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### Motor Vehicle Air Pollution Control: The Remaining Issues

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Motor Vehicle Air Pollution Control  
The Remaining Issues

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AIR QUALITY PROTECTION IN THE WEST

2800 North Dinwiddie Street  
Arlington, Virginia 22207

November 27-28, 1989

## I. Introduction

### A. Summary

In spite of over 20 years of control, vehicle related air pollution remains a serious problem in the US and around the world. Fortunately, a variety of additional measures appear promising and appear to be on the horizon if current legislative efforts come to a fruitful conclusion. However, continued growth in the number and use of vehicles in the US and in other corners of the world remains a long term problem.

### B. General References

Authored by Michael P. Walsh unless otherwise noted

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## II. Background

Motor vehicles have been and remain the dominant pollution source in the US, emitting significant quantities of carbon monoxide, hydrocarbons, nitrogen oxides, fine particles and lead. In an effort to minimize the motor vehicle pollution problem, emission rates from cars in the US have been limited by legislation since the 1968 model year. Frustrated with the rate of progress in controlling pollution in light of the increasing evidence of adverse effects which were occurring, Congress decided during the late 1960's to accelerate the pace of control. Because evidence was growing that vehicles were

substantially exceeding their "lenient" standards in-use, Congress also decided to pay special attention to the compliance program.

In December of 1970, when the Clean Air Act was amended by Congress, it took particular notice of the significant role of the automobile in the nation's effort to reduce ambient pollution levels by requiring a 90% reduction in emissions from the level previously prescribed in emissions standards for 1970 (for CO and HC) and 1971 (for NOx) models. It was clearly the Congress' intent to aid the cause of clean air by mandating levels of automotive emissions that would significantly diminish the role of the automobile from the pollution picture. In 1977, the Act was "fine tuned" by Congress, delaying and slightly relaxing the auto standards, imposing similar requirements on trucks, and specifically mandating in use directed vehicle inspection and maintenance programs in the areas with the most severe air pollution problems.

### III. The Evolution of the US Motor Vehicle Program

#### A. Emissions Standards

With passage of the Clean Air Act Amendments in 1970, the Congress knowingly imposed standards which could not then be achieved. To comply with the law, auto manufacturers were required to develop and commercialize technologies which existed only in research laboratories or on prototypes. The adoption of these "technology forcing" emissions standards for carbon monoxide, hydrocarbons and nitrogen oxides was complemented by a comprehensive regulatory structure for assuring compliance with these standards. Congress also charged EPA with responsibility to determine how vehicles were to be tested to assure compliance with standards. Standards adopted to date for automobiles (converted to 1975 FTP equivalents) are listed below:

Model Year	Hydro- Carbons	Carbon Monoxide	Nitrogen Oxides
Pre-1968	8.2	90.0	3.4
1968-1971	4.1 (50)	34.0 (62)	none
1972-1974	3.0 (63)	28.0 (69)	3.1 (9)
1975-1976	1.5 (82)	15.0 (83)	3.1 (9)
1977-1979	1.5 (82)	15.0 (83)	2.0 (41)
1980	0.41(96)	7.0 (92)	2.0 (41)
1981+	0.41(96)	3.4 (96)	1.0 (76)

( ) percent reduction from uncontrolled levels

\* not standards but approximate levels prior to adoption of standards.

All automobile standards in Table 1 have been expressed in terms of the 1975 Federal Emissions Test Procedure, which has been in effect since the 1975 Model Year.

While specific numbers were not spelled out in the law, the Clean Air Act also authorized EPA to set standards for all other categories of motor vehicles.

The technology necessary to meet the standards has been developed sufficiently that all 1983 and later model gasoline fueled cars have been "certified" to the most stringent levels. Without exception, all new gasoline automobiles sold in the US today and since the 1980 Model Year are equipped with catalytic converters and require the use of lead free fuel.

#### B. Compliance Program

In addition to the standards themselves, EPA has completed implementation of the full set of enforcement tools which Congress provided to assure compliance with those standards -- most notably, Certification, Assembly Line Testing, Recall and Warranty. When viewed in the aggregate, these compliance tools were intended to address in a comprehensive fashion the problem of controlling emissions from "properly maintained" in-use cars. They assure that attention is paid to vehicle design before mass production begins, place constraints on quality assurance on the assembly line and through the combination of recall and warranty impose a discipline on manufacturers to be concerned about emissions from in-use cars.

#### IV. Where Do We Stand Today

##### A. Current Air Quality

During 1988, over 100 areas of the country exceeded healthy levels for ozone. For carbon monoxide, 44 areas exceeded healthy levels. While there was a slight decline in the unhealthy CO areas, the ozone problem was much worse. According to EPA estimates, over 130 million Americans live in these unhealthy areas, more than half the country.

##### B. The Continuing Importance Of Transportation

During 1987, transportation sources were responsible for 40 percent of nationwide lead emissions, 70 percent of the CO, 34 percent of the volatile organic compounds (HC), 45 percent of the NOx, and 18 percent of the particulate. In some cities, the mobile source contribution is even higher. Even these contributions don't include the impact of "running losses", gasoline vapors emitted from the vehicle while it is driving. Accounting for these emissions, the vehicle contribution rises significantly. Including running losses, the overall contribution of transportation to total nationwide emissions is as illustrated in Figures 1. Compared to other individual source categories, Figures 2 and 3 show that transportation is clearly dominant.

Growth in vehicle miles travelled (as illustrated in Figure 4, vehicle miles travelled in the US is growing at approximately 25 billion miles per year.), poor control during the second half of an

automobile's life and less stringent controls on other mobile sources are offsetting the overall gains from the automobile standards. Without additional vehicle control, therefore, it is just a question of time until motor vehicle emissions begin to increase again.

The speed with which future increases will occur and the steepness of the increase depends in large part on future growth rates in vehicle miles travelled as illustrated in Figures 5, 6 and 7 for NOx, HC and CO. Since VMT growth is currently increasing more rapidly than over the past few years, greater vehicle control per mile driven will be needed to offset these increases.

#### V. These Pollutants Cause Adverse Effects

Vehicle emissions cause or contribute to adverse health effects in many individuals, in addition to harming terrestrial and aquatic ecosystems, causing crop damage, and impairing visibility. Some of these effects will be described below.

##### A. Carbon Monoxide

Over 90 percent of the carbon monoxide emitted in cities generally comes from motor vehicles. (During the Winter, wood burning stoves are an important additional source in some areas.) Because the affinity of hemoglobin in the blood is 200 times greater for carbon monoxide than for oxygen, carbon monoxide hinders oxygen transport from blood into tissues. Therefore, more blood must be pumped to deliver the same amount of oxygen. Numerous studies in humans and animals have now demonstrated that those individuals with weak hearts are placed under additional strain by the presence of excess CO in the blood. For example, in a recent assessment conducted under the auspices of the Health Effects Institute and summarized at that group's 1988 annual meeting, it was concluded that "low levels of COHb produce significant effects on cardiac function during exercise in subjects with coronary artery disease." Another recent study of tunnel workers in New York City found that "exposure to vehicular exhaust, more specifically to CO, in combination with underlying heart disease or other cardiovascular risk factors could be responsible for a very large number of preventable deaths."

##### B. Tropospheric Ozone

The most widespread air pollution problem in areas with temperate climates is ozone, one of the photochemical oxidants which results from the reaction of nitrogen oxides and hydrocarbons in the presence of sunlight. Many individuals exposed to ozone suffer eye irritation, cough and chest discomfort, headaches, upper respiratory illness, increased asthma attacks, and reduced pulmonary function.

Further, studies presented at the 1988 US/Dutch Symposium on ozone indicate that healthy young children suffer adverse effects from exposure to ozone at levels below the current air quality standard.

Numerous studies have also demonstrated that photochemical pollutants inflict damage on forest ecosystems and seriously impact the growth of certain crops. Finally, tropospheric ozone is a greenhouse gas. Ozone absorbs infrared radiation and increased ozone concentrations in the troposphere will contribute to climate modification.

### C. Oxides of Nitrogen

In addition to their role in causing ozone, NO<sub>x</sub> emissions from vehicles and other sources produce a variety of adverse health and environmental effects.

Exposure to nitrogen dioxide (NO<sub>2</sub>) emissions is linked with increased susceptibility to respiratory infection, increased airway resistance in asthmatics, and decreased pulmonary function. Short term exposures to NO<sub>2</sub> have resulted in a wide ranging group of respiratory problems in school children (cough, runny nose and sore throat are among the most common) as well as increased sensitivity to urban dust and pollen by asthmatics.

Oxides of nitrogen have also been shown to affect vegetation adversely. Some scientists believe that NO<sub>x</sub> is a significant contributor to the dying forests throughout central Europe. This adverse effect is even more pronounced when nitrogen dioxide and sulfur dioxide occur simultaneously.

Acid deposition results from the chemical transformation and transport of sulfur dioxide and nitrogen oxides. Recent evidence indicates that the role of NO<sub>x</sub> may be of increasing significance with regard to this problem. Several acid deposition control plans have therefore targeted reductions in NO<sub>x</sub> emissions in addition to substantial reductions in sulfur dioxide. Furthermore, the ten participating countries at the 1985 International Conference of Ministers on Acid Rain committed to "take measures to decrease effectively the total annual emissions of nitrogen oxides from stationary and mobile sources as soon as possible". One result has been the recent NO<sub>x</sub> protocol freezing emissions at 1987 levels by 1994; several European countries have additionally committed to a 30 percent reduction.

### D. Toxic Emissions

Toxic emissions from mobile sources are a serious problem. While substantial improvements in certain toxics have resulted as a by-product of the overall motor vehicle pollution control program - lower exhaust benzene and polynuclear aromatics (PNA's) from catalysts, lower diesel organics from particulate controls, mobile sources remain a substantial contributor to the overall health risks associated with air toxics. A variety of studies have found that in individual metropolitan areas, mobile sources are one of the most important and possibly the most important source category in terms of contributions to health risks associated with air toxics. For example, according to the US EPA, mobile sources may be responsible



for between 629 and 1874 cancer cases per year. Potentially significant toxics from mobile sources will be reviewed below.

### 1. Diesel Particulate

Uncontrolled diesels emit approximately 30 to 70 times more particulate than gasoline-fueled engines equipped with catalytic converters and burning unleaded fuel. Virtually all of these particles are small and respirable (less than 2.5 microns) and consist of a solid carbonaceous core on which a myriad of compounds adsorb. These include:

- \* unburned hydrocarbons
- \* oxygenated hydrocarbons
- \* polynuclear aromatic hydrocarbons
- \* inorganic species such as sulfur dioxide, nitrogen dioxide and sulfuric acid.

These emissions may cause cancer and exacerbate mortality and morbidity from respiratory disease. As noted in "the Harvard project" "most of the toxic trace metals, organics, or acidic materials emitted from automobiles or fossil fuel combustion are highly concentrated in the fine particle fraction". Recently, health experts in Germany concluded that occupational exposures to diesel particulate reflect a cancer risk in the workplace. Also in 1988, the Swedish National Institute of Environmental Medicine noted:

"One occupational group with exposure to diesel exhaust is forklift truck drivers, and a considerable number of studies of such truck drivers have been carried out...nine of these showed a statistically significant association between exposure to diesel exhaust and lung cancer. Several of the studies which did not produce any statistically significant results showed a tendency to increased incidence of lung cancer. As a whole, these studies suggest that there is an excess risk of lung cancer among such truck drivers in the order of 30 to 50%."

### 2. Aldehydes

Formaldehyde and other aldehydes are emitted in the exhaust of both gasoline- and diesel-fueled vehicles. Formaldehyde is of particular interest both due to its photochemical reactivity in ozone formation and suspected carcinogenicity. Formaldehyde can also be a short-term respiratory and skin irritant, especially for sensitive individuals. Aldehyde exhaust emissions from motor vehicles correlate reasonably well with exhaust hydrocarbon (HC) emissions, and diesel vehicles generally produce aldehydes at a greater percentage rate of total HC emissions than gasoline vehicles. Formaldehyde can also be generated by photochemical reactions involving other organic emissions.

### 3. Benzene

Benzene is present in both exhaust and evaporative emissions. Several epidemiology studies on workers have identified benzene as a carcinogen causing leukemia in humans. Mobile sources (including refueling emissions) dominate the benzene emission inventory in most countries. For example, according to the US EPA, roughly 70.2% of the total benzene emissions come from vehicles. Of the mobile source contribution, 70% comes from exhaust and 14% from evaporative emissions.

### 4. Non-Diesel Organics

Gasoline-fueled vehicles emit far less particulate than their diesel counterparts. However, the mutagenicity of the gasoline soluble organic fraction (SOF) per mass of particulate collected, is greater than diesel SOF. Because gasoline fueled vehicles accumulate so much travel, the overall impact from gasoline particulate might be significant. It should be noted that the emissions factors and unit risk estimates for gasoline particulate are far more uncertain than those for diesel fueled vehicles.

### 5. Asbestos

Asbestos is used in brake linings, clutch facings and automatic transmissions. About 22 percent of the total asbestos used in the US in 1984 was used in motor vehicles. Health impacts of asbestos exposure have been known for some time, including cancer, asbestosis, and mesothelioma.

### 6. Metals

Toxicological impacts of metals, especially heavy metals, have been studied for some time. In addition, many are now being analyzed for their carcinogenic potential, including several for which unit risk values have been published. EPA has identified mobile sources as a significant contributor to nationwide metals inventories including 1.4% of beryllium and 8.0% of nickel. The California Air Resources Board is also analyzing these metals as mobile source pollutants, as well as arsenic, manganese and cadmium. Because of a relatively high unit risk value, emissions of chromium may also be a concern although the health risk tends to be associated with hexavalent chromium which doesn't appear to be prevalent in mobile source emissions.

### 7. Conclusions Regarding Toxics

Unregulated mobile source emissions represent a potentially significant source of toxic compounds. Fortunately, control of exhaust and evaporative hydrocarbons generally lowers toxic emissions as well; catalytic converters tend to selectively eliminate a greater proportion of the more biologically active compounds and therefore are very beneficial for toxic control. However, metallic additives are not desirable because of potential toxic effects and in some

cases carcinogenicity. Further, while alcohol fuel blends are of some benefit for exhaust emissions, they may actually increase aldehydes. Neat methanol has the potential to substantially lower toxic emissions from diesel and gasoline fueled vehicles.

#### E. Motor Vehicles and Global Warming

A major environmental concern which has emerged during the last few years is the emergence of global warming or the greenhouse effect as a major international concern. Pollutants associated with motor vehicle use (e.g., CO, CH, NO, etc.) can increase global warming by changing the chemistry in the atmosphere in ways that either allow more of the sun's hot rays to reach the surface of the planet or reduce the ability of these rays to escape. These "greenhouse gases" have been shown to be accumulating in recent years. Also the release of chlorofluorocarbons used in vehicle air conditioning equipment can destroy the protective ozone shield.

Motor vehicles already play a significant role in climate modification and have the potential to play an even greater role in the future. This conclusion would be true even if vehicles were only responsible for their HC and NOx emissions which cause high and globally increasing levels of ozone near the Earth's surface (tropospheric ozone). However, vehicles are also responsible for other important greenhouse gases including carbon monoxide (CO), carbon dioxide (CO<sub>2</sub>), and chlorofluorocarbons (CFC-11, CFC-12). On a global level, each of these gases has been increasing.

##### 1. The Role of Carbon Monoxide

Carbon monoxide emissions may be very important for climate modification. For example, hydroxyl radicals (OH) which scavenge many anthropogenic and natural trace gases from the atmosphere, are themselves removed by carbon monoxide. As summarized by Ramanathan in a recent Science article,

"The highly reactive OH is the primary sink for many tropospheric gases and pollutants including O<sub>3</sub>, CH<sub>4</sub>, CO, and NO. Hence, increases in CH<sub>4</sub>, such as those during the last century [135% increase] could have caused a substantial (20 to 40%) reduction in OH, which in turn, could cause an increase in tropospheric O<sub>3</sub> by as much as 20%. Since CH<sub>4</sub> oxidation leads to the formation of H<sub>2</sub>O, an increase in CH<sub>4</sub>, an important greenhouse gas, can lead to an increase in H<sub>2</sub>O in the stratosphere. Likewise, an increase in the CO concentration can tie up more OH in the oxidation of CO. Thus, through chemical reactions, an increase in either a radiatively active gas such as CH<sub>4</sub> or even a radiatively inactive gas such as CO<sub>2</sub> can increase the concentration of several important greenhouse gases."

The role of CO is especially significant in view of the evidence that global CO levels are now also increasing. As noted by Khalil and Rasmussen,

"the average tropospheric concentration of CO is increasing at between 0.8% and 1.4% per year, depending on the method used to estimate the trend, and the 90% confidence limits of the various estimates range between 0.5% and 2.0% per year."

## 2. Motor Vehicles and CFCs

Chlorofluorocarbons are the most radiatively active gases, now contributing about 15 to 20 percent of the total global warming effect. About 30 percent of European production of CFCs and 40 percent of the United States' is devoted to refrigeration and air conditioning. Mobile air conditioning accounted for 56,500 metric tons of CFCs -- 28 percent of the CFCs used for air conditioning and refrigeration in the United States, or about 13 percent of total production. In contrast, home refrigerators accounted for only 3,800 metric tons. Thus, approximately one of every eight pounds of CFCs manufactured in the US is used, and eventually emitted, by motor vehicles. (CFCs also are used as a blowing agent in the production of seating and other foamed products but this is a considerably smaller vehicular use.)

## 3. Motor Vehicles and Carbon Dioxide

Carbon dioxide is the other major greenhouse gas. A single tank of gasoline produces between 300 and 400 pounds of CO when burned. Motor vehicles emit almost 15 percent of the world's total CO emissions today. This quantity is directly related to the quantity of energy demanded by motor vehicles. As vehicle fuel use grows, it is likely that CO emissions will increase in the future.

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## 4. Impact On Tropospheric Ozone

It is important to note that global warming may have a significant impact on local ozone air pollution episodes. As recently pointed out,

"the increase in ultraviolet B radiation resulting from even a moderate loss in the total ozone column can be expected to result in a significant increase in peak ground based ozone levels...these high peaks will occur earlier in the day and closer to the populous urban areas in comparison to current experience, resulting in a significant, though quantitatively unspecified, increase in the number of people exposed to these high peaks."

## F. Conclusions

Motor vehicle emissions, therefore, can be seen as a major source not only of adverse health and other environmental effects from ground level pollution but also a significant and growing contributor to climate modification. In addition, tropospheric pollution and climate modification have been found to be directly linked by a variety of mechanisms related to motor vehicle emissions. To deal with these problems in a coordinated fashion requires the simultaneous minimization of carbon monoxide, carbon dioxide, hydrocarbons, nitrogen oxides and chlorofluorocarbons.

## VI. Potential Strategies For Additional Control

Figures 8, 9 and 10 illustrate the potential emission reduction benefits which could occur in the future from a variety of alternative strategies which have been suggested.

### A. Oxides of Nitrogen

Tightening the auto standard from the current 1.0 gram per mile to 0.4 (the current California standard) by 1993 and requiring the standard to be met for 100,000 miles starting in the 1995 Model Year, will reduce emissions by about 35%. Enhanced I/M will add another 10% reduction and adoption of the so called Stage 2 standard, 0.2 grams per mile, by the year 2000 would add another 10%, thereby increasing the overall reduction to 55%.

### B. Hydrocarbons

Not surprisingly, adoption of onboard HC refueling controls (OBD) and 9.0 RVP gasoline would help substantially; adoption of 9.0 lb. RVP would lower HC from cars by 23% and onboard refueling HC controls by another 10 percent. Tightening the standard from the current 0.41 gram per mile to 0.25 by 1993 and requiring the standard to be met for 100,000 miles starting in the 1995 Model Year, will reduce emissions by about the same as onboard, 10%. Enhanced I/M will add another 10% reduction and adoption of the so called Stage 2 standard, 0.125 grams per mile, by the year 2000, will increase the reduction by another 5% for a total of 58%.

### C. Carbon Monoxide

Adoption of 9.0 RVP gasoline would lower CO from cars by 20%. Extending the useful life to 100,000 miles starting in the 1995 Model Year will reduce emissions by another 15%. Enhanced I/M will add another 20% reduction and adoption of the so called Stage 2 standard, 1.7 grams per mile by the year 2000 will increase the reduction to 58%.

### D. Conclusions Regarding Vehicles

- 1) Without further controls, emissions from cars will bottom

out during the next decade and start to increase shortly thereafter; by 2010, auto emissions will be generally as high or higher than at present.

- 2) Even this assessment may understate the seriousness of the problem as it doesn't account for driving under conditions of lower temperatures or higher speeds beyond those encountered during the official EPA test procedure. Further, it doesn't account for the increased congestion which will inevitably occur in many cities as a result of the increased growth in vehicle miles travelled which is occurring.
- 3) Further tightening of exhaust standards, extending the useful life to reflect actual real world lifetimes, less volatile gasoline, onboard hydrocarbon refueling control and enhanced I/M would each bring about significant reductions from the base case which would otherwise occur and implemented together could cut existing auto pollution levels in half.

## VII. Carbon Dioxide Standards

### A. The Importance Of Motor Vehicles

#### 1. Overall Historical Trends

Since 1950, the average annual growth rate for cars worldwide has been 5.9 percent; for trucks and buses, it has been only slightly less, 5.6 percent per year. Most recently the trends have remained quite high but commercial vehicles have actually been growing more rapidly than cars. For example, since 1970, annual car growth has averaged 4.7 percent per year while truck and bus registrations averaged 5.1 percent per year. Overall, as a result of this growth, the total worldwide vehicle population in 1985 was 500 million, with cars just slightly under 400 million.

#### 2. The Current Fleet

Europe and North America each have slightly more than a third of the world's car population, with the remainder divided between Asia, South America, Oceania and Africa, in that order. With regard to trucks and buses, North America has about 40 percent followed closely by Asia and then Europe.

It is important to emphasize the dominant role of North America as a potential vehicle market. While the percentage growth in vehicle production is quite high in other countries and to a lesser extent the percentage growth in vehicle registrations is also quite high, the "highly industrialized" US market is so large as to dominate the world and it is likely to continue to do so for the foreseeable future. The significance of this is that to a large extent, vehicle characteristics in the US will have a significant impact on vehicle characteristics in other areas. For example, it seems likely that

increased stringency of emissions or fuel economy requirements in the United States would lead to similar improvements in other vehicle markets, especially those where vehicle production is increasing with an eye toward export to the highly industrialized markets. The converse is, of course, also true - weak requirements in the US likely means weak controls in the developing areas.

Beyond new vehicles, it also appears that much of the vehicle population growth in some rapidly industrializing, developing countries comes from imports of used vehicles from highly industrialized areas. In this way also, therefore, fundamental designs which are either high or low in emissions or fuel consumption are perpetuated and can increase or decrease overall emissions and fuel consumption in these rapidly industrializing countries.

## B. Fuel Consumption and CO Emissions

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### 1. The Fuel Consumption Experience

Auto fuel economy in the US rose during the 1970's but has remained fairly flat since the early 1980's. It is important to note that during the 1970's when emissions standards were substantially tightened, average miles per gallon improved substantially. (This observation is also true even if fuel economy improvements due to vehicle weight reductions are not included.) However, during the 1980's when vehicle emission standards have generally stabilized, fuel economy gains have been minimal. Further, without the stimulus of regulatory requirements or market incentives due to higher fuel prices, manufacturers quickly reverted to historical patterns of competing on the basis of horsepower and acceleration rather than fuel economy or emissions. The lesson seems to be that, just as with emissions, stringent regulation is the surest path to the desired goal.

On a worldwide basis at present very little if any fuel efficiency improvement is occurring. The governmental push of the late 1970's and early 1980's has stalled and market competition now appears to be focused primarily on performance improvements rather than fuel economy gains. The significance of this for global CO is that motor vehicle CO emissions will skyrocket over the next forty to fifty years. Modest improvements on the scale of 1 percent per year would barely reduce this growth and certainly not reverse it.

### 2. Carbon dioxide

Overall, the transport sector uses approximately 56 quads of energy each year. The consumption varies considerably between regions of the world, with the US far and away the largest consumer, using over 35% of the world's transport energy. Transport consumes almost one-third of the total energy consumed in the world, again highly variable by region.

Because of this high overall energy consumption, it is not surprising

that motor vehicles emit over 1100 Tg of carbon, approximately 25 percent of the world's output; in the US, transport is responsible for almost 30 percent of the total CO emissions. The US accounts for more than one third of the global transport budget, emitting almost as much CO from the transport sector as Eastern Europe, Asia, China, Africa, Latin America and the Middle East combined. In fact, the CO emissions in the US from the transport sector alone exceed total CO emissions from all sources in all of Latin America, or all of Africa and most individual countries of eastern Europe.

### C. Linkage Between CO and Conventional Pollutants

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Experience gained during the 1970's and 1980's in the US suggests that the dual goals of low emissions (CO, HC and NOx) and improved energy efficiency (and therefore lower CO) are not only compatible but mutually reinforcing as illustrated in Figure 11.

In spite of this historical record, some argue that it would be a mistake to tighten tailpipe standards for conventional pollutants such as CO, HC and NOx, because such standards will lead to increased fuel consumption (and therefore carbon dioxide and global warming). To investigate this issue, a data set of 1989 model year cars was obtained from EPA. The test car list data includes test measurements of HC, CO, NOx and CO for 891 1989 model cars including nearly all combinations of engine, transmission and test weights for most car models.

Data from these vehicles were analyzed by carrying out a linear regression with the CO emissions in grams per mile as the dependent variable and NOx, HC or CO emissions in grams per mile as the independent variable.

The resulting regression equations are as follows:

$$\text{CO} = 23.9 \times \text{NOx} + 371.12$$

$$\text{CO}_2 = 638.3 \text{ HC} + 270.3$$

$$\text{CO}_2 = 26.1 \text{ CO} + 337.45$$

2

The equations suggest that, in fact, carbon dioxide emissions will tend to go down as NOx, HC or CO are reduced. This result tends to support the observation that more stringent emissions standards tends to encourage the more advanced air fuel and spark management systems with the result that overall fuel economy also tends to improve.

### VIII. COLD TEMPERATURE CO

The current EPA test procedure was designed to test emissions during a trip to work in Los Angeles during a temperature regime of high photo-oxidant production. However, for CO, other factors become important. Cold engine choking to assure starting increases both CO and HC emissions; at colder temperatures, this is even more



important. Heavily congested traffic leads to lower speeds and greater stop and go conditions, leading to higher engine out CO and HC emissions and slower catalyst light off. As a result, the overall CO reductions under the conditions of most concern are substantially less than the 90 percent intended. EPA presented an analysis at its CO workshop last year which indicated that the CO problem in many areas may not improve in the future because emissions are not adequately controlled under CO specific conditions.

In 1970, Congress intended a 90 per cent reduction throughout the range of operating conditions reflective of serious air pollution problems. To carry out this intent, EPA should issue regulations which specifically mandate a 90 percent reduction from 1970 vehicles throughout a temperature range of 20 to 80 degrees F. These cold temperature CO requirements should apply equally to all gasoline vehicles i.e., the same percentage reduction should be required from 20 degrees F to 80 degrees F as is required under normal EPA test conditions.

Beyond CO increases, it should be noted that rich A/F excursions typical of cold temperature operation can also increase benzene, H S, and other unregulated emissions.

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#### IX. Stringent US Controls Benefit The World

By taking advantage of light duty vehicle emission control advances which have occurred, and by fostering developments in heavy duty controls, more stringent vehicle standards, of course, are primarily addressed at improving the US environment; however, they will also enable many other countries to also improve and since many environmental problems transcend national boundaries, they should help to improve our global environment.

Because of the tremendous worldwide growth in vehicles, the proportion of the world experiencing serious environmental problems from motor vehicle emissions continues to increase. Just as in highly industrialized areas of the world, many rapidly industrializing areas are now starting to note unhealthy air quality levels. Cities such as Sao Paulo, Seoul, Mexico City, Singapore, Hong Kong, Manila, Bangkok, Taipei and Beijing are each starting to experience unacceptable air quality or are projecting that they will in the relatively near future.

Fortunately, in large measure due to the US motor vehicle control program, technologies have been developed which have made it possible to dramatically lower emissions from cars and increasingly countries around the world have been taking advantage of them. For example, most of Western Europe is on the verge of adopting similar controls while some countries such as Austria, Switzerland and Sweden already have. The Netherlands and the Federal Republic of Germany have adopted innovative economic incentive approaches to encourage purchase of low pollution vehicles. Canada has implemented US standards and Mexico will start to introduce them in 1991. Other

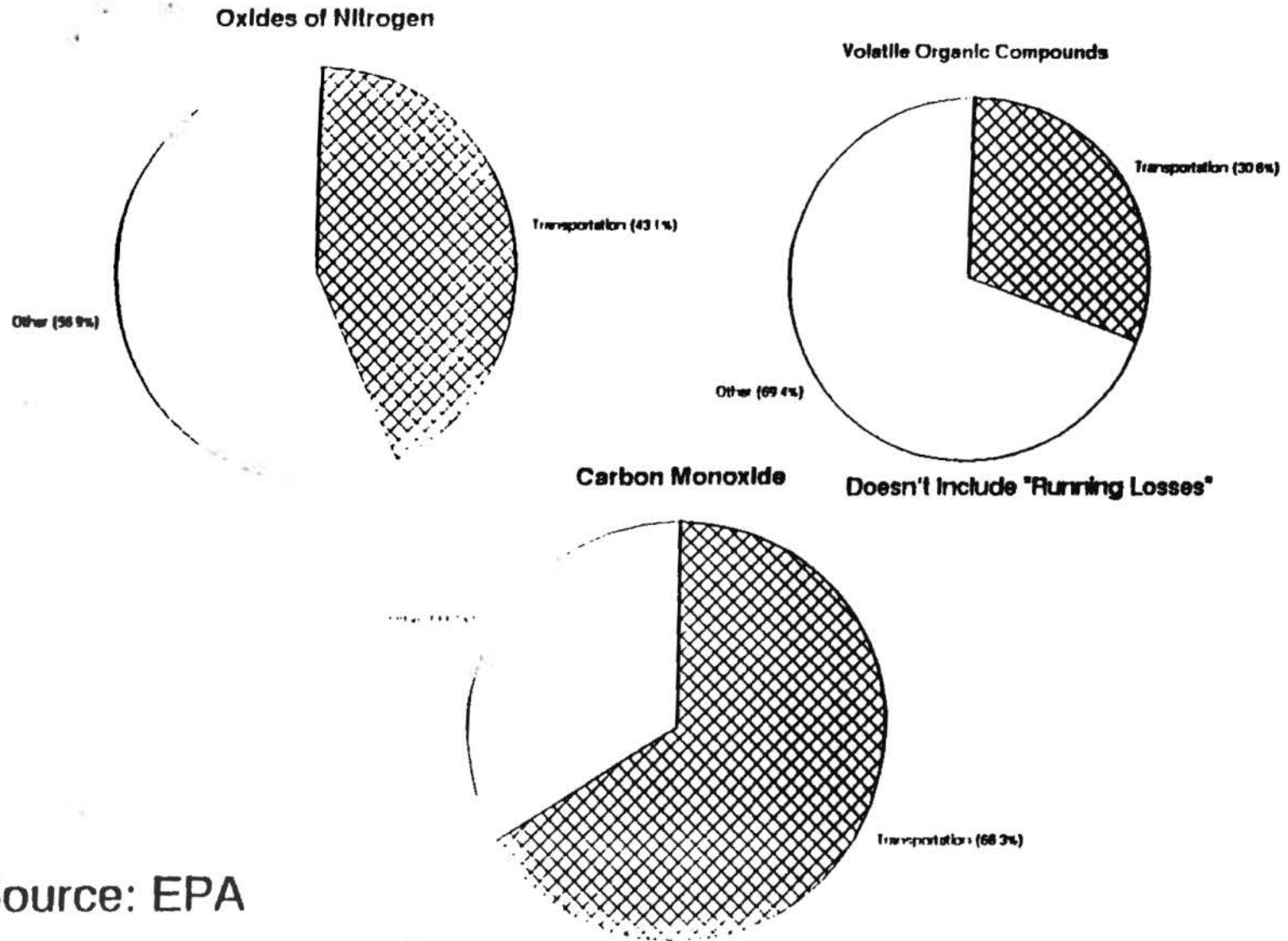
rapidly industrializing, developing countries such as Brazil, Taiwan and South Korea have also adopted stringent emissions regulations.

Continuing progress in developing lower polluting vehicles in the US, therefore has the potential to significantly improve the environment in many other parts of the world in addition to the US. One side benefit for the US is that since more and more of the serious environmental challenges which we are starting to address transcend US national boundaries (e.g., long range transport problems, global warming, etc.), improvements in other countries will also tend to improve our environment.

#### X. Conclusions

It has been twelve years since the Clean Air Act has been amended. It seems reasonable to conclude that the provisions adopted now will shape the national air pollution control effort for the remainder of this century. Improving the existing program is necessary not only to fine tune the various elements to address previously existing problems, but also to deal with a number of new and serious problems. Technological and programmatic solutions exist to address these problems but they will not be implemented and the air will not be made clean and healthy unless this Congress mandates very specific standards and steps.

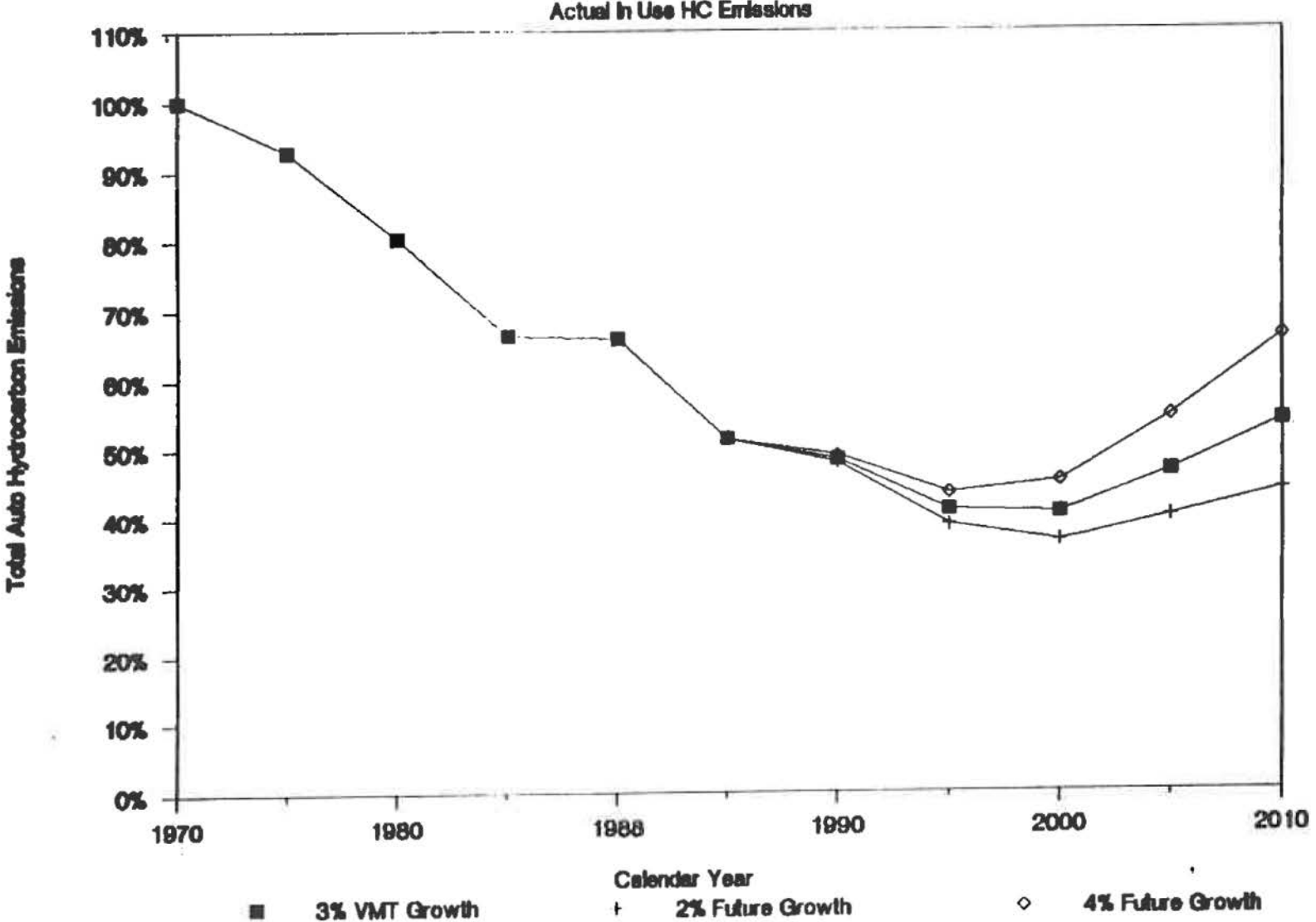
# 1987 NATIONWIDE EMISSIONS FROM TRANSPORTATION



Source: EPA

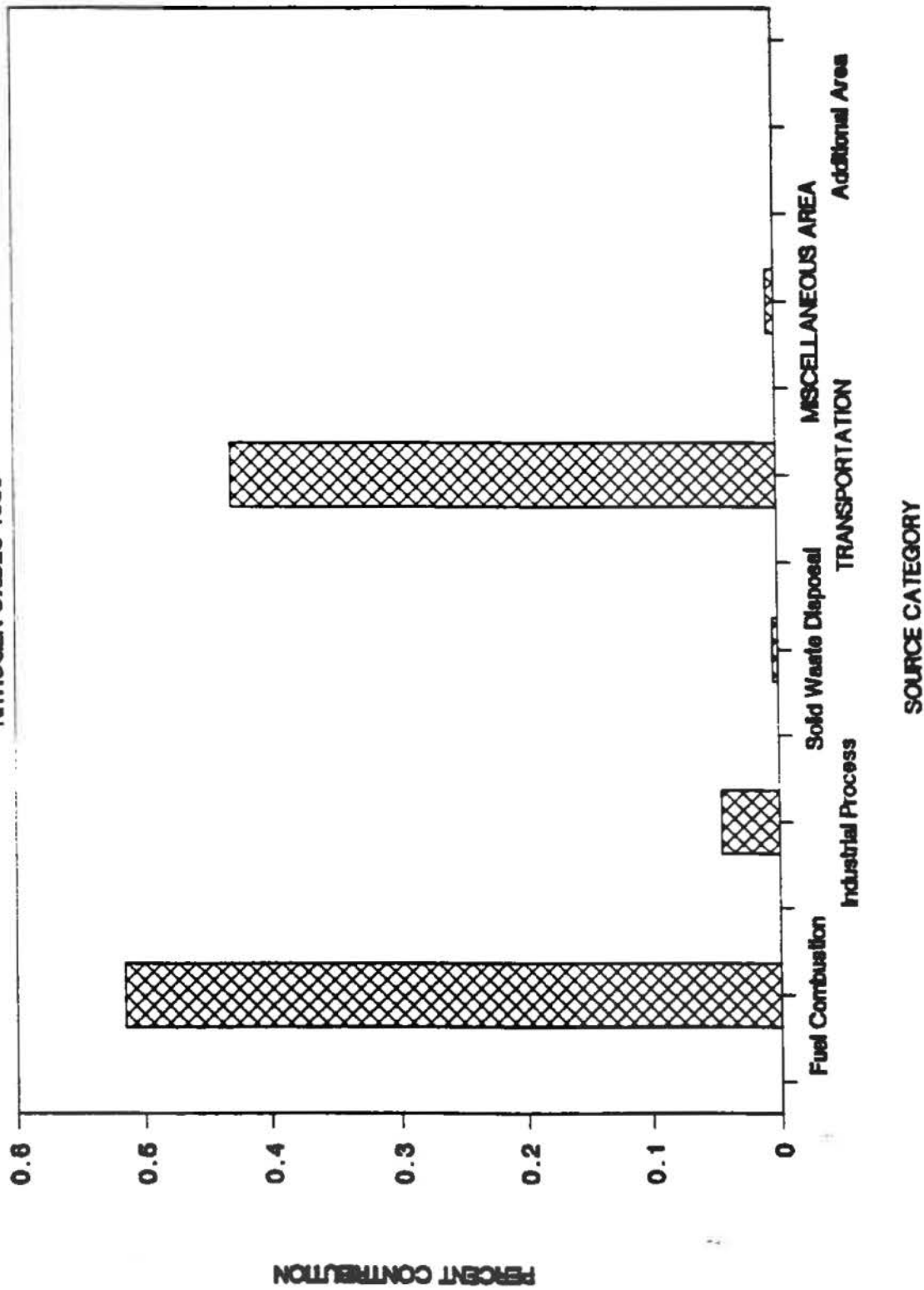
FIGURE 1

# Trends In Light Duty Vehicle Emissions



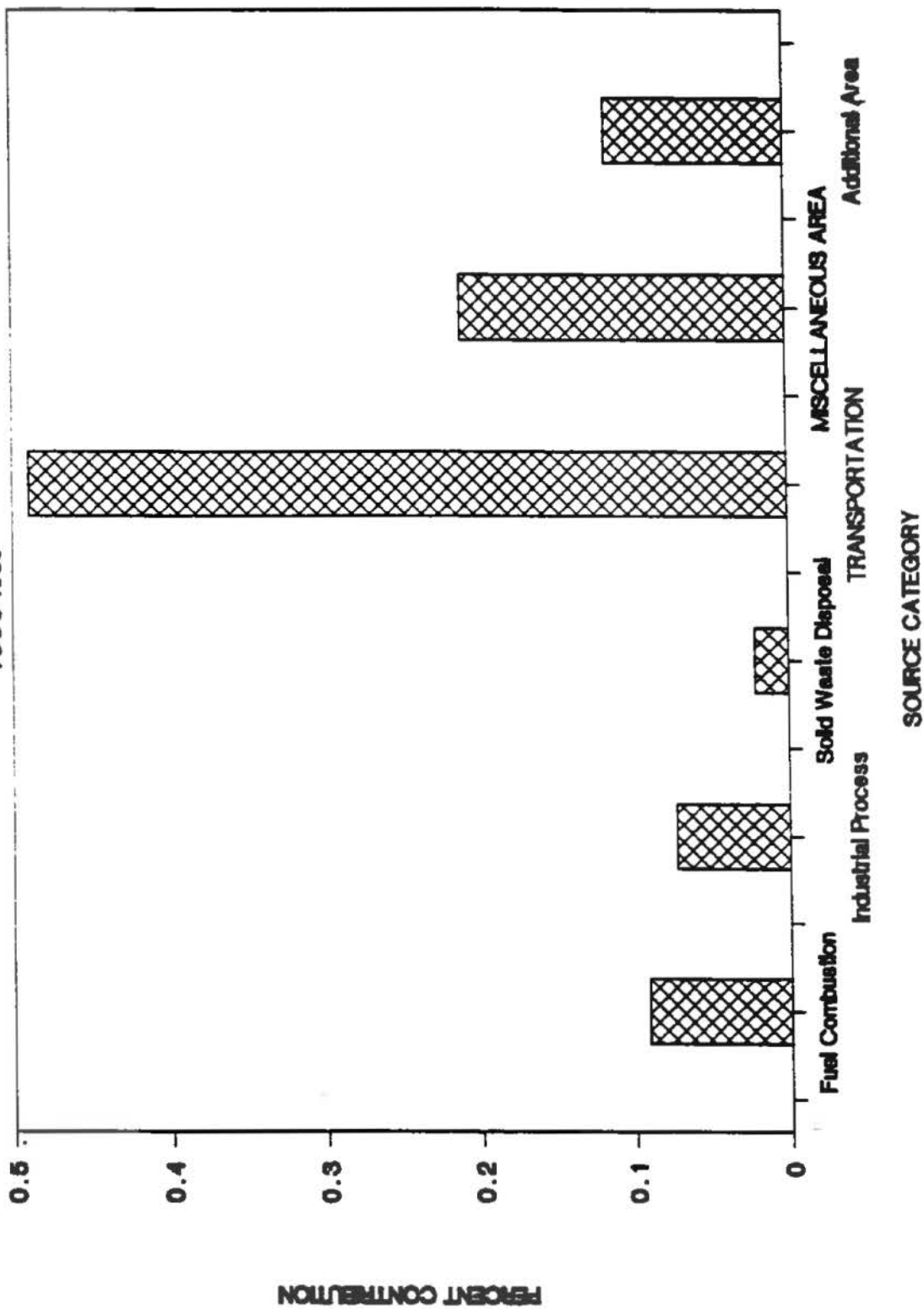
# SOURCES OF NATIONWIDE EMISSIONS

NITROGEN OXIDES 1985



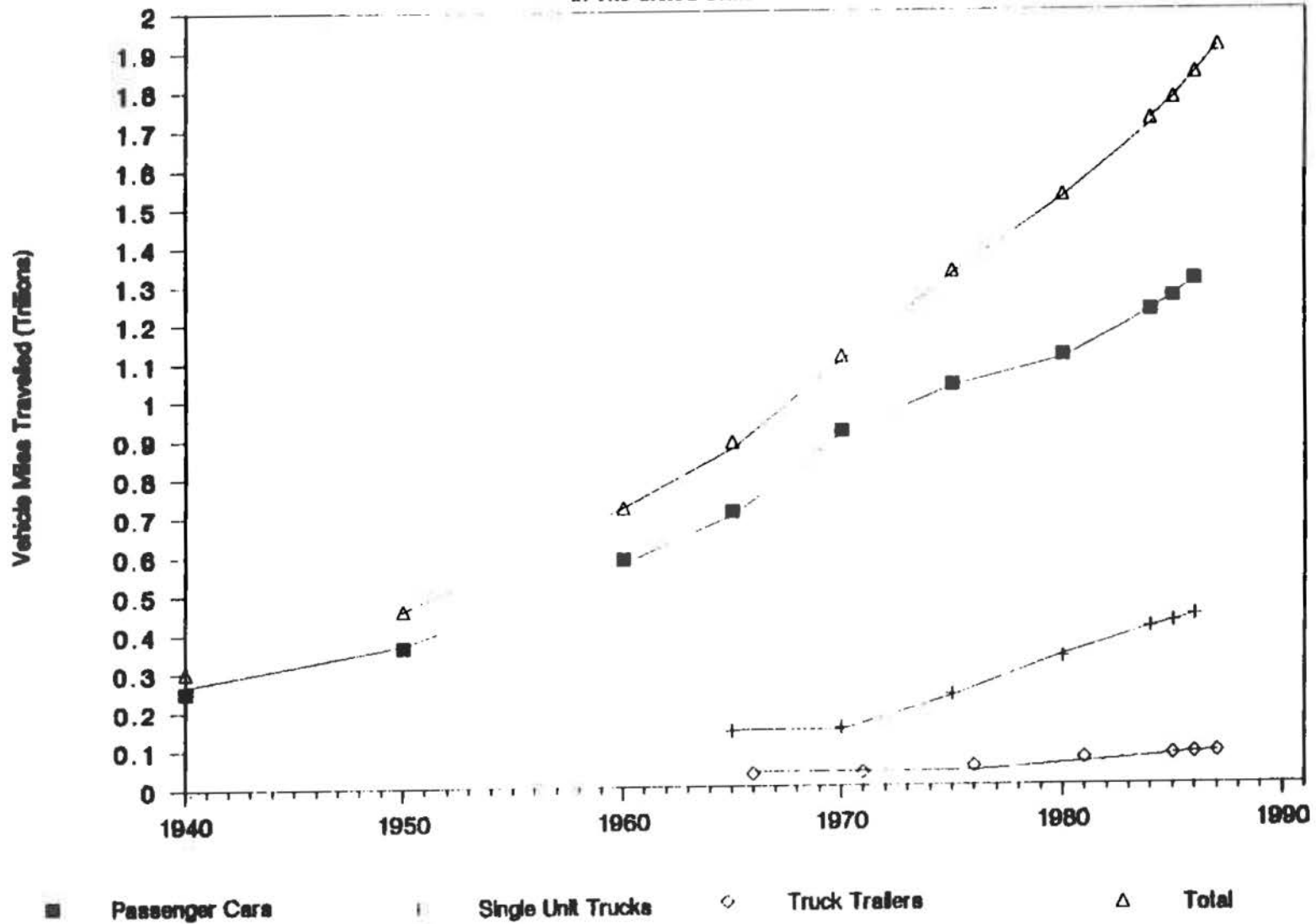
# SOURCES OF NATIONWIDE EMISSIONS

VOC's 1985

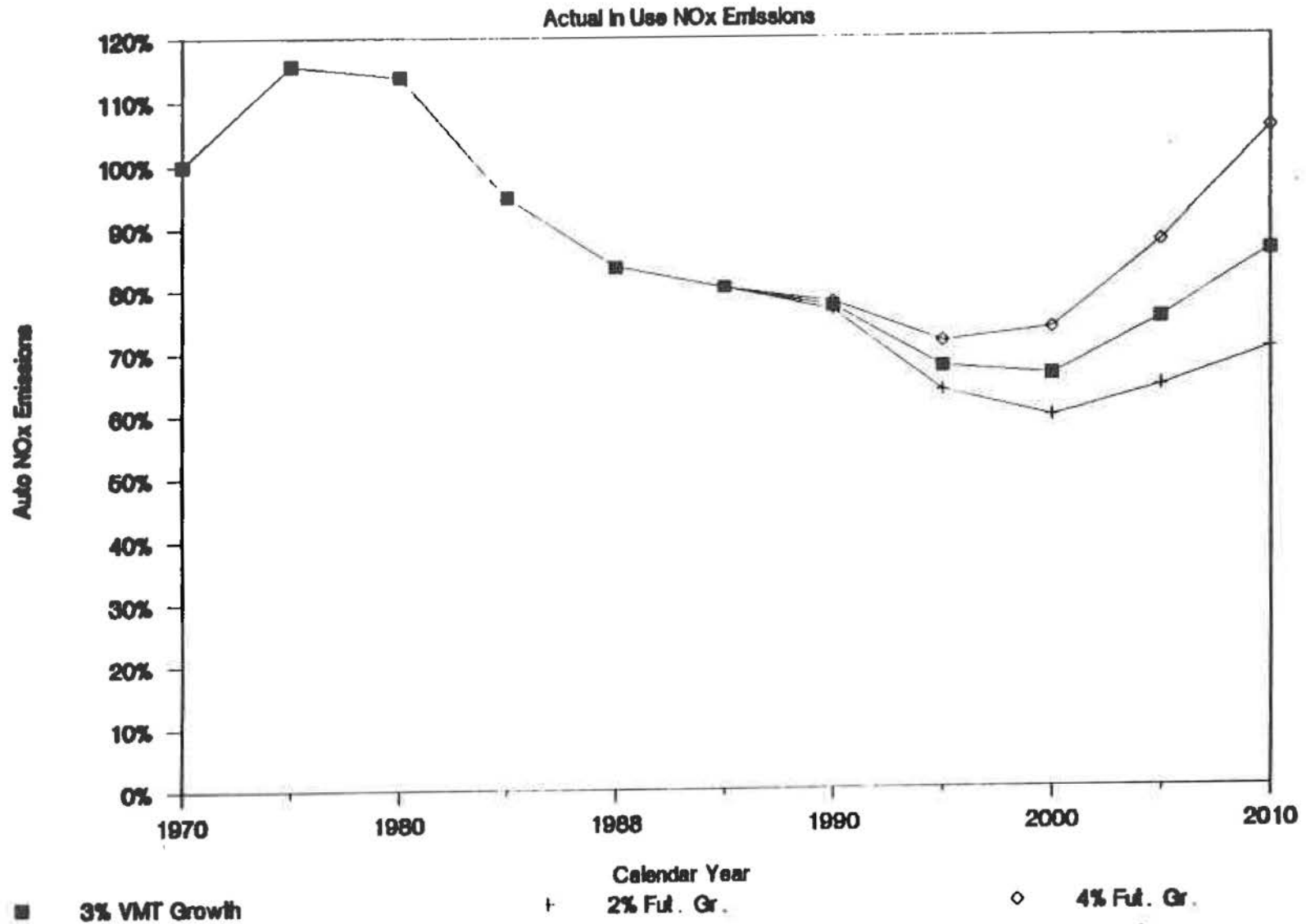


# Vehicle Miles Travelled Per Year

In The United States Alone



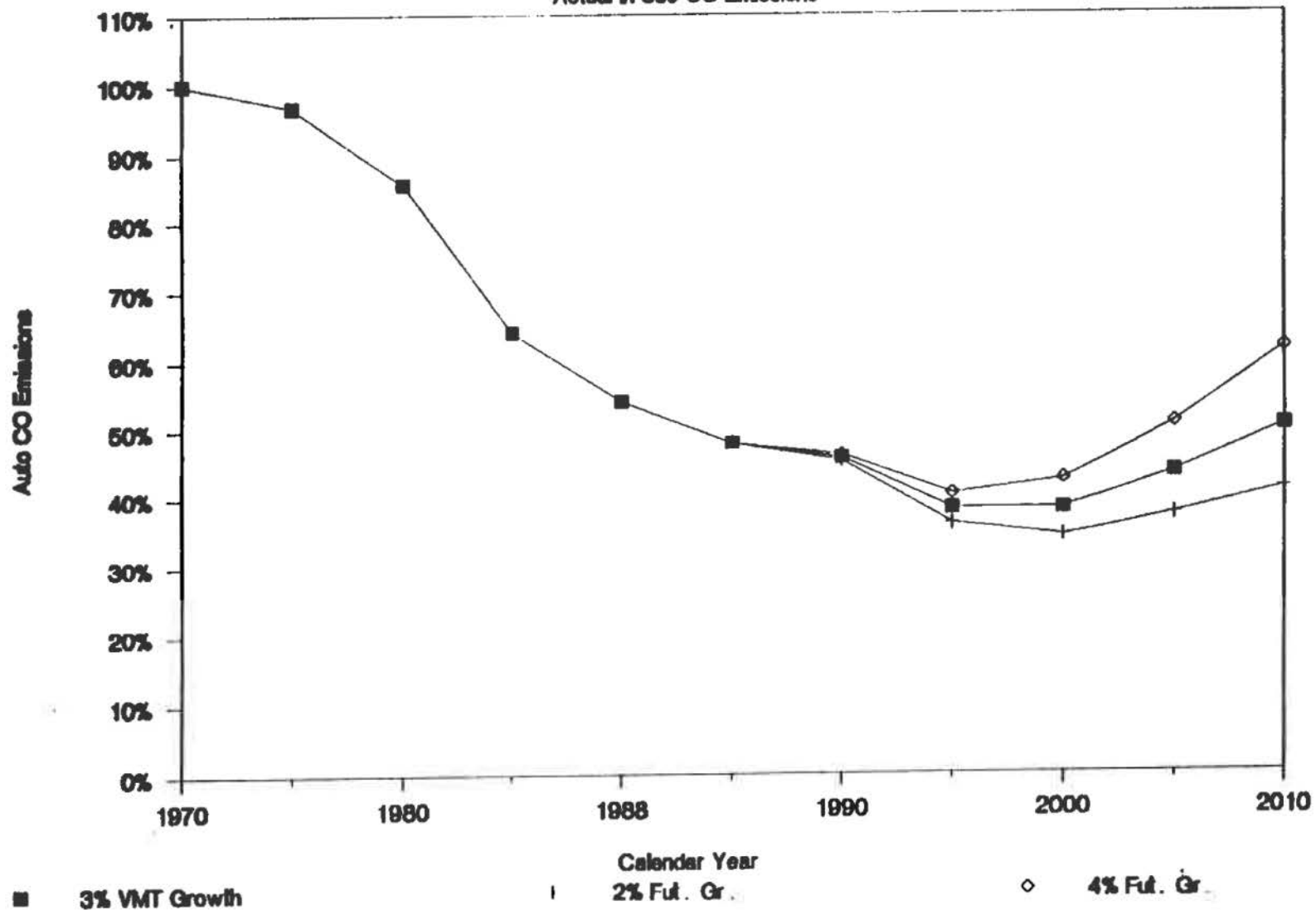
# Trends In Light Duty Vehicle Emissions



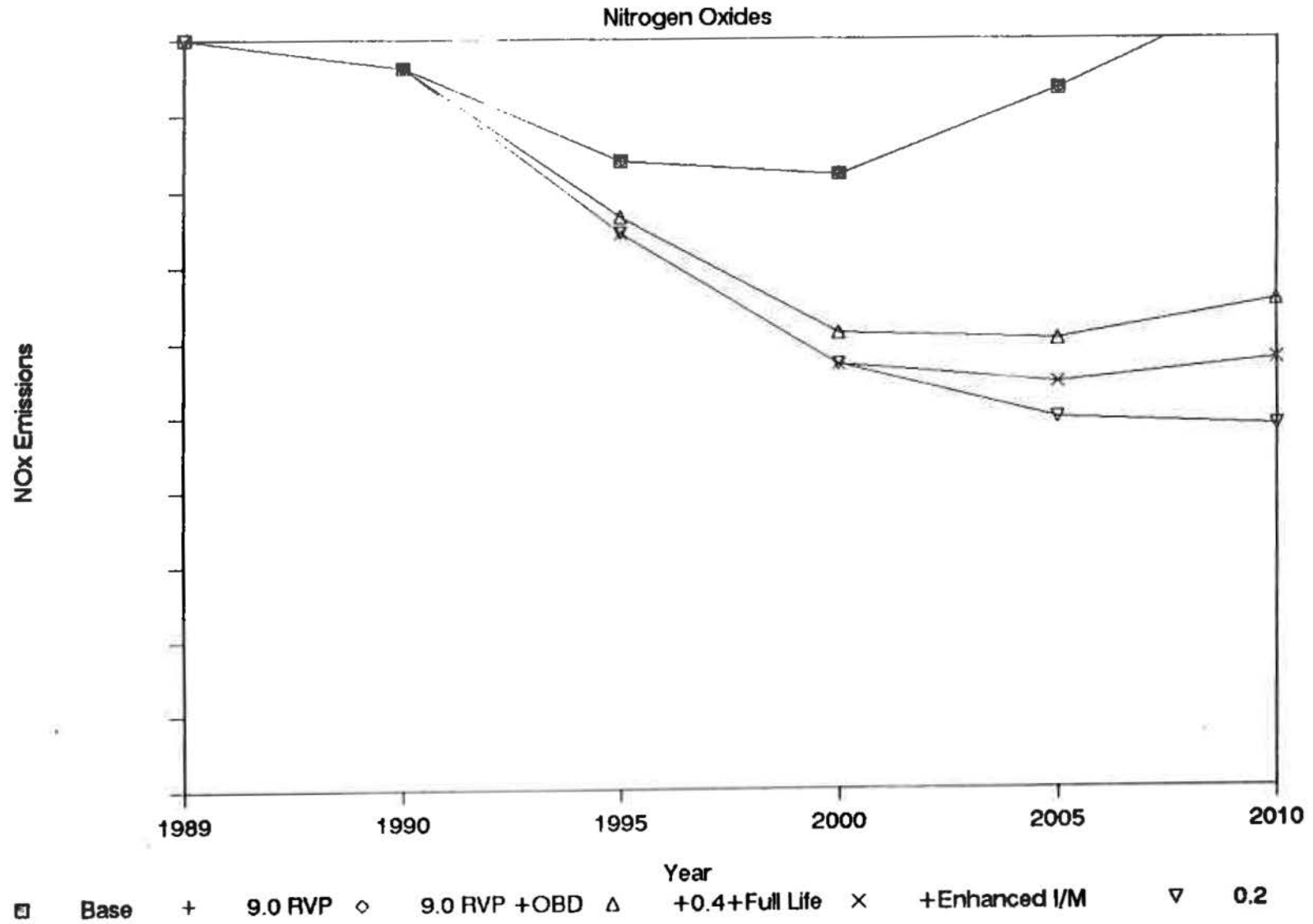


# Trends In Light Duty Vehicle Emissions

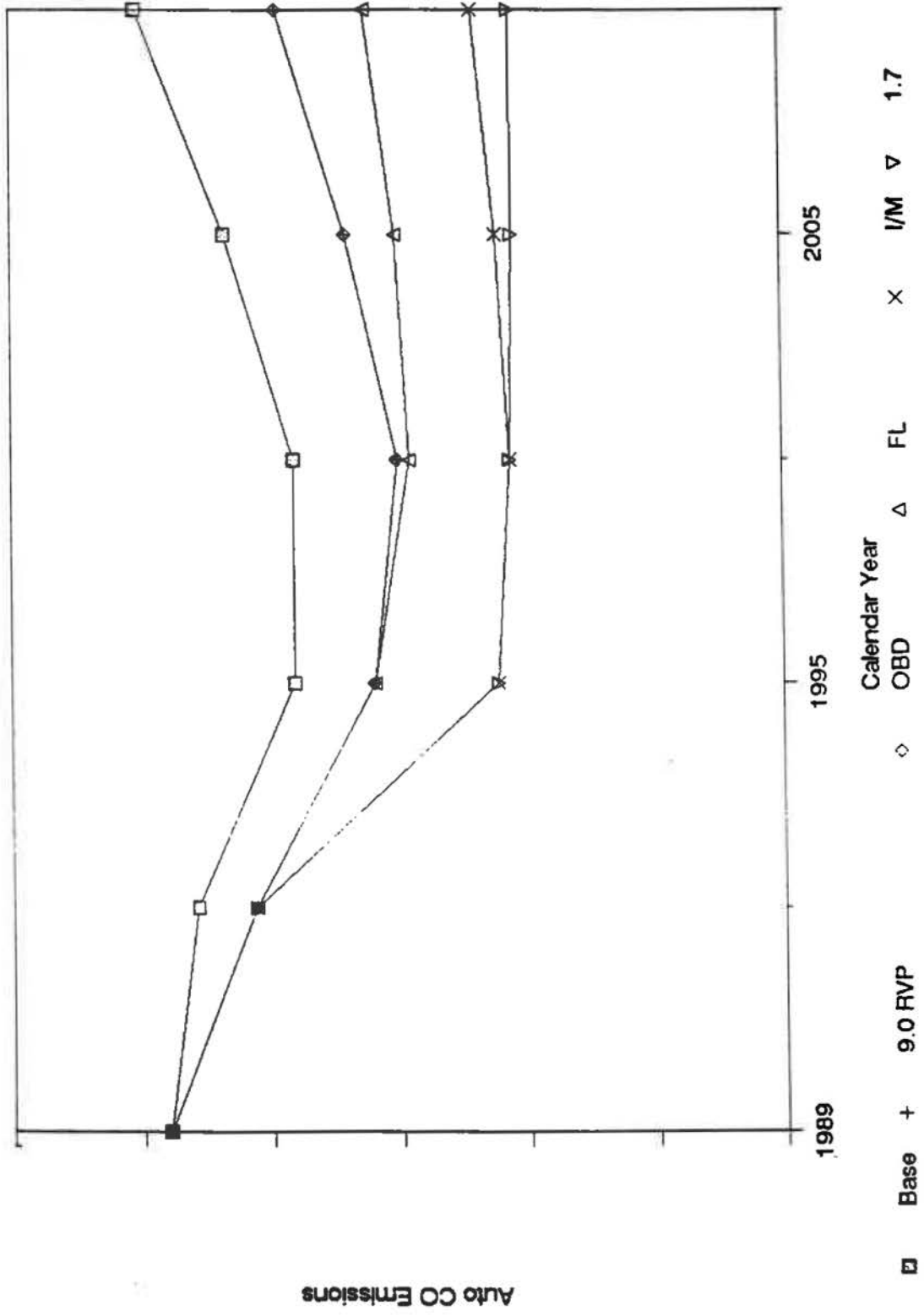
Actual In Use CO Emissions



# Future Alternative Emissions Scenarios



# Trends In Light Duty Vehicle Emissions



# Trends In Light Duty Vehicle Emissions

