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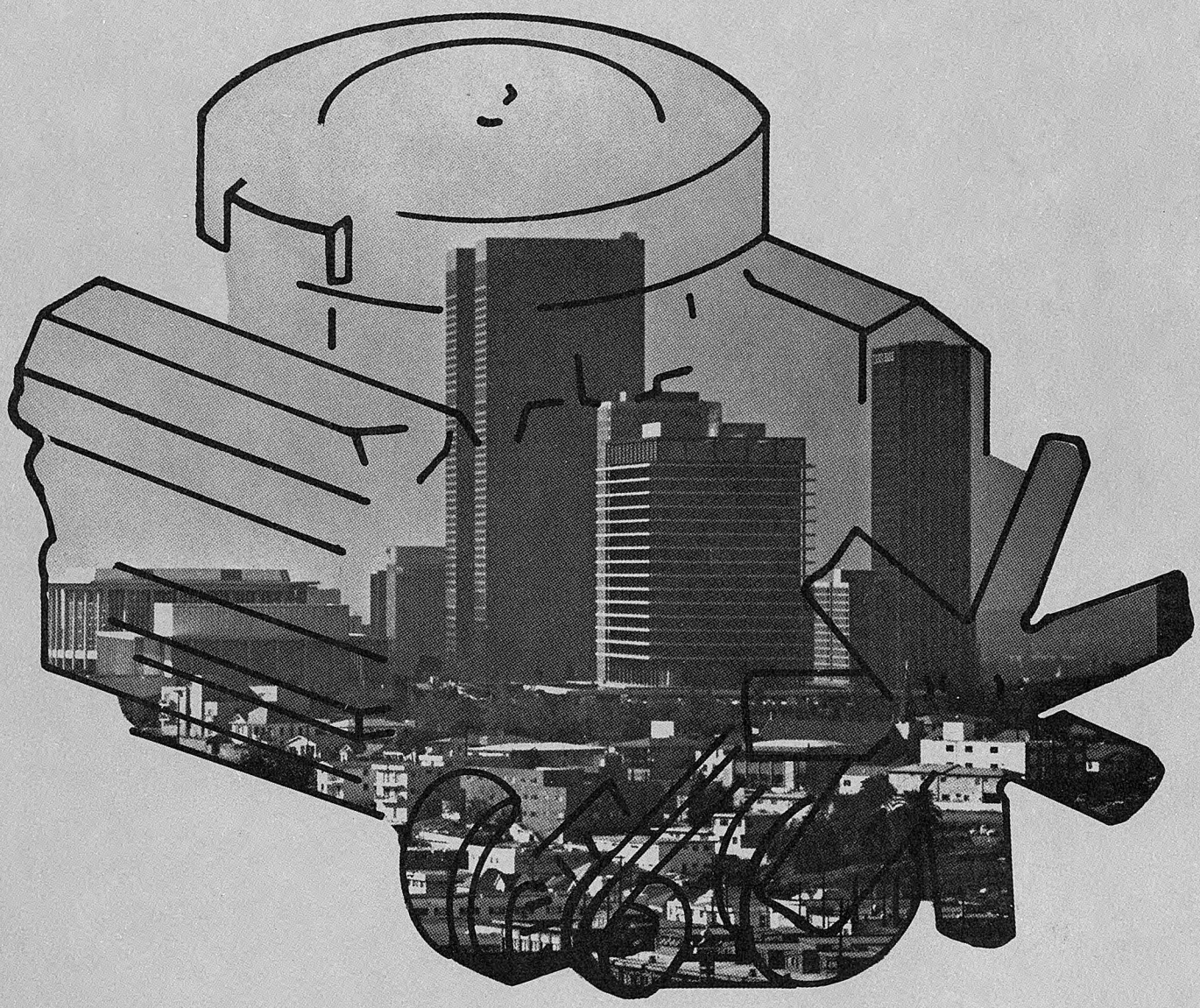
EQL Report #4

A Report to the People of the South Coast Air Basin

by the Environmental Quality Laboratory Staff



California Institute of Technology
ENVIRONMENTAL QUALITY LABORATORY

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PUBLICATIONS OF THE ENVIRONMENTAL QUALITY LABORATORY

EQL Report No. 1	*People, Power, Pollution* Peter Borrelli Mahlon Easterling Burton H. Klein Lester Lees Guy Pauker Robert Poppe	September 1, 1971
EQL Report No. 2	*Implications of the Growth in Demand for Commercial and Industrial Electrical Energy in the South Coast Air Basin* Lester Lees	November, 1971
EQL Report No. 3	*Energy Use in California: Implications for the Environment* E. John List	To appear shortly

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A Report to the People of the South Coast Air Basin

by the Environmental Quality Laboratory Staff

Part I. The EQL Strategy - A Summary (including Figures 1-14)

Part II. The EQL Strategy - Legislative and Administrative Action Required

Supported in part by the National Science Foundation,
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Pasadena, California
January 15, 1972

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Foreword

The Environmental Quality Laboratory traces its origins to a series of discussions initiated by Caltech President Harold Brown on the feasibility of a Caltech Air Pollution Laboratory aimed at alleviating the smog problem in the South Coast Air Basin. In an address to the Institute for the Advancement of Engineering on February 28, 1970[1] Dr. Brown summarized the main conclusions of a faculty-JPL study group on smog led by Professor Carver Mead that preceded the formation of the EQL. To quote from Dr. Brown's address, the most important conclusion "is that there are other factors which are as important or more important than the technological ones . . . . . Unless expert social scientists are available—and I mean not only economists to examine the economic balance, but political scientists, sociologists, psychologists, and so on—the study will be done in too narrow a context. Although it will give the right answers to its own questions, it will prove to have overlooked questions more important than those which it asked."

Our experience in working on the smog problem over the past year fully confirms Dr. Brown's observations. Every member of the EQL staff—social scientists, engineers and graduate and undergraduate students—contributed to this study. We have also had the benefit of numerous discussions with people in industry, in environmental action groups, and in government at all levels who are concerned with air pollution.

This document sets forth a strategy for achieving drastic reductions in the number of "smoggy" days in the Basin by the end of 1977. The EQL strategy is based on new "technical" control measures on stationary sources and *used* motor vehicles, combined with a set of social and economic incentives and disincentives designed to encourage the shift to low-pollution motor vehicles, to encourage the use of multiple-occupancy vehicles (buses, carpools, etc.) and to halt or at least reduce the annual rate of increase in gasoline consumption in the Basin. If the EQL strategy is followed we estimate that the average number of days per year on which the California ambient air quality standard on photochemical oxidant is violated would be reduced from 241 days in 1970 to 50 days by the end of 1975, and to 25 days by the end of 1977.

The measures we propose are neither painless nor inexpensive. We did not find any "magic solutions." For example, the cost of the EQL strategy for this Basin is estimated at about one billion dollars through the end of

[1]Brown, H.: "The University and Environmental Research," *Bulletin of the California Institute of Technology,* Vol. 79, No. 1, March 7, 1970.

1975, or about $100 per head. Whether or not the results that could be achieved are worth the effort and expense is up to the people of the South Coast Air Basin to decide.

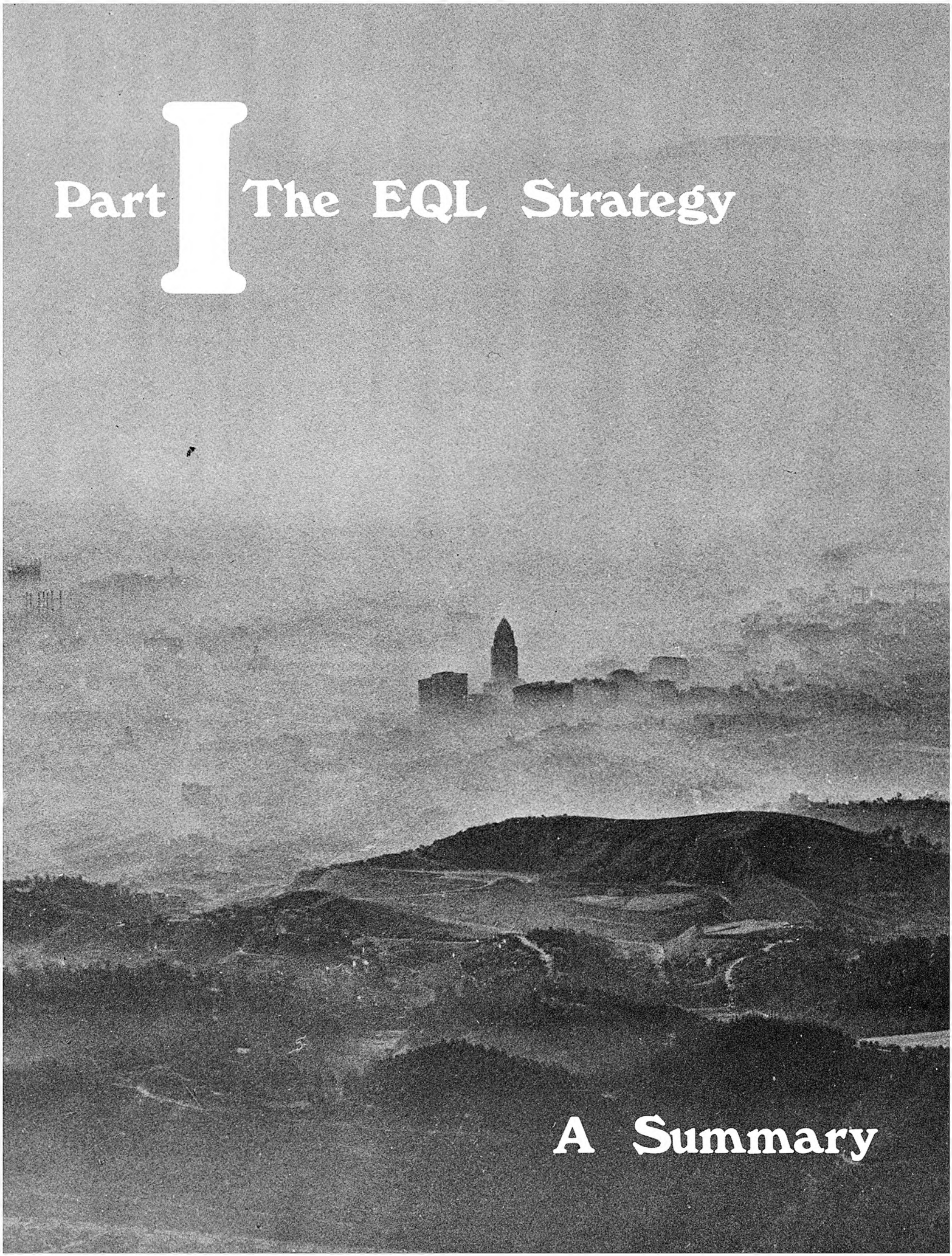
Part I of this report contains a summary of the EQL strategy (including 14 graphs), and Part II briefly outlines the legislative and administrative actions required. Part III of the report, entitled "Supporting Information and Analysis," will appear early in 1972.

Our work on a short-term (1972-1977) air pollution control strategy raised important and difficult questions about the long-range (post-1977) problem of controlling air pollution in the South Coast Air Basin. Members of the EQL staff are already studying new technologies, social and economic incentives, modes of transportation and patterns of land use and development in an attempt to formulate a long-range strategy. We intend to issue a report on this work toward the end of 1972.

Lester Lees

Lester Lees
Director, Environmental Quality Laboratory

Pasadena, California
December 23, 1971



Part I The EQL Strategy

A Summary

I. THE EQL STRATEGY—A SUMMARY

I.1 NEED FOR A NEW AIR POLLUTION CONTROL STRATEGY FOR THE SOUTH COAST AIR BASIN

Twenty five years ago the California State Legislature passed its first air pollution control legislation. During the last quarter-century California has come to be recognized as a world leader in air pollution control. Yet in 1970 the California state ambient air quality standard on photochemical oxidants (including ozone), chosen so that it lies "below that associated with aggravation of respiratory diseases,"[2] was violated on 241 days in the South Coast Air Basin. In that same year the standard on nitrogen dioxide was exceeded on 115 days and the standard on carbon monoxide (12 hour average) was violated on 203 days.[3]

Slow Progress Toward Clean Air

Without the air pollution control measures on stationary sources and new motor vehicles now in effect the situation would be even worse. "Smog alerts" were called in Los Angeles on 9 days in 1970 when the photochemical oxidant concentration reached a level five times higher than the state standard. Without controls the number of "smog alerts" would have been far larger. However, if the present control program is followed for the rest of this decade it will lead at best to a relatively slow improvement in air quality in this Basin. For example, it is estimated that the California standard on oxidants will still be violated on 140 days in 1975 and on 85 days in 1980. The two principal reasons for this slow progress are: (1) the low "death rate" of dirty old cars and the low "birth rate" of new motor vehicles that meet stringent exhaust emission and evaporative control standards; (2) the increase in gasoline consumption at a rate of about 4% per year. The EQL is certainly not the only group to conclude that a new air pollution control strategy that would deal effectively with these two problems is urgently needed (Section 1. 1.).[4]

The Lower Bound For Clean Air

Because of the enormous rates of consumption of gasoline, oil and natural gas in this Basin even the best technology likely to be available in this decade will not be able to reduce total emissions of "reactive" hydrocarbons[5] much below about 150 tons/day and nitrogen oxide emissions below about 250 tons/day.[6] Taking into account the known frequency of low inversion layer heights in this Basin these lower limits on emissions lead to a lower bound of 10-15 days per year on which the state standard on photochemical oxidants would be exceeded. The EQL strategy is designed to drive toward these lower limits as rapidly as feasible by introducing new control measures on stationary sources and *used* motor vehicles, combined with a set of social and economic incentives and disincentives that would encourage the shift to low-pollution motor vehicles and stationary sources, encourage the use of multiple-occupancy vehicles, and reduce the annual rate of increase in gasoline consumption.

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[2]Air Resources Board, Annual Report to Governor Ronald Reagan and the Legislature, entitled "Air Pollution Control in California, 1970," January, 1971, Table 1, p. 24.

[3]Profile of Air Pollution Control, L.A. A.P.C.D., 1971.

[4]Section numbers refer to sections of Part III of the report entitled, "Supporting Information and Analysis."

[5]"Reactive" hydrocarbons are those hydrocarbons that react with oxides of nitrogen in sunlight in a relatively short time of the order of one or two hours (or less).

[6]E. John List, *Energy Use in California—Implications for the Environment*, to be published as an EQL Report.

The EQL proposals are made at a time when the Federal government is exerting pressure for a much faster rate of improvement in air quality than the present State and local strategy can possibly provide (Section I. 2). On April 30, 1971 the Administrator of the Environmental Protection Agency, acting under the provisions of the Federal Clean Air Act of 1970 (as amended), published new Federal air quality standards that are even more stringent than the California standards. Except for the standard on nitrogen dioxide, the Federal standards are not to be exceeded more than once a year. By January 31, 1972 every state is required to submit an adequate air pollution abatement plan to the EPA that must provide for the implementation, enforcement and maintenance of the Federal ambient air quality standards. These standards must be attained within three years of the date of final approval of the state plan, except that an extension of up to two years may be granted by the Administrator.

New Federal Air Quality Standards

Thus, the South Coast Air Basin would be required to meet the new Federal ambient air quality standards by 1975, or by 1977 *at the latest* if a two-year extension is granted.

If the state agencies do not prepare a satisfactory implementation plan, the Act empowers the Administrator of EPA to develop such a plan, and if the states do not have the authority to carry out the plan, the Act has given broad authority to the Administrator. Even if the Administrator does not act, private citizens and groups can sue under the Act to force compliance with Federal ambient air quality standards.

In contrast to these new Federal requirements the Los Angeles County Air Pollution Control District stated in its 1971 annual report[7] that the present strategy would bring air quality up to the California state standards by 1990!

The Need for Management Standards

Thus, the present California control program places "clean air" so far in the future that any improvements in air quality might well be overtaken by population and economic growth long before the distant "target date" is reached. But to reduce violations of air quality standards from the present level of 241 days per year for photochemical oxidants (for example) to literally *one day per year* within the period allowed by the Clean Air Act would require drastic curtailments in the rates of consumption of gasoline, natural gas and residual oil in the Basin, and a sudden brake on economic activity. The most effective practical approach must lie somewhere in between these two extremes.

I. 2 *THE EQL STRATEGY*

I. 2. 1 *General Features*

The EQL strategy depends on the concept of "management standards," based on technical, economic and social feasibility, that would serve as milestones enroute to the clean air required by both the California and Federal ambient air quality standards. These management standards would set a first "target date," by which time significant *percentage reductions* are to be achieved in the number of days per year that ambient air quality standards are violated in the Basin. By the second "target date" substantial percentage reductions would have to be made in the *remaining* number of these "objectionable" days, etc. This approach provides the flexibility re-

[7]Profile of Air Pollution Control, L.A. A.P.C.D., 1971.

quired, and allows for "feedback" from the public as it assesses the beneficial effects of specific control measures, measured against the economic and social costs of these measures.

The Clean Air Act (as amended in 1970) appears to give the Administrator of the EPA discretionary authority to approve such an approach by a State during the period in which a time extension is in effect. Such extensions can be granted when (among other reasons) the necessary technology is unavailable; when the State has implemented reasonable alternatives (as would be the case if a strategy similar to the EQL strategy were adopted); when reasonable interim measures are provided for (the basis of the EQL strategy). EPA regulations published in the Federal Register on August 14, 1971 encourage each state "to consider the socio-economic impact and the relative costs and benefits" of alternative strategies. Public welfare and productive capacity are to be weighed as well as public health.

General Features Of a Realistic Strategy

Before discussing specific control measures contained in the EQL strategy certain desirable main features of any such strategy are outlined as follows:

1. In order to be credible the "target dates" for the achievement of management standards ought to be set well within the present decade, and not in the vague future one or two decades hence. December 31, 1975 is a reasonable first target date (corresponding roughly to the end of the 3-year period allowed under the Clean Air Act), and December 31, 1977 is a reasonable second target date (corresponding to the end of the 2-year extension period).

2. These management standards should be expressed in terms of percentage reductions in the average number of days per year on which the California (or Federal) standards on oxidants, nitrogen dioxide and carbon monoxide are exceeded. For example, a reasonable goal is to reduce these "objectionable" days in the South Coast Air Basin from the 1970 level of 241 per year to a level of 50 days per year by the end of 1975 (a reduction of 80%). By the second target date, at the end of 1977, the objectionable days should be reduced to 25 (an additional reduction of 50%).

3. Because of the relatively short time periods involved, the "technical" control measures required to reach these management standards will have to be based mainly on existing technology that can be developed and introduced within the next 2-4 years.

There Isn't Any One Magic Solution

4. Any strategy must rely on a number of different control measures, each of which provides a modest improvement. It is the cumulative effect which is significant. There is no one "magic solution."

One such strategy is described in the next sub-section. The control measures that are proposed are not supposed to be all-inclusive, nor are the control costs supposed to be minimized. Our purpose is to illustrate the kinds of measures that must be taken if the requirements listed above are to be met. In most of the discussion to follow we are making the "conservative" assumption that *new* motor vehicles for model years beyond 1974 will meet the 1974 California exhaust emissions standards, but not the more stringent 1975/76 Federal standards. Some of the figures to be presented in Part III will show the additional benefits to be gained (at additional cost!) if new motor vehicles do in fact meet the Federal standards beginning in 1975.

I. 2. 2 *Specific Control Measures*

The nature and extent of the specific control measures that are needed depend on the magnitude of the reductions in emissions of reactive hydrocarbons and nitrogen oxides that are required in order to meet the management air quality standards set forth in the EQL strategy. At present no general theory exists that would enable us to predict ambient air quality for photochemical oxidants, nitrogen dioxide and carbon monoxide in terms of the emissions level of the primary contaminants. In lieu of such a theory, the relationship between air quality and emissions levels is here established by means of a statistical analysis of air quality monitoring data obtained at the ground-level stations of the Los Angeles Air Pollution Control District over the last several years.[8] An important simplifying physical assumption is introduced in this analysis—namely, the assumption that *for given meteorological conditions* the atmospheric concentrations of carbon monoxide and the "early morning"[9] concentrations of reactive hydrocarbons and nitrogen oxides are directly proportional to their respective emissions levels.

Measuring the Pay-off of Control

The application of this simple idea to the statistical data is best illustrated by dealing first with the contaminant nitrogen dioxide, which tends to be approximately proportional to the total input of nitrogen oxides. Statistical data is displayed in terms of the average number of days per year that the maximum atmospheric concentration exceeds a given level for at least one hour, plotted against the concentration (Figure 1). (The solid curve in Figure 1 corresponds to the 1969 average of about 1000 tons per day of nitrogen oxides emissions in the Basin.) As expected, "low" one-hour maximum concentrations of nitrogen dioxide around 10 pphm[10] are exceeded quite frequently, but "high" concentrations around 50 pphm are rarely exceeded at this emissions level. These observations correspond roughly to the relatively high frequency of occurrence of maximum mixing layer heights (or heights of the base of the infamous inversion layer) that are 3500 feet or less, compared to the infrequent appearance of maximum mixing layer heights that are 700 feet, or less. These relatively infrequent low inversion layers markedly concentrate the pollutants near the ground.

A Simple Predictive Model For Air Quality

Suppose that by means of a set of control measures the level of emissions of nitrogen oxides in the Basin is reduced by 50% to 500 tons per day. For the *same meteorological conditions,* atmospheric concentrations of nitrogen dioxide are also cut in half (dashed curve in Figure 1). In other words, if emissions are reduced by 50% the simple rule to follow is that the number of days per year on which a particular maximum one-hour concentration of nitrogen dioxide is exceeded is the same as the number of days per year on which twice this concentration was exceeded at twice the emission level (horizontal dashed line in Figure 1). By following this rule, we see that at the new emissions level, a concentration of 25 pphm for one hour (California state standard) is exceeded on the same number of days per year as a concentration of 50 pphm was exceeded at the old emissions level. But the frequency of occurrence of concentrations of 50 pphm for one hour is much less than one half the frequency of concentrations of 25 pphm;

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[8]This analysis was carried out by Mr. John Trijonis as part of his Caltech PhD thesis research on the economics of air pollution control.

[9]By "early morning" we mean before 9:30 a.m., in Los Angeles, or before photochemical reactions have begun.

[10]parts per hundred million

so a 50% reduction in emissions level leads to a much larger percentage reduction in "objectionable" days per year (vertical dashed line in Figure 1). Typical improvements in air quality for nitrogen dioxide as nitrogen oxides emissions are reduced are shown in Figure 2 for several stations in L.A. County.

The situation for photochemical oxidants is more complicated than for nitrogen dioxide because the peak one-hour oxidant level depends on "early-morning" concentrations of reactive hydrocarbons and nitrogen oxides, on sunlight intensity, temperature and other variables in a complex manner. In spite of this difficulty, by using the L.A. APCD data Trijonis was able to work out "summer" and "winter" correlations between daily one-hour average oxidant level and "early-morning" concentrations of reactive hydrocarbons and nitrogen oxides. The effect of reductions in emissions levels on the concentrations of these two substances is calculated just as nitrogen dioxide was analyzed in the simple illustrative example given earlier.[11]

A Target for 1975

Our calculations show that in order to reduce from 241 to 50 the average number of days per year on which the maximum daily one-hour average oxidant concentration of 0.10 ppm is exceeded[12] (first "target" of the EQL strategy) the total emissions of reactive hydrocarbons from all sources in the Basin must be reduced to *28% of present levels,* and emissions of nitrogen oxides must be reduced to about *45% of present levels.* If these reductions were made, the California ambient air quality standards for nitrogen dioxide of 25 pphm for one hour would be exceeded on 10 days per year as compared with 130 days in 1970. The "health warning"[13] level of a one-hour average oxidant concentration of 0.20 ppm (twice the State standard) for persons with coronary artery diseases or chronic respiratory diseases would be exceeded on 15 days per year, as compared with 150 days per year in 1970.

Thus, Phase 1 of the EQL strategy is designed to reduce total emissions of reactive hydrocarbons to 28% of present levels and nitrogen oxide emissions to 45% of present levels by December 31, 1975.

These objectives would be accomplished by means of the following *Phase 1 control measures,* combined with the effects of the new cars introduced into the Basin.

A. Motor Vehicles

The EQL Strategy Phase 1

1. Mandatory conversion of all gasoline-burning commercial motor vehicles of model years 1970 and later in both small and large fleets (trucks, taxis, buses, cars) to burn a gaseous fuel, such as compressed natural gas or liquid propane gas, by *December 31, 1973* in the South Coast Air Basin. This measure means that about 33% of the gasoline now burned in the Basin would be replaced by gaseous fuels.

(2) (a) Mandatory installation on 1960-1965 gasoline-powered cars of a currently-available control device known as the "capacitor discharge, ignition optimization system" that reduces hydrocarbon emissions by about 60% and NO_x emissions by about 35% on pre-1966 cars.

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[11]Estimates of the number of objectionable days per year for each pollutant were obtained for Central Los Angeles. The average number of days per year on which the California ambient air quality standards are violated at *some* station in the entire Basin is significantly higher. For photochemical oxidant the number of objectionable days for the entire Basin is 1.7 times higher on the average than in Central L.A., and for nitrogen dioxide the number of such days is 2.3 times higher on the average.

[12]California State ambient air quality standard.

[13]Proposed by the Los Angeles County Medical Association.

(b) Mandatory installation on 1966-1970 gasoline-powered cars of a currently-available control device known as the "vacuum spark advance disconnect" (VSAD) that reduces nitrogen oxides emissions by about 44% and hydrocarbon emissions by about 23% in these cars.[14]

(3) Mandatory installation of an evaporative control device on gasoline-powered 1966-1969 vehicles that reduces fuel tank evaporative emissions by 90%. (Starting with the 1970 models new cars have such controls.) Since this device is estimated to cost approximately $150 to purchase and install, some subsidy or cost-sharing would be required. (Less expensive retrofit devices are currently under study at the EQL.) If such a subsidy were to be paid to vehicle owners for installation of this device an equal subsidy ought to be made available to vehicle owners who elect any other step that would reduce reactive hydrocarbon emissions in the Basin by a comparable amount. *Example:* purchase of a post-1969 vehicle to replace an older vehicle that is sold to a new owner who lives and works outside the Basin.

Technical Controls

4. A mandatory vehicle emissions inspection system that would: (1) insure that new and used gasoline-powered vehicles meet the emissions standards set for them by present and proposed control measures; (2) insure that vehicles operating on gaseous fuels are properly tuned to achieve the low exhaust emissions levels qualifying them for the 7 cents/gallon (equivalent) State fuel tax remission;[15] (3) form the basis for a system of emissions taxes.

5. Social and economic incentives and disincentives designed to encourage the shift to low-pollution motor vehicles by motorists and vehicle manufacturers, to encourage the use of multiple-occupancy vehicles, and to halt or at least reduce the annual rate of increase in gasoline consumption. Such measures include: (1) emissions taxes assessed on car owners in proportion to the amount of emissions their cars discharge into the air; (2) reserved "fast lanes" on freeways for buses and carpools; (3) controlled access to freeways so that buses and carpools are given priority during rush hours; (4) free or subsidized parking for carpoolers; (5) buses and demand-jitneys or "dial-a-bus" systems partially subsidized by revenues collected from emissions taxes; (6) *as a last resort,* additional gasoline taxes and/or a limit on the total consumption of gasoline in the Basin at 2.7 billion gallons per year by a system of freely-auctioned coupons, giving motorists in the Basin gasoline purchase rights up to this total amount, but no more.[16]

Socio-economic Measures

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[14]In November, 1971, Governor Reagan signed the Sieroty-Cologne Bill, which requires that beginning in 1973, all 1966-1970 cars must be equipped with a device that will "significantly" cut nitrogen oxide emissions. The certification that such a device is installed on the car is to be made on initial registration, on transfer of ownership or on renewal of registration. A limit of $35 is set on the initial cost of such a device, including installation charges, and the bill specifies that it should not require maintenance more than once every 12,000 miles at a maximum cost of $15. The State Air Resources Board must now set the standards for such equipment. If the cost limitation were raised to $40 by action of the Legislature the "capacitor discharge, ignition optimization system" could be utilized also by 1966-1970 cars. This device reduces HC emissions by 10% and NO_x emissions by 55% in these cars. At the EQL, undergraduate students in the Clean Air Car Project are investigating the operating characteristics of a simple disconnect of the vacuum spark advance on 1966-1970 gasoline-powered cars that would cost about $10.

[15]California law presently exempts vehicles operating with propane or natural gas conversion systems approved by the Air Resources Board from the State tax on vehicle fuel.

[16]According to E. J. List, the actual rate of gasoline consumption in 1969 was 4 billion gallons a year. The figure of 2.7 billion gallons represents what is left after one-third of current gasoline demand is converted to gaseous fuels.

In our calculations we assumed that by December 31, 1975 the combined effect of all the measures under #5 amounts to a 20% reduction in the motor vehicle pollution remaining after measures #1-#4 are put into practice.

B. Stationary Sources

1. *Nitrogen Oxides.* Mandatory installation of two-stage combustion and/or gas recirculation (or other control devices) designed to cut NO_x emissions by 50% by the end of 1973 in all fossil-fuel power plants.[17] Mandatory use of low "excess" air in industrial boilers and heaters using natural gas with a rating in excess of 30 million BTU/hour (about 8.5 megawatts).

2. *Hydrocarbons.* (i) Substitution of non-reactive materials by users of organic solvents emitting "high reactivity" HC (as defined by the L.A. APCD) in order to cut these emissions by 50% by 1973.[18] (ii) Mandatory recirculation of vapors from gasoline storage tanks in filling stations back to tanker trucks during filling operations.

Phase 2

* * *

Phase 2 of the EQL strategy consists of a limited number of "smog alerts" to be called in the Basin during the period July through September when the oxidant level exceeds 0.20 ppm at any station in the Basin, or when early morning inversion layer height and temperature indicate a high probability that this level will be exceeded.[19] Beginning in 1973 two or three such alerts would be called, and by 1975 the number of such alerts would be increased to 6-8. Although we do not attribute any specific reduction in the number of "objectionable" days to Phase 2 it seems clear that the two phases of the EQL strategy are mutually reenforcing. Incentives for reducing emissions are created by calling smog alerts that shut down or curtail emission sources, while reductions in emissions require fewer smog alerts. If the EQL target of about 15 days per year for an oxidant level of 0.20 ppm is reached by the end of 1975 these smog alerts could be discontinued.

1. During these smog alerts only "low emission" vehicles,[20] vehicles with two or more passengers, and buses and jitneys would be permitted on the freeways.

2. During an alert all stationary sources of "high reactivity" HC emissions would be shut down.

The Cost

Rough cost estimates indicate that the cost of Phase 1 of the EQL strategy for the South Coast Air Basin is about one billion dollars through December 31, 1975, which amounts to about $100 per head, or $300 per household ($25 per head per year or $75 per household per year). The cost breakdown is as follows: (1) loss of Federal and State tax revenues by conversion to gaseous fuels—$400 million; (2) VSAD—$70 million; (3) evapora-

[17]Such control devices are now being installed in the large electric power plants of Southern California Edison and the L.A. Dept. of Water and Power.

[18]Approximately 100 tons/day of "high reactivity" HC are emitted by these sources. Another 550 tons/day of "low reactivity" HC emissions from stationary sources would not be affected by this program.

[19]At present first stage smog alerts are called when the oxidant level exceeds 0.50 ppm (five times the State air quality standards). No emissions sources are curtailed during these alerts.

[20]These vehicles could be identified by means of special windshield stickers.

tive control retrofit—$225 million; (4) mandatory motor vehicle inspection program—$200 million; (5) controls for stationary sources—$100 million.[21]

By the second target date of December 31, 1977 the EQL strategy calls for no more than 25 days per year on which the California ambient air quality standards for oxidants is violated in the Basin. Our calculations show that in order to achieve this objective the total emissions of reactive hydrocarbons in the Basin must be reduced to about *22% of present levels* and nitrogen oxides emissions must be reduced to about *38% of present levels*. If the Phase 1 control measures are successful in reaching their targets by the end of 1975 it turns out that the *additional* reductions in total emissions that are required by the end of 1977 could be achieved by means of two specific control measures: (1) continued conversion of gasoline-burning commercial vehicles to burn a gaseous fuel, as long as emissions from new vehicles are significantly higher than emissions from gaseous-fueled vehicles (maintaining the level of ⅓ of the gasoline replaced by gaseous fuels at all times); (2) continuation of mandatory vehicle emissions inspection program (A.4 of Phase 1). The social and economic incentives and disincentives listed under A.5 of Phase 1 would almost certainly be necessary in the long-run (See Section I. 3), but no *additional* reductions in emissions after 1975 are attributed to these measures in the present "conservative" calculations. The *additional* cost of this program from the end of 1975 to the end of 1977 is estimated at about $380 million. (The total cost of the new cars for 1976 and 1977 is estimated at about $300 million in this Basin.)

A Second Target—1977

In Section 2 of Part III of this report the reductions in emissions from motor vehicles and stationary sources that can be achieved by each of the control measures in the EQL strategy are discussed in detail. In Figures 3 and 4 we show the breakdown in reductions in reactive automotive hydrocarbons and nitrogen oxide emissions for L.A. County. Figures 5 and 6 show the contribution from stationary sources and the reductions in *total* reactive hydrocarbons and nitrogen oxides emissions. Based on these reductions the projected improvements in ambient air quality for photochemical oxidant and nitrogen dioxide are calculated by methods already outlined and described in detail in Section 2.2 and Appendix B of Part III. In Figures 7 and 8 the results of these calculations are illustrated for the "present strategy" and for the EQL strategy. Figure 9 shows the projected reductions in the number of "health warning" days (proposed by the Los Angeles County Medical Association for persons suffering from coronary artery diseases or chronic respiratory diseases).

Supporting Documents For EQL Strategy

Control measures A.1 and A.5 on motor vehicles will also greatly reduce carbon monoxide emissions into the atmosphere of the Basin, as shown in Figure 10. In Figure 11 we show the corresponding projected improvements in ambient air quality for carbon monoxide according to the "present strategy" and the EQL strategy. By 1977 the EQL strategy would virtually eliminate the carbon monoxide problem in L.A. County.

In Sections 3 and 4 of Part III the feasibility of the "technical" control measures A.1-A.4 and B.1 and 2 for motor vehicles and stationary sources is examined. By feasibility we mean supply, distribution and marketing of gaseous fuels; economics of conversion to gaseous fuels; safety, insurance

[21]The costs to the buyers of new cars that meet the California exhaust emission standards is estimated at approximately $400 million over this same period. This estimate is based on an additional cost of pollution controls of $50/car in 1972, $150/car in 1973 and $300/car in 1974 and 1975.

and reliability of gaseous-fueled motor vehicles; economics and performance of "retrofit" devices on used cars; availability and performance of control devices for stationary sources. No important technical or economic difficulties were uncovered in this study. However, a considerable amount of "risk capital" and organizational effort is required to put these control measures into effect on the time schedule adopted in the EQL strategy. On the other hand, the program provides some attractive opportunities for profitable business ventures and for employment of presently under-employed or unemployed skilled people in the Los Angeles area.

Is There Enough Propane and Natural Gas?

In Section 3 the controversial question of the conversion of commercial motor vehicles to burn a gaseous fuel is discussed in some detail. The supply problems for compressed natural gas (CNG) and propane (LPG) in this Basin were studied carefully, not only by the EQL staff but also independently by a well-known oil and gas consulting firm retained by the EQL—The Pace Company of Houston, Texas. The Pace Company report concluded that supplies of CNG and LPG are adequate to replace up to 33% of the gasoline burned in the Basin.[22] The report recommended a "mix" of 25% CNG and 8% LPG to make up the figure of 33%. This amount of CNG is eqivalent to 250 million cubic feet per day. In the "smoggy" summer months "firm" customer demand for natural gas is about 500 million cubic feet per day, leaving about 2.5 billion cubic feet per day for "interruptible" users (Figure 12). About 10% of the "interruptible" supply would have to be diverted from electric power plants and industrial users to motor vehicles. Such a diversion could be accomplished by means of a small price differential. In the relatively "smog-free" winter months natural gas is in short supply because of large "firm" customer demand. Thus motor vehicles converted to CNG are almost always equipped with "dual-fuel" systems that allow them to switch to gasoline in the winter months, or when they are outside the Basin.

If 8% of the projected gasoline consumption in the Basin is replaced by propane by 1975 the requirement for propane amounts to about 10 million barrels per years, a quantity equal to the total consumption of propane in California in 1970 (Figure 13). However, propane supply is increasing rapidly in the 1970's, Canadian propane supplies are available, and the figure of 8% is regarded by the Pace Company as a reasonable initial target that would not place too great a strain on refineries and other sources (mainly natural gas fields).

Feasibility of Vehicle Conversion

So far as distribution of CNG is concerned commercial fleets generally would have their own fueling facility, including compressor and storage tank. Recently the Union Oil Co. and Pacific Lighting Corp. announced a cooperative pilot program whereby two service stations in Riverside, California, will sell CNG to motor vehicles. This system could be expanded rapidly to include a certain fraction of the service stations in the Basin. Propane, on the other hand, is already available at about 54 stations in the Los Angeles area, and another 42 stations now selling propane to campers could easily obtain the necessary permit to sell this fuel to motor vehicles. This distribution system could also be expanded once the demand was established.

Similar conclusions about feasibility were reached regarding the pos-

[22]Excerpts from the Pace Co. report and the major conclusions are contained in Appendix C of Part III.

sible rate of conversion of motor vehicles to burn a gaseous fuel. After several days of training, a good mechanic can convert one vehicle in about one working day. Thus 1000 mechanics working 250 days per year could convert the estimated 500,000 commercial fleet vehicles in the Basin in about 2 years.

Pilot Programs to Test Socio-economic Policies

In contrast to these technical-economic measures, the detailed effects of the social and economic measures listed under A.5 (and discussed in detail in Section 5 of Part III) are very difficult to forecast. The whole purpose of this set of incentives and disincentives is to provide alternate modes of transportation and to influence human behavior. Lacking a predictive theory of human behavior we need to introduce demonstration or "pilot" programs in order to obtain "feedback" from the public in a reasonably short time period. In the case of the emissions tax, for example, an iterative procedure could be utilized, in which a certain reasonable tax schedule is set and the effects observed for one year, after which the schedule is revised as needed. These pilot and iterative programs are necessary first steps toward a long-range strategy for the post-1977 period.

I. 3 *A GLIMPSE AT THE POST-1977 PERIOD AND LONG-RANGE NEEDS.*

Beyond 1977

Sometime in the early 1980's emissions of reactive hydrocarbons, nitrogen oxides and carbon monoxide into the atmosphere and the number of smoggy days in the Basin will begin to increase again, even if the EQL strategy is fully implemented (Figure 14). The projected growth in population and in the rate of consumption of gasoline, natural gas and oil in the Basin makes this outcome inevitable—*if no new steps are taken.* Section 6 of Part III of this report contains a brief discussion of two different (but not mutually exclusive) approaches to the long-term air pollution problem in the Basin: (1) introduction of new technology, e.g., electric commuter cars, replacement of natural gas and oil-fueled industrial burners by electric-powered devices, replacement of electric power plants inside the Basin by new power plants located outside the Basin; (2) limitations on population, industry and commerce in the Basin, provision for a balanced transportation system, and important changes in life-style. The Environmental Quality Lab intends to issue a report on a possible long-range air pollution control strategy toward the end of 1972.

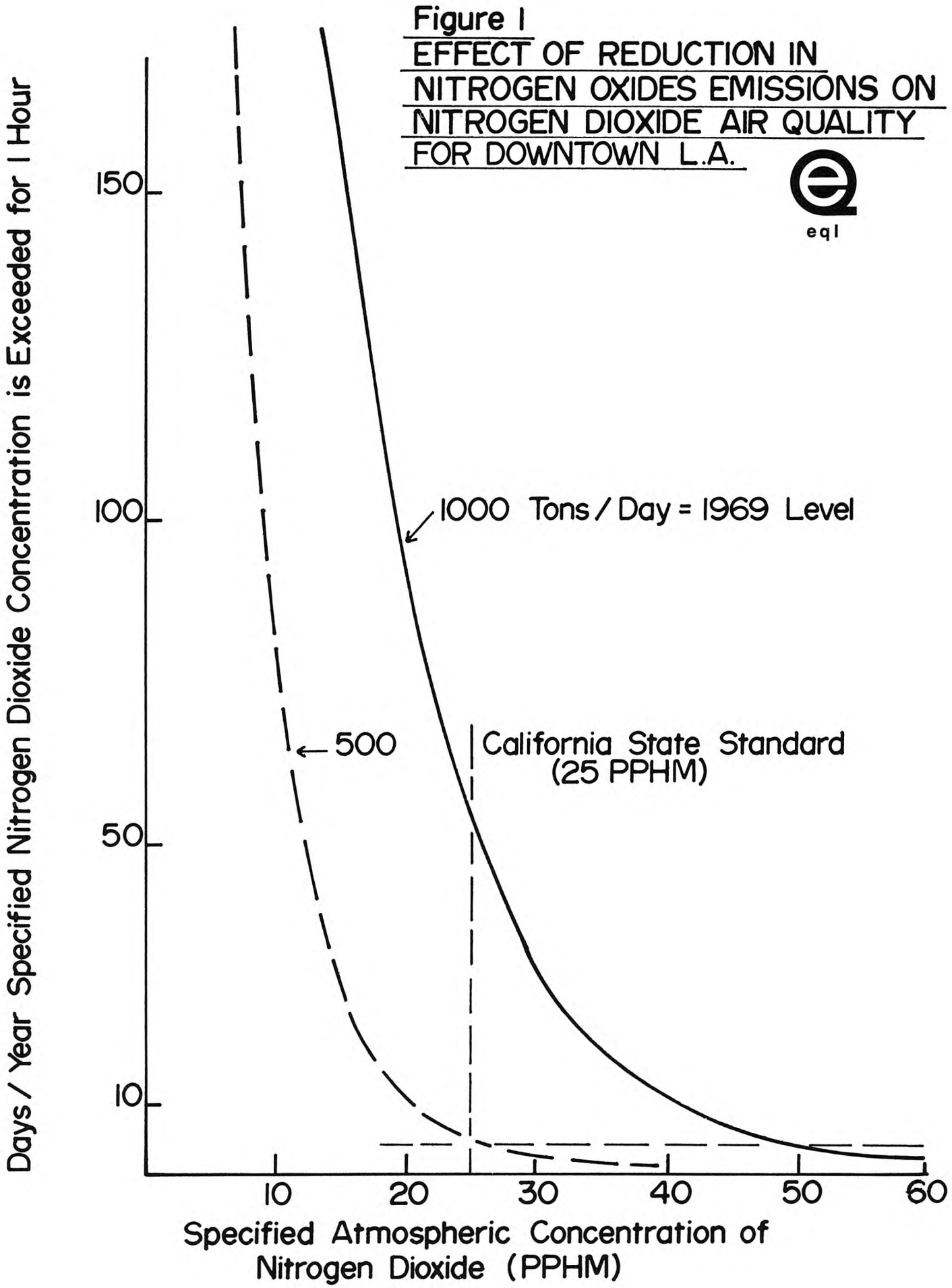


Figure 1
EFFECT OF REDUCTION IN NITROGEN OXIDES EMISSIONS ON NITROGEN DIOXIDE AIR QUALITY FOR DOWNTOWN L.A.
eql
Days / Year Specified Nitrogen Dioxide Concentration is Exceeded for 1 Hour
150
100
50
10
1000 Tons / Day = 1969 Level
500
California State Standard
(25 PPHM)
10
20
30
40
50
60
Specified Atmospheric Concentration of
Nitrogen Dioxide (PPHM)

Figure 2

NITROGEN DIOXIDE AIR QUALITY VS. EMISSIONS FOR VARIOUS STATIONS

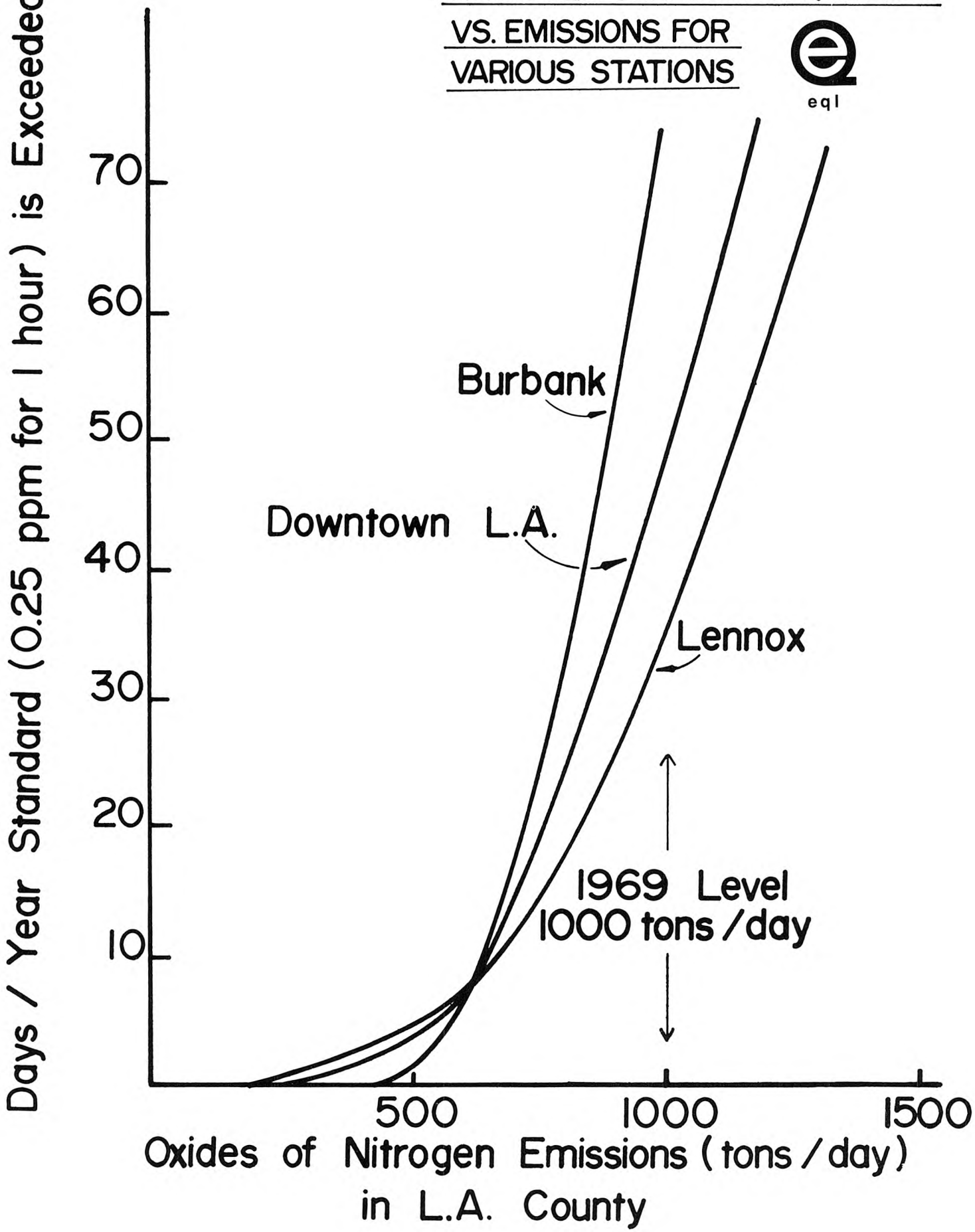


Figure 3

BREAKDOWN OF REDUCTIONS IN REACTIVE AUTOMOTIVE HYDROCARBON EMISSIONS FOR L.A. COUNTY

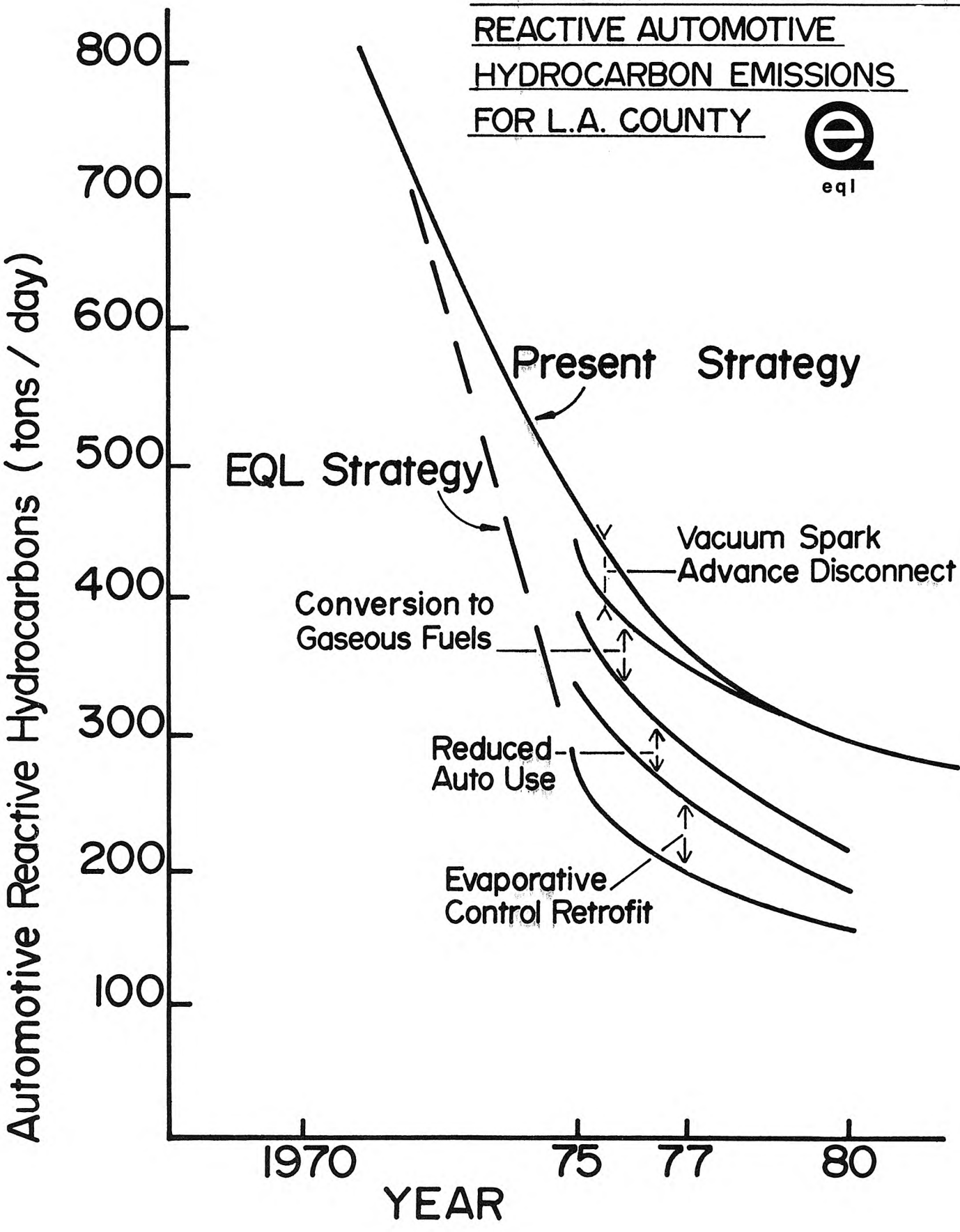


Figure 4

BREAKDOWN OF REDUCTIONS IN AUTOMOTIVE OXIDES OF NITROGEN EMISSIONS FOR L.A. COUNTY

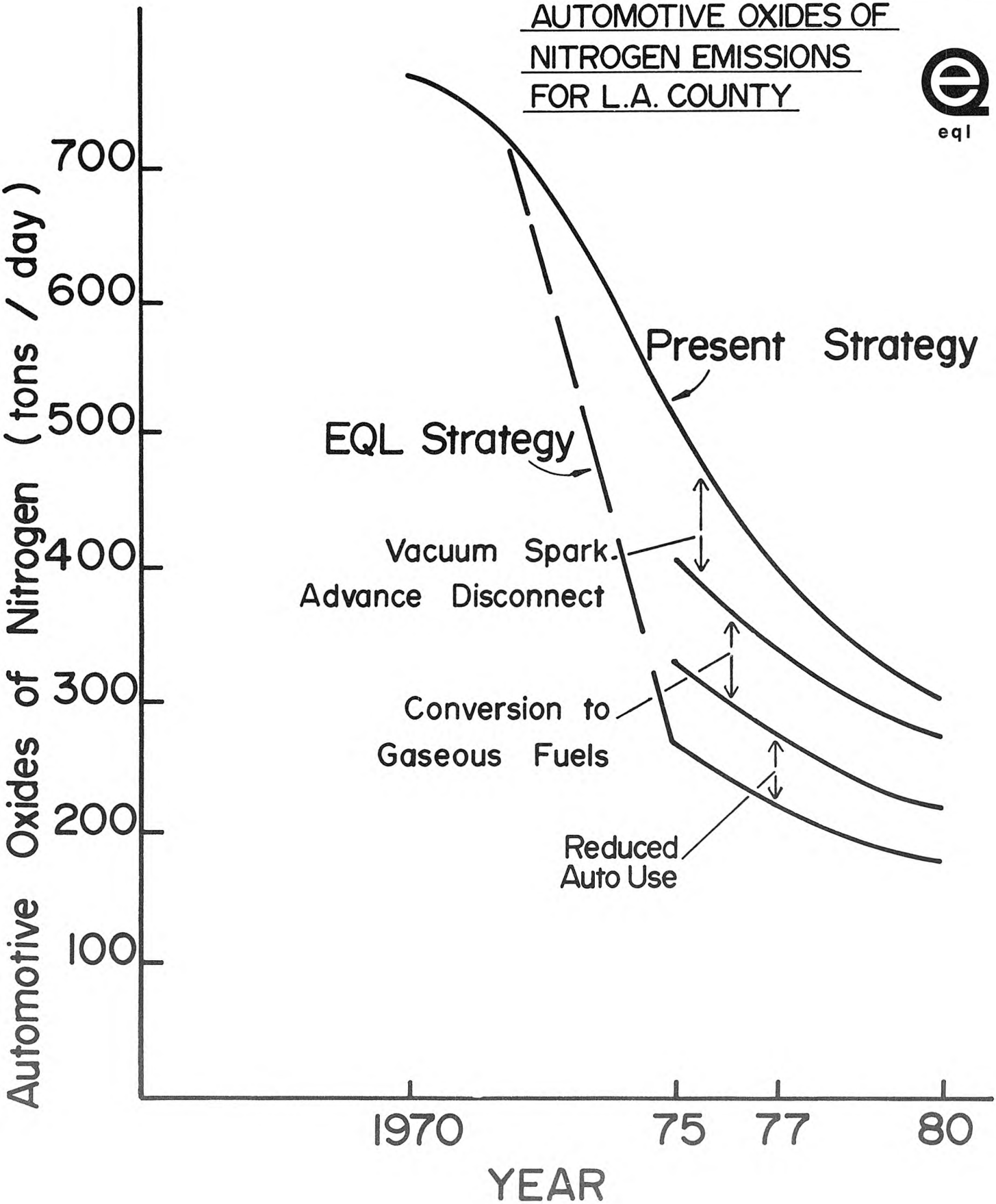


Figure 5

REDUCTION IN TOTAL REACTIVE HYDROCARBON EMISSIONS FOR L.A. COUNTY

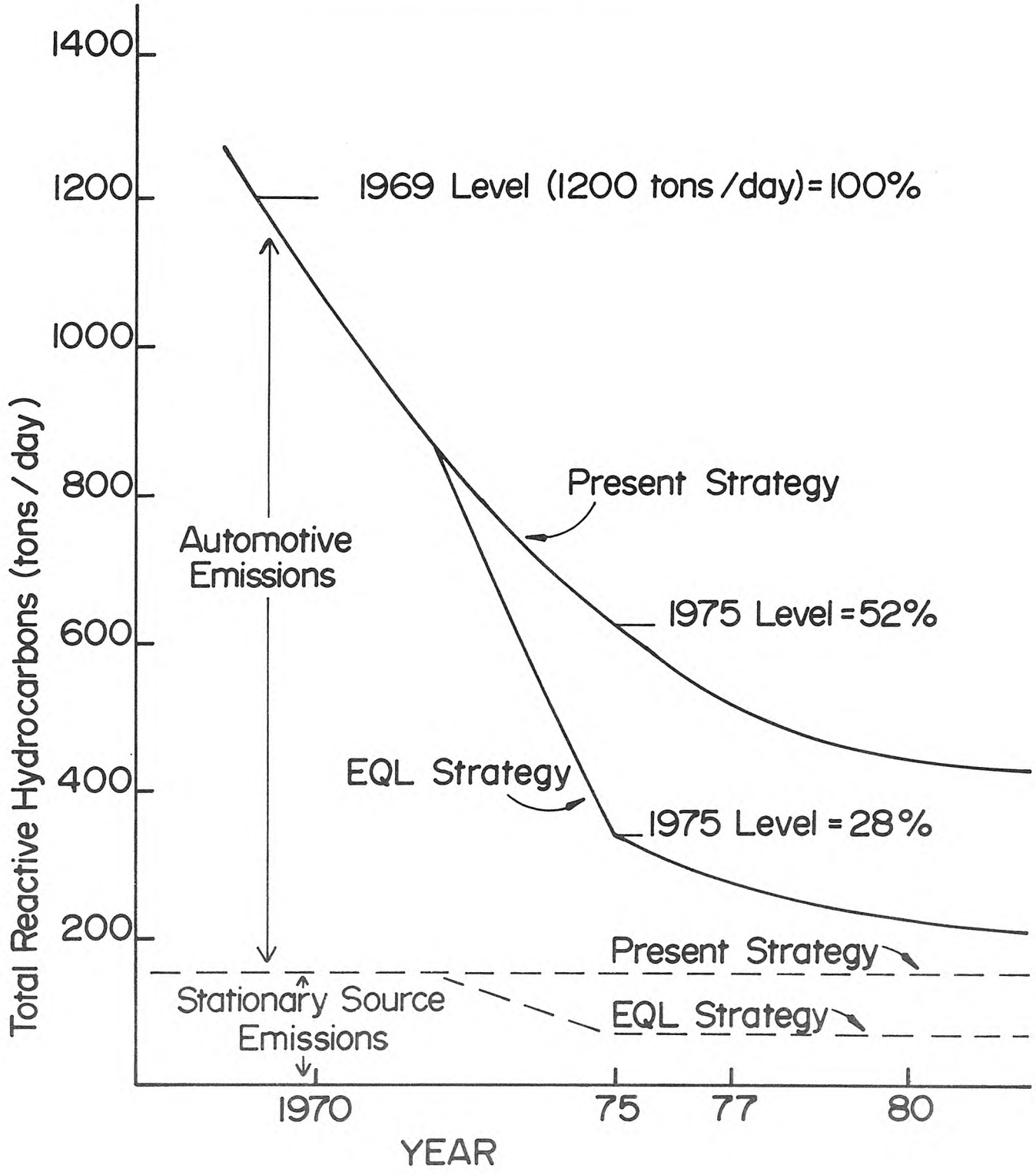


Figure 6

REDUCTION IN TOTAL OXIDES OF NITROGEN EMISSIONS FOR L.A. COUNTY

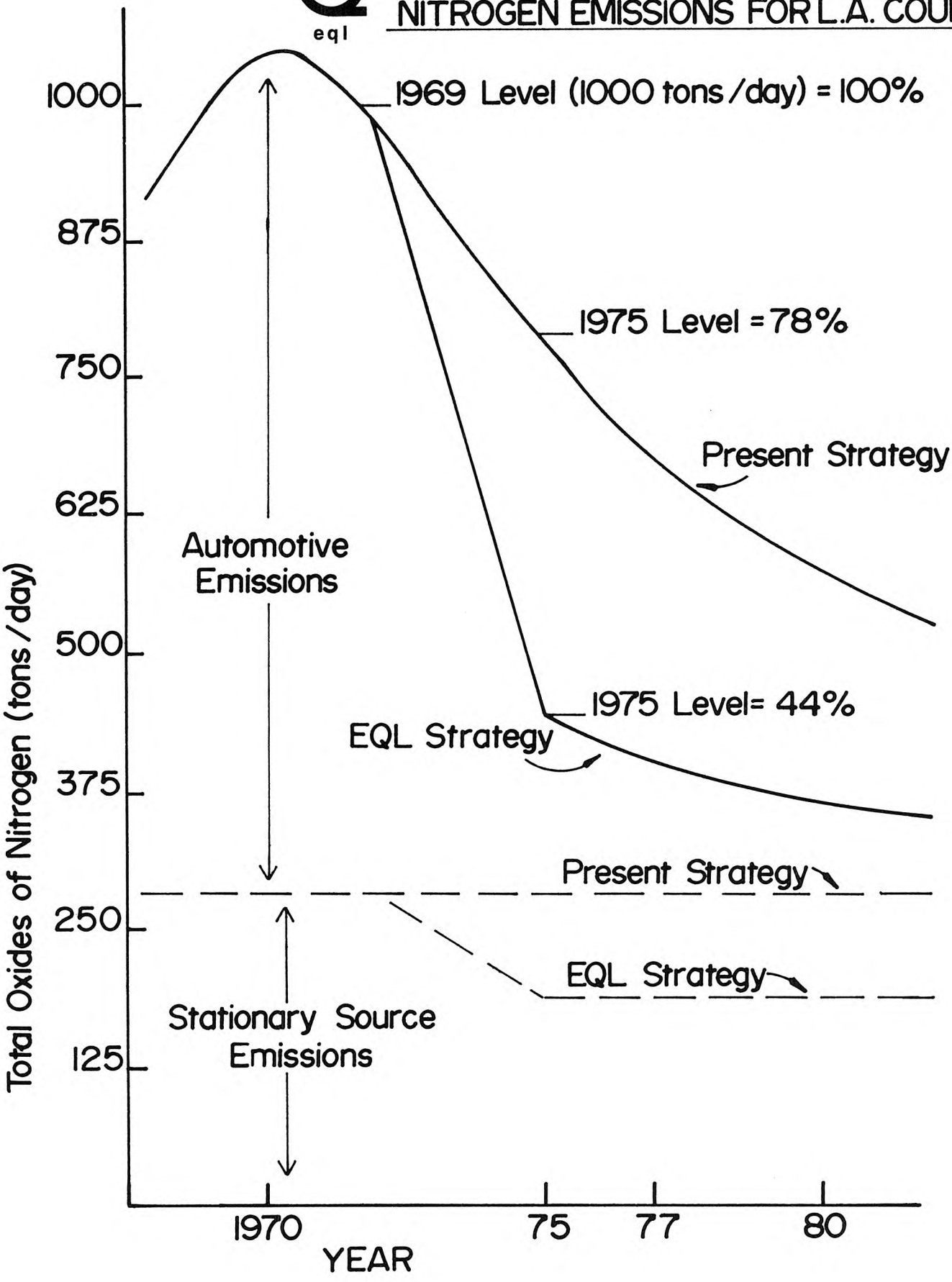


Figure 7

IMPROVEMENT IN OXIDANT AIR QUALITY FOR THE SOUTH COAST AIR BASIN

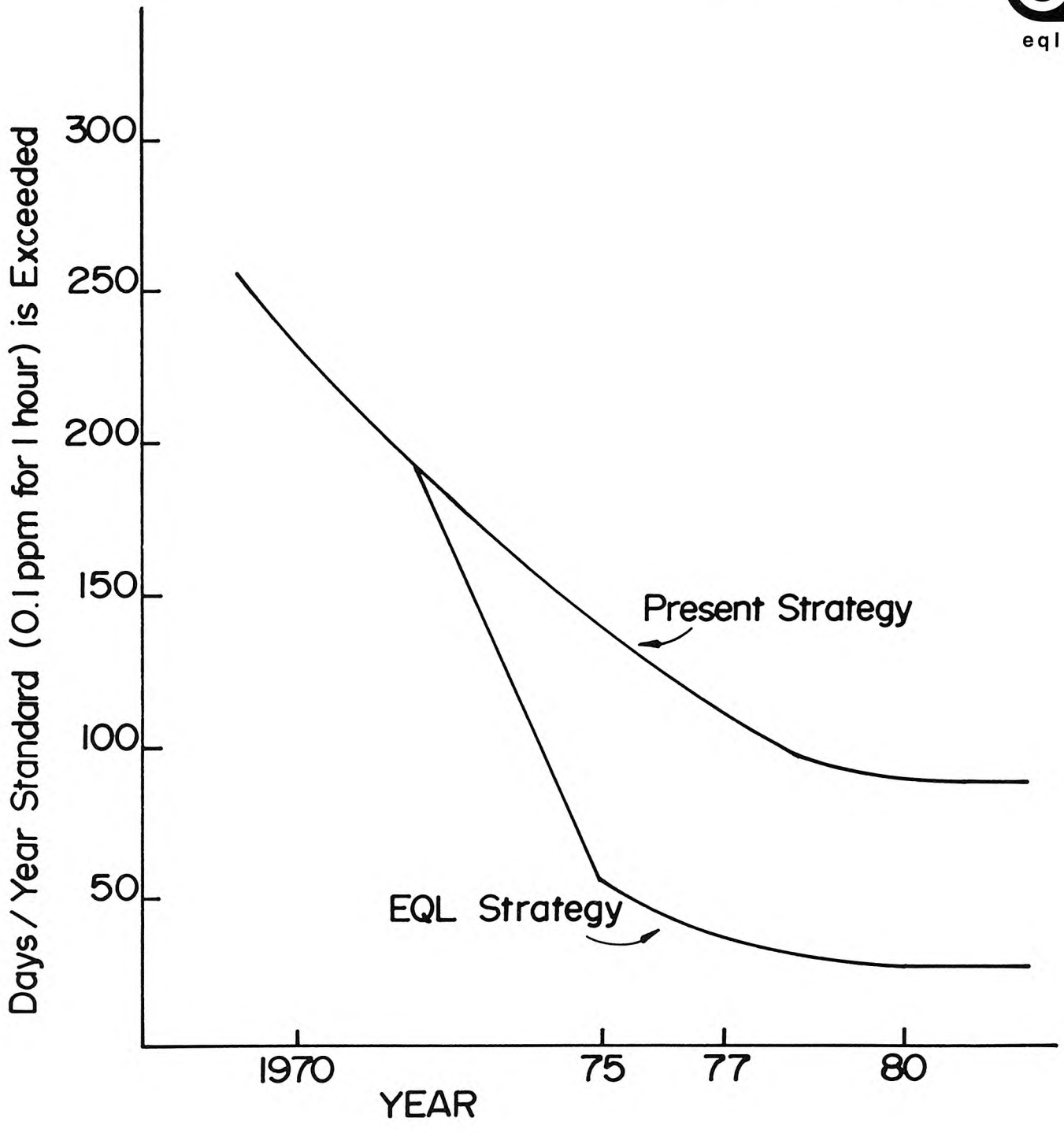


Figure 8

IMPROVEMENT IN NITROGEN DIOXIDE AIR QUALITY FOR THE SOUTH COAST AIR BASIN

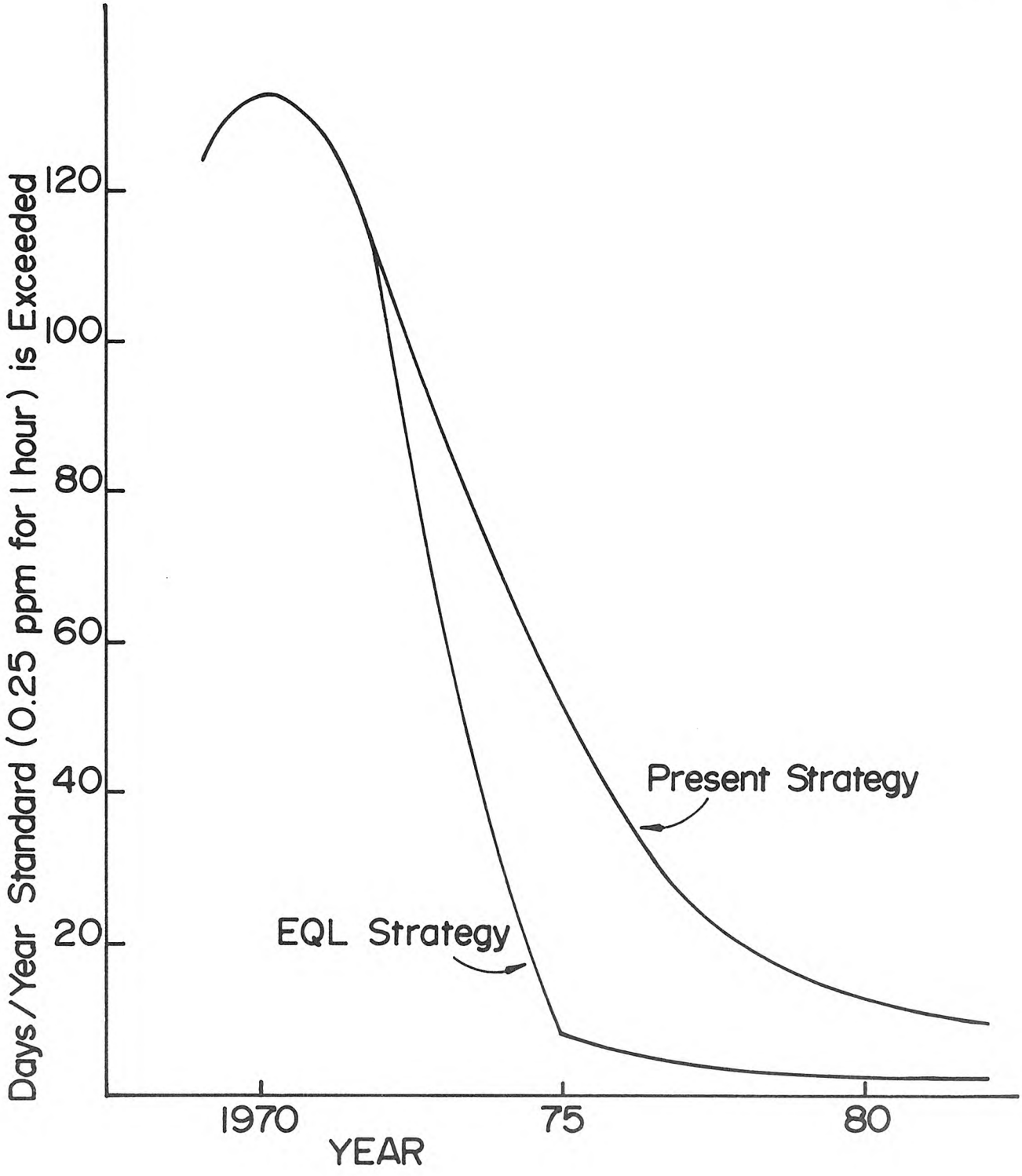


Figure 9

IMPROVEMENT IN OXIDANT AIR QUALITY FOR THE SOUTH COAST AIR BASIN

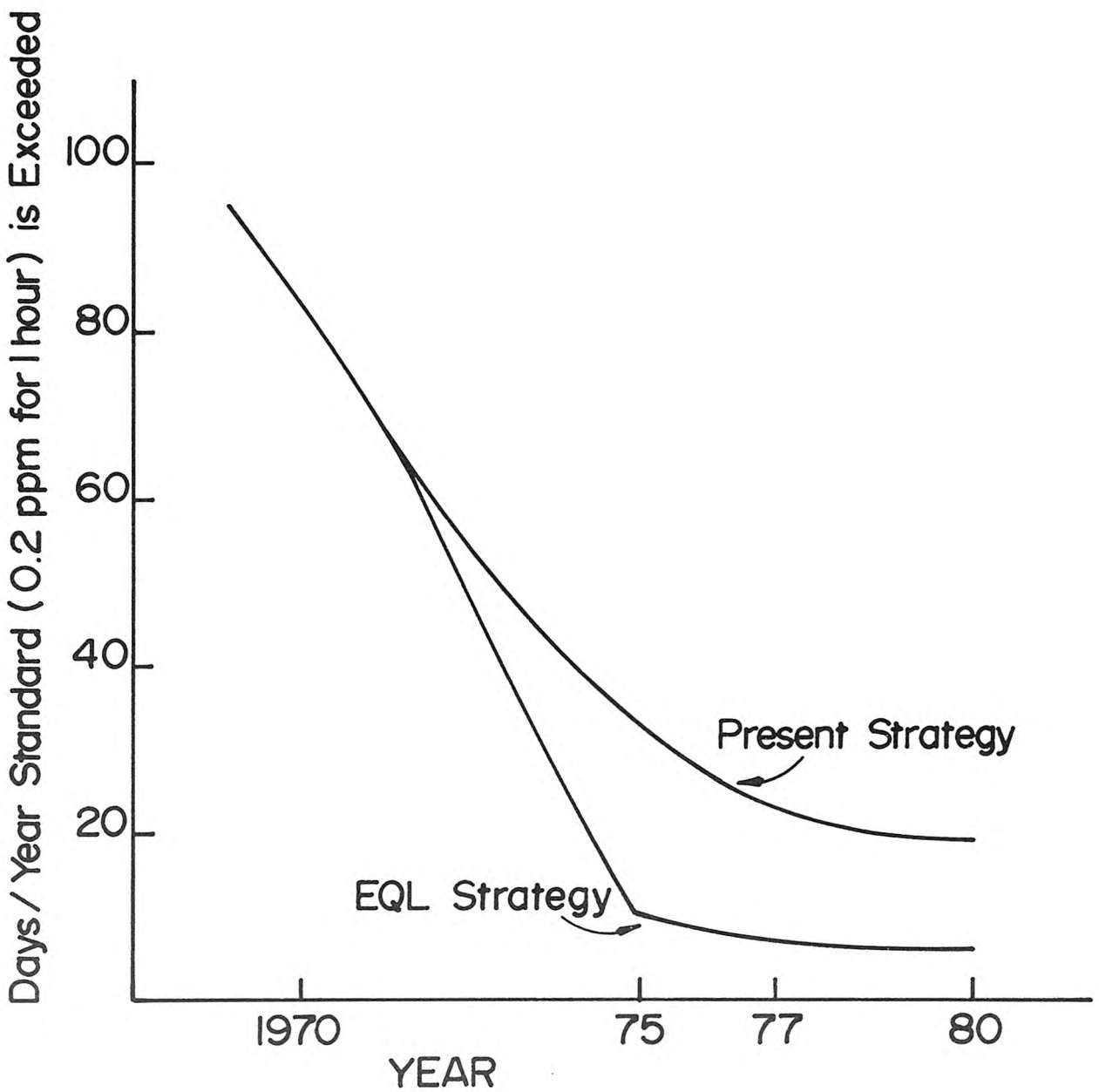


Figure 10

BREAKDOWN OF REDUCTIONS IN AUTOMOTIVE CARBON MONOXIDE EMISSIONS FOR L.A. COUNTY

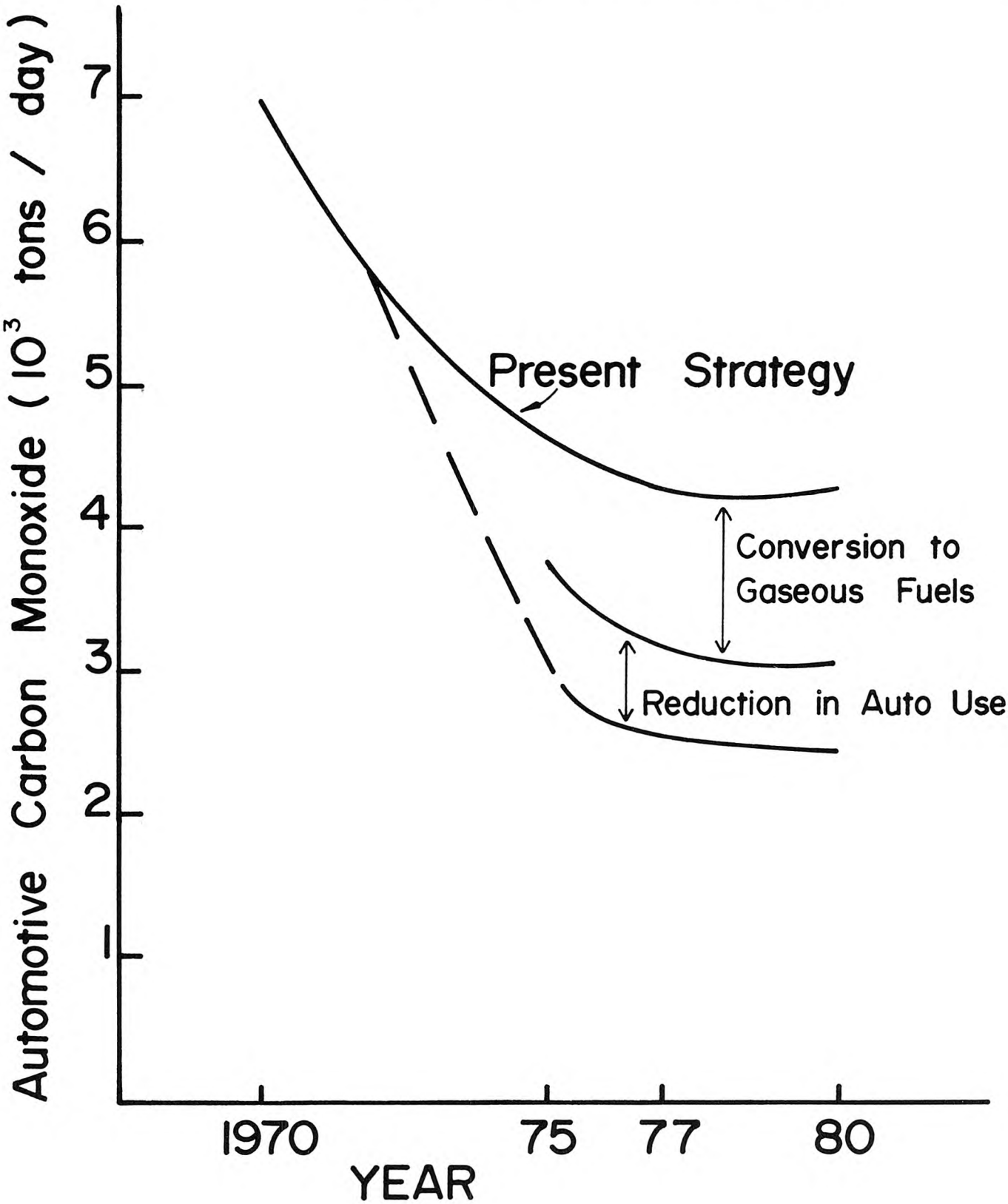


Figure 11

IMPROVEMENT IN CARBON MONOXIDE AIR QUALITY FOR L.A. COUNTY

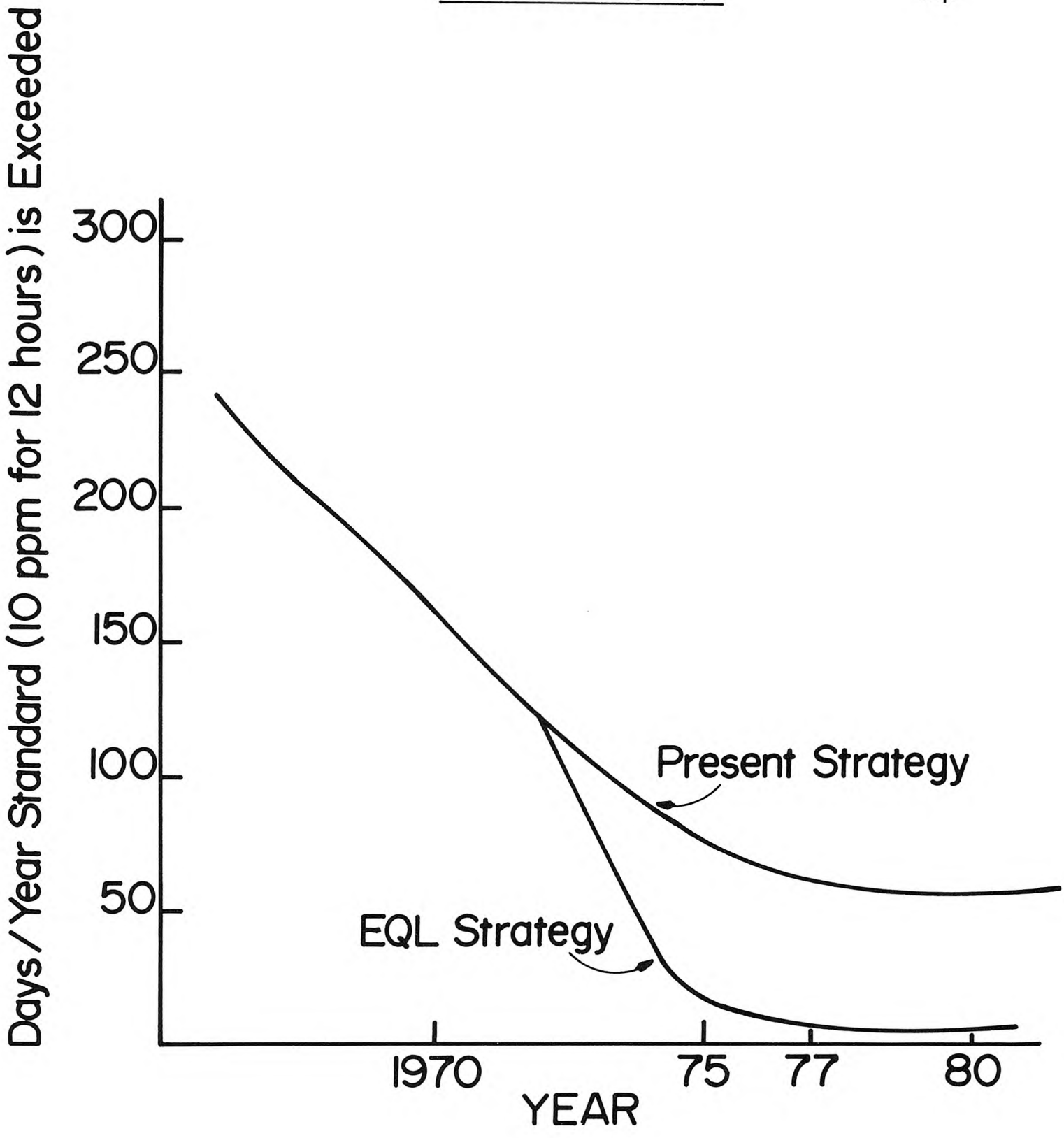


Figure 12

SUPPLY AND DEMAND OF NATURAL GAS IN AUGUST 1975 FOR SOUTHERN CALIFORNIA

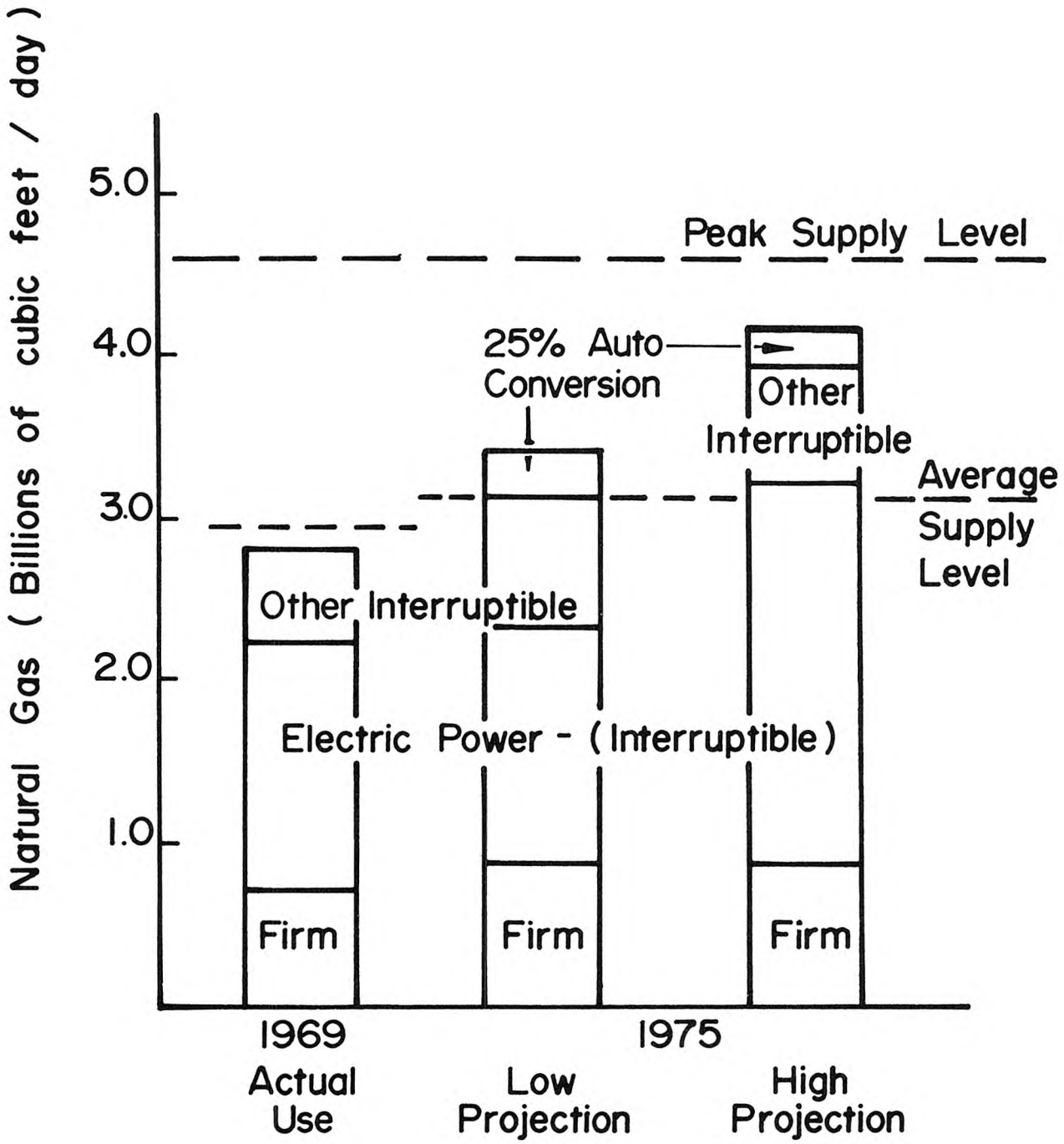


Figure 13

SUMMARY OF PROPANE SUPPLY AND DEMAND

ANNUAL AVERAGES FOR CALIFORNIA

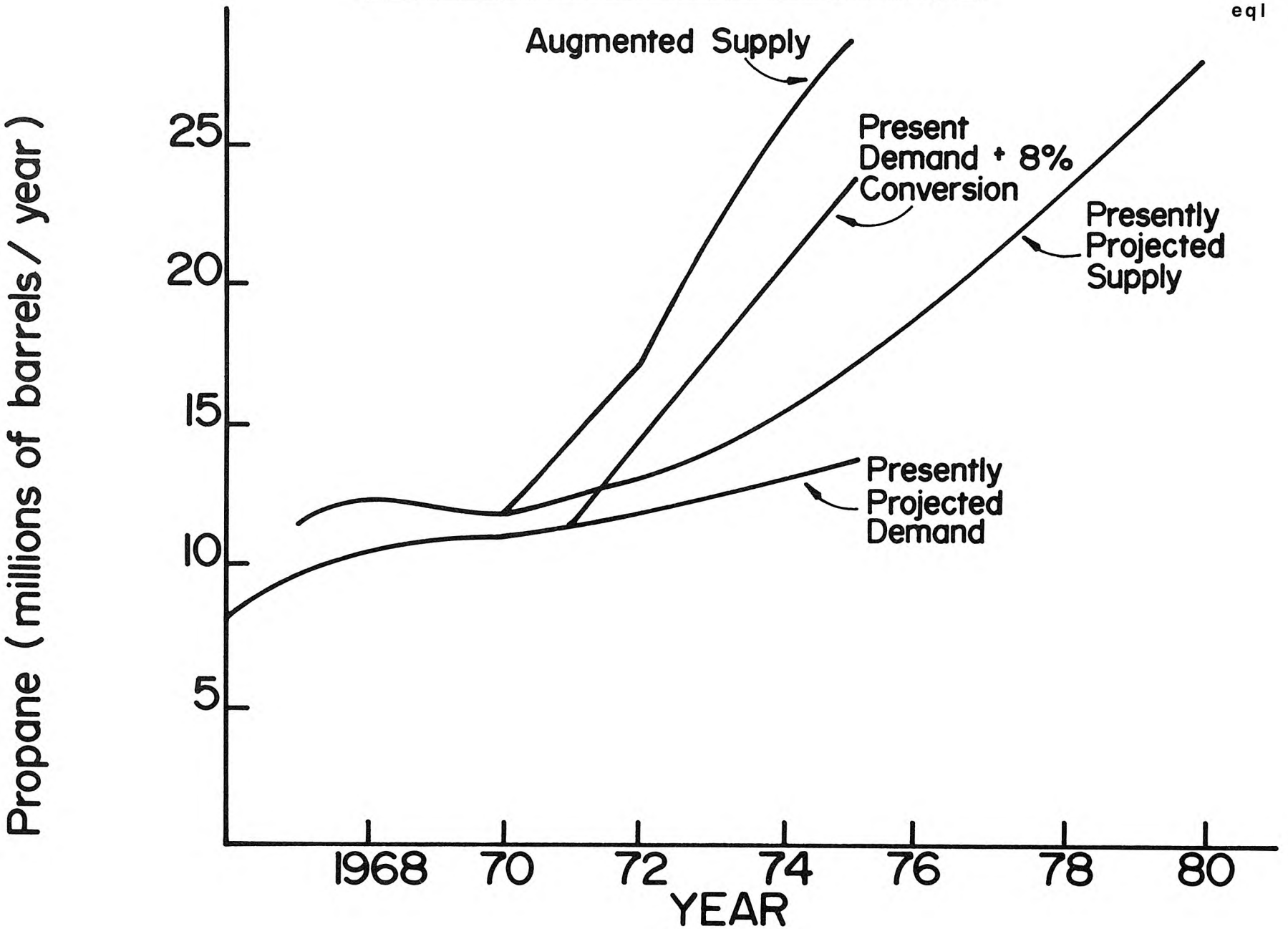
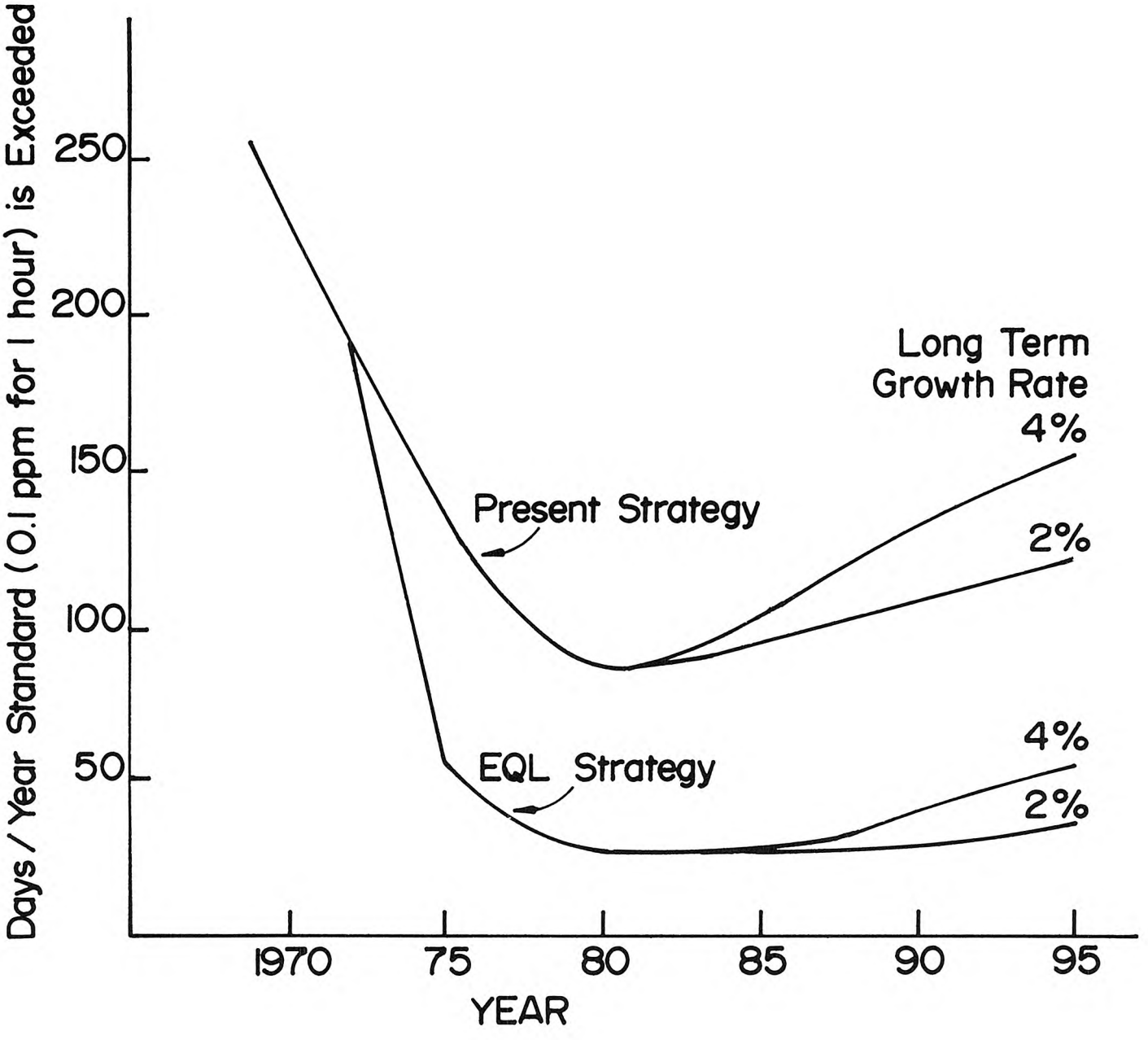
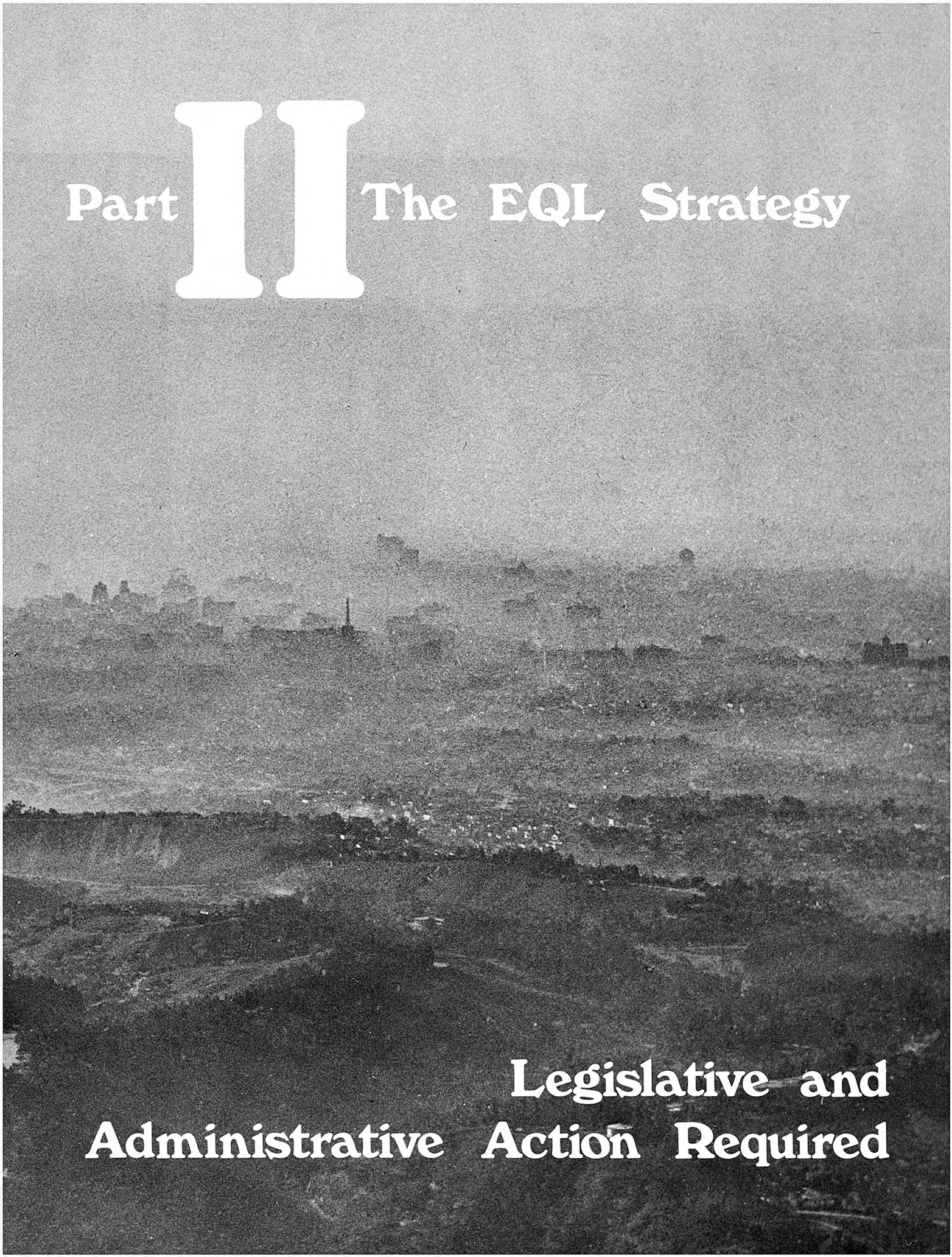


Figure 14

LONG RANGE PROJECTION OF OXIDANT AIR QUALITY FOR THE SOUTH COAST AIR BASIN





Part II The EQL Strategy

Legislative and Administrative Action Required

II. THE EQL STRATEGY

LEGISLATIVE AND ADMINISTRATIVE ACTION REQUIRED

A. MOTOR VEHICLES

A. 1 *Mandatory conversion of all commercial vehicles in the South Coast Air Basin to burn a gaseous fuel by December 31, 1973.*

In spite of the favorable economics provided mainly by the exemption from the state fuel tax for gaseous fuels (Part III, section 3.2) conversions of motor vehicles in the Basin, although increasing, are not proceeding fast enough to make a significant impact on automotive emissions. State legislation making such conversions mandatory for commercial vehicles in this Basin by a certain date is apparently required.

At present propane (LPG) and liquefied natural gas (LNG) are subject to the 4 cents/gallon Federal tax, but compressed natural gas (CNG) is not. In order to stimulate conversion to gaseous fuels, and to place all gaseous fuels on the fairest competitive basis, the Federal tax on LPG and LNG should be waived when these fuels are used in vehicles that meet the 1974 California exhaust emission standards, or their equivalent. Federal legislation along these lines is under consideration.

Certain additional incentives could be useful. For example, A.B. 2546, which was introduced in the 1971 California legislative session but was killed in committee, would have required the State to reimburse cities and counties for one half the cost of purchase and installation of any emission control systems for city and county vehicles.

A. 2 and A. 3 *Emissions and Evaporative Control Devices for Used Cars*

In his Special Message to the Legislature on "Smog" (March 11, 1971) Governor Reagan called for "realistic emission standards and pollution control device requirements for 1955-1965 model used cars"—now the last remaining "uncontrolled" source of emissions. Legislation is required to carry out the Governor's request.

State legislation is also required to give the State Air Resources Board (ARB) the authority to require the installation of a "modern" evaporative control device on all gasoline-powered 1966-1969 vehicles (or on all such vehicles in this Basin) by a date certain, and to set standards for such equipment. Since the device is expensive, companion legislation would almost certainly be necessary to grant a partial or full subsidy of the cost of such a device. Such a state subsidy could take the form of a credit to be applied against the motorist's personal or corporate State income tax, or against the motor vehicle license fee, or it could be provided from a special fund derived from emissions taxes. As suggested in Part I (A.3 on page 12), if such a subsidy were to be paid to vehicle owners for installation of this device, an equal subsidy ought to be made available to vehicle owners who elect any other step that would reduce emissions of reactive hydrocarbons by a comparable amount—for example, purchase of a post-1969 car to replace an older vehicle sold to a new owner who lives and works outside the Basin.

A. 4 *Mandatory Motor Vehicle Emissions Inspection System*

One possible system is described in a report prepared for the ARB and the State

legislature by the Northrop Corp.[23] Implementation should begin in the South Coast Air Basin in 1972 on a pilot or demonstration project basis so that the impact of the program could be felt first in the basin with the worst air quality.

A. 5 *Social and Economic Incentives and Disincentives Designed to Encourage the Shift to Low-Pollution Motor Vehicles, to Encourage the Use of Multiple Occupany Vehicles, and to Reduce the Annual Rate of Increase in Gasoline Consumption (Part III, Section 5).*

(1) *Emissions taxes.* State legislation is required giving the State ARB the authority to set up a schedule of emissions taxes based on the amount of emissions motor vehicles put into the atmosphere.

(2) *Reserved "fast lanes" on freeways* for buses and carpools. The Department of Public Works should implement AB #1 (1970) by designating reserved freeway lanes in this Basin for multiple-occupancy vehicles during rush hours.

(3) *Controlled access to freeways.* The program of the State Division of Highways involving metered traffic signals at freeway on-ramps should be accelerated so that it is completed in two years instead of ten. This program should be reoriented as a means of giving priority to buses, carpools and other multi-passenger vehicles during rush hours.

(4) *Free or subsidized parking for carpoolers; an end to subsidized parking for driver-only cars.* Requires coordinated action by government agencies, business firms and labor unions in this Basin to stimulate carpooling, including computer carpool matching services, and to discourage driver-only commuting.

(5) *Buses and demand-jitneys or dial-a-bus systems partially subsidized by emissions taxes or gasoline taxes.* Assembly Constitutional Amendment 16, defeated in the 1971 legislative session, would have submitted to the voters a proposed amendment of Article 26 of the State Constitution permitting motor vehicle tax revenues to be used to finance "public transportation" as well as highways and roads. Public transportation includes not only buses and jitneys but parking lots at bus terminals, etc.

(6) *Additional gasoline taxes or auction coupon system of limiting gasoline consumption.* A "last-resort" measure requiring careful study in interim legislative hearings (and in the EQL and other groups interested in this approach).

B. STATIONARY SOURCES

The control measures recommended in B.1 and B.2 can be put into effect by the APCD's in this Basin by strengthening or modifying existing rules, such as L.A. APCD rule #68 for nitrogen oxides and Rule #66 for reactive hydrocarbons. The APCD's have broad powers under the California Health Safety Code, Sections 24260 through 24263.

PHASE 2—SMOG ALERTS

As mentioned earlier, the APCD's already have broad powers. These powers can be used to call smog alerts during which emissions from stationary sources would be curtailed as recommended by the EQL strategy. Vehicular sources, such as high-pollution and single-passenger vehicles, could be prohibited from the freeways during smog alerts by means of the Division of Highways freeway access control program.

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[23]Northrop Corporation Electro-Mechanical Division, *Mandatory Vehicle Emission Inspection and Maintenance*, Final report, prepared under Contract ARB 1522, June, 1971.

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EQL, the Environmental Quality Laboratory, is an informally organized group of engineers, natural scientists, and social scientists who are dealing with broad, strategic problems of environmental control. Their "laboratory" is actually the world in which these problems must be solved. They interact with decision-makers in industry, government, and the ecology movement. Organized at the California Institute of Technology in 1970 in cooperation with the Jet Propulsion Laboratory, The RAND Corporation, and the Aerospace Corporation, EQL is supported by the National Science Foundation and private gifts.