment, storage, and disposal facilities
Federal controls on architectural **coatings**.
Onboard controls on motor vehicles to capture gasoline vapor during refueling.
Stage II control devices on gas pumps to capture gasoline vapor during motor vehicle refueling.
Gasoline volatility controls which limit the rate of gasoline evaporation.
Enhanced inspection and **maintenance (I/M)** programs for cars and light-duty trucks
New **highway-vehicle emission standards** for passenger cars and light-duty gasoline trucks.
Methanol fuels as a substitute for gasoline as a motor vehicle fuel.

SOURCE: Office of Technology Assessment, 1989.

Table 6-8-Potential Emissions Reductions in 2004 Compared to 1985 Emissions From Source-Specific Control Strategies
(emissions reductions in 1,000 tons per year)[a]

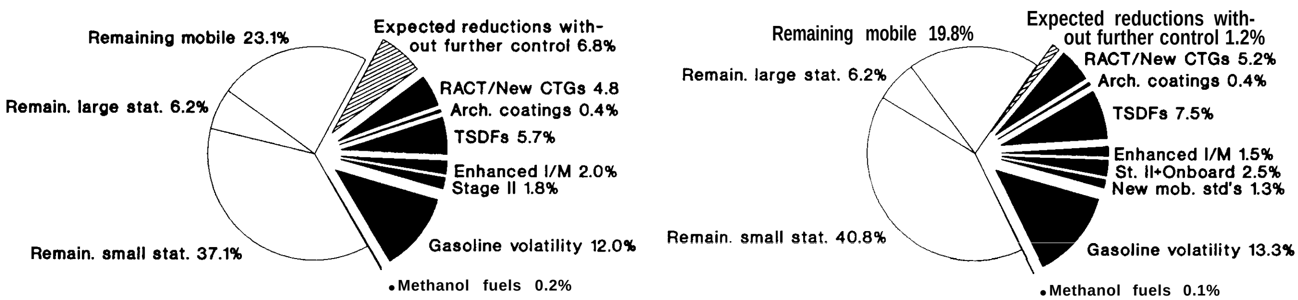
	RACT	New CTGs	TSDFs	Architectural coatings	Onboard	Stage II	Combined Stage II & Onboard	Gasoline volatility control[b]	Enhanced I/M	New highway vehicle emission standards	Methanol fuels[c]	(Existing controls)[d]	All Controls[e]
Nonattainment cities by design value category (in ppm O_3)													
0.13-0.14	130	30	360	16	68	70	74	470	53	37	0	56	1,200
0.15-0.17	250	49	440	25	120	120	130	820	80	68	0	40	2,000
0.18-0.26	78	12	42	9	40	37	43	210	25	22	9	4	460
> 0.26	19	16	4	0	27	0	27	0	17	17	7	39	150
Total (nonattainment)	470	110	840	50	260	220	280	1,500	170	140	16	140	3,700
Attainment areas	0	0	0	68	280	0	280	2,200	0	190	0	310	3,100
Total	470	110	840	120	530	220	550	3,700	170	330	16	450	6,800

[a]Totals are rounded.
[b]Estimates are equivalent annual reductions. Actual reductions are required only 5 months out of the year.
[c]These estimates assume the use of fuel that is 85 percent methanol and 15 percent gasoline in light-duty cars and trucks in fleets of 10 or more.
[d]Emissions reductions from the existing Federal Motor Vehicle Control Program.
[e]"All controls" includes RACT, new CTGs, TSDFs, Federal controls on architectural coatings, combined Stage II and Onboard, gasoline volatility controls, enhanced I/M, new high standards, methanol fuels, and existing controls. Note that total reductions are slightly lower than ttre sum of each component category. This is because the reductions achieved by lowering gasoline volatility in combination with an enhanced I/M program, a combined Staga II and Onboard program, and methanol fuels, are slightly lower than instituting each one alone.

Strategy Descriptions
RACT = "Reasonable Available Control Technology" on all existing stationary sources that emit more than 25 tons par year of VOC.
Maw **CTGs** . new Control Technique Guidelines for existing stationary sources that emit more than 25 tons per year of VOC.
TSDFs = controls on hazardous waste treatment, storage, and disposal facilities.
Federal **controls** on **architectural coatings**.
Onboard controls on motor vehicles to capture gasoline vapor during refueling.
Stage II control devices on gas pumps to capture gasoline vapor during motor vehicle refueling.
Gasoline volatility **controls** which limit the rate of gasoline evaporation.
Enhanced inspection and **maintenance (I/M)** programs for cars and light-duty trucks.
New **highway-vehicle emission standards** for passenger cars and light-duty gasoline trucks.
Methanol fuels as a substitute for gasoline as a motor vehicle fuel.

SOURCE: Office of Technology Assessment, 1989.

Figure 6-9-Potential Volatile Organic Compound (VOC) Emissions Reductions and Remaining Emissions in 1904 and 2004 as a Percentage of 1985 Emissions in Nonattainment Cities

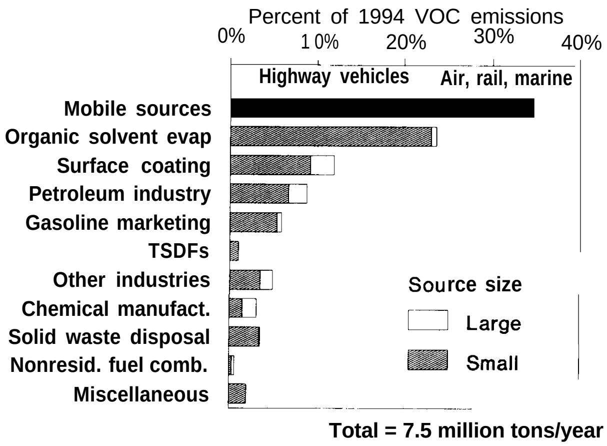


• Average percent reduction in cities in which it is required equals about 0.6 percent.

The pulled-out slices represent emissions that can be eliminated by each control method. The three connected slices represent emissions that remain after ail control methods are applied. **The category 'Expected Reductions without Further Control" represents reductions achieved from** the existing Federal Motor Vehicle Control Program. "Remaining Small Stationary" represents emissions from stationary sources that emit less than 50 tons per year of VOC. See text for description of control methods.

SOURCE: Office of Technology Assessment, 1989.

Figure 6-10—Volatile Organic Compound (VOC) Emissions in Nonattainment Cities in 1994, by Source Category, After All Additional Control Methods Are Applied



Stationary sources that emit more than 50 tons per year of VOC are included in the "Large" categories. (See figure 6-1 for 1985 emissions in nonattainment cities before additional controls applied.)

SOURCE: Offce of Tehnology Assessment, 1989.

in 1994. Percentage reductions increase because a large fraction of organic solvent use was not controllable given the measures we analyzed. Therefore lowering solvent emissions by 50 percent lowered total "baseline" emissions in 1985 while not changing future emissions reductions by much.

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

Reasonably Available Control Technologies (RACT) on All Stationary Sources

The Clean Air Act requires that each State adopt, as part of its State Implementation Plan (SIP), ''reasonably available control technologies" (RACT) regulations for existing stationary sources of VOC in nonattainment cities. In our analysis, we have applied RACT-level controls on 40 stationary source categories for which a regulation already exists in any SIP. These sources include petroleum refining, certain types of chemical manufacturing, paper surface coating, automobile surface coating, gasoline terminals, service stations, and drycleaning.

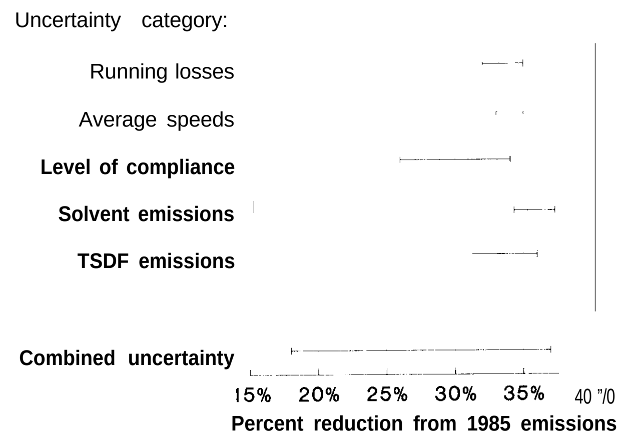
Table 6—Estimate of Uncertainty in VOC Emissions Reductions After All Controls Are Applied in Nonattainment Cities In 1094

	Total emissions reductions (million tons/year)	Percent of 1985 emissions
Running losses (grams/mile)		
0	3.2	320/o
1.5 [a]	3.8	340/0
2.5	4.2	350/0
Average highway-vehicle speeds (miles/hour)		
20	4.2	3570
28°	3.8	34%
35	3.6	330/0
Level of compliance with current and/or future stationary source regulations		
Current-100%, Future—100% [a]	3.8	34%
Current-80%, Future-80%	3.6	26%
Hazardous waste treatment, storage and disposal facility emissions 1uncertain~		
Low	3.0	31%
Medium [a]	3.4	35%
High	3.7	38%
Organic solvent emissions uncertainty		
Low	3.6	37%
Combined uncertainty		
Low	1.5	18%
Medium [a]	3.8	34%
High [d]	5.0	37%

[a] This estimate was used throughout our analysis.
[b] The low estimate represents SO percent compliance with future regulations assuming pre-control emissions which are 50 percent of reported estimates In the current emissions inventory. Tha medium estimate represents 100 percent compliance on 100 percent of reported emissions. High estimate represents 100 percent compliance on 150 percent of reported emissions.
[c] Low estimate is calculated without any running losses, with average vehicle speeds of 35 miles per hour, and assuming the level of compliance with current, existing stationary source regulations is SO percent, and the low estimate for both hazardous waste treatment, storage and disposal facilities, and organic solvent emissions.
[d] The N@ estimate assumes running losses total 2.5 grams per mile, average vehicle speeds of 20 miles per hour, current and future regulatory compliance equals 100 percent and 100 percent, respectively, the high estimate for TSDFs, and organic solvent emissions as reported in the NAPAP inventory.

SOURCE: Office of Technology Assessment, 19S9.

Figure 6-n—Uncertainty in VOC Emissions Reductions From All Additional Controls In Nonattainment Cities in 1994



The following assumptions were analyzed: 1) the rate of gasoline evaporation from in-use highway vehicles ("running losses"), 2) average highway-vehicle speeds, 3) level of compliance with current and future stationary source VOC control regulations, **4) emissions from organic solvent evaporation sources, and 5) emissions from hazardous waste treatment, storage, and disposal facilities (TSDFs).**

SOURCE: Office of Technology Assessment, 1989.

The sources of our estimates of the percentage reduction in VOC emissions from RACT and of the data we used to calculate the cost of these controls, are reports prepared for EPA by Alliance Technologies Corp. [3] and E.H. Pechan & Associates, Inc. [4]. EPA made available to us a series of memos detailing the methods used, technical references, and economic assumptions used by Alliance, from which our estimates are drawn. A complete list of our control cost assumptions, including control efficiencies and associated costs for each source type, is included in an appendix.

Currently, many States require RACT-level controls only on existing sources which emit more than 100 tons of VOC per year in nonattainment areas. We estimated the emissions reductions achievable through RACT-level regulations by simulating controls on all existing stationary sources *that emit more than 25 tons of VOCs per year* in those nonattainment cities that did *not* have an existing RACT regulation for a particular source category in their SIP as of 1985. States are only required to provide EPA with emissions data from *individual sources* which emit *more* than 50 tons per year; emissions from sources less than 50 tons per year are calculated indirectly by EPA and then aggregated at the county level. Therefore, we had to make assumptions regarding the fraction of inventory that originates from sources which emit between 25 and 50 tons per year.

We estimate that applying RACT-level controls to all sources in nonattainment cities would lower VOC emissions by approximately 440,000 tons per year in 1994, representing a 4-percent decline based on 1985 levels. Reductions increase slightly over time, with total reductions in nonattainment cities in 2004 estimated to be about 470,000 tons per year, from 1985 levels.

Adoption of New "Control Technique Guidelines" (CTGs)

In the previous subsection, we analyzed the emissions reduction potential of applying all RACT-level regulations currently in place in *any* State to *all* existing stationary VOC sources emitting more than 25 tons per year of VOC. Many States now are urging EPA to develop new RACT guidelines for several additional stationary source categories. These would be issued as "Control Technique Guidelines" (CTGs). Like the RACT controls analyzed in the previous section, nonattainment cities would be required to adopt these 'new" RACT regulations on all *existing* stationary VOC sources that emit more than 25 tons of VOCs per year.

We are able to analyze the emission reduction potential from controls on: 1) wood furniture coating, 2) autobody refinishing, 3) plastic parts coating, 4) coke oven byproduct plants, 5) publicly owned treatment works, and 6) bakeries. (Hazardous waste treatment, storage, and disposal facilities is another category, but is discussed in the next subsection.) These six categories represent about 2 percent of the entire VOC inventory. The control efficiency assumptions we used for these sources are listed in an appendix.

Emissions reductions from applying RACT-level controls to these categories are estimated to be about 100,000 tons per year in 1994, or about a l-percent reduction based on 1985 emissions. This annual total is expected to increase by a few thousand tons in 2004.

Controls on Hazardous Waste Treatment, Storage, and Disposal Facilities

Hazardous waste TSDFs have recently been recognized as potentially significant sources of VOC, accounting for about 1.4 million tons per year, nationwide, and about 580,000 ton per year in nonattainment areas in 1985 (or about 6 percent of the total emissions) [34]. More recent data has shown that the nationwide total could be as high as 2 million tons per year [30]. By 2004, nonattainment area TSDF emissions are about 930 million tons per year. These totals are not based on emissions data from individual facilities, but are estimated indirectly on a nationwide basis and, therefore, are subject to potentially large, unquantified uncertainties.

We estimate that reasonably available controls on TSDFs can eliminate approximately 640,000 tons per year of VOCs in nonattainment cities in 1994, or about 6 percent of 1985 emissions. As mentioned earlier, if we account for potential uncertainty in reported TSDF emissions, the emissions reduction potential from this category may range between 3.1 and 8.4 percent from 1985 levels. Control technologies such as covers placed over TSDFs together with add-on emission control devices (e.g., carbon adsorbers, incinerators, etc.) and/or process modifications can reduce VOC emissions by about 90 percent **[30].**

Federal Controls on Architectural Surface Coatings

Many small sources of VOCs do not lend themselves to traditional forms of regulation (e.g., application of an add-on control device to reduce emissions). These sources individually emit small amounts of VOCs, but when aggregated over a region, they collectively contribute a significant portion of the VOC inventory. Such sources include consumer and commercial solvents, architectural surface coatings, agricultural pesticides, adhesives, and others. Although several categories have been proposed as candidates for new Federal controls in recent bills, we are only able to analyze architectural surface coatings. This category represents about 2 percent of the NAPAP emissions inventory as adjusted by OTA.

EPA control efficiency estimates range between 23 percent [25] and 65 percent [26] for architectural surface coatings. For our analysis, we assume a 25 percent control efficiency. Since this category would be federally regulated, emissions reductions would occur nationwide (in nonattainment *and* attainment areas).

In 1994, federally regulated controls on architectural surface coatings are estimated to reduce VOC emissions by 47,000 tons per year in nonattainment cities, and about 61,000 tons year in attainment areas. By 2004 in nonattainment cities, emissions reductions will reach about 50,000 tons per year.

Consumer and commercial products are also a potentially large source of VOC emissions, but because control technology information is lacking for this category we have excluded it from our overall emissions reduction potential and cost analyses. According to the 1985 NAPAP inventory, emissions from consumer and commercial products are about 860,000 tons per year in nonattainment cities, representing about 8 percent of total emissions. We must stress that the emission estimates for this category are subject to potentially large uncertainties. It is interesting to note that, on a per-capita basis, the 1985 NAPAP inventory contains about two times more VOC emissions from consumer products than local California emissions inventories such as the South Coast air basin [18].

Also, the degree to which VOCs can be eliminated from consumer products is not well understood at the present time. However, the South Coast Air Quality Management District estimates that VOC emissions from these products can be reduced by about 50 percent in the year 2000 through a ban of aerosols products containing VOCs and reformulation of other non-aerosol products [19]. Controlling emissions from consumer products is discussed further in chapter 7.

Controls on Gasoline Emissions From Vehicle Refueling

Gasoline vapors that escape from vehicle fuel tanks during refilling can be controlled by two fundamentally different methods. One method involves installation of a vapor recovery system on service station gasoline pumps, referred to as 'Stage II" vapor recovery. The other method relies on a control device installed on each vehicle as part of the emission control system (referred to as "Onboard" controls) .21 Stage II programs can become fully effective within a few years. The emissions reduction benefits of an Onboard control program gradually increase over time and achieve full potential after about 10 years, when most older, non-equipped vehicles have been replaced. In the following subsections, we describe the emissions reduction potential of each program individually, and in combination.

"Onboard" Refueling Controls on Motor Vehicles

For this analysis, we assume that Onboard controls are required on all ***new*** gasoline vehicles starting in 1994 and that by 2004, *most* gasoline vehicles on the road will be equipped with Onboard controls due to fleet turnover. Assumptions regarding fleet turnover and control efficiencies are obtained from EPA's recent gas-marketing regulatory impact analysis [28].[22] Because these controls apply to all new gasoline vehicles, emissions reductions will occur nationwide (in both nonattainment *and* attainment areas).

We estimate that in 1999, Onboard controls will eliminate about 180,000 tons per year of VOC emissions in nonattainment cities, and 370,000 tons per year nationwide, representing about a 1.6-percent reduction, compared to 1985 emissions. In 2004, total nationwide VOC reductions increase to about 530,000 tons per year, or about a 2. l-percent reduction based on 1985 levels. These results reflect only Onboard controls for vehicle refueling and do not include reductions from additional Stage II controls. An analysis of a combined Onboard and Stage II vapor recovery program is presented later.

"Stage II" Refueling Vapor Recovery

Unlike Onboard controls, which are applied nationwide, we assume Stage 11 controls are only installed in nonattainment cities. Congressional proposals have generally limited the Stage 11 requirement to these areas. Emissions reductions in 1994 and 2004 are estimated to be about 200,000 and 220,000 tons per year, respectively, which amounts to about a 2-percent reduction in both 1994 and 2004, relative to 1985 emissions. We assume a control efficiency of 79 percent, which represents

[21] There is a continuing debate between EPA, industry, and the National Highway Transportation Safety Administration, over possible safety concerns and in-use feasibility of Onboard controls.

[22] We assume that the percent reduction in refueling emissions from use of Onboard controls, as derived from EPA's gas marketing analysis [28, p. 3-18], is 28 percent, 58 percent, and 76 percent in 1994,1999, and 2004, respectively. EPA estimates that Onboard controls can reduce refueling emissions by about 93 percent [28, p. 2-9].

EPA's average estimate for a Stage II program with annual enforcement [28].[23] Note that the percent emissions reductions ultimately achievable with Stage II and Onboard controls are roughly comparable. However, in 1999, Onboard is less effective than Stage II because complete fleet turnover will not have occurred yet.

Combined Stage II and Onboard Controls

If both Stage II and Onboard controls are adopted, the percent emissions reductions in nonattainment cities in 1999 and 2004 are estimated to be about 2 and 3 percent, respectively, relative to 1985 emissions. As the reduction benefits from Onboard controls increase through time (due to fleet turnover), the benefits from the combined strategy is only slightly greater than either method above. We assume a combined control efficiency of about 83 percent derived from EPA data [28].

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

For this analysis, we define an *enhanced* motor vehicle inspection and maintenance (I/M) program as one including all requirements of the existing California I/M program (among the most stringent in the Nation), *plus the* following improvements: annual testing for all pollutants (VOC, NO_x, carbon monoxide, and particulate) on all vehicles, improved visual inspection of the emissions control system to detect tampering and other functional defects, and a repair cost ceiling of $500 per year.[24] We have assumed that enhanced I/M programs are instituted in all nonattainment areas.

For cities without an existing I/M program as of 1987, the full emission reduction benefit of an enhanced I/M program is applied. If a city already had an I/M program as of 1987, then an incremental emission reduction benefit, representing the reductions achieved by going from an existing to an enhanced program, is applied. Estimates of the percentage reduction in emissions are taken from Sierra Research, Inc. [15]. We assume that the VOC emission reduction potential of existing I/M programs is about 12 percent. The full benefit of enhanced programs is about 29 percent, while the incremental benefit gained by switching from an existing to an enhanced program is about 17 percent. These control benefits apply *only to the exhaust fraction* of light-duty car and truck emissions, and do not affect emissions resulting from the gasoline evaporation.

We estimate that enhanced I/M programs in nonattainment cities will reduce VOC emissions by about 220,000 tons per year in 1994 and by 170,000 tons per year in 2004.[25] This represents about a 2-and l-percent reduction in 1994 and 2004, respectively, based on 1985 emissions. The emissions reduction benefits decline through time because average fleetwide exhaust emission rates also decline due the benefits from the existing Federal Motor Vehicle Control Program.

More Stringent Highway-Vehicle Emission Standards

This analysis includes the VOC 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 [15].[26] Sierra Research assumes that these standards can be met during 50,000 miles of *controlled test* driving (certification testing) for passenger cars, and 120,000 miles for light-duty trucks; however, VOC emission

[23] Under this scenario, stations which pump less than 10,000 gallons per month are not required to install controls.

[24] According t. Sierra Research, Inc. [16], if expensive major emission control systems were covered by a 10-year/100,000-mile manufacturer's warranty, the repair cost ceiling could be lowered to $200 per vehicle per year.

[25] Nitrogen oxides, carbon monoxide, and particulate emissions reduction benefits are also gained by I/M programs. Carbon monoxide and particulate reduction benefits are not calculated in our analysis; NO_x benefits are calculated in a later chapter.

[26] The new emission standards used in our analysis are as follows: (in grams of pollutant emitted per mile traveled [g/mile] for 11011 -methane hydrocarbons [NMHC] and NO_x)
Passenger cars- NMHC: 0.25 g/mile; NO_x: 0.4 g/mile
Light-duty gasoline trucks (by truck weight)—
(less than 3,750 lbs) NMHC: 0.34 g/mile; NO_x: 0.46 g/mile
(3,751 to 6,000 lbs) NMHC: 0.43 g/mile; NO_x: 0.80 g/mile
(6,000 to 8,500 lbs) NMHC: 0.55 g/mile; NO_x: 1.15 g/mile

rates after 50,000 miles (for cars) and 120,000 miles (for trucks) of *actual* use by vehicle owners would likely exceed these standards. We assume that new standards go into effect in 1994 for both passenger cars and light-duty trucks.

We estimate that in 1999 new highway vehicle standards reduce VOC emissions by about 77,000 tons per year in nonattainment cities and 180,000 tons per year, nationwide, or about 0.7 percent compared to 1985 emissions. By 2004, reductions increase to about 140,000 tons per year in nonattainment cities and 330,000 tons per year, nationwide, or about 1.3 percent compared to 1985 levels. The slight increase in emissions reductions during this period is due to the gradual replacement of older vehicles with newer, cleaner ones.

As mentioned above, we assumed that the 0.25 gram-per-mile hydrocarbon emission standard for new passenger cars will be met during 50,000 miles of certification testing. Some congressional proposals have called for this standard to be met during 50,000 miles of actual driving use. If this more stringent ''in-use" requirement was actually achieved by passenger cars, total emissions reductions from all new emission standards would increase from 140,000 to 210,000 tons per year in nonattainment cities in 2004. If passenger cars were required to meet a 0.25 gram-per-mile "in-use" standard during 100,000 miles of actual driving, if achieved, total reductions from new emission standards would increase to 250,000 tons per year in nonattainment cities in 2004.

Limits on Gasoline Volatility

Lowering gasoline volatility (i.e., lowering the rate of evaporation) reduces emissions during refueling at the gas pump and during refilling of underground gasoline storage tanks, reduces evaporative emissions from vehicle fuel systems, and lowers exhaust emission rates. For this analysis, we assume that gasoline volatility is reduced to 9 pounds per square inch (psi) Reid Vapor Pressure (RVP) during the 5-month summertime period when ozone concentrations most often exceed the standard. Emissions reductions would occur only during the summer period and not year-round. However, for the purposes of comparison with other VOC control methods which are in effect over the entire year, we have scaled up seasonal emissions reductions fromI volatility control to an *equivalent annual* estimate. This scaled-up estimate should *not* be viewed as a year-round estimate, but as an equivalent annual tons-per-year estimate based on the highway-vehicle evaporative and running loss emissions which would occur on a typical summertime day in a nonattainment city. Data for the analysis comes from EPA [27].

We estimate that limiting gasoline volatility would lower VOC emissions in 1994 by about 12 percent in nonattainment cities, and about 14 percent in attainment areas. Equivalent annual emissions reductions in 1994 are about 3.3 million tons per year, nationwide, of which about 1.3 million tons per year are eliminated in nonattainment cities. Again, these estimates are based on highway-vehicle evaporative emissions occurring on a typical summertime day, when ozone concentrations exceed the standard, not on an average annual day.

The above estimates assume that gasoline evaporation from in-use highway vehicles (running losses) averages about 1.5 grams per mile on warm summer days with gasoline volatility at levels prevailing during 1985. It does not take into account the recently promulgated regulation requiring volatility limits of 10.5 psi during the summer months.

Given the uncertainty in running loss estimates, the percentage reduction, in 1994, due to gasoline volatility limits in nonattainment cities could be as low as 6 percent (assuming running losses equal zero) or as high as 16 percent (running loss equal to 2.5 grams per mile). We have assumed that running loss emissions can be reduced by 65 percent if gasoline volatility is reduced from levels prevailing in 1985 to 9.0 psi based on data from EPA's MOBILE 4 model.

Methanol Fuels for Motor Vehicle Vehicles in the Worst Nonattainment Cities

Methanol vehicles used within the next 10 years will probably operate on blends of methanol and gasoline (probably 85 percent methanol and 15 percent gasoline, by volume). EPA estimates that both exhaust and evaporative emission rates for light-duty vehicles operated on blends of methanol and gasoline would effectively[27] be about 30 percent lower than for gasoline vehicles meeting current standards and operated on low-volatility gasoline (9 psi) [1,29]. Beyond the next 10 years, if vehicles can be produced to operate on 100 percent (straight) methanol and they are designed and adjusted to generate minimal VOC emissions, EPA suggests that rates for both exhaust and evaporative emissions could effectively be reduced by up to 90 percent [1]. However, significant advances in vehicle technology would be required to achieve such low VOC emission rates. EPA's proposed regulations for light-duty methanol vehicles would apply the same carbon monoxide and nitrogen oxides emissions standards for methanol as for gasoline [9], so no reductions in these pollutants would be expected.

In our analysis, we consider the use of alternative fuels in fleets of 10 or more vehicles, in areas with ozone design values of 0.18 ppm or higher. In 1986, 6 million cars and 2 million light-duty trucks in centrally owned fleets of 10 or more vehicles accounted for about 13 percent of light-duty vehicle-miles-traveled nationwide [2].[28] Use in fleets is expected to be easier to promote or require than general use, because a less extensive network of refueling stations would be required. Because methanol is likely to be expensive, at least in the near term, we assume that its use would be limited to those areas with the most severe ozone problems.

For areas with design values of 0.18 ppm or higher, if 30-percent reductions in VOC emission rates were obtained, we estimate that year-round operation of fleet vehicles on methanol would be equivalent to total annual reductions of VOC emissions of about 14 thousand tons per year in 1994, or about 0.5 percent of total 1985 emissions in these areas. An upper bound on the level of reductions that could ultimately be achieved with methanol is about 53,000 tons per year[29] in 1994, or about 2 percent of 1985 emissions in cities with design values of 0.18 ppm or higher. This estimate assumes that emission rates are reduced by 90 percent using straight methanol.

Use of methanol or compressed natural gas (CNG) as fuel for light-duty vehicles is discussed in more detail in a later chapter.

COMPARISON OF POTENTIAL EMISSIONS REDUCTIONS AND REDUCTIONS NEEDED TO ATTAIN THE OZONE STANDARD

Without Additional Controls

The graph on the left-hand side of figure 6-12 shows the variability among nonattainment cities in the changes in VOC emissions predicted to occur between 1985 and 1994, assuming no change in State and EPA regulations in place as of 1987. For each city, at its design value, we have graphed the percentage change in emissions from the 1985 baseline expected to occur due to the regulations included in State Implementation Plans (SIP) as of 1985, the current Federal Motor Vehicle Control Program, and population and economic growth.

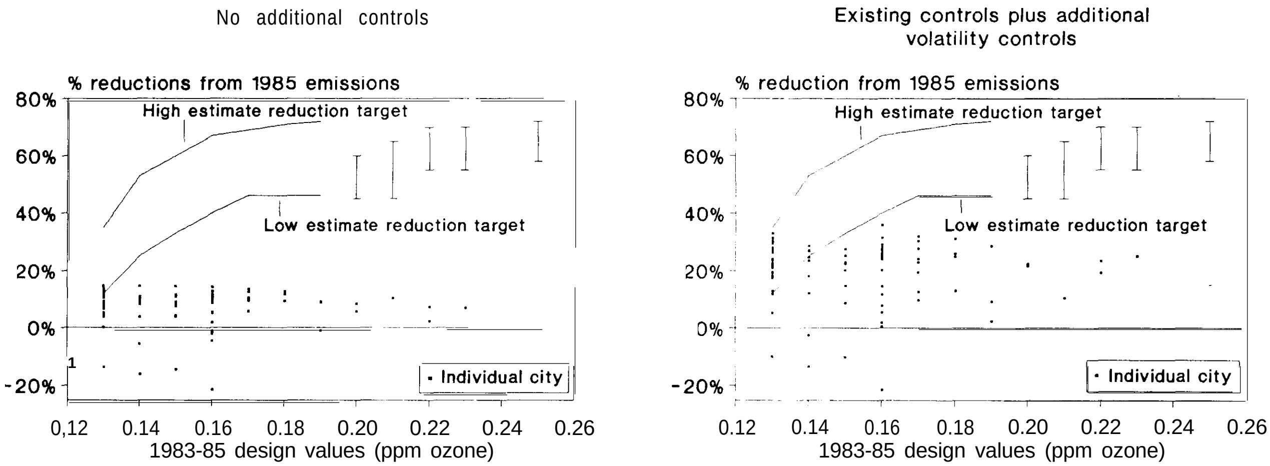
We have graphed cities by design value because it is a reasonable predictor of the emissions reductions needed to reach the standard. The graph also displays estimates of the reductions needed to reach the ozone standard of 0.12 ppm, as a function of design value. As discussed in chapter 5, the two curves arching across the graph represent high and low estimates of the percentage reduction in emissions that typical cities falling within a given range of design values need to attain the standard. The five vertical bars to the right of the two curves represent estimates of emissions reduction requirements for individual cities with design values above 0.19 ppm. We have omitted three cities with design values greater than 0.26 ppm (all three are in southern California). As stated in chapter 5, control require-

[27] Under EPA'S proposed regulations [9] for methanol-fueled vehicles, total VOC emissions, i.e. the total mass of carbon emitted, would be the same as with gasoline, but the emissions would ''effectively" be lower because methanol produces less ozone than the VOCS emitted with gasoline.

[28] 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 the vehicles in general use.

[29] Reductions in Vehicle refueling from the use of straight methanol accounts for about 22 percent of this total. Reductions in vehicle exhaust and evaporative emissions account for the remaining 78 percent. No reductions in refueling emissions would be anticipated if gasoline were displaced by a methanol/gasoline blend. This is assuming 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.

Figure 6-12-Volatile Organic Compound (VOC) Emissions Reductions Between 1985 and 1994, Assuming No Change From 1987 VOC Regulations and Assuming Additional Volatility Controls



Each square represents a nonattainment city. In the chart on the left, the location on the graph shows the VOC emissions reductions (as a percentage of 1985 levels) by 1994 given the local, State, and federal VOC regulations in place in 1987. The chart on the right shows the reductions each city can achieve by 1994 if gasoline volatility limits are adopted in addition to the local, State, and Federal VOC regulations in place as of 1987. Cities below the "O%" line experience a net increase in emissions between 1985 and 1994. The horizontal axis shows the "design value," a measure of peak ozone concentration used to determine the emissions reductions needed to attain the ozone standard. The two curves arching across the graph and vertical bars to the right of the curves show the upper and lower bounds of VOC reductions needed to **attain the standard. The vertical bars show estimated control requirements** explicitly for major urban areas with area-wide design values greater than 0.19 ppm.

SOURCE: Office of Technology Assessment, 1989.

ments for individual nonattainment areas could actually fall outside of the ranges presented here. In particular, areas with large contributions from transported pollutants or vegetative VOC emissions are not well represented. Moreover, the model used in the calculations is intended to provide only rough estimates of control requirements, based on a minimal amount of input information,

Summarizing how to read figure 6-12, the *squares* show the change in VOC emission in each nonattainment city *projected* for 1994 (assuming existing regulations) and the curves and vertical bars show the upper and lower bounds of the change *needed,* in each city, to attain the ozone standard by 1994.

As the graph on the left-hand side of figure 6-12 illustrates, the change in VOC emissions that would occur by 1994 without further control ranges from an increase of about 20 percent to a reduction of about 15 percent. Emissions in most cities are expected to decline, due to the replacement of today's cars with lower emitting, new cars. However, emissions may increase in some cities that are expected to experience high population growth.

Note that without additional controls only a few cities with design values of 0.13 ppm maybe able to attain the ozone standard by 1994. Most nonattainment areas will not be much closer to meeting the standard than they are today.

With Additional Gasoline Volatility Limitations

In the previous subsection, we analyzed the emissions reductions which would be expected in 1994 if only State and Federal regulations existing in 1985 were to be applied; these estimates represent a ''no-further-control" scenario from which we can gauge the effectiveness of additional control measures. Recently, EPA announced proposals requiring limits on gasoline volatility [8]. Several States in the Northeast have already adopted regulations which would limit gasoline volatility to 9 pounds per square inch (psi) during the summer months [5]. Because this control method could become law, nationwide, in the near future, its exclusion from a baseline "no-further-control" scenario in a future year may not be appropriate. Therefore, this subsection shows how the adoption of volatility controls, alone, would affect future emissions reductions.

The graph on the right-hand side of figure 6-12 illustrates the percent reductions that would be achieved in 1994 from existing regulations *plus* gasoline volatility limits of 9 psi. On average, in 1994, gasoline volatility limits in nonattainment cities will lower emissions by about an additional 12 percent below 1985 levels. As noted earlier, this percentage represents emissions reductions that would likely occur on a typical day when ozone concentrations might exceed the standard and have been scaled up to equivalent annual reductions for the purposes of comparison with other year-round control methods. As illustrated in figure 6-12, when volatility controls are added, the percent reductions in many cities with design values of 0.13 ppm fall between the two curves. These cities may be able to attain the ozone standard in 1994.

With All Control Strategies Analyzed by OTA

Figure 6-13 illustrates the percent reduction in VOC emissions that could be achieved by requiring *all the* control strategies listed in the beginning of this section. In most cities, emissions in 1994 would be lowered between about 20 and 50 percent, depending on the city. As the figure shows, emissions reductions do not substantially change between 1994 and 2004. This "flat" trend between 1994 and 2004 is due to the competing influences of population growth (which drives new emissions growth) and the effects of additional emission control measures. The emissions reduction benefits from these measures act to cancel out new emissions growth due to rising populations.

For typical cities with design values between 0.13 and 0.14 ppm, the VOC emissions reductions from all controls may be more than needed to attain the ozone standard. For other nonattainment cities with slightly higher design values, the reductions projected for 1994 fall within the range of reductions which might be needed. However, for most cities with design values of 0.16 ppm or higher, projected reductions fall considerably below the amount needed to meet the standard. (Recall from chapter 5 that in each range of design values, the reduction requirements shown in the above figures may underestimate the reductions in local manmade VOC emissions that are needed in areas that have atypically large contributions from transported pollutants or vegetative VOC emissions.) In a later section, we discuss the extent to which the adoption of all control strategies in nonattainment cities achieves less than, or more than the emissions reductions required to attain the standard.

As stated earlier, the emissions reductions reported here represent control methods that we know can be applied in the near term. This does not imply that additional VOC reductions beyond those analyzed here are not possible, but that they should not be counted on within the next 5 to 10 years.

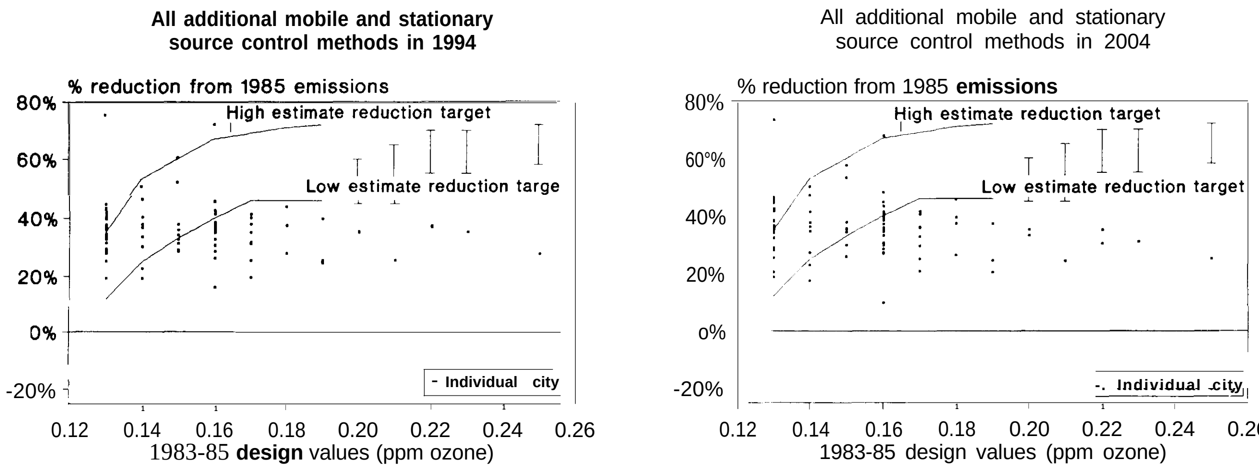
Estimates of Possible Excesses and Shortfalls in Emissions Reductions Required To Attain the Ozone Standard

In this section we estimate: 1) the extent of *overcontrol* in nonattainment cities with the lowest design values, and 2) the *shortfall* in nonattainment cities with higher design values, expected to occur after applying *all* of the VOC controls discussed earlier. Figure 6-14 displays our estimates of potential overcontrol and undercontrol from all VOC control strategies in 1994 expressed in tons of emissions reductions and as a percentage of 1985 emissions. The bars shown in the figure represent ranges of uncertainty associated with our method of estimating the VOC reductions needed to attain the standard in each city.

As discussed in an earlier section and in chapter 5, because of the uncertainty associated with estimating the emissions reductions required to attain the ozone standard, the reduction target we chose for each city could be too low or too high. Therefore, the adoption of all additional controls in an individual city may result in either a shortfall or an excess in the emissions reductions required to meet the standard. For this reason, we present estimates for both undercontrol and overcontrol.

We estimate that adoption of all controls in all nonattainment areas might overcontrol VOC emission by about 160,000 to 920,000 tons per year in

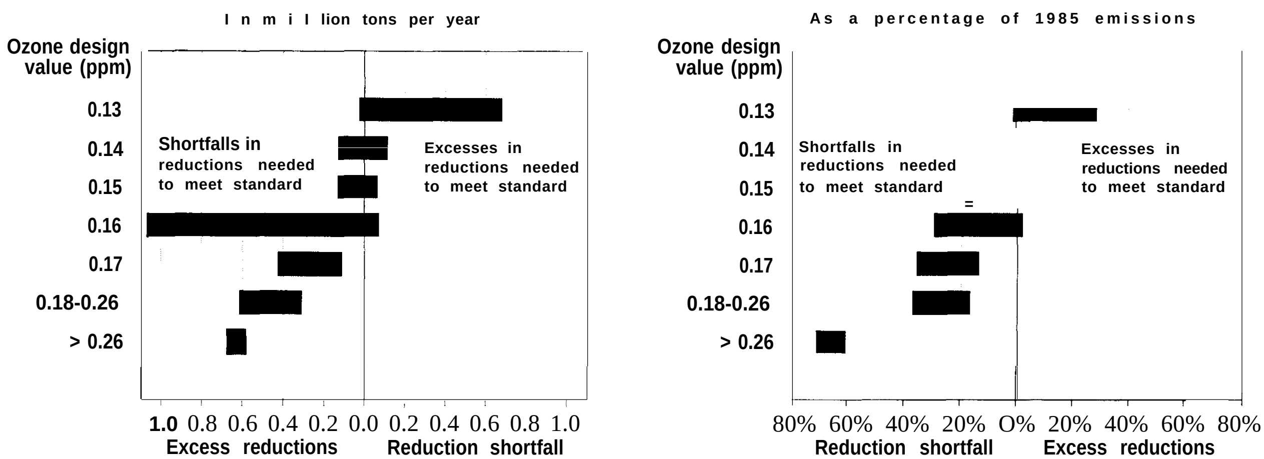
Figure 6—13-Volatile Organic Compound (VOC) Emissions Reductions Between 1965 and 1994, and 1985 and 2004, Including All Additional Mobile and Stationary Source VOC Control Methods



Each square represents a nonattainment city. The location **on the graph shows the projected VOC emissions reductions (as a percentage of 1985 levels) that each city can achieve by 1994 and 2004** if all additional mobile and stationary source control methods we analyzed are adopted in addition to the State and EPA VOC regulations in place in 1985. The horizontal axis shows the “design value,” a measure of peak ozone concentration used to determine the emissions reductions needed to attain the ozone standard. The two curves arching across the graph and vertical bars to the right of the curves show the upper and lower bounds of VOC reductions needed to attain the standard. The vertical bars show estimated control requirements explicitly **for major urban areas with area-wide design values greater than 0.19** ppm.

SOURCE: Office of Technology Assessment, 1989.

Figure 6-14-Estimates of Possible Excesses and Shortfalls in Emissions Reductions Needed to Attain the Ozone Standard in 1094



The graph on the left shows reductions and shortfalls expressed as tons of emissions in 1994 while the graph on the right displays these results as a percentage of 1985 emissions. The bars shown above represent ranges of uncertainty associated with our method of estimating the VOC reductions needed to attain the standard in each city. Because of the uncertainty associated with estimating the emissions reductions required to attain the ozone standard, the reduction target we chose for each city could be too low or too high. Therefore, the adoption of all additional controls in an individual city may result in either a shortfall or an excess **in the emissions reductions required to meet the standard. For this reason, we present estimates for both undercontrol and overcontrol.**

SOURCE: Office of Technology Assessment, 1989.

1994, or about 1 to 8 percent of 1985 emissions in these cities. Figure 6-14 shows that the adoption of all VOC control strategies in cities with 1983-85 ozone design values equal to 0.13 ppm (17 in all) will very **likely** result in excess emissions reductions of about 160,000 to 680,000 tons per year in 1994, or about 7 to 29 percent of their total 1985 total emissions. Even given the uncertainty in estimating emissions reduction targets, these cities probably will not likely fall short of the reductions needed to meet the ozone standard. Potential overcontrol in cities with design values equal to 0.14 and 0.15 ppm may average about 26,000 tons and 21,000 tons in 1994, respectively, or about 3 percent of their 1985 emissions. Overcontrol, therefore, may not be as much of a factor here compared to the cleaner cities. We estimate that undercontrol in cities with design values of 0.14 and 0.15 ppm may be more of a problem, averaging about 37,000 and 58,000 tons in 1994, or about 5 and 8 percent of their 1985 emissions, respectively.

VOC reductions in *attainment* areas are a potentially significant source of overcontrol in the sense that these areas do not need to reduce their emissions any further to meet the ozone standard locally. We know that there will be some benefit to nonattainment cities from controls in attainment areas, especially those in ozone transport regions, but we are not able to estimate how much. Moreover, even in cities that already meet the standard, lowering ozone concentrations even further will provide some benefit. The total emissions reduction in all attainment areas from application of the *nationwide* control measures only[30] is about 2 million tons of VOCs per year, in 1994, or about 14 percent, based on 1985 emissions.

Figures 6-14 also presents our estimates of the additional VOC emissions reductions nonattainment cities must achieve to attain the ozone standard after all controls have been applied. Calculation procedures are similar to those discussed above. We estimate that after all controls are applied, nonattainment cities still fall about 1.2 to 3.1 million tons per year short of the emissions reductions needed to attain the standard in 1994, or about 11 to 27 percent of 1985 emissions. Given that the adoption of all additional controls will reduce total VOC emissions by about 34 percent in 1994, we estimate that nonattainment cities will still need an additional one-third *more* emissions reductions to attain the standard, based on 1985 levels. Of course, individual cities may require higher or lower percentage emissions reductions to achieve the standard depending on severity of the nonattainment problem. (Possible long-term strategies that cities could use to further reduce VOC emissions and measures to control NO_x emissions are discussed in chapter 7.)

The shortfall of emissions reductions will be most significant in cities with design values greater than or equal to 0.16 ppm (48 cities). In general, as the severity the ozone problem in individual cities increases, so too does the relative magnitude of the shortfall, measured as a percentage of 1985 emissions. Undercontrol will be most severe in cities with design values greater than 0.26, with a possible shortfall of about 630,000 tons per year in 1994, or about two-thirds of 1985 emissions.[31] The emissions reduction shortfall in cities with design values between 0.18 and 0.26 ppm (13 cities) is estimated to be about 300,000 to 630,000 tons in 1994, or about 18 to 38 percent of 1985 emissions. Therefore, given that the adoption of all control methods will reduce VOC emissions by about 29 percent in 1994, based on 1985 levels, an additional 50-percent reduction would be necessary to attain the standard in these cities. The reduction shortfall in cities with design values 0.16 and 0.17 ppm is estimated to be, on average, about 880,000 tons per year, or about 18 percent of 1985 emissions.

COSTS OF CONTROL STRATEGIES ANALYZED BY OTA

This section summarizes the costs of the control strategies analyzed by OTA. Because we are unable to analyze the cost of *additional* emission controls required to make up the shortfall discussed above, we are not able to estimate the total costs of attaining the standard in all nonattainment cities.

[30] Includes Federal controls on architectural coatings and gasoline volatility limits. Emissions reductions from Onboard controls and more stringent tailpipe standards are also achieved in attainment areas but are assumed to go into effect after 1994.

[31] These cities have already adopted gasoline volatility limits, Stage 11 refueling controls, and architectural surface coatings regulations (a proposed federal control), and therefore, additional emissions reductions benefits for these controls were not assigned.

We estimate that the total cost of all controls analyzed by OTA in nonattainment cities will be about $4.2 billion to $7.1 billion per year, in 1994.[32] By 2004, costs will increase to about $6.6 billion to $10 billion per year in nonattainment cities, primarily because of the higher percentage of highway vehicles with more stringent controls. However, some controls that we considered apply nationwide. Total nationwide costs in 1994 and 2004 are about $4.4 billion to $7.9 billion per year and $8.8 billion to $13 billion per year, respectively. Again, this is total cost of achieving about two-thirds of the VOC reductions needed to attain the standard in all areas.

Some of the control methods we analyzed simultaneously reduce other air pollutants in addition to VOCS. Since enhanced motor vehicle inspection and maintenance (1/M) programs also reduce carbon monoxide, about $1.2 billion of the total cost in 1994 is attributable to the control of this pollutant ($1.5 billion per year in 2004).[33] Also, both enhanced I/M programs and more stringent highway-vehicle standards reduce NO_x emissions and, hence, we estimate that about $2.5 billion per year of the total nationwide costs in 2004 are attributable to the control this pollutant.

Table 6-10 displays the costs in 1994, 1999, and 2004 by source category. Figure 6-15 displays the ranges of costs in nonattainment cities in 1994 and 2004. Table 6-11 presents the "cost-effectiveness" (the cost per ton of VOC eliminated) of specific control measures for the three forecast years. Figure 6-16 illustrates the cost-effectiveness of control measures in nonattainment cities in 1994.[34] The solid bars represent the average cost-effectiveness in all nonattainment cities. Uncertainty in the cost-effectiveness estimates is denoted by the thin horizontal lines. Note the wide range in average cost-effectiveness across control measures, from about $440 per ton for limits on gasoline volatility to about $30,000 per ton for methanol fuels.

We also analyzed the cost and emissions reduction impacts of excluding control methods that cost more than $5,000 per ton of VOC reduced. We estimate that in 1994, by *not* requiring controls costing more than $5,000 per ton, total costs would drop to about $2.7 billion to $5.1 billion per year in nonattainment areas, representing a 30- to 35-percent decline. Nationwide costs would drop to about $2.9 billion to $4.7 billion per year. In 2004, total costs would drop to about $2.9 billion to $3.3 billion per year in nonattainment cities, representing a drop of about 56 to 67 percent. Nationwide costs would drop to about $5.1 billion to $6.1 billion per year in 2004, representing a decline of about 42 to 53 percent. The percentage decrease in total costs in 2004 is larger than in 1994 because the cost-effectiveness of I/M programs is greater than $5,000 by 2004 and, therefore, these programs would be excluded.

In 1994, about 190,000 tons per year of VOC emissions reductions would be lost in nonattainment cities if a $5,000 cost-effectiveness cap is imposed, increasing total emissions from about 34 percent below, to about 32 percent below, 1985 levels. In 2004, about 360,000 tons of the emissions reductions in nonattainment cities would also be lost, increasing emissions from about 33 percent below, to about 30 percent below, 1985 levels. Controls on many sources in the "RACT" and "New-CTGs" categories exceed the $5,000 per ton cost ceiling; methanol fuels would be completely eliminated while enhanced I/M programs would be eliminated in 2004. Since I./M programs would not be required in 2004 under this scenario, the costs associated with carbon monoxide control no longer have to be considered when interpreting total costs.

Figure 6-17 shows the cumulative cost of achieving various levels of VOC emissions reductions in nonattainment cities in 1994 and 2004. This figure shows that in 1994, a 25-percent reduction in VOC emissions (from 1985 levels) will cost about $900 million per year, while in 2004, the same reduction will cost about $1.6 billion per year. The total cost of a 25-percent emissions reduction is somewhat

[32] In addition to VOC control costs, these estimates also include the cost of NO_x and carbon monoxide control associated with enhanced I/M programs, and NO_x control associated with more stringent highway-vehicle standards.

[33] Motor vehicle inspection and maintenance programs reduce VOC, NO_x, and carbon monoxide. Since many ozone nonattainment cities also violate tbe Federal carbon monoxide standard, we arbitrarily assume that about 50 percent of the cost are attributable to carbon monoxide control.

[34] In the figure, the cost-effectiveness of Onboard controls, combined Stage II and Onboard controls, and more stringent tailpipe standards are presented for 2004 since mobile source-related measures take effect after 1994.

Table 6-10—Estimated Costs of Selected Control Strategies Analyzed by OTA (costs in million dollars per year)[a]

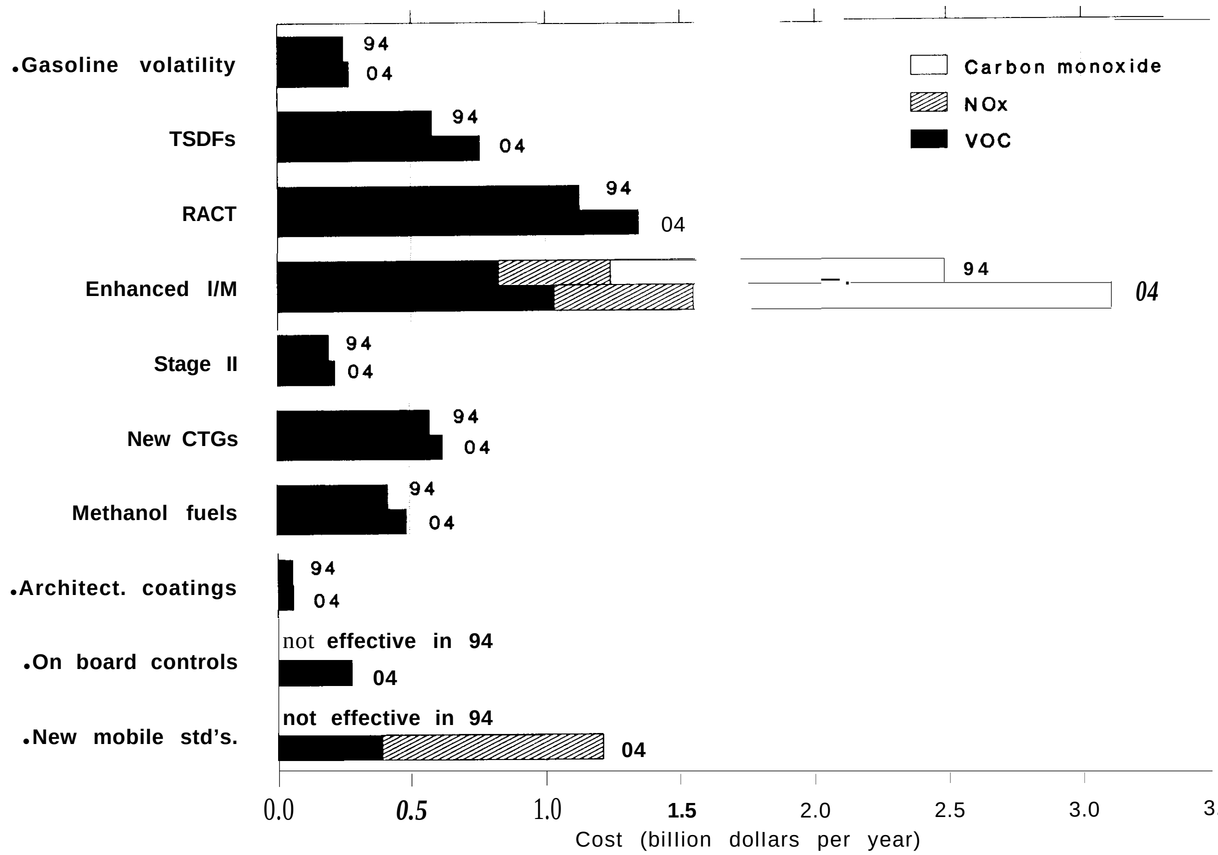
	1994			1999			2004		
	Nonattainment cities	Attainment areas	Total	Nonattainment cities	Attainment areas	Total	Nonattainment cities	Attainment areas	Total
RACT	1,100	—[b]	1,100	1,200	—	1,200	1,300	—	1,300
New CTGs	570	—	570	600	—	600	620	—	620
TSDFs	580	—	580	660	—	660	760	—	760
Architectural coatings	54	70	120	56	74	130	58	79	140
Onboard	—not effective in 1994—			190	220	410	270	320	590
Stage II	200	—	200	210	—	210	220	—	220
Enhanced I/M[c]	2,500	—	2,500	2,800	—	2,800	3,100	—	3,100
Gasoline volatility[d]	250	360	600	250	370	620	270	400	670
New highway vehicle standards[e]	—not effective in 1994—			660	910	1,600	1,200	1,700	2,900
Methanol fuels[f]	420	—	420	450	—	450	490	—	490
Total (low estimate)[g]	4,200	170	4,400	5,500	1,300	6,800	6,600	2,200	8,800
Total (high estimate)[h]	7,100	690	7,800	8,700	1,800	10,000	10,000	2,800	13,000

[a]Totals are rounded.
[b]"—" means control strategy applied only in nonattainment cities.
[c]We assume that half of the costs are attributable to the control of ozone and the other half to carbon monoxide. Totals include costs of VOC, NO_x, and carbon monoxide control. Total costs range between $1.5 billion and $3 billion per year in 1994.
[d]These costs are accrued during the five-month summer period. Costs range between $0.17 billion and $1.0 billion per year, nationwide, in 1994.
[e]Includes costs of both VOC and NO_x control.
[f]These controls are included in nonattainment cities with ozone design values equal to 0.18 ppm or higher. Costs range between $120 million and $710 million per year in 1994.
[g]These estimates include approximately $0.74 billion, $0.83 billion, and $0.93 billion per year for carbon monoxide control from enhanced I/M programs in 1994, 1999, and 2004, respectively.
[h]These estimates include approximately $1.7 billion, $1.9 billion, and $2.2 billion per year for carbon monoxide control from enhanced I/M programs in 1994, 1999, and 2004, respectively.

Strategy Descriptions
RACT = "Reasonable Available Control Technology" on all existing stationary sources that emit more than 25 tons per year of VOC.
New CTGs = new Control Technique Guidelines for existing stationary sources that emit more than 25 tons per year of VOC.
TSDF = controls on hazardous waste treatment, storage, and disposal facilities.
Federal controls on architectural coatings.
Onboard controls on motor vehicles to capture gasoline vapor during refueling.
Stage II control devices on gas pumps to capture gasoline vapor during motor vehicle refueling.
Gasoline volatility controls which limit the rate of gasoline evaporation.
Enhanced inspection and maintenance (I/M) programs for cars and light-duty trucks.
New highway-vehicle emission standards for passenger cars and light-duty gasoline trucks.
Methanol fuels as a substitute for gasoline as a motor vehicle fuel.

SOURCE: Office of Technology Assessment, 1989.

Figure 6-15-Estimated Coat of Volatile Organic Compound Emission Control Methods in 1994 and 2004 in Nonattainment Cities



•Costs in attainment cities not shown.

In 1994, total annual costs in nonattainment cities range between $4,2 billion and $7.1 billion per year. Total costs in nonattainment areas in 2004 range between $6.6 billion and $10 billion per **year. See text for description of control methods.**

SOURCE: Office of Technology Aessessment, 1989.

more expensive in 2004 because additional reductions are needed to offset anticipated emissions growth over the intervening decade. A 30-percent reduction in nonattainment area VOC emissions will cost about $2 billion per year in 1994 and about $3.4 billion per year in 2004. Total annual costs begin to increase more sharply beyond a 30-percent reduction. A 33-percent reduction will cost about $4.6 billion per year in 1994 and $8.4 billion per year in 2004. Again, control costs are greater in the later years because greater reductions are required to offset emissions growth. Greater reductions are also possible because more stringent tailpipe standards and Onboard controls have become effective by the later year.

Control methods in figure 6-17 are ranked by cost-effectiveness; that is, the total cost of control per ton of VOC reduced. The most cost-effective controls are represented in the lower lefthand portion of the curve, while the less cost-effective controls appear farther up the curve, to the right. For this figure, the cost-effectiveness of enhanced I/M programs and new highway-vehicle standards includes the VOC control costs and the cost of NO_x and

Table 6-11—Estimated Cost-Effectiveness of Selected Control Strategies Analyzed by OTA (dollars par ton of VOC reduced)[a]

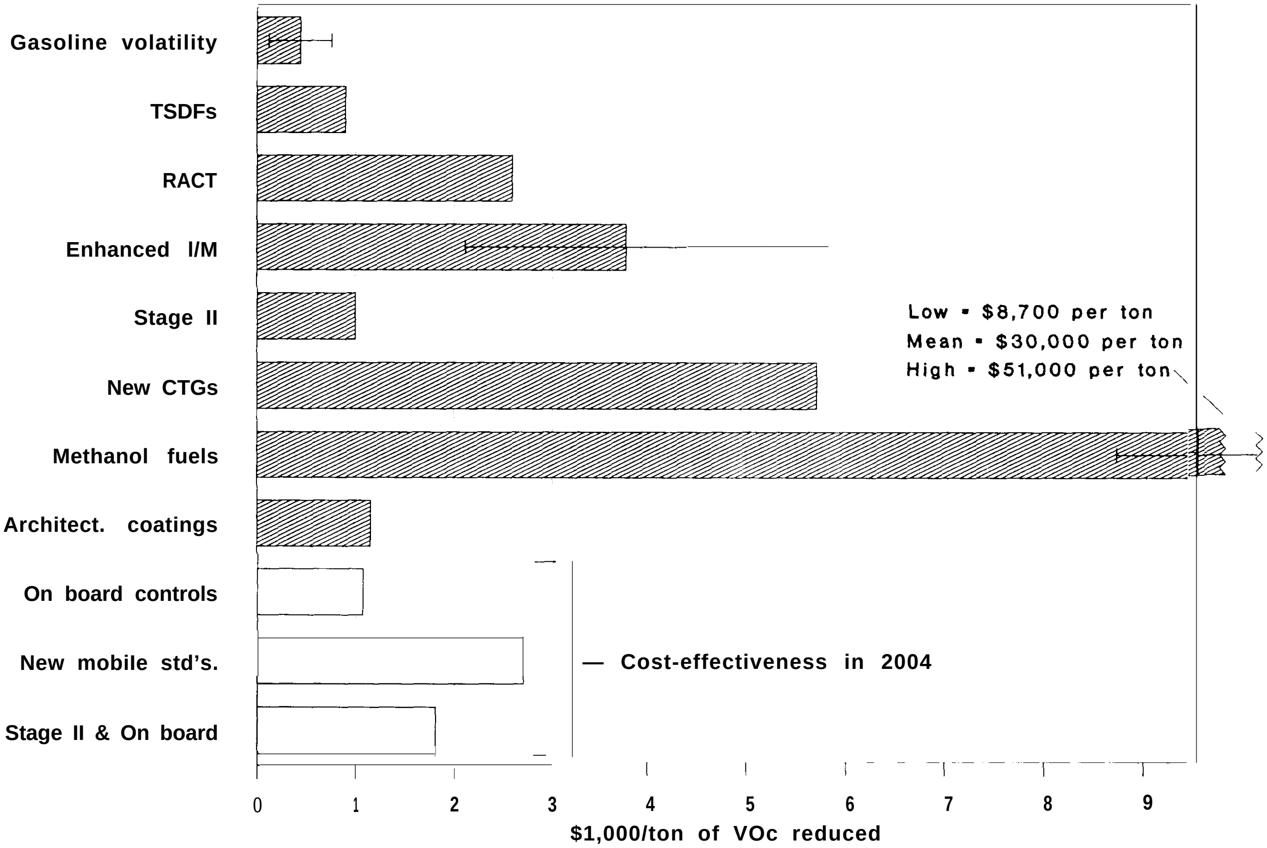
	1994			1999			2004		
	Nonattainment cities	Attainment areas	Total	Nonattainment cities	Attainment areas	Total	Nonattainment cities	Attainment areas	Total
RACT	2,200-6,600	—[b]	—	2,300-6,700	—	—	2,400-6,800	—	—
New CTGs	5,300-6,600	—	—	5,400-6,700	–	—	5,400-6,700	—	—
TSDFs	900	—	—	900	—	—	900	—	—
Architectural coatings	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100
Onboard	-not effective in 1994-			1,000-1,200	1,100	1,000-1,200	1,000-1,200	1,100	1,000-1,200
Stage II	**1,000**	—	—	**1,000**	—	—	**1,000**	—	—
Combined Onboard & Stage II	**1,000**		—	**1,200-1,700**	**1,100**	**1,100-1,700**	**1,200-1,900**	**1,100**	**1,100-1,900**
Enhanced I/M[c]	**2,100-5,800**	—	—	**3,000-8,500**	—	—	**3,300-9,700**	—	–
Gasoline volatility[d]	**120-760**	**120-770**	**120-770**	**120-730**	**120-750**	**120-740**	**120-740**	**120-750**	**120-750**
New highway vehicle standards	**-not effective in 1994-**			**2,700**	**2,700**	**2,700**	**2,700**	**2,700**	**2,700**
Methanol fuels	**8,700-51,000**	—	—	**8,700-51,000**	—	—	**8,700-51,000**	—	—

[a]Ranges represent variability among nonattainment cities and should not be contrued as uncertainty in our estimates.
[b]"—" means control strategy applied only in nonattainment cities.
[c]Estimates reflect costs associated with VOC control only. We assume that one-third of the total cost of enhanced I/M programs is attributable to VOC control, with em-half and one-sixth to carbon monoxide and NO_x control, respectively. Range in I/M coats represents uncertainty in repair cost and frequency.
[d]Estimates reflect ~st-effectiveness during the 5-month summertime period when controls are required.

Strategy Descriptions
RACT = "Reasonable Available Control Technology" on all existing stationary sources that emit more than 25 tons par year of VOC.
New **CTGs** = new Control Technique Guidelines for existing stationary sources that emit more than 25 tons per year of VOC.
TSDFs = controls on hazardous waste treatment, storage, and disposal facilities.
Federal controls on **architectural** coatings.
Onboard controls on motor vehicles to capture gasoline vapor during refueling.
Stage N control devices on gas pumps to capture gasoline vapor tiring motor vehicle refueling.
Gasoline **volatility controls** which limit the rate of gasoline evaporation.
Enhanced **inspection** and **maintenance (I/M)** programs for cars and light-duty trucks.
New **highway-vehicle emission standards** for passenger cars and light-duty gasoline trucks.
Methanol fuels as a substitute for gasoline as a motor vehicle fuel.

SOURCE: Office of Technology Assessment, 1969.

Figure 6-16-Estimated Cost-Effectiveness of Volatile Organic Compound Emission Control Methods in 1994 in Nonattainment Cities



The cost-effectiveness of enhanced inspection and maintenance (I/M) programs and new mobile standards include only the cost of VOC control. Since Onboard controls and new mobile standards do not take affect until after 1994, we present the cost-effectiveness in 2004. The thick horizontal bars represent the average cost-effectiveness in nonattainment cities. The thin horizontal lines for gasoline volatility, methanol fuels, and **I/M programs represent ranges of uncertainty associated with assumptions we used to estimate total annual costs. The very large uncertainty associated with the methanol fuels is due to the uncertainty of methanol prices relative to** gasoline prices. We were unable to estimate cost-effectiveness uncertainty for other control methods. See text for a description of control methods.

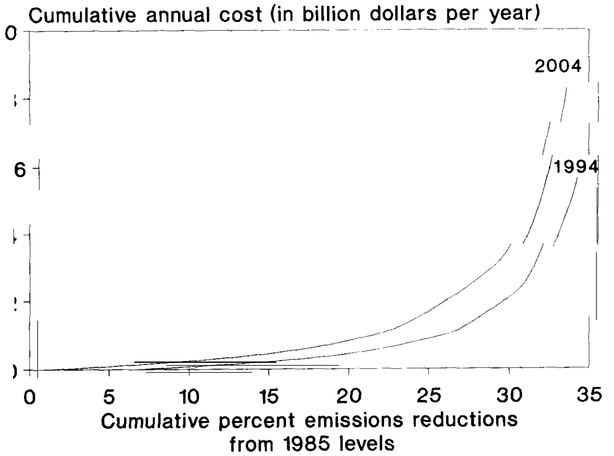
SOURCE: Office of Technology Assessment, 1989.

carbon monoxide control (1/M programs, only). If the two **least** cost-effective control programs in 2004-enhanced I/M programs and methanol fuels-are eliminated, total costs would drop by approximately $3.6 billion per year, representing a 40-percent decline.

As described in an earlier section, the adoption of all additional control measures in nonattainment cities with design values of 0.13 ppm may result in about 400,000 tons per year *more* emissions reductions than what is necessary to attain the ozone standard. If "New-CTGs, " hazardous waste TSDFs, and enhanced I/M programs are *not* required in these areas, excess emissions reductions could be cut by about 380,000 tons per year in 1994, representing a 30-percent decline in emissions reductions. Total costs in these areas would drop from about $1.7 billion per year to about $0.5 billion per year, or about a 70-percent decline.

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

Figure 6-1 7-Cumulative Annual Cost of, and Percent Emissions Reductions From, VOC Control Methods



Control methods are ranked by cost-effectiveness; that is, the total cost of control per ton of VOC reduced. For example, the most cost-effective controls (e.g., gasoline volatility) are located in the lower left portion of the curve. In this figure, the costs of enhanced I/M programs and new highway-vehicle standards includes the VOC control costs **and** the cost of NO_x and carbon monoxide control (1/M programs, only).

SOURCE: Office of Technology Assessment, 1989.

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

Reasonably Available Control Technologies (RACT) on All Stationary Sources

Total costs in nonattainment cities for this category are estimated to be about $1.1 billion per year in 1994, averaging about $2,200 to $6,600 per ton of VOC removed depending on city.

As mentioned in an earlier subsection, this control strategy applies to about 40 broad source categories such as petroleum refining, certain types of chemical manufacturing, gasoline stations, etc. A complete list, with our assumptions about control efficiencies and cost-effectiveness for each source type, is included in an appendix.

Adoption of New "Control Technique Guidelines" (CTGs)

As stated earlier, we analyzed six stationary source categories currently being considered as candidates for new CTGs: wood furniture coating, plastic parts coating, automobile refinishing, coke-oven byproduct plants, bakeries, and publicly owned treatment works. (Hazardous waste treatment, storage and disposal facilities are discussed in the next subsection.)

We estimate that new CTGs would cost about $570 million per year in 1994, all of which would be incurred in nonattainment cities. The cost-effectiveness averages about $5,700 per ton with a range of $5,300 to $6,600 per ton depending on the cities in which these controls are adopted.

Controls on Hazardous Waste Treatment, Storage, and Disposal Facilities

We estimate that emission controls on TSDFs will cost about $580 million per year in nonattainment cities in 1994. This estimate is based on a cost-effectiveness of $900 per ton of VOC reduced for controls such as covered storage tanks and carbon adsorbers.

Federal Controls on Architectural Surface Coatings

The small amount of cost data available for architectural surface coatings revealed a wide range of estimates, from a net *savings* to default costs of $2,000 per ton of reduction. We assume that controls for this source cost about $1,100 per ton of VOC reduced. Commercial and consumer products are also potentially important sources of VOC emissions, but were excluded from our analysis because of a lack of adequate control technology information.

We estimate that, in 1994, Federal controls on architectural surface coatings would cost about $120 million per year, nationwide, with about $54 million per year incurred in nonattainment cities.

Controls on Gasoline Emissions From Vehicle Refueling

"Onboard" Refueling Controls on Motor Vehicles

We estimate the cost of Onboard controls by 1999 to be about $410 million per year, nationwide, with about $190 million per year incurred in nonattainment cities. By 2004, costs would total $590 million per year, nationwide, because of the higher percentage of Onboard-equipped vehicles on the road. The average nationwide cost-effectiveness is estimated to be about $1,100 per ton in 1999.

For this analysis, we assume that all gasoline vehicles manufactured in 1994 and later will be equipped with Onboard controls to capture gasoline vapors during refueling. By 2004, most gasoline vehicles on the road will be equipped with these controls. We assume that Onboard controls cost about $25 per vehicle, which is close to EPA's upper bound estimate [28]. Note, however, that others conclude that the costs are higher. A study for the Motor Vehicle Manufacturers Association estimates that the average per-vehicle cost of Onboard controls for the first model year is about $80 [13].

"Stage 11[99] Refueling Vapor Recovery

We estimate the cost of Stage II controls to be about $200 million per year in 1994, all of which is incurred in nonattainment cities. This estimate is based on a cost-effectiveness of $1,000 per ton of VOC removed. This figure represents EPA's upper bound range as presented in the recent gas-marketing regulatory impact analysis [28]. EPA estimates that the total installed cost of Stage 11 controls, *per station,* ranges from $5,270 for the smallest stations to $22,190 for the largest [28].

Combined Stage 11 and Onboard Controls

We assume that the cost of a combined Stage 11 and Onboard program is the sum of the cost of each individual program. Therefore, in 1999, we estimate the cost to be about $610 million per year, nationwide, with approximately $400 million per year incurred in nonattainment cities. Nationwide costs increase to about $810 million per year in 2004. The combined cost-effectiveness in nonattainment cities in 1999 is estimated to be about $1,600 per ton of VOC reduced and is expected to increase to about $1,800 per ton by 2004 because of fleet turnover. The cost-effectiveness is higher than either Stage 11 and Onboard alone because the emissions reductions achieved from a combined system do not substantially increase compared to each one separately. The nationwide combined cost-effectiveness in 1999 and 2004 is estimated to be about $1,400 and $1,500 per ton, respectively. The cost-effectiveness is lower nationwide because we assume that Stage 11 controls are not required in attainment areas.

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 $1.9 billion and $4.3 billion per year. About half of this total is for ozone control ($0.74 billion to $1.7 billion per year in 1994, and $0.93 billion to $2.2 billion per year in 2004),[35] Of the portion that is assigned to ozone control, we estimate that about two-thirds would be for VOC control and one-third for NO_x control. Thus, the cost-effectiveness for VOC reductions is estimated to be between $2,100 and $5,800 per ton in 1994. In 2004, the cost-effectiveness will increase to between $3,300 to $9,700 per ton; this rise is due to the fact that cars and trucks will be cleaner in 2004. Note that we have estimated the cost-effectiveness of improving existing I/M programs to the more stringent "enhanced" program described earlier.

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. [15]. 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.[36] Sierra Research's analysis concludes that an enhanced I/M program can reduce VOC emissions from cars and light-duty trucks by about 30 percent. This is about 17 percent higher than current I/M programs. For those cities that already have an I/M program in place, we credit $20 per vehicle as the cost of the existing program.

These costs are quite a bit higher than EPA estimates [11]. The major difference seems to be

[35] The other half of the costs are assigned to carbon monoxide control.

[36] 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 whicl fail; the h@ estimate assumes $100 repair cost on 35 percent of the vehicles,

assumptions about whether repair costs drop after the program has been operating a few years.

More Stringent Highway-Vehicle Emission Standards

We estimate that the total cost of tighter emission 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 will total about $2.9 billion per year, nationwide, because a higher percentage of vehicles on the road will be equipped with new controls. These totals include the costs attributed to *both* VOC and NO_x control on new passengers cars and light-duty gasoline trucks. Costs are based on an OTA contractor report by Sierra Research, Inc., that estimated new emission control costs of about $140 per vehicle for combined VOC and NO_x control [15]. Reductions of VOC in nonattainment cities in 1999 and 2004 are estimated to cost about $2,700 per ton of VOC reduced. As described earlier, we analyzed more stringent standards that can be met up to 50,000 miles of driving under *controlled* conditions for cars, and 120,000 miles for light-duty trucks; tailpipe VOC emissions may exceed these standards after 50,000 miles (for cars) and 120,000 miles (for trucks) of *actual* use by individual vehicle owners.

Limits on Gasoline Volatility

We estimate that reducing gasoline volatility (i.e., the rate of evaporation) during the 5-month summertime period costs between about $0.17 billion and $1.0 billion per year nationwide in 1994. During the 5-month summer period, costs are between about 0.5 and 3.2 cents per gallon of gasoline. The lower cost estimate is derived from a recent EPA analysis of proposed nationwide limits on gasoline volatility [27], while the high estimate was obtained from a petroleum industry analysis [20,33] .37 In 1994, the cost-effectiveness ranges between $120 to $800 per ton of VOC reduced. Our estimates of cost-effectiveness are lower than EPA's because we have increased the emissions reduction potential from highway vehicles by including a 1.5 gram-per-mile running loss to the existing inventory.

Methanol Fuels for Motor Vehicle Vehicles in the Worst Nonattainment Cities

In the near term, use of blends of methanol and gasoline could easily be several times more expensive per ton of VOCs reduced than any other measure we have considered. **If** advances in vehicle technology yielded reductions in emissions rates on the order of 90 percent, the estimated costs of using straight methanol could be more in line with other control measures we have evaluated. In all cases, the costs are extremely sensitive to prices assumed for gasoline and methanol.

Automobile manufacturers estimate 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 [32]. In larger runs, methanol and gasoline-fueled vehicle production costs could be comparable [32]. For centrally owned fleets, assuming a vehicle life of 6 years (150,000 miles) and an 8 percent discount rate, the annualized added cost of a methanol vehicle could thus range from $0 to about $215.

Based on a range of 40 to 60 cents per gallon as the wholesale price of methanol, we estimate that straight 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 and thermal efficiency of the two fuels.[38] These estimates can be compared to current national average prices for regular and premium unleaded gasoline of $0.95 and $1.10 per gallon, respectively [24]. Assuming that fleet vehicles average 26,000 miles per year and get the energy equivalent of 26.5 miles per gallon of gasoline, use of a blend of 85 percent methanol and 15 percent gasoline would increase annual fuel costs by about $130 to $480 per vehicle.

In the near term, assuming methanol is blended with 15 percent gasoline and yields VOC emissions

37The study by Turner, Mason & CO. for the American Petroleum Institute (API) estimated that EPA's volatility proposal would cost about $1.5 billion per year. The standard we analyzed was somewhat less stringent than EPA's original proposal and, hence, total costs, as evaluated by API, were estimated to be about $1.0 billion per year.

38See ch. 7 for details.

rates that are 30 percent lower than gasoline-fueled vehicles, we estimate that using methanol in fleets would cost about $120 million to $710 million per year in 1994, or about $8,700 to $51,000 per ton of VOC reduced. The low estimate assumes vehicle and fuel costs most favorable to methanol, while the high estimate represents costs which are least favorable.

Use of methanol or compressed natural gas (CNG) as fuel for light-duty vehicles is discussed in more detail in the next chapter.

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