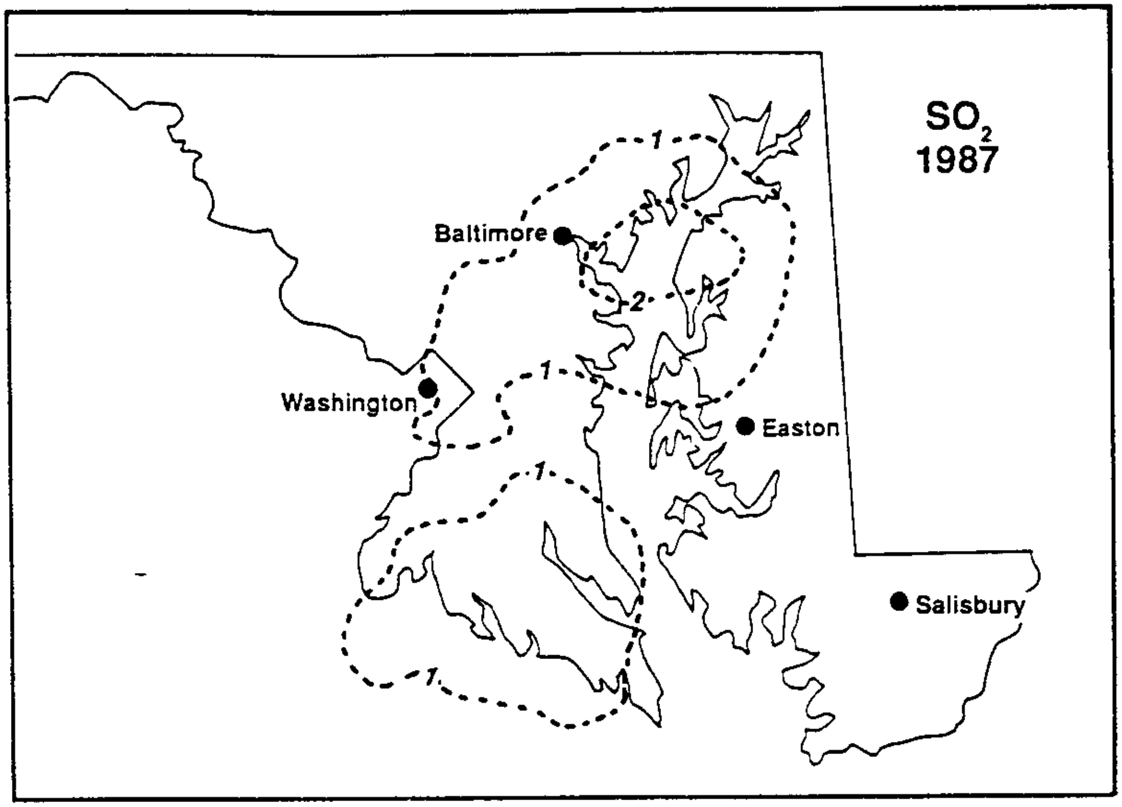

Figure 3-5. Contours of model-predicted annual SO_2 ground level concentrations for 1987 due to Maryland power plants (contour interval is 1.0 µg/m³). Maximum concentration is 3.5 µg/m³.

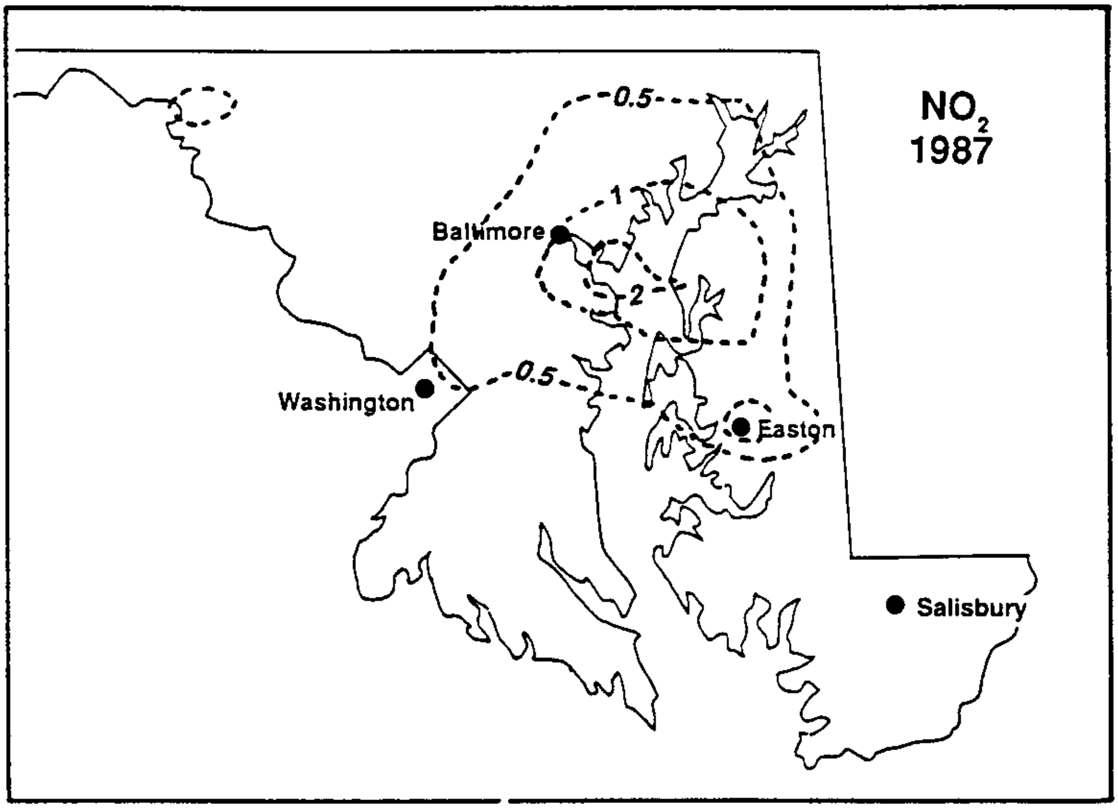

Figure 3-6. Contours of model-predicted annual NO_2 ground level concentrations for 1987 due to Maryland power plants (contour interval is 0.5 µg/m³). Maximum concentration is 2.35 µg/m³.

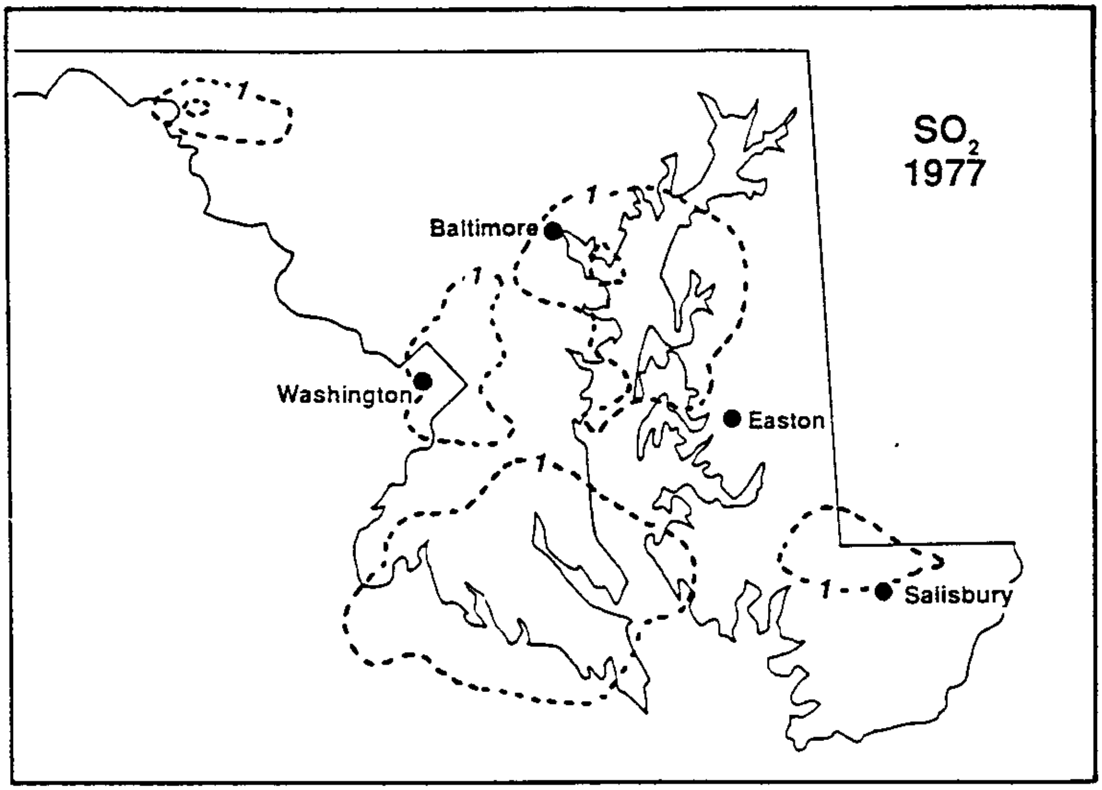

Figure 3-7. Contours of model-predicted annual SO_2 ground level concentrations for 1977 due to Maryland power plants (contour interval is 1.0 µg/m³). Maximum concentration is 4.9 µg/m³.

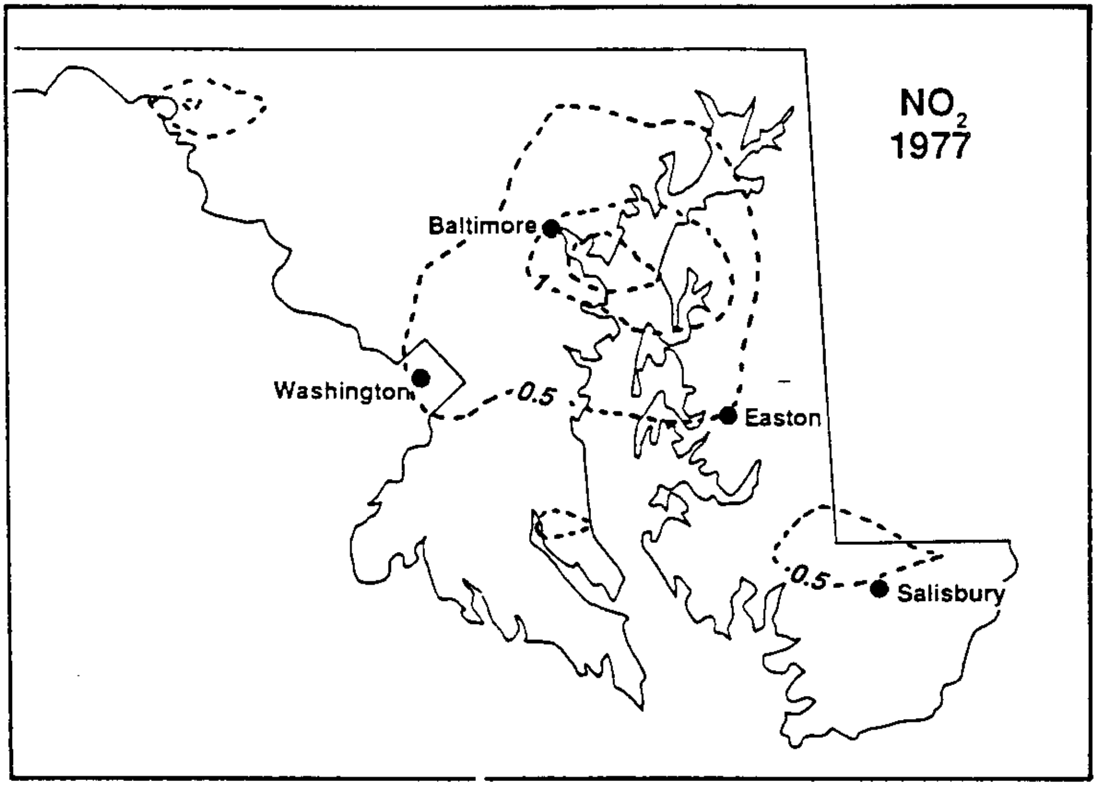

Figure 3-8. Contours of model-predicted annual NO_2 ground level concentrations for 1977 due to Maryland power plants (contour interval is 0.5 µg/m³). Maximum concentration is 2.5 µg/m³.

chemistry of these three nitrogen species is fairly complex. Generally, once in the atmosphere, NO undergoes chemical reactions with ozone and water to form nitric acid.

Compared to NO and NO_2, the quantity of N_2O formed in the combustion process is quite small. This gas is unreactive relative to other oxides of nitrogen. Notable properties of N_2O are its extremely long lifetime and its high radiative characteristics; its presence in the atmosphere is significant primarily because of its contribution to the greenhouse effect (see Section H) (Makansi 1988).

Compared to NO_x, SO_x formation is straightforward. It is almost entirely dependent on the sulfur content of the fuel, and is formed by the oxidation of the sulfur species. Natural gas is treated to remove sulfur compounds prior to its purchase by utilities, so its combustion results in a negligible amount of sulfur oxides. Oil and particularly coal often contain appreciable concentrations of sulfur compounds, so their combustion results in significant quantities of SO_x. Unless control systems are used, almost all of the sulfur in fuels is emitted as SO_2 during the combustion process. The balance of the sulfur is left in the ash or is emitted as SO_3 or sulfate particulate matter.

SO_x emissions can be reduced by add-on emissions control equipment that removes sulfur oxide from either the exhaust gas or the combustion gases. However, no Maryland utilities currently use add-on SO_x control systems. SO_x emissions from power plants in Maryland are controlled by limiting the sulfur content of the fuel.

Regulatory Factors

- Federal and State Emission Limitations

State and Federal limitations have been established for NO_x and SO_2 emissions from combustion equipment in power plants. Federal emissions limitations for both boilers and turbines are contained in the NSPS (40 CFR 60, Subparts D, Da, GG). These standards are applicable for boilers of specified size constructed after 17 August 1971 and turbines of specified size constructed after 3 October 1977. Additional NSPS were later promulgated which are specific to source type and construction date.

The current NSPS for boilers requires up to a 90 percent reduction of the uncontrolled SO_2 emissions and limits those emissions to 0.2 to 1.2 lb/MMBtu, depending on fuel type, boiler size, construction date, and the percent reduction achieved. The NSPS for turbines restricts the fuel sulfur content to 0.8 percent or SO_2 emissions to 0.015 percent by volume at 15 percent oxygen on a dry basis.

The NSPS for boilers requires control of NO_x emissions to levels of 0.2 to 0.8 lb/MMBtu depending on the fuel type, boiler size and date of construction. NOx control is also mandated for turbines, based on fuel type and the nitrogen content of the fuel.

The Code of Maryland Regulations incorporate, by reference, Federal NSPS (COMAR 26.11.06.12). MDE also has the authority to impose limitations on older fuel-burning equipment (constructed before 12 May 1972) in the metropolitan Baltimore and Washington areas (COMAR 26.11.09.08).

- Changes in PSD Requirements

Two significant changes have recently occurred in the PSD process: EPA has added an NO_2 increment and has reevaluated the manner in which BACT is determined. Air quality analyses for recently proposed power plant expansions indicate that PSD increments will ordinarily not be a major issue in the licensing of new power plants. Three existing power plants -- Dickerson, Chalk Point, and Perryman -- are all in the process of adding substantial generating capacity through the installation of gas turbines, as well as combined cycle facilities at Dickerson and Perryman. The air quality analysis requirements for these projects included modeling for NO_2 increment consumption, and the results showed the maximum predicted concentration was significantly less than the allowable increment.

By contrast, the implementation of the "top-down" BACT analysis and the revision of EPA review procedures may significantly impact utility expansion plans. By requiring the applicant (i.e., the utility) to consider all technically feasible NO_x and SO_x control technologies for new projects, the top-down BACT policy has forced the utilities to evaluate more effective, and often more costly, control alternatives than might otherwise have been considered.

Control Technologies

- NO_x Control

There are several technically feasible control technologies available to reduce NO_x emissions from fuel-burning equipment. They can be divided into two groups: modifications that can reduce the formation of NO_x during combustion; and post-combustion, or add-on, control systems. Also, the type of fuel burned has a direct influence on the quantity of NO_x formed.

One means of reducing NO_x emissions from fuel combustion sources is to control the variables of the combustion process that affect NO_x formation. For boilers, the available methods of control include minimizing the amount of excess air and reducing the peak flame temperature. The amount of excess air is usually regulated with oxygen controllers. Several techniques are available to reduce the peak flame temperature in boilers, some of which utilize low-NO_x burners, staged combustion, and flue gas recirculation. Low-NO_x burners, available for new units as well as for retrofit installations, are designed for uniform combustion. Staged combustion is achieved by creating two combustion zones, which serves to reduce the peak flame temperature. Flue gas recirculation involves mixing a portion of the post-combustion stack gases with the combustion air. These gases have higher concentrations of inert compounds, which absorb heat, thus reducing the peak flame temperature (Martin and Johnson 1984).

In gas turbines, several modifications can be made to reduce the amount of NO_x that is formed. One of these involves injecting water or steam into the combustion zone, which reduces the temperature and thereby the amount of thermal NO_x formed. In some cases, modifications are made to the combustion zone to allow the injection of more water, resulting in lower temperatures. A third control technology, called "dry combustor" technology, involves mixing the air and fuel in a premixing chamber, which also results in lower flame temperatures. This technology has not been commercially demonstrated on all combustion turbines.

Post-combustion or add-on controls are designed to remove the NO_x from the flue gas formed during combustion. One of these technologies is selective catalytic reduction (SCR), in which NO_x is chemically reduced to elemental nitrogen and water by mixing the flue gases with ammonia in the presence of a catalyst. SCR can achieve NO_x reductions of 80 to 90 percent when burning natural gas, but has potential environmental hazards associated with the required handling of ammonia (Makansi 1988). This technology has been used for several years with gas in California, and the Northeastern States for Consolidated Air Use Management has recently endorsed SCR use with gas turbines. Several installations of SCR are currently in place, or proposed to be constructed, in the Northeast and mid-Atlantic states, but there are currently none in Maryland. Installations of SCR have not been commercially demonstrated on oil-fired combustion turbines or simple cycle combustion turbines.

- SO_x Control

As discussed previously, the formation of SO_x is more straightforward than that of NO_x, since the primary variable is the concentration of sulfur in the fuel. The techniques used to control SO_x emissions fall into three categories:

- the use of fuels that contain less sulfur (accomplished by cleaning the fuel to remove the sulfur, by fuel blending, or simply by using only those fuels that contain very little sulfur);
- modifications to conventional combustion techniques; and
- post-combustion controls such as flue gas desulfurization systems.

The use of natural gas almost eliminates SO_x emissions, since it contains only trace amounts of sulfur. Fuel oil and coal are available with varying amounts of sulfur. Generally, fuels containing less sulfur are more expensive than those with more. The cost for low-sulfur fuels may substantially increase as tighter restrictions on SO_2 emissions increase the demand for them. SO_2 emissions can also be reduced by removing the inorganic sulfur from the fuel before it is combusted. Physical coal cleaning processes are not effective, however, in removing the organic sulfur; chemical cleaning processes that would do so are currently under development.

Another potential pre-combustion technology is coal gasification. In this process, coal is gasified, treated to remove particulates and sulfur, and routed to combustion turbines. Chapter 9 discusses integrated coal gasification combined cycle technology. This technology is currently being considered at PEPCO's Dickerson Station H site.

Combustion modifications include fluidized bed combustion technology, limestone injection, and use of coal/limestone pellets. To date, the most frequently used of these technologies has been atmospheric fluidized bed combustion (AFBC). This alternative to conventional coal boilers utilizes a system that serves both as a furnace and a mode of flue gas desulfurization. A sorbent in the bed where combustion takes place captures the majority of the sulfur in the fuel. Additional advantages are that AFBCs emit lower levels of NO_x than do conventional coal boilers (Babcock and Wilcox 1989), and can be used to burn a wide variety of fuels, from coal to biomass. This technology is also being considered for a future power plant in Maryland.

Flue gas desulfurization (FGD) techniques remove sulfur oxides from the exhaust gases after combustion. These treatment options include wet, semi-dry, and dry processes. FGD technologies are frequently grouped according to whether they produce a reusable scrubbing solution (regenerable) or one that requires disposal (nonregenerable). Most of the retrofit FGD systems being installed in the U.S. are nonregenerable processes, because of the extensive energy requirements, higher costs, and more complex operations of the alternative. Some of the disadvantages of nonregenerable systems include higher solid waste disposal, water consumption, and wastewater discharge rates.

Post-combustion scrubbing techniques to remove both NO_x and SO_x are currently in the demonstration and development phase. These techniques can be grouped into process modifications to existing FGD systems to allow absorption of NOx, flue gas treatment processes designed to control both pollutants, and fuel reburning combined with sorbent injection into the furnace or downstream for further SO_2 removal. The last process is scheduled for full-scale demonstration in late 1990.

The Future Outlook for SO_x and NO_x Emissions: Effect of New Legislation

Acid rain legislation will regulate SO_2 emissions from certain existing and all future fossil-fueled power plants. The approach calls for controls to be implemented in two phases. Under Phase I, fossil fuel generating stations of over 100 MW capacity would be required to limit their emissions by 1995 to 2.5 lb/MMBtu. In Maryland, units at the C.P. Crane, Morgantown, and Chalk Point facilities would be affected by the requirements of Phase I. Under Phase II, all electric generating units larger than 75 MW with emission rates greater than 1.2 lb/MMBtu would be required to limit their emissions to 1.2 lb/MMBtu by the year 2000.

Another component of the proposed amendments allows for utilities to "trade" their allocations of emissions among one another. Further, new plants will be required to offset their emissions by obtaining allocations of emissions from existing plants. These emissions could be acquired from utilities that are shut down or whose control actions result in emission reductions beyond the required amount, or from industrial plants that elect to voluntarily reduce their SO_2 emissions. The bill also contains a series of provisions designed to promote clean coal technologies.

Table 3-3 contains a list of the units in Maryland that will be affected by the proposed requirements, and shows which units will be affected under each of the two phases. Also included in the table is the amount of emissions that will be allocated to each unit. It can be seen that compared to the 1987 values, Phase I (1995) will achieve a rather modest estimated decrease in utility SO_2 emissions of approximately 3 percent, while Phase II (2000) is predicted to cause a decrease of almost 50 percent. These projections assume that the emissions from all new equipment will be offset through emissions allocations from existing Maryland plants.

The proposed acid deposition control legislation also mandates a reduction of NO_x emissions but is less specific about which sources will have to reduce their emissions. Assuming that the sources required to reduce SO_2 emissions will be required to reduce NO_x emissions to approximately 0.5 lb /MMBtu, the total power plant NO_x emissions for the state will decrease by approximately 20 percent by the year 2000. For more material on acid deposition legislation and its costs, see Chapter 8, Section F.

D. Influence of Power Plant Emissions on Ozone Formation

Ozone is a toxic colorless gas, which is formed in the atmosphere by a variety of photochemical mechanisms, particularly during the oxidation of atmospheric hydrocarbons in sunlight. Unlike the ozone layer present in the upper atmosphere, which provides protection to the earth by absorbing ultraviolet radiation, ozone in the atmosphere near the ground is a potential health threat. Ozone in the lower atmosphere can cause or exacerbate respiratory conditions. Ozone concentrations exceed health-based standards in most major U.S. cities, including Washington, D.C., and Baltimore. Emissions controls to produce attainment of these standards is a major thrust of Maryland's air pollution control programs. This section summarizes the adverse effects of atmospheric ozone, describes some major features of ozone formation in the atmosphere, and discusses the importance of power plant emissions to ozone attainment activities.

Adverse Effects

Hazardous levels of ozone have been linked to decreases in lung function in both children and adults, and may exacerbate preexisting lung conditions (EPA 1986). Ozone also causes damages to crops, particularly trees (Wang *et al.* 1986), and food crops such as soybeans, corn, and peanuts (Heck *et al.* 1983; EPA 1986). For many plant species, adverse effects are reportedly observable at concentrations only slightly exceeding the normal background concentration of 35 parts per billion (Heck *et al.* 1983).

Table 3-3
Plant/Unit SO2 emissions

Plant		1985 Emissions lb/MMBtu	 T/yr	Phase I (1995) T/yr	Phase II (2000) T/yr
BG&E					
Wagner	Unit 3	1.292	9,938	9,938	9,126
Crane	Unit 1	2.828	9,654	10,300	4,960
	Unit 2	2.844	9,716	9,230	4,430
PEPCO					
Morgantown	Unit 1	2.667	29,221	35,200	16,900
	Unit 2	2.651	38,003	38,500	18,500
Dickerson	Unit 1	2.145	11,470	11,470	6,683
	Unit 2	2.157	10,651	10,651	6,310
	Unit 3	2.165	11,760	11,760	6,680
Chalk Point	Unit 1	2.574	20,420	21,900	10,500
	Unit 2	2.574	27,427	23,900	11,700
	Unit 3	1.900	9,283	9,283	5,232
DELMARVA					
Vienna	Unit 8	2.121	2,241	2,241	2,075
POTOMAC EDISON					
R.P. Smith	Unit 3	1.440	1,074	1,074	320
	Unit 4	1.440	2,180	2,180	2,593
Subtotal			193,038	197,627	106,009
Emissions from Existing Sources (1985)			57,144	45,706	28,761
Total (Assuming no increase from future equipment)			250,182	243,333	134,770

Unit number designations based on Department of Energy Unit numbers.

Ozone Formation

Ozone is formed when compounds known as reactive hydrocarbons are oxidized in the presence of sunlight and NO_x. Ozone formation is a regional phenomenon. For example, ozone accumulates during daylight hours in a parcel of air, or plume, over an urban area as it is transported over a variety of emitting sources. Ozone in the lowest levels of the atmosphere is readily destroyed at night through chemical reactions with other atmospheric gases, primarily nitric oxide (NO), that result from combustion sources. However, urban plumes containing ozone may be transported within the upper atmosphere, resulting in the phenomenon of "second day" ozone formation (NAS 1978; EPA 1986). Major features of the formation of tropospheric ozone relevant to this CEIR have recently been reviewed by Walther (1988) and Seinfeld (1989).

Ozone formation in a parcel of air depends on the amount of sunlight, the nature of the hydrocarbons present, and the ratio of non-methane hydrocarbon to NO_x concentrations in the atmosphere. In urban plumes, the concentration ratio varies with time and travel distance and decreases when the plume is transported into pristine areas as more reactive hydrocarbons are removed. However, interactions of urban and source plumes rich in NO_x with hydrocarbons emitted by trees to form locally high ozone concentrations have also been postulated.

Occurrence

Primary and secondary NAAQS for ozone have been established at 235 $\mu g/m^3$ (one-hour average). Because high ozone concentrations generally persist for several hours, a "violation day" is defined as any day on which the standard is exceeded for one or more hours. Progress toward compliance is tracked in terms of the number of violation days per year.

In Maryland, concentrations of ozone have regularly exceeded 235 $\mu g/m^3$ at monitors located in the non-attainment areas of the state. Ozone "episodes" (multiple exceedances occurring on successive days) are frequently observed. These episodes tend to occur during extended periods of high temperatures, clear skies, and light winds. The summer of 1988, probably because of meteorological factors, produced particularly high ozone concentrations (MDE 1988). The NAAQS was exceeded during 1988 at the 14 monitoring sites in non-attainment areas in Maryland; only one site in an attainment area, Wicomico County on Maryland's eastern shore, was spared. Despite intensive efforts to reduce hydrocarbon emissions from anthropogenic sources in recent years, no decrease is evident in either the number of days on which ozone concentrations exceeded the NAAQS (Figure 3-9) or the highest reported values (Figures 3-10 and 3-11). It can be seen from Figure 3-11 that, although non-methane hydrocarbons decreased by about an order of magnitude since 1979, ozone levels were unchanged.

The figure also indicates that NO levels have increased, while NO_2 levels have remained fairly constant. The increase in NO may be related to the decrease in

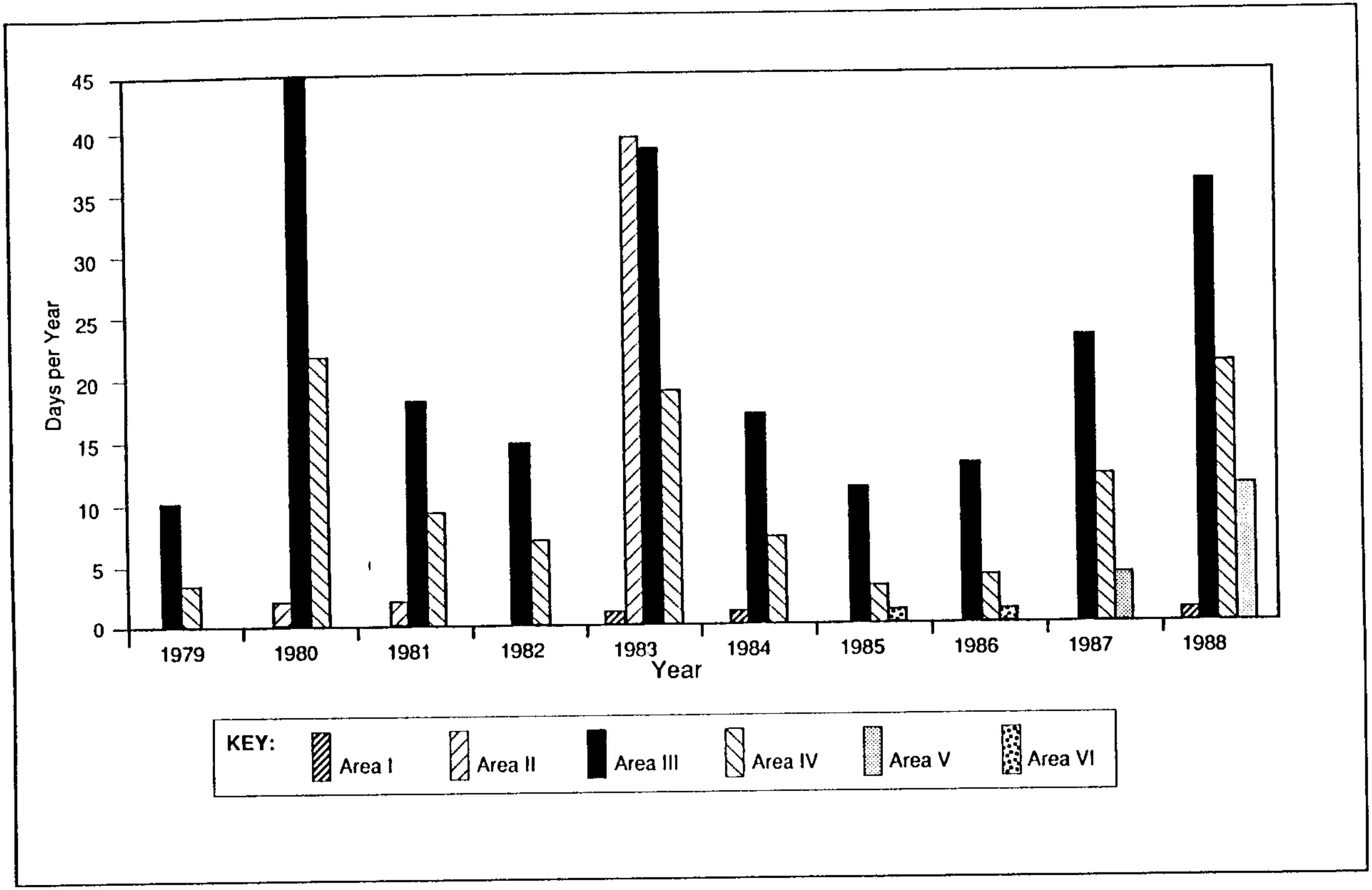

Figure 3-9. **Historical annual ozone violation days in Maryland by AQCR**

Source: MDE 1988

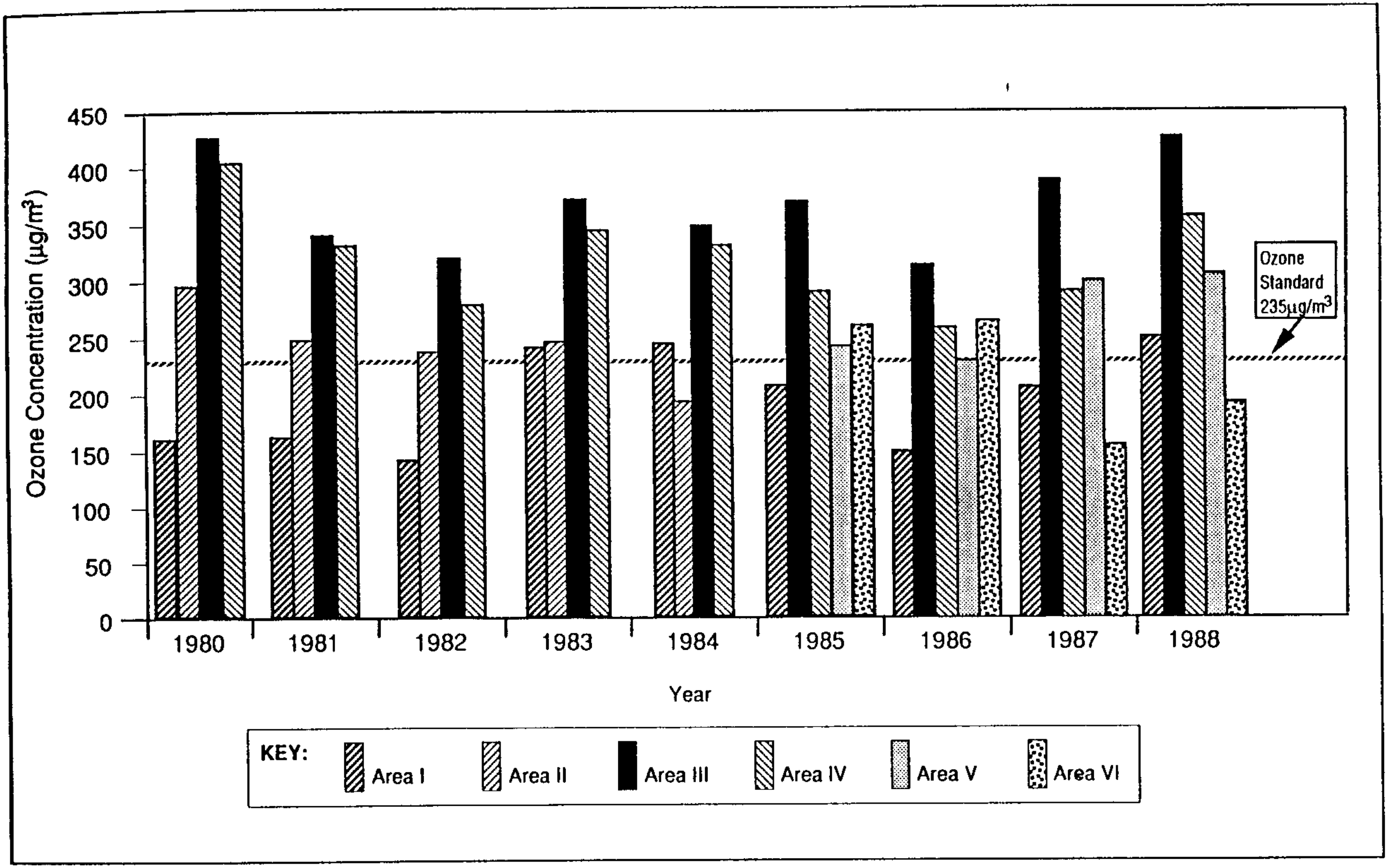

Figure 3-10. Historical maximum 1-hour ozone concentrations in Maryland by AQCR

Source: MDE 1988

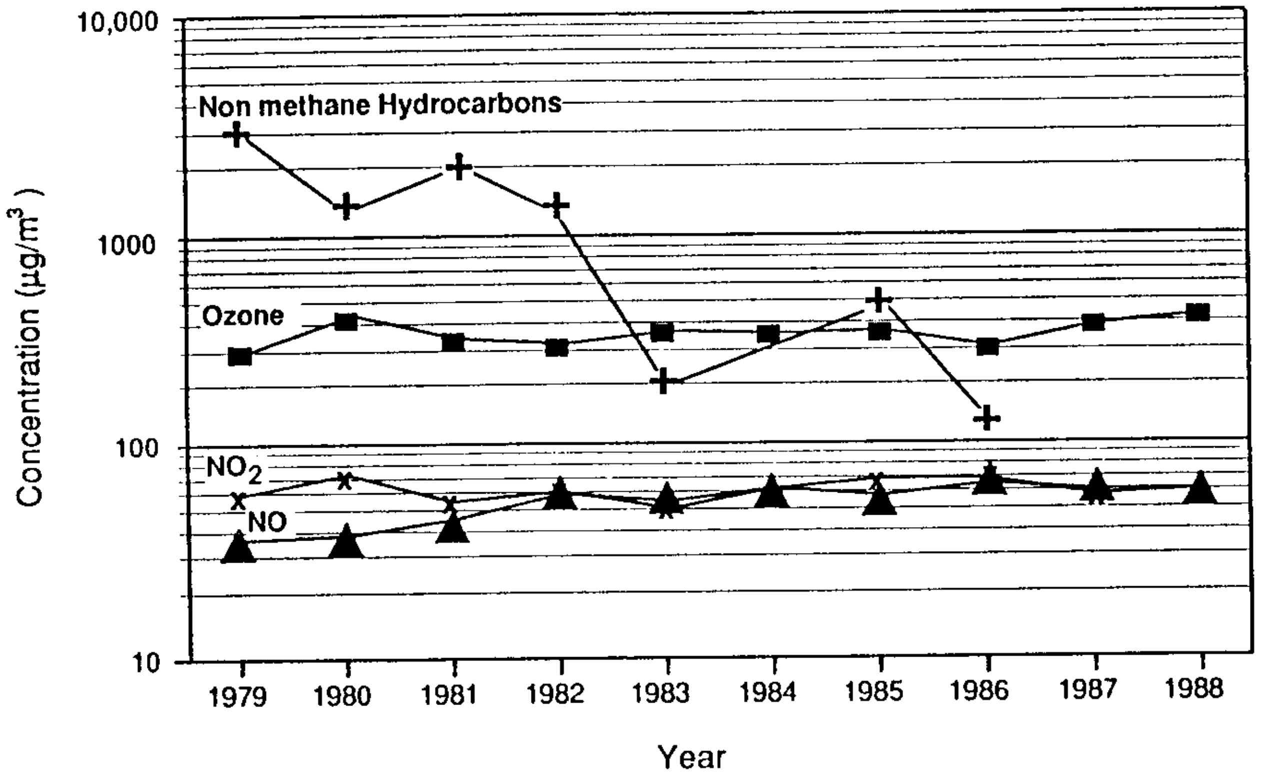

Figure 3-11. Historical comparison of ozone and precursor trends in Area III

Source: MDE 1988

levels of a class of hydrocarbons known as volatile organic compounds (VOCs). This suggests that, in the non-attainment areas of Maryland, ozone levels are not solely governed by VOC emissions, and that strategies for controlling ozone may have to consider other factors, such as NO_x emissions. The greatest ozone concentrations in Maryland for each of the years from 1986 to 1988 occurred at Edgewood, not in the downtown Baltimore area, indicating that both regional ozone formation and ozone transport are important features of ozone episodes in the state.

Significance of Power Plant Emissions

Power plants emit very small amounts of hydrocarbons relative to other pollutants, considering the amount of fuel burned. Power plants contribute only 0.2 percent of the total VOC emissions in Maryland; on the other hand, power plants contribute almost 40 percent of the NO_x emissions in the state (Figure 3-12). The particular role of NO_x emissions in ozone formation is not well-defined. At locations near power plants, NO_x in the plume reacts with ozone to reduce ambient ozone. Such reductions have been observed from instrumented aircraft flying through elevated power plant plumes and may persist for tens of miles (Davis *et al.* 1974; Sexton and Westberg 1983). Some modeling results indicate that emissions of NO_x from urban power plants may in fact cause widespread decreases in urban ozone concentrations (Ames *et al.* 1985).

Conclusion

The contribution of Maryland power plants to ozone non-attainment in urban areas of the state is not currently known. Modeling studies now being conducted by MDE using the EPA-preferred Urban Airshed Model should provide relevant information on this issue. Hydrocarbon emissions from power plants currently account for less than one percent of the total regional VOC emissions in Maryland. Although power plants are not major contributors to hydrocarbon emissions, they are significant emitters of NO_x. A growing body of evidence suggests that NO_x is more important to ozone formation than traditional analyses may have indicated.

Some research indicates that reductions in NO_x emissions may be required to achieve attainment with ozone standards on the east coast. If these preliminary findings are substantiated, power plants, which account for about 40 percent of NO_x emissions in Maryland, may be subjected to new pressures for NO_x emissions control. Additional data on these matters and on future regulatory actions affecting power plant emissions should be anticipated in the next few years as ozone control strategies proceed.

E. Carbon Monoxide Non-attainment Issues

Carbon monoxide is a colorless, odorless gas that is a product of incomplete combustion of organic fuels. When inhaled it is readily absorbed into the bloodstream, where it combines with hemoglobin and interferes with the normal transport of oxygen to body tissues. Prolonged human exposure to high

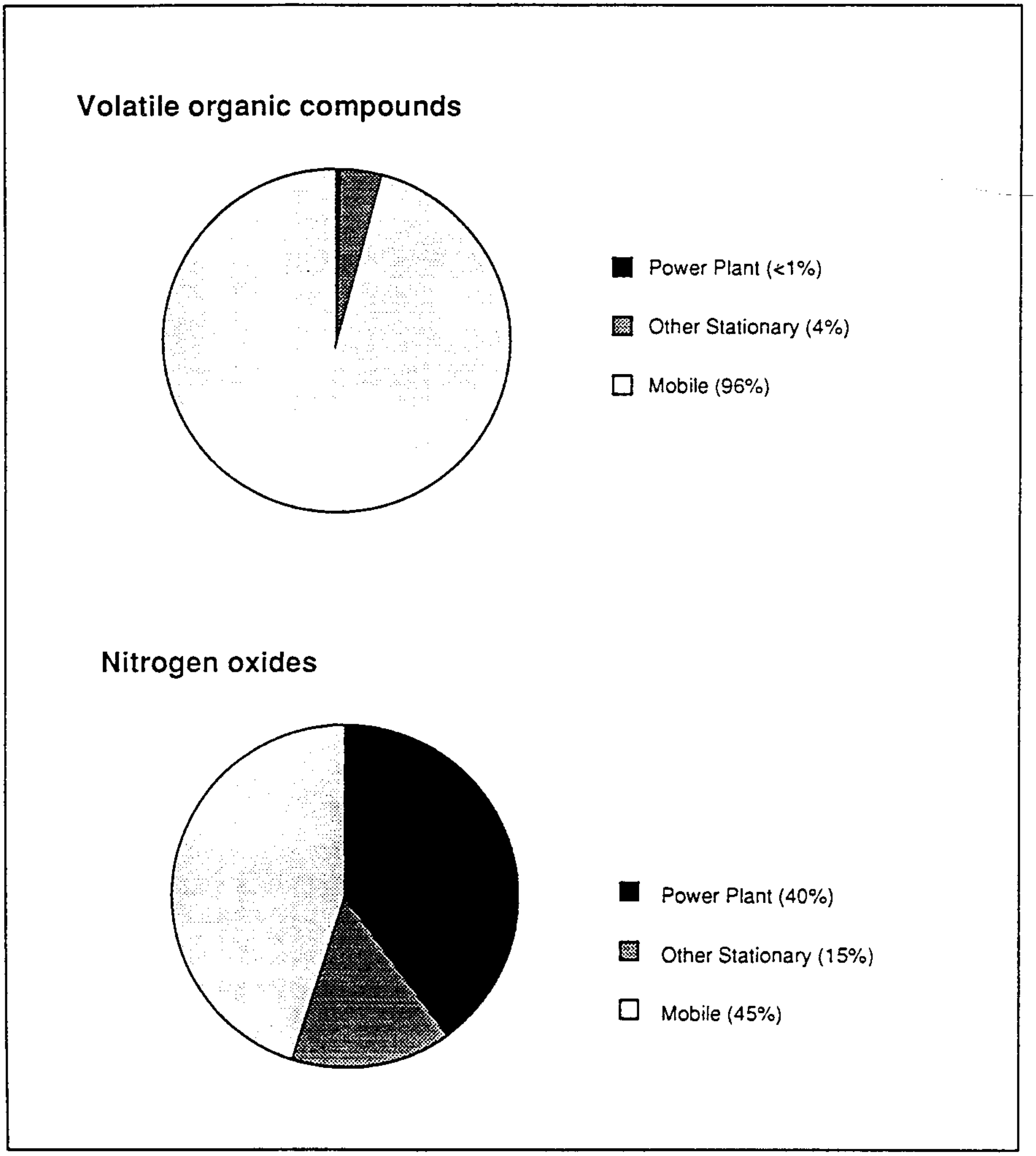

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Figure 3-12. Relative 1987 emissions of ozone precursors by source type in Maryland

Source: MDE 1989, Meszler 1990

concentrations in the atmosphere leads to slowed reaction times and impaired judgment and may lead to heart attacks in those with reduced cardiac capacity. EPA has established an NAAQS of 5 parts per million (ppm) (one-hour average) to protect sensitive individuals.

Carbon monoxide levels exceed allowable standards at congested traffic intersections in downtown Baltimore and suburban Washington, D.C. Automobiles are major sources of CO, and their emissions increase rapidly with decreasing vehicle speed. MDE attributes the non-attainment status to emissions of CO from automobiles coupled with poor local atmospheric ventilation.

There is little reason to suspect that power plants contribute significantly to the non-attainment status for CO. On a statewide basis, power plants produce less than 0.5 percent of the total CO (Figure 3-13). Furthermore, CO emissions from utility boilers are released from tall stacks and will therefore have little impact on ground level concentrations. Nevertheless, the presence of non-attainment areas could potentially force prospective power plants in AQCRs III or IV to comply with non-attainment review regulations for CO emissions.

F. Particulate Emissions

From an air pollution viewpoint, particulate matter is any airborne material other than water that exists as a liquid or solid at standard conditions. Other pollutants (e.g., VOCs, NO_x, and CO) exist as gaseous materials at standard conditions. Examples of PM include smoke, dusts, fumes, mists, and sprays.

Total suspended particulates (TSP) was formerly used for measuring ambient concentrations and determining compliance with NAAQS. TSP is defined as all particles that can be collected by a certain type of sampling device. By contrast, PM is defined as all particulate matter, and has been used when quantifying emissions. PM10, particles less than 10 microns in diameter, is now used both to describe ambient concentrations and for emission quantification.

PM emissions associated with power plants may contain small amounts of materials known to be toxic; Section G addresses the potential impacts of these toxic emissions. This section focuses on the emissions, the impacts, the control technologies, and the regulations associated with PM as a whole.

Adverse Effects

The adverse health effects of particulate emissions are observed mainly in the human respiratory system. Particles greater than 10 microns in diameter collect in the upper part of the respiratory system, and are trapped by nasal hair and expelled by sneezing, coughing, etc. Particles one to ten microns in size can collect in the tracheobronchial region of the respiratory system, and particles less than one micron in diameter may collect in the most remote portions of the lungs, the air sacs. The smaller particles (those less than 10 microns) pose a greater health risk than larger ones. Because of these concerns, particulate matter

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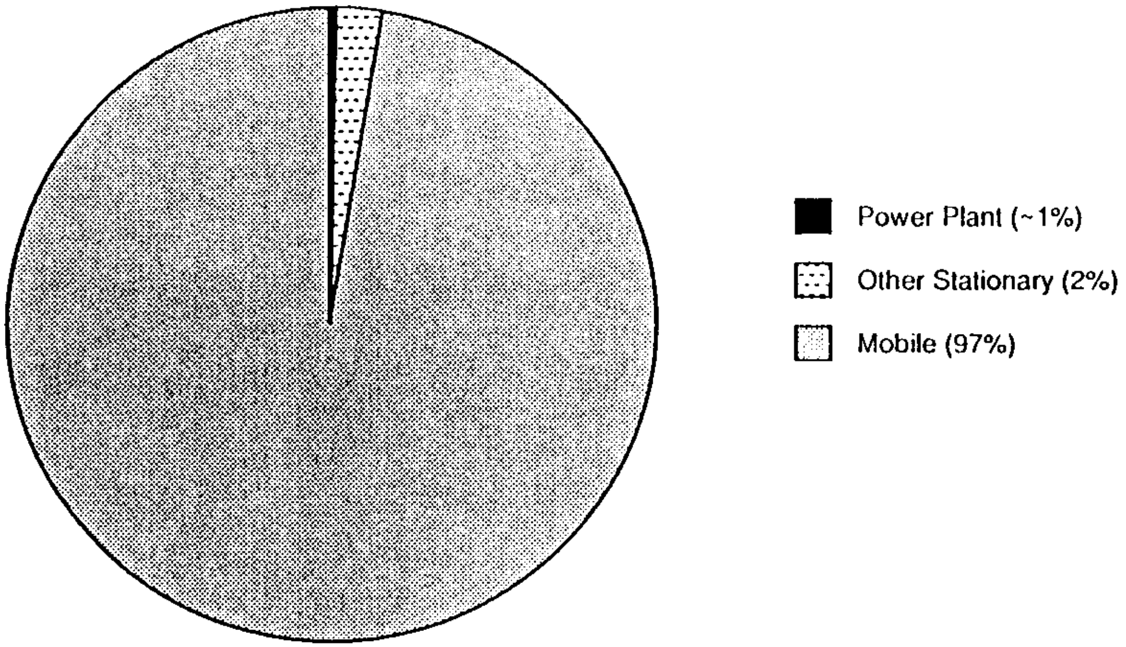

Figure 3-13. Relative 1987 emissions of carbon monoxide by source type in Maryland

Source: MDE 1989, Meszler 1990, Simpson 1989 smaller than 10 microns in diameter has become the focus of recent research, and new air pollution standards have been promulgated to regulate their control.

Emissions of Particulate Matter From Power Plants

Emissions of particulates from power plant stacks consist of particles formed during combustion. The amount of particulate matter formed during combustion is typically greater for the higher ash and/or high sulfur fuels such as coal and (to a lesser extent) residual oils. While units burning "cleaner" fuels such as distillate oils and natural gas tend to contribute smaller amounts of particulate matter, it should be noted that the particulate matter formed from natural gas and distillate oil is essentially all PM10. Roughly 70 percent of the uncontrolled particulate emitted from residual oil combustion is PM10; from coal combustion only about 25 percent is PM10.

In addition to the type of fuel, the magnitude of particulate emissions from a given combustion unit depends on a number of other process and control factors. These include the type of combustion process employed, the combustion efficiency, and the effectiveness of any air pollution controls. Stack releases of particulates have been fairly well-characterized via stack testing and the development of emission factors.

There are various types of pollution control technologies for particulates that are proven to be effective in reducing emissions from power plants. Electrostatic precipitators (ESPs) and fabric filters (baghouses) are the favored control technologies for reducing particulate matter emissions from stacks. Both of these technologies have removal efficiencies of greater than 99 percent for total particulate matter emissions, with about 98 percent efficiency in the control of PM10 emissions. Other control technologies that are currently employed in Maryland include cyclones, multiple cyclones and wet particulate scrubbers, although these methods are less effective, particularly for PM10.

Fugitive emissions are also associated with certain power plant operations. These fugitive emissions are generally those that are not collected and routed through a stack. Fugitive emissions of particulate matter from power plants, largely limited to installations burning coal, are generated during the transport, handling, preparation, and storage of coal and during fly and bottom ash handling, transport, and storage. The magnitude of fugitive particulate emissions is site-specific and depends on a variety of factors. This uncertainty is exacerbated by the difficulty of actual measurement due to the wide variation in conditions and problems associated with collecting representative samples. The impacts of fugitive emissions on terrestrial ecosystems are discussed in Chapter 7.

The various types of fugitive sources within a power plant require an array of pollution controls. Examples of controls for fugitive dusts include latex coatings or covers for piles and delivery cars; silos or buildings for storage; wind guards, watering, or cyclones for crushing operations; wetting of flyash; paving, oiling, or wetting of roads; enclosed transfer stations and conveyors; and baghouses.

Figure 3-14 presents current trends in actual stack emissions of particulate matter from Maryland power plants. It can be seen that from 1984 to 1987, particulate matter stack emissions decreased from 6,300 to 4,500 ton/yr. Data indicate that particulate matter emissions from power plant combustion contribute an estimated 30 percent of all particulate matter emissions from stationary sources within Maryland (MDE 1989). It is important to note that these estimates are limited to stack releases since no historic data are available on fugitive emissions.

Figures 3-15 and 3-16 show the 1987 PM and PM10 emissions for Maryland power plants by fuel type. These data indicate that coal- and residual oil-fired units contribute more than 99.5 percent of the PM stack emissions with coal alone accounting for approximately 75 percent. The analysis of PM10 stack emissions by fuel type reveals a similar trend.

Power Plant TSP and PM10 Concentrations in Ambient Air

Total suspended particulate concentrations, measured on an annual average basis, remained essentially constant between 1982 and 1988, averaging between 49 and 53 $\mu g/m^3$ (Figure 3-17). In 1984, MDE also began monitoring PM10 concentrations. These data are shown in Figure 3-18.

It appears that only a minor portion of the TSP and PM10 ambient concentrations can be attributed to power plants. Modeling results (see Section C) indicate that the combined effect of Maryland power plant stack emissions are relatively low, compared to ambient measured levels. The modeling predicts that power plant stack emissions in 1987 contributed a maximum of 0.14 $\mu g/m^3$ to annual average ambient TSP levels (Figure 3-19), which is only about 4 percent of the measured ambient levels. For comparison, the TSP modeled results for 1977 are also provided (Figure 3-20). The highest modeled value for 1977 was 0.21 $\mu g/m^3$.

Due to the many variables affecting their quantification, fugitive emissions were not included in this modeling effort. Fugitive emissions from coal-fired power plants could have significant localized ambient impacts. Dispersion modeling has indicated that the maximum ground level concentrations resulting from fugitive emissions can be significantly higher than those resulting from stack emissions. This ratio would depend greatly on the controls used and on the location of the fugitive sources.

The high ambient concentrations due to fugitive emissions can be explained in part by the characteristics of their points of release. Fugitives are generally emitted at lower elevations, temperatures, and flow rates than are emissions from power plant stacks. Generally, emissions at higher elevations, temperatures, and flow rates are dispersed more widely.

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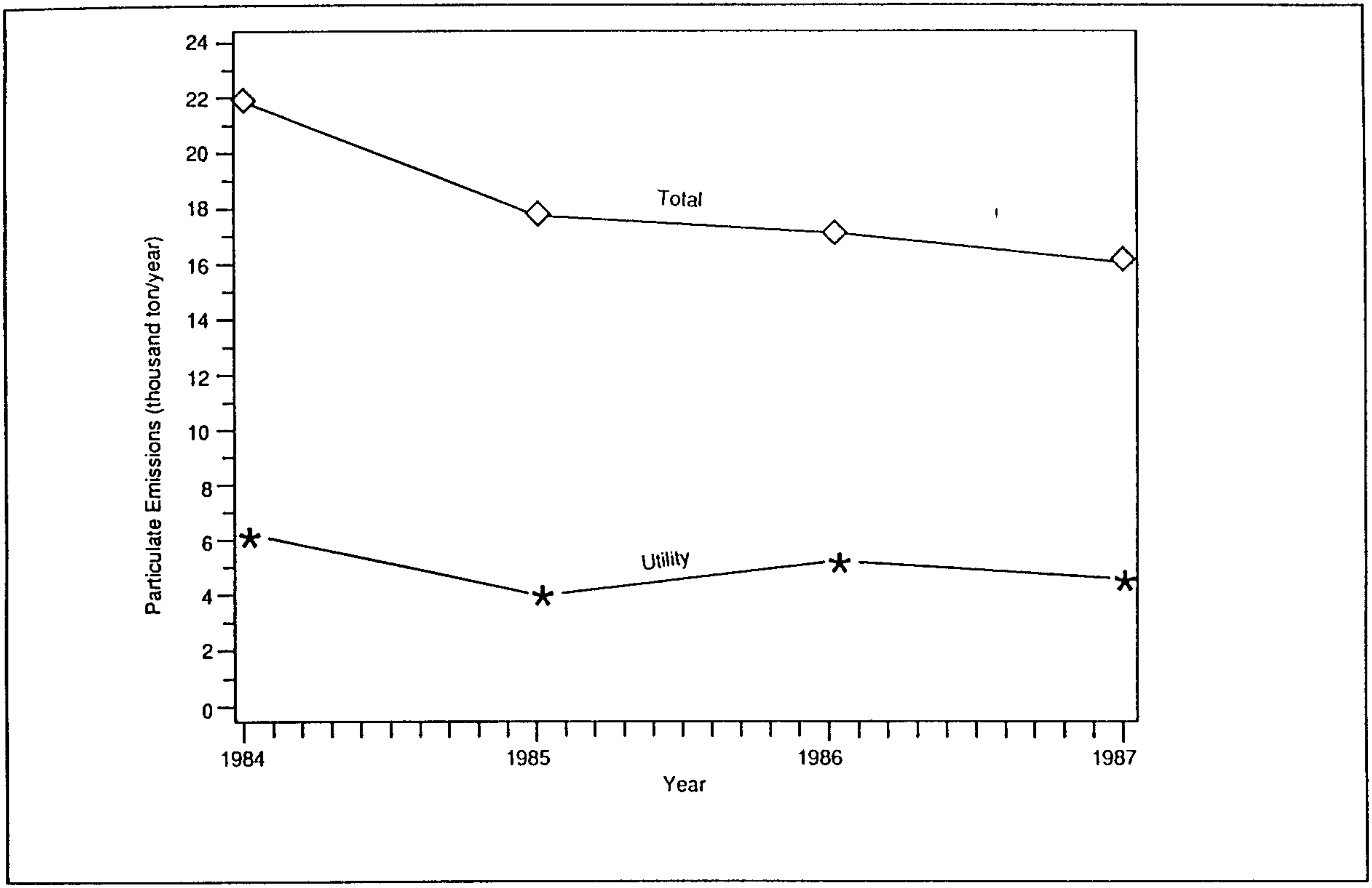

Figure 3-14. Historical comparison of particulate emissions from power plant stacks to the emissions from all stacks in Maryland

Source: MDE 1989

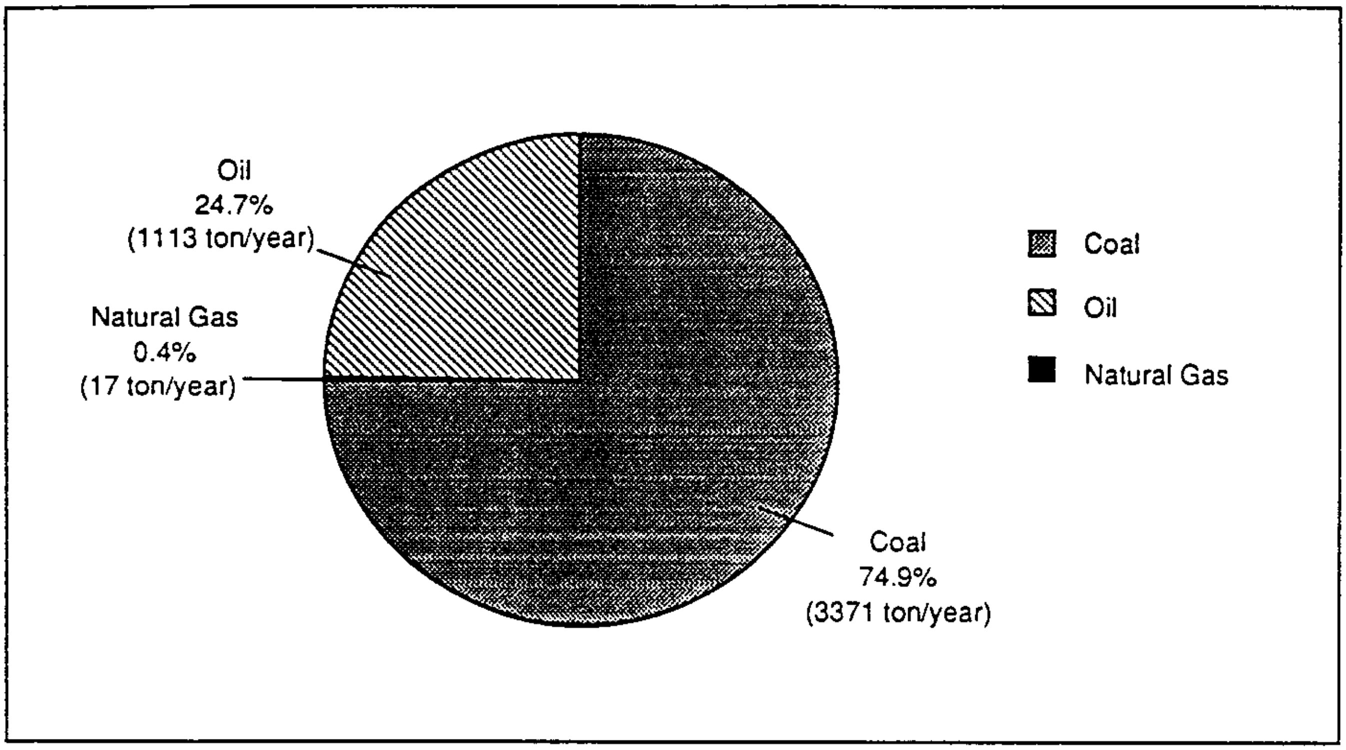

Figure 3-15. Maryland 1987 power plant particulate emissions by fuel type

Source: MDE 1989

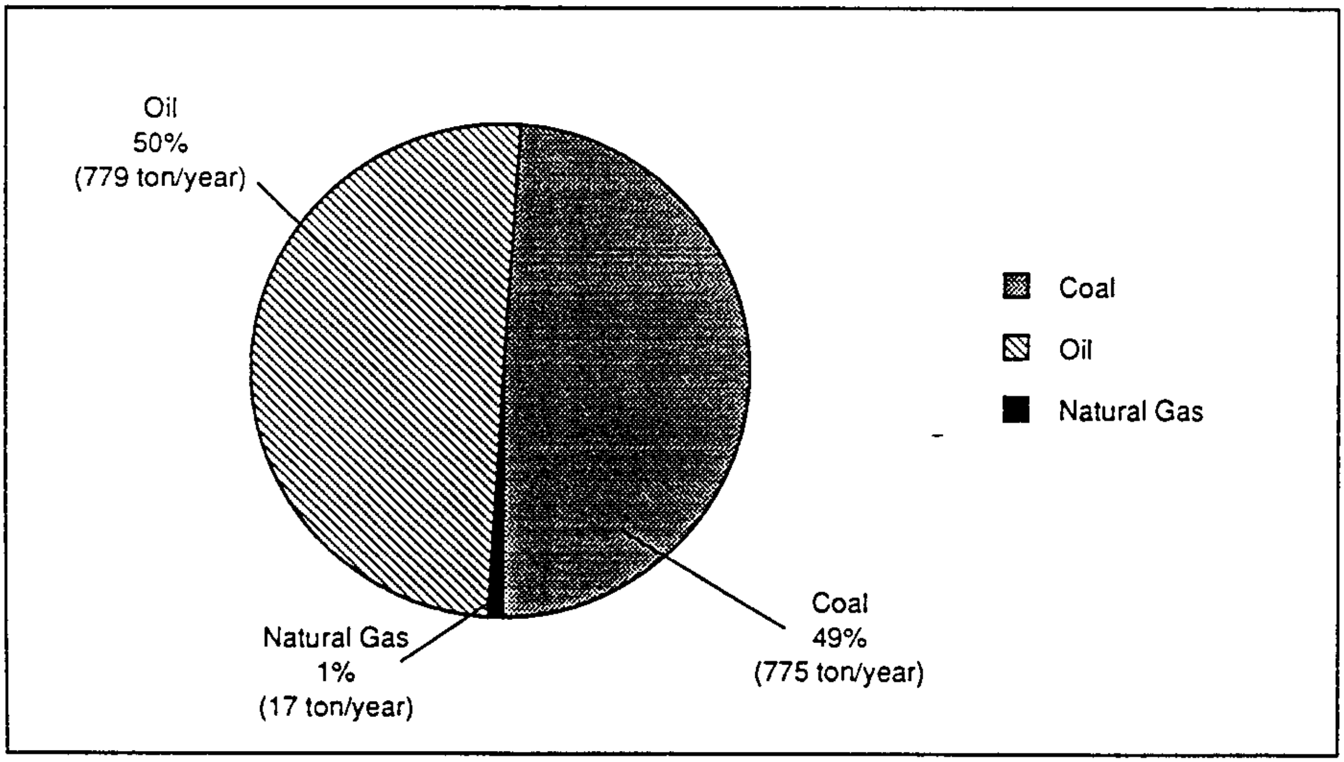

Figure 3-16. Maryland 1987 power plant PM10 emissions by fuel type

Source: MDE 1989

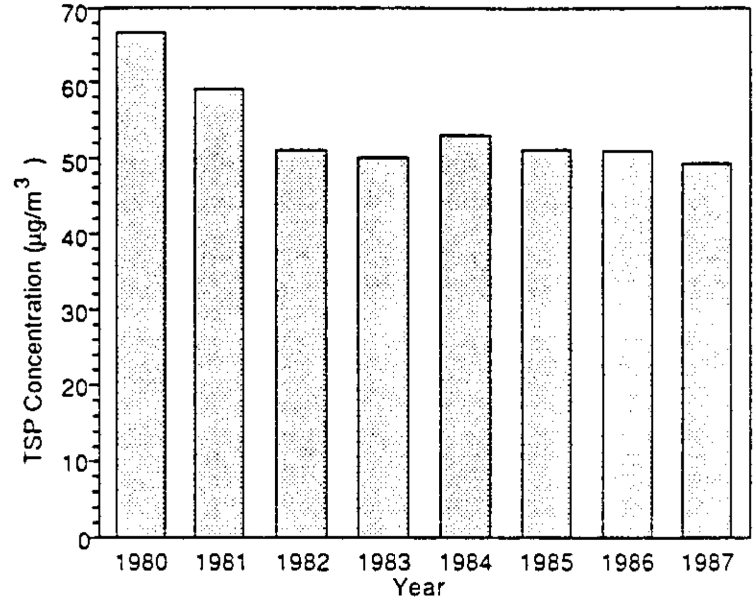

Figure 3-17. Historical average annual geometric mean ground level concentration of TSP in Maryland

Source: MDE 1988

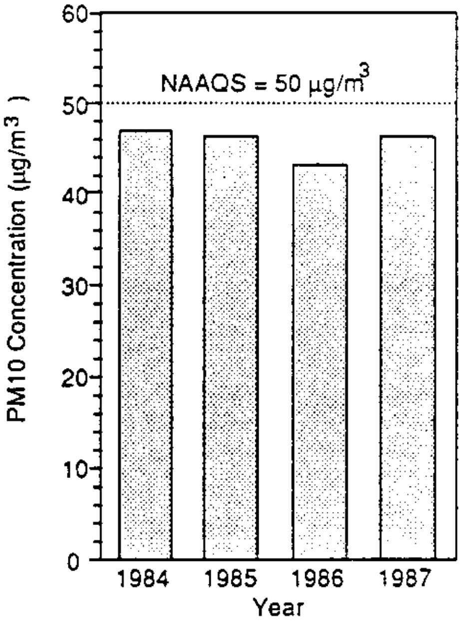

Figure 3-18. Historical average annual arithmetic mean ground level concentration of PM10 in Maryland

Source: MDE 1988

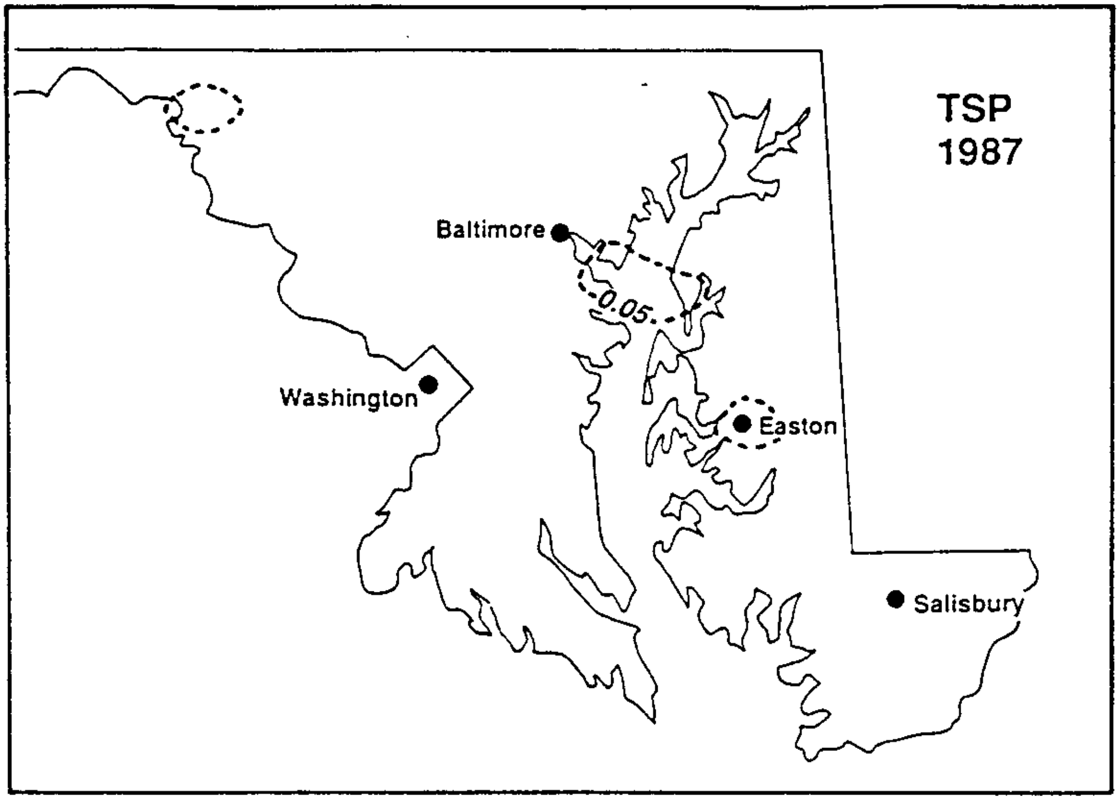

Figure 3-19. Contours of model-predicted annual TSP ground level concentrations for 1987 due to Maryland power plants (contour interval is 0.05 $\mu g/m^3$). Maximum concentration is 0.14 $\mu g/m^3$.

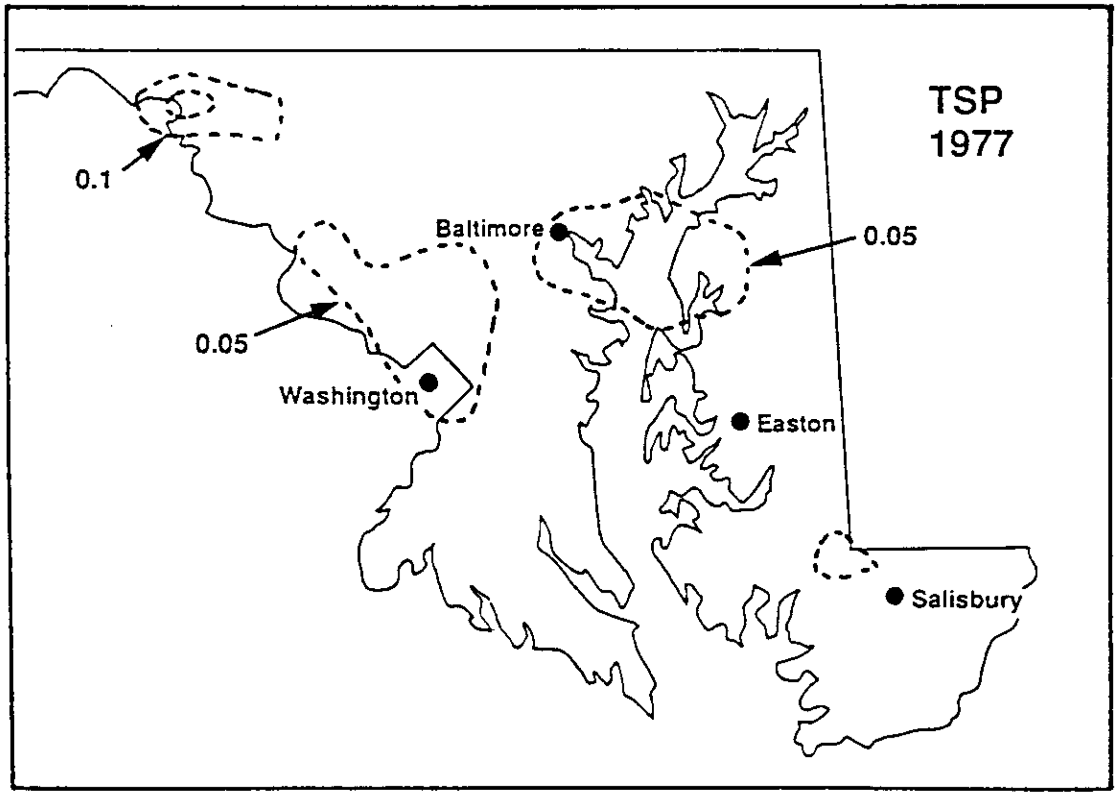

Figure 3-20. Contours of model-predicted annual TSP ground level concentrations for 1977 due to Maryland power plants (contour interval is 0.05 $\mu g/m^3$). Maximum concentration is 0.21 $\mu g/m^3$.

Regulatory Considerations

A number of state and federal regulations govern ambient levels of particulate matter. On 1 July 1987, EPA adopted rules changing the indicator of particulate matter from TSP to PM10 and establishing NAAQS and pre-construction monitoring requirements for the new indicator. However, the old statutory standards and increments for TSP were retained. Consequently, new sources have been analyzing both emissions and ambient air impacts for both TSP and PM10 indicators in preparing permit applications.

On 5 October 1989, the EPA proposed rules to include PM10 in the PSD program. The effect of the PM10 increments are intended to be equivalent to existing TSP increments on most sources; therefore, changing the indicator from TSP to PM10 should not affect the amount of particulate matter increment consumed to date. As states adopt the PM10 provisions, existing increments for TSP, along with TSP pre-construction monitoring requirements, will no longer be considered.

There are also PM emission limitations at the state and federal levels. The NSPS that applies to fossil fuel-fired steam generators 250 MMBtu/hr and greater that were constructed after 17 August 1971 allows a maximum particulate emission rate of 0.10 lb/MMBtu. The particulate emissions from units constructed after 18 September 1978 must not exceed 0.03 lb/MMBtu for all fuels. Additionally, with liquid or solid fuels, emissions must be controlled at efficiencies of 70 percent and 99 percent respectively.

Currently all of Maryland is in attainment with the TSP standard; however, one section of Area III in Baltimore City may not be attaining the PM10 standard. If that area is determined to be non-attainment for PM10, then any major increase of PM10 emissions from any source impacting that area must undergo an NSINA review, as discussed in Section B.

Future Trends in Particulate Emissions from Power Plants

Although the amount of electricity needed by the year 2003 is expected to increase significantly over current demands, particulate emissions are not expected to increase proportionately. The 1987 power plant stack emissions of total particulates and PM10 were approximately 4,500 and 3,200 tons, respectively. The projected particulate stack emissions in 2003 are expected to be roughly 25 percent higher.

Several factors can be attributed to the relatively small projected particulate emissions increase. First, there will probably be a shift toward burning greater amounts of natural gas and distillate oil, which inherently release less particulate matter than do residual oil and coal. Second, modern particulate control devices such as ESPs are considerably more effective, particularly at controlling PM10, than some of the older devices such as cyclones. Particulate emissions from new equipment will have to comply with control limitations at least as stringent as the NSPS and MDE regulations that are applicable for newer sources. Third, because the magnitude of particulate emissions depends partially on sulfur content, the expected controls for acid deposition in the Clean Air Act Amendments may also have the effect of reducing particulate emissions from existing sources.

G. Toxic Air Pollutants

The release of toxic air pollutants into the environment is a growing concern. Public concern over TAPs has grown over the past decade, in part because of:

- Increased awareness due to media coverage of events involving catastrophic toxic releases, either at industrial facilities or during transport of toxic materials, resulting in evacuations and, occasionally, injuries and deaths;
- results of ambient air monitoring studies that reveal measurable levels of toxic air pollutants, including carcinogens, especially in urban areas (Calabrese and Kenyon 1989);
- reports of the build-up of toxic metals in soils downwind of certain industrial sources; and
- reported higher incidence of lung cancer in some urban areas, even though there is much controversy as to the significance of air pollution's contribution (Calabrese and Kenyon 1989).

Because of increased public concern, federal and state lawmakers have responded with a variety of proposed emissions control initiatives. For example, the recent Clean Air Act Amendments include a fairly substantial section on toxic air pollutants. In addition, many states either have promulgated or are developing regulations for releases of toxic air pollutants.

Sources of toxic air pollutants are found in all sectors: industrial, transportation, commercial, and residential. Power plants also emit small amounts of toxic pollutants contained in fuels and formed in the combustion process. These may include metals such as arsenic, mercury, and cadmium, and polycyclic organic compounds such as benzo(a)pyrene.

Regulatory Programs for Non-criteria Toxic Air Pollutants

The majority of toxic compounds that have been identified in source emissions and in ambient air are not regulated by EPA. Several toxic air pollutants are covered by the NESHAPs program, but the majority are not subject to any federal emissions limitations. In many states, including Maryland, pollutants not regulated under federal programs (but which may nevertheless pose a public health hazard) are regulated under the state air toxics regulations.

- Federal Regulation

Currently, few regulations concerning toxic air pollutants affect power plants in Maryland. The PSD regulations (40 CFR 52.21) require emissions estimates and air quality impact analyses for all pollutants regulated under the CAA that are emitted in significant quantities. Control of toxic pollutants must also be considered in the determination of BACT. This requirement is applicable to all sources subject to PSD review.

The CAA Amendments will comprehensively regulate toxic air pollutants. Specifically, the amendments will achieve this by:

- identifying chemicals to be regulated;
- focusing on major sources of toxic air pollutants;
- mandating Maximum Achievable Control Technology (MACT), a technology-based approach that would consider cost and feasibility;
- defining a fixed schedule within which to regulate sources; and
- employing a health-based risk assessment approach to eliminate any remaining risk after MACT is applied.

It has not been determined to what degree the toxics regulations of the new CAA will apply to utilities. The EPA is required to conduct studies of the public health hazards from exposure to toxic emissions from utilities, to determine if there is a need to regulate these emissions.

- Maryland Regulation

Maryland's air toxic regulations (COMAR 26.11.15) became effective on 27 September 1988. Generally, they require quantification of toxic emissions, use of best available control technology for toxics, and the assurance that emissions will not cause concentrations that unreasonably endanger public health. Emissions from power plants burning fossil fuels (not refuse-derived fuels) are exempt from the Maryland air toxic regulations, but are subject to site-specific review and regulations through the comprehensive environmental evaluation and PSC licensing process.

Significance of Power Plant Toxic Emissions

- Emissions Characterization

Toxic emissions from combustion sources at power plants are affected by the type of source (i.e., boiler, turbine, fluidized bed, gasification system, etc.); the design, size, and age of the combustor; the fuel used; and the pollution controls employed. Trace amounts of metals and organic compounds are emitted from fossil fuel combustion. The latter includes both residual components of the original fuel and products of incomplete combustion. A reliable estimation of toxic emission rates from power plant sources is difficult to achieve. Test methods are immature and available data are limited, thus the ranges of published emission factors are extremely wide in most cases.

In general, more toxics are released from coal combustion than from oil or natural gas combustion. The amount is related to the trace constituents found in the fuel and not completely burned during combustion. For example, dioxin and polychlorinated biphenyl (PCB) emissions are negligible from natural gas and fuel oil combustion because of the virtual absence of the precursors to their formation. Finally, many toxic emissions, including the trace metals, are negligible during natural gas combustion because natural gas is a relatively clean, uncontaminated fuel.

- Emissions Control

Toxic air pollutants may be emitted as gases, as particles, or as gases adsorbed on particles. Because many of the toxic pollutants from fossil fuel combustion are associated with particulate matter, many toxic emissions are reduced by using particulate collection systems. Co-control, where one category of pollutant (such as toxics) is controlled as a result of the purposeful control of another category of pollutant (such as particulate matter or VOCs), is an effective mitigation approach for air toxics from power plants.

- Toxic Emissions in Perspective

Toxic air pollutants are continuously being released into the air. Emissions result from transportation, space heating, electricity generation, industrial and manufacturing processes, chemical use and production, incineration, and hazardous waste facilities. The risk from toxics in the ambient air is related to the types of pollutants released as well as to stack and emissions characteristics. Figure 3-21 shows the typical contribution of various sources to urban toxic air pollution in the United States. These results come from a five-city measurement study performed by EPA (1989a). On a nationwide basis, the combustion of fossil fuels (exclusive of transportation), of which power plant combustion is just a part, accounts for only about two percent of the air toxics in urban areas. Automobiles are by far the largest contributor. Gaseous toxic emissions (such as formaldehyde and other organic compounds) from mobile sources are of primary concern; however, mobile sources also release some toxic particulate trace metals such as lead and cadmium.

- Health Risk of Power Plant Toxic Emissions

Exposure of humans to toxic air pollutants may occur directly through inhalation, or indirectly through ingestion or skin contact. Emitted pollutants are dispersed in the air and deposited at ground level on soil, vegetation, or surface water. Pollutants may be deposited directly onto the surfaces of food crops or animal fodder, or they may be absorbed by these plants after being deposited onto the soil. Humans may eat contaminated plants or soil directly, or they may ingest

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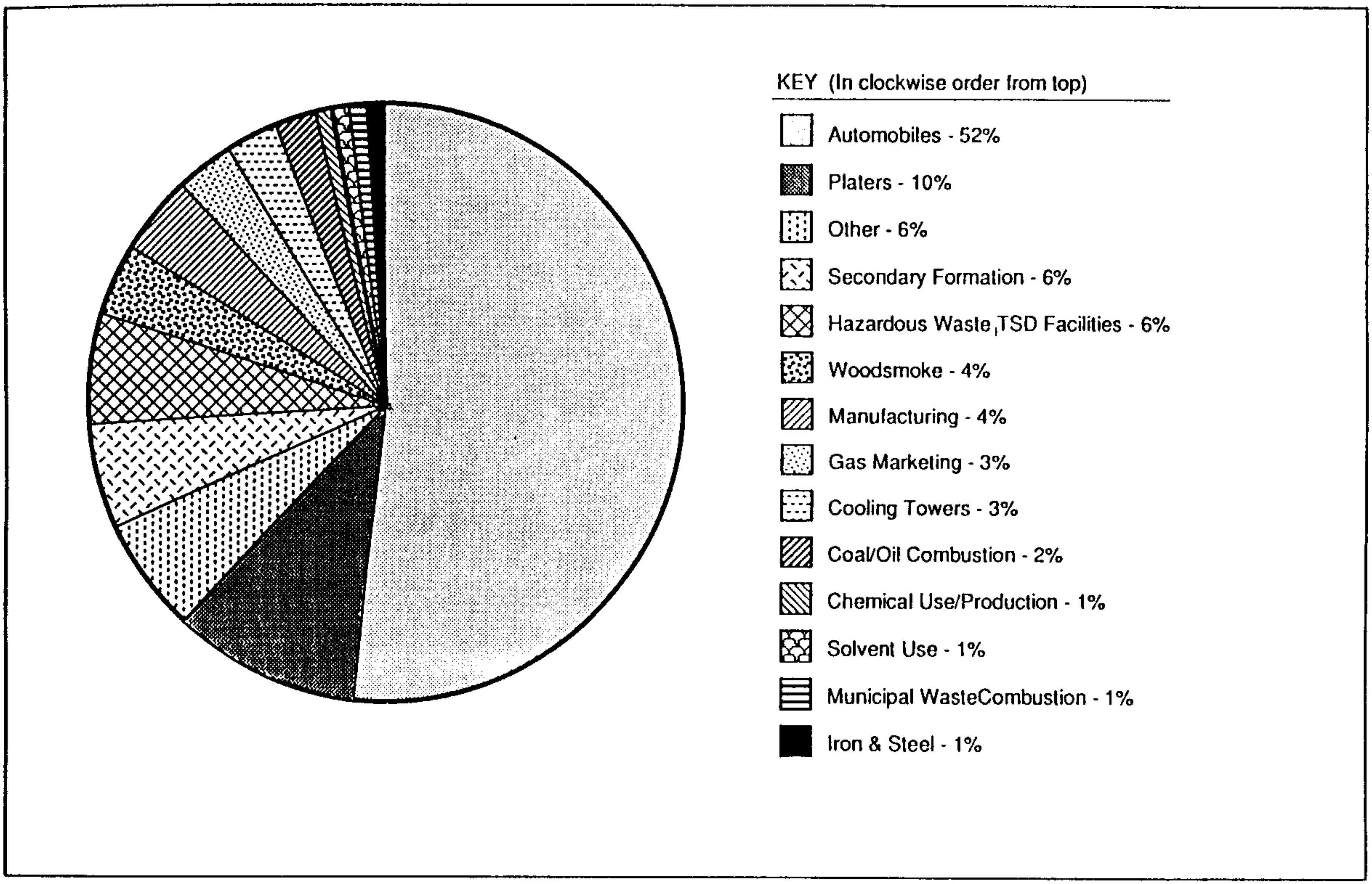

Figure 3-21. Sources of toxic air pollutants in urban areas

Source: EPA 1989a

meat, eggs, or dairy products from animals that may have eaten contaminated feed, soil, or water. In addition, pollutants deposited onto soil may leach into ground water, possibly contaminating drinking water supplies. Contaminated soil and ground water can also wash into surface waters and, along with direct pollutant deposition onto surface waters, can contaminate drinking water supplies and enter the aquatic food chain, potentially leading to human ingestion.

Preliminary studies indicate that toxic pollutants emitted from existing fossil fuel-fired power plant stacks pose little inhalation threat to the health of Maryland residents under normal circumstances (PPER 1989). Expected human exposure appears to be at least an order of magnitude below the conservative levels generally chosen to define a public health risk. Some of these results are preliminary and limited in scope. Further studies are needed to confirm or identify any exceptions.

By contrast, ingestion of food, water, or soil contaminated by toxic emissions, rather than inhalation, may be a significant exposure route for some residents. A comprehensive assessment of the potential ingestion pathway was performed for the existing power plant and the proposed Station H facility at the Dickerson site in northwestern Montgomery County (PPER 1989). Despite the fact that assessment is much more complex and uncertain for ingestion exposure than for inhalation exposure, the conservative assessment for the Dickerson site revealed that ingestion exposure to power plant toxic pollutants by the terrestrial food chain poses little health risk. However, very conservative screening analyses did not entirely rule out the possibility of significant contamination of local fish and ground water; levels of contamination and their significance are very uncertain at this time. Uncertainties concerning emissions and health effects data are similar to those for inhalation. However, additional uncertainties exist involving pollutant deposition rates, pollutant uptake rates by plants and animals, pollutant degradation or loss rates, and other food chain assumptions. Further efforts are required to estimate potential ingestion exposure more reliably. The Dickerson study is also discussed in Chapter 7, Section C.

Toxic emissions of other fuel technologies may differ from those of the combustion technologies used in Maryland today. For instance, pollutant levels are expected to be low from the combustion of synthetic gas produced by coal gasification. While gasification itself produces toxic pollutants, operational data indicate that emissions to the air will likely be minor because of a tight gas stream (no significant leaks). In addition, toxics emitted while burning refuse-derived fuels may be much different than those emitted while burning more conventional fuels.

H. The Global Environment

Two global atmospheric issues captured a great deal of attention in the 1980s: the possible enhancement of the atmospheric "greenhouse effect" and the resulting climate change during the next century; and the depletion of the ozone layer, which is located far above the Earth's surface in the stratosphere. Power plants are a major source of carbon dioxide (CO_2), a primary contributor to the greenhouse effect. Stratospheric ozone depletion is mainly due to chlorofluorocarbons (CFCs), which are unrelated to power plant emissions. Therefore, the issue of interest for Maryland utilities is the greenhouse effect, and the contribution of power plant emissions to the potential problem.

Contribution of Greenhouse Gases to the Greenhouse Effect

The greenhouse effect is caused by the interception of sunlight and the trapping of the energy contained in the sun's rays. As the Earth orbits the sun, it constantly intercepts sunlight. A sizable fraction of this light is reflected back into space by clouds and the surface of the Earth, but that which remains is absorbed by the atmosphere (especially by clouds) and by the Earth's surface. The absorbed solar energy is re-emitted as heat at longer, invisible infrared wavelengths. Since the atmosphere contains clouds and trace gases, which selectively absorb infrared radiation, a portion of the radiation emitted from the Earth's surface is effectively trapped, raising temperatures in the lower atmosphere. This phenomenon, the greenhouse effect, helps to maintain the earth's average temperature at livable levels. The present concern is over an enhancement of the greenhouse effect due to human activities, which may lead to increased global warming.

Greenhouse gases are those gases that trap and absorb the longwave heat re-radiated by the earth's surface. The important greenhouse gases include CO_2, methane (CH_4), CFCs, and N_2O. Carbon dioxide currently contributes approximately half of the total greenhouse effect (Figure 3-22). The present CO_2 concentration in the atmosphere (350 ppm) is approximately 25 percent higher than pre-industrial levels. CO_2 levels are thought to be increasing at a rate of about 0.4 percent per year (EPA 1989c).

- CO_2 as a Greenhouse Gas

Because man-made CO_2 sources are but a small fraction of the CO_2 that is continually exchanged between the earth's surface and the atmosphere (Figure 3-23), it is difficult to estimate the effect of increasing emissions on the levels of CO_2 in the atmosphere. It is generally believed that human activities are responsible for the observed increase in CO_2 in the atmosphere. The combustion of fossil fuels (coal, oil, and natural gas) is the most significant man-made source of CO_2 (Figure 3-24), and most of this man-made CO_2 comes from burning coal (Figure 3-25). In the United States, the utility industry accounts for roughly 35 percent of fossil fuel-derived CO_2 emissions (Figure 3-26). In Maryland specifically, the utilities generated approximately 22 million tons of CO_2 in 1984, less than 0.1 percent of the man-made, worldwide CO_2 emissions. Data from the Federal Energy Regulatory Commission indicates that in Maryland, utility CO_2 emissions from coal, oil, and natural gas combined have risen since 1980 (Figure 3-27).

The combustion of fossil fuels accounts for about 65 to 85 percent of the total global man-made emissions of CO_2 (EPA 1989b). Today the U.S. contributes the most emissions of any country, accounting for approximately 23 percent of worldwide fossil fuel-derived CO_2 emissions. However, because U.S. emissions are only a

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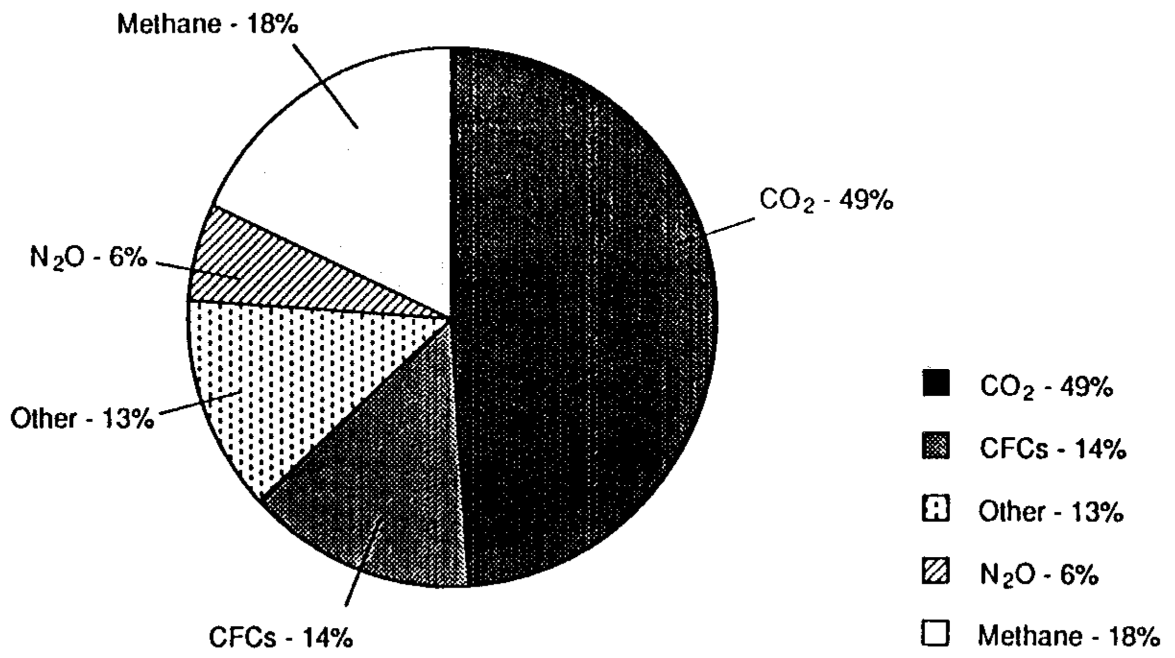

Figure 3-22. Estimated contribution of gases currently in the atmosphere to the greenhouse effect

Source: Hansen et al. 1988

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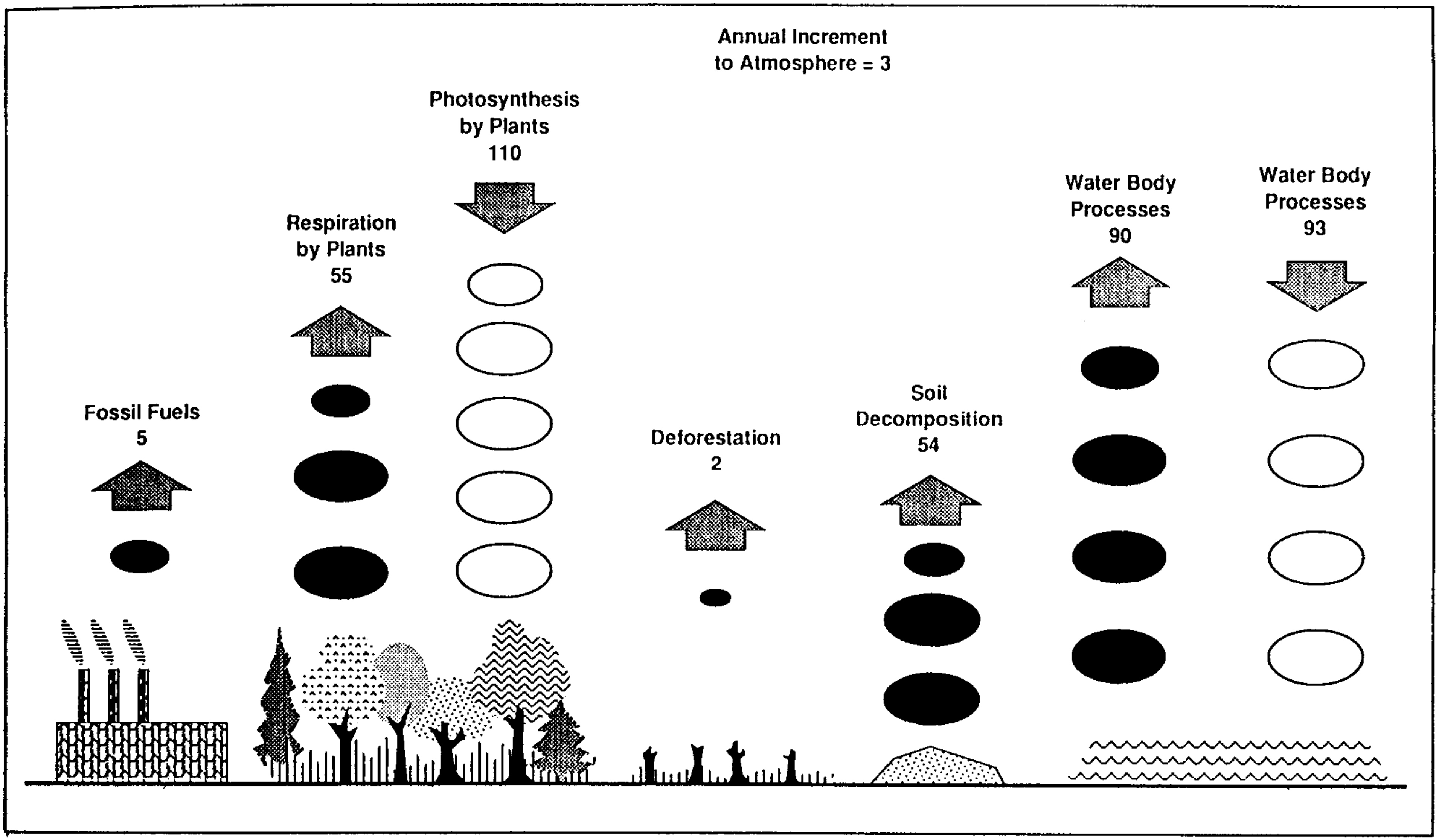

Figure 3-23. Contributions of various carbon dioxide atmospheric fluxes (expressed in billion metric tons of carbon) with an annual net increase of about 3 billion metric tons. (Solid ovals denote addition to atmosphere; open ovals denote addition to surface.)

Source: Schneider 1989

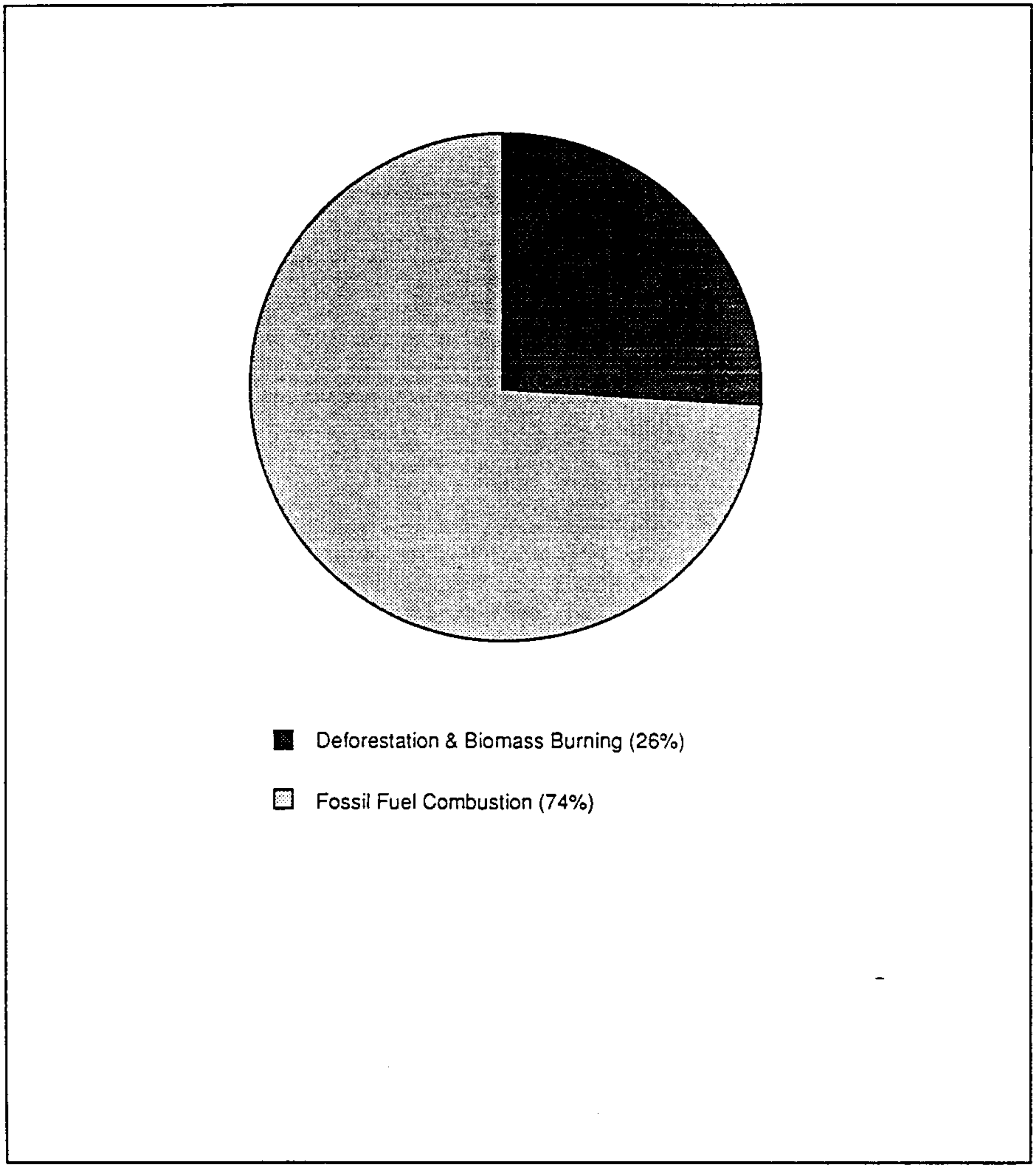

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Figure 3-24. Relative impact of worldwide human activities on CO_2 levels in the atmosphere

Source: EPA 1989c

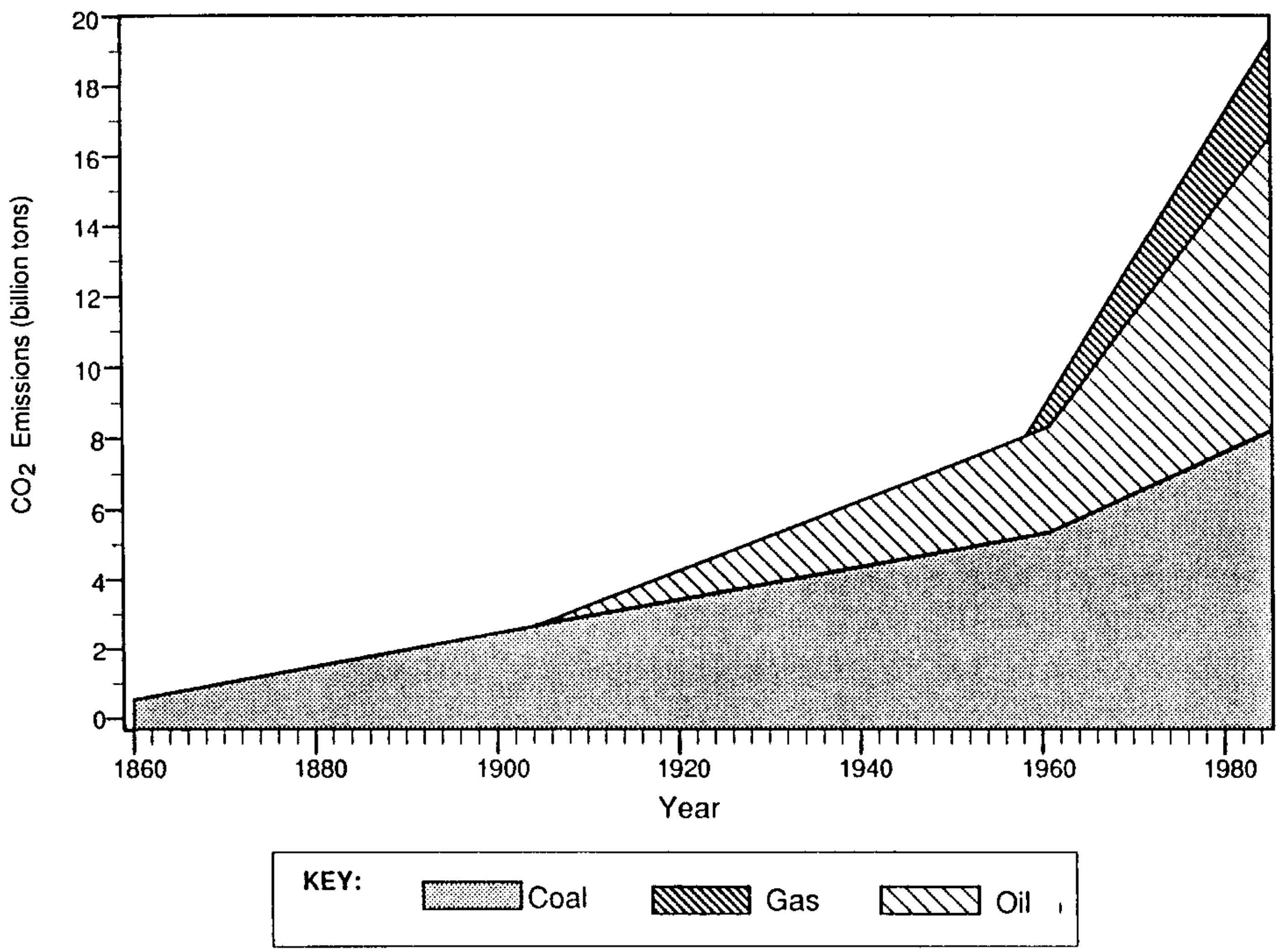

Figure 3-25. Historical worldwide CO_2 emissions from fossil fuel combustion by fuel type

Source: EPA 1989c

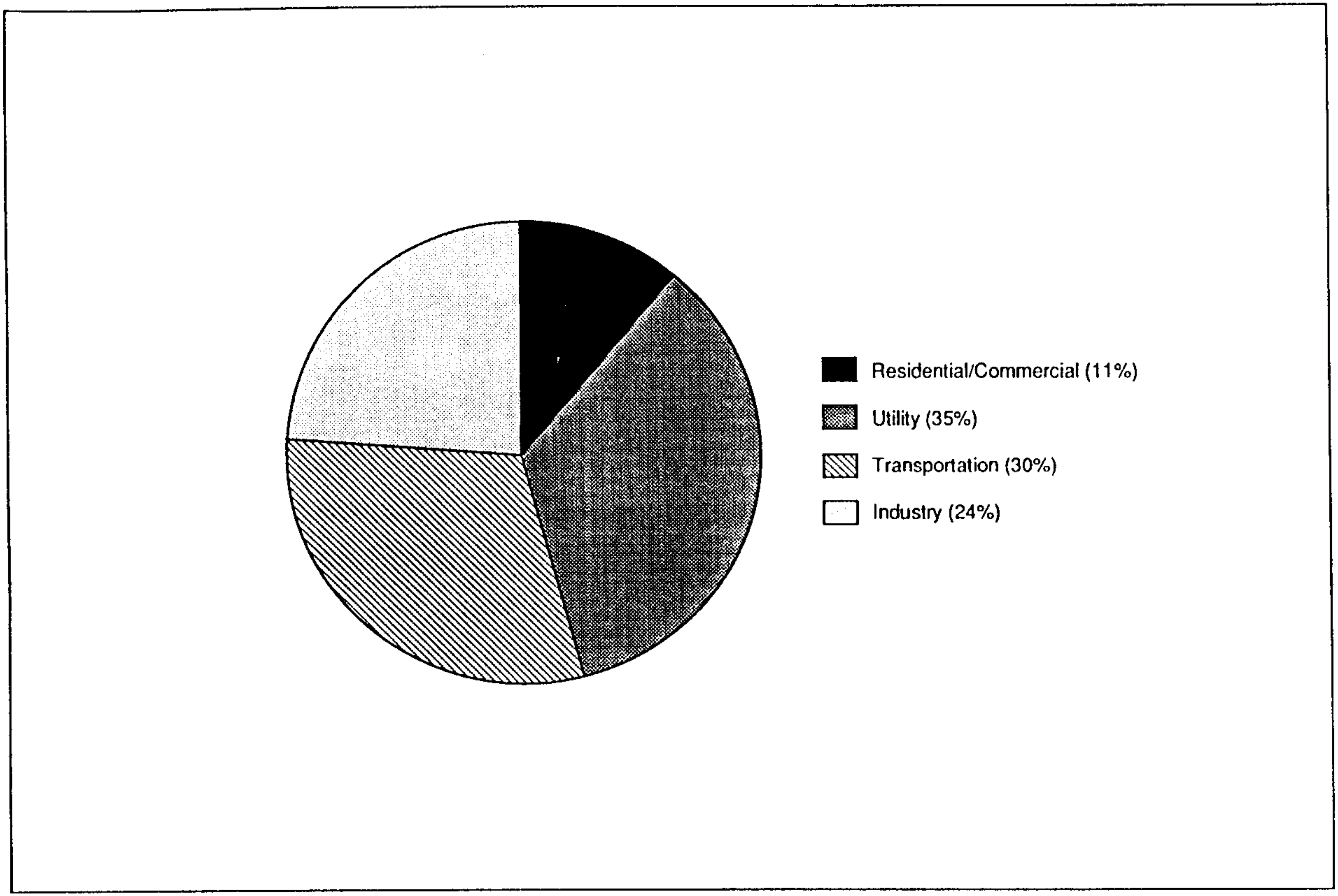

Figure 3-26. Contribution of fossil fuel derived CO_2 sources in the U.S.

Source: Perhac 1989

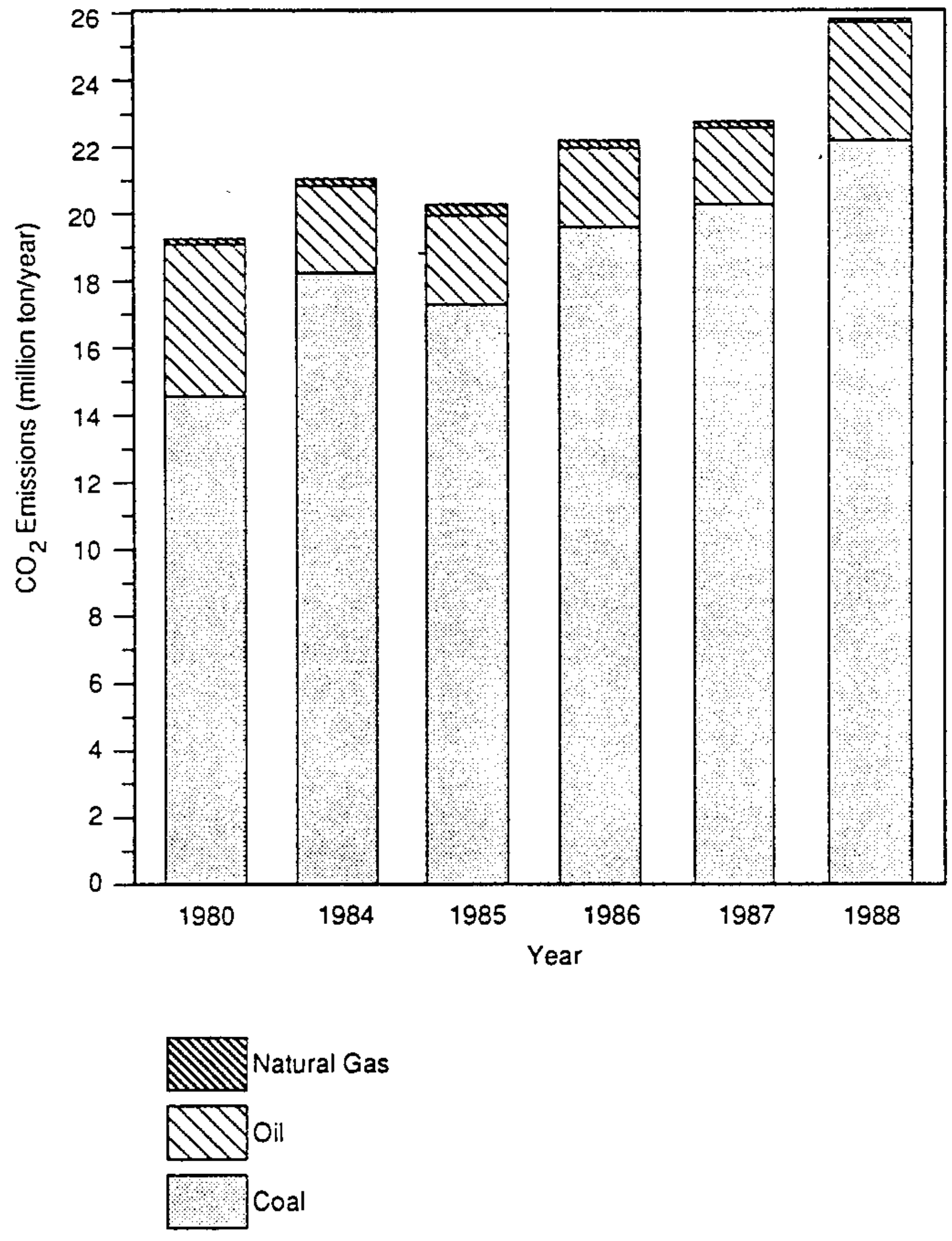

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Figure 3-27. **Historical annual Maryland power plant CO_2 emissions by fuel type**

Source: FERC 1977 - 1988