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UPDATED PROJECTIONS OF AIR QUALITY IMPACTS
FOR ELECTRIC CARS

By
M. M. Collins

July 1979

Work Performed Under Contract No. EY-76-C-03-1180

Systems Technologies Group
General Research Corporation
Santa Barbara, California

U. S. DEPARTMENT OF ENERGY

Division of Transportation Energy Conservation

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MASTER

Internal Memorandum 2238

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SYSTEMS TECHNOLOGIES GROUP

GENERAL
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ABSTRACT

Future air pollution emissions and resulting air quality are projected for the five primary air pollutants: total suspended particulates (TSP), sulfur oxides (SO_x), nitrogen oxides (NO_x), total hydrocarbons (THC), and carbon monoxide (CO). Separate projections are made for three future years--1980, 1990, and 2000--and for three assumed levels of electric car use--zero, 10 percent, and 100 percent. Emissions and air quality are analyzed for each of the 24 Air Quality Control Regions (AQCRs) having the largest populations in 1975. Emission projections are made using an improved version of the Regional Emissions Projection System which uses the 1975 National Emissions Data System, 1977 state OBERS growth projections, recent state implementation plans and new source performance standards, and electric utility fuel forecasts from the Recharge Capacity Projection System.

Electric cars are found to increase SO_x emissions in the AQCRs, while decreasing their NO_x , THC, and CO emissions. For example, in 2000 with 10 percent electric cars, urban NO_x emissions would drop by eight-tenths of a percent, SO_x would rise by three-tenths of a percent, THC would decrease by 1.3 percent, and CO would decrease by 3.8 percent. Using the SEAS air pollution weighting factors, 100 percent electric cars in 2000 would reduce overall air pollution in most of the AQCRs. Several are singled out as benefiting the most by having electric cars.

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1 METHODS AND ASSUMPTIONS

1.1 BACKGROUND

As part of the Electric and Hybrid Vehicle Research, Development, and Demonstration Act of 1976, the Department of Energy (DOE) has been continually assessing the long-range pollution effects resulting from or in connection with the electrification of urban traffic. Initial estimates of the impact of electric personal passenger cars on air pollution have been reported in the first and second Electric and Hybrid Vehicle Program Annual Reports to Congress.

General Research Corporation (GRC) has been assisting the Department of Energy in predicting these long-range impacts. Impacts are being assessed in terms of changes in the quantity of air pollution and resulting air quality in major urban regions in the country occurring as a result of large numbers of electric cars.

This report is an update of an earlier report¹ submitted to DOE by GRC in February 1978. This revised report contains updated projections for 1980, 1990, and 2000 of urban air pollution in the 24 most populated urban regions in the country with zero, 10, and 100 percent electric personal passenger cars. The new numbers reflect recent base year emission data, new growth forecasts, and the latest promulgated and proposed emission control regulations.

It is known that the amount of pollution produced by conventional automobiles and electric utilities would change with widespread use of electric cars. Since electric cars do not emit pollutants themselves, except for small amounts of particulates due to tire wear, emissions produced by conventional cars, primarily nitrogen oxides, hydrocarbons, and carbon monoxide, would be reduced with electric cars in proportion to the vehicle kilometers driven by the electrics. On the other hand, with electric cars power plant emissions would increase to the extent that

fossil fuels were used to generate the additional electricity to recharge the electric car batteries. If the power plants were located in urban areas, then the added emissions would increase pollution in those areas. Thus, the net impact on emissions and air quality varies from region to region depending on the location of the power plants that serve the region, the fuels used to generate recharge electricity, the vehicle kilometers driven by the electric cars, and to some extent, the characteristics of the region, including their local emission regulations and the vehicle mix.

It is necessary, therefore, to perform any impact analysis on a regional basis. For this study, the 24 air quality control regions (AQCRs) containing the largest populations were selected. Together they contain more than 43 percent of the population of the United States. Not only do they include most of the poor air quality areas in the country, but they are also the areas where personal electric passenger cars are most likely to be used. Figure 1.1 is a map showing the boundaries of the 24 AQCRs. Appendix H lists population and growth assumptions for each AQCR.

1.2 METHODOLOGY

For each AQCR, it was necessary to perform the following analyses:

1. Establish levels of emissions and air quality for 1975 to be used as initial values in projections to 1980 and beyond.
2. Using reference values from 1975, project emissions and air quality to 1980, 1990, and 2000, assuming no electric cars (baseline case).
3. For 1980, 1990, and 2000, estimate the effects of electric cars by modifying baseline emissions and air quality.

Regional emissions for 1975 were obtained from the National Emissions Data System (NEDS),² a large, computerized data base maintained by the Environmental Protection Agency (EPA). Computer tapes were provided that listed the tons of emissions per year from each major point and area source

Figure 1.1. The 24 Air Quality Control Regions in the United States Containing the Urbanized Areas with the Largest Populations

in each AQCR. Separate figures were given for total suspended particulates, sulfur oxides, nitrogen oxides, total hydrocarbons, and carbon monoxide.

Air quality in 1975 in the AQCRs of interest was estimated using the EPA Storage and Retrieval of Aerometric Data (SAROAD) System.³ This system contains ambient air quality data collected by county, state, and federal agencies and reported to EPA quarterly as required by the Clean Air Act. The maximum concentrations of the five primary pollutants--particulates, sulfur oxides, nitrogen oxides, photochemical oxidants, and carbon monoxide--are used as the measure of air quality.

Future baseline emissions were projected using a computer model developed by EPA called the Regional Emissions Projection System (REPS).⁴ The GRC project staff spent considerable time improving this model, correcting certain deficiencies, and adding recently-derived mobile source emission factors, a variety of proposed federal new source performance standards, and state implementation plan emission control regulations.

REPS uses current emission inventories, projected regional growth and demographic characteristics, emission factors, new and existing source performance standards, and user-provided data to estimate future individual point and area source emissions. The REPS model uses the following data contained in the NEDS point source inventory for each source:

- . Source Classification Code (SCC)
- . Net annual emissions
- . Emissions permitted by existing regulations and compliance with those regulations
- . Throughput
- . Ash and sulfur content of the fuel

REPS also uses the data in the area source inventory which define the levels of area source emission-producing activity in the base year. This activity

includes transportation, fuel combustion, evaporation, and miscellaneous area sources. Appropriate growth factors are applied to the data in order to calculate emissions in the projection year.

Figure 1.2 illustrates the data flow within the REPS system. Output is in terms of tons of emissions per year and BTUs of fuel use per year for each emission source. It can be aggregated into over 300 different emission source categories. The major categories are shown in Table 1.1. Those subcategories that will be impacted by electric cars are:

- . Electricity Generation
- . Cars--Gasoline
- . Petroleum Refining
- . Petroleum Transportation and Marketing
- . Gasoline Handling Evaporation Loss (area sources)

Economic, demographic, and industrial growth characteristics come from a computer tape of the 1977 state OBERS projections developed by the Bureau of Economic Analysis, US Department of Commerce. OBERS is made up of projections of state economic activity including personal income, employment earnings, and output for each of 28 industrial groups for each year from 1975 through 2000. These growth factors are mapped in state/AQCR growth factors for each SCC code and area emission category.

The electric utility growth projections produced by OBERS are modified based on more detailed and accurate projections from GRC's electric utility capacity and demand model (RECAPS).⁵ This model projects demand growth by location and type of generating unit (coal-fired, external combustion, nuclear, hydroelectric, pumped storage, etc.) using a very complex scheduling algorithm and the latest utility and government forecasts.

The final step of the REPS emission projection methodology is to adjust the projected emissions to include the effect of emission controls required for each type of source in the projection year.

*WHEN AVAILABLE

†INCLUDED IN REPS PACKAGE; OTHER AEROS OUTPUTS OPTIONAL

Figure 1.2. REPS System Flow and Data Sources

TABLE 1.1

MAJOR EMISSION SOURCE CATEGORIES

FUEL COMBUSTION

External Combustion
 Residential
 Electricity Generation
 Industrial
 Commercial/Institutional
 Internal Combustion
 Electricity Generation
 Industrial
 Commercial/Institutional
 Engine Testing

INDUSTRIAL PROCESSES

Chemical Manufacturing
 Food/Agriculture
 Primary Metals
 Secondary Metals
 Mineral Products
 Petroleum Industry
 Wood Products
 Metal Fabrication
 Leather Products
 Textile Manufacturing
 In-Process Fuel

EVAPORATION

SOLID WASTE DISPOSAL

TRANSPORTATION

Highway Vehicles
 Cars--Gasoline
 Light-Duty Trucks--Gasoline
 Heavy-Duty Trucks--Gasoline
 Heavy-Duty Trucks--Diesel
 Off-Highway Vehicles
 Gasoline
 Diesel
 Rail

AIRCRAFT

VESSELS

MISCELLANEOUS

The REPS system includes the effects of control regulations in two ways. First, if any point source had emissions during the base year that were greater than those allowed, then the projected emissions for that point source are reduced to the level allowed. The allowable emissions are specified in the NEDS point source inventory. In addition, if there are State Implementation Plan (SIP) control regulations specified for that point source category, then the projected emissions are further adjusted, if necessary, to satisfy the SIP controls.

Second, Federal New Source Performance Standards (NSPS) which govern new and retrofit industrial equipment, are included in the REPS system. Standards already promulgated in the Federal Register are included, as well as proposed standards which are likely to be promulgated in the future. The effect of controls on future emissions is determined in REPS by estimating the portion of projected activity which will involve equipment or facilities governed by the standards. In addition to the new facilities or equipment, REPS also assumes that existing facilities will be retired and replaced by new facilities at the rate of 2.5 percent per year. Because of uncertainty regarding future SIP regulations and NSPS, REPS allows for alternative controls to be assumed. Three future control scenarios were run, and their impact on the projections is described later in this section. The scenario assumed in this report is that the most stringent promulgated NSPS for electric utilities will be achieved as well as the SIP NO_x, particulate, and SO_x emission regulations published in the Federal Register.

After future emissions are projected, the linear rollback formula is used to relate the emissions to future air quality. In essence, the linear rollback equation states that changes in air quality are proportional to changes in emissions. The standard formula is

$$R = \frac{(PAQ) - (DAQ)}{(PAQ) - (B)} \quad (1.1)$$

where

R = fractional reduction in emissions

PAQ = present air quality (highest concentration recorded)

DAQ = desired air quality

B = background concentration of pollutant (concentration unavoidably present due to natural causes)

Since the purpose is to estimate future air quality (DAQ), given current air quality (PAQ), the background level (B), and the fractional reduction in emissions (R), it is necessary to solve Eq. 1.1, which yields

$$DAQ = PAQ(1 - R) + (R)(B) \quad (1.2)$$

R is estimated from

$$R = 1 - \frac{E_k}{E_{1975}} ; \quad k = 1980, 1990, 2000$$

where E_k are the baseline emissions for the year k .

This model is most accurate for the simple case of only one type of source uniformly distributed across an area. Therefore it often works well in predicting concentrations of CO due to mobile sources. Because of the impact of point sources in the production of particulates and SO_x , and the reactive nature of NO_2 and oxidants, the model provides only crude estimates of concentrations of these pollutants. Several factors influenced the selection of the rollback formula. Foremost was the unavailability of additional data which would have been needed to apply more complex models. Second was the experience with air quality forecasting obtained in the Los Angeles study.⁶ In the Los Angeles study, GRC spent

several years of intensive data analysis and modeling to quantify the air quality changes which could be expected with electric cars. There, the DIFKIN photochemical-diffusion model and rollback technique were both used to predict maximum ozone and NO_2 concentrations. Rollback was remarkably close to the DIFKIN model in estimating baseline maximum ozone concentrations, and was 16 to 30 percent high in estimating maximum NO_2 concentrations. The study found that rollback was sufficient for assessing electric car air quality impacts, since impacts were relatively small and small changes tended to improve the accuracy of the linear approximation. To improve upon rollback as a way to project SO_x or particulate concentrations would require detailed point source plume location and meteorological information. A study has been made⁷ relating SO_x and particulate emissions by source to ground-level ambient air quality concentrations, but it has not been validated sufficiently to judge its applicability to the AQCRs of concern in this study. Therefore, rollback was selected as the air quality projection model. It is recognized by EPA as an acceptable tool for developing air quality maintenance plans.

Table 1.2 lists the background concentrations assumed, as well as the current primary air quality standard for each pollutant. THC emissions are used to estimate future oxidant air quality using rollback, and are checked against an alternative procedure described by EPA for relating hydrocarbon emissions and oxidant concentrations known as Appendix J.⁸

Several other simple statistics relating emissions to air quality are calculated: tons per square kilometer and million person metric tons per square kilometer per year. The second statistic, million person metric tons per square kilometer, is suggested by Edward Pechan of DOE as a measure of population exposure.⁹

Finally, an attempt is made to rank AQCRs in terms of the potential impact of electric cars on overall air pollution. Equivalent tonnages of emissions are calculated using the SEAS pollutant weighting factor.¹⁰

TABLE 1.2
BACKGROUND CONCENTRATIONS AND CURRENT PRIMARY STANDARDS

	<u>Background Concentrations</u>	<u>Primary Standard</u>
Particulates	10 $\mu\text{g}/\text{m}^3$ (11)	75 $\mu\text{g}/\text{m}^2$ (annual geometric mean)
Sulfur Oxides	0 (12)	80 $\mu\text{g}/\text{m}^3$ (annual mean)
Nitrogen Dioxide	10 $\mu\text{g}/\text{m}^3$ (13)	100 $\mu\text{g}/\text{m}^3$ (annual mean)
Total Hydrocarbons	1 mg/m^3 (14)	*
Photochemical Oxidants	20-100 $\mu\text{g}/\text{m}^3$ (15)	160 $\mu\text{g}/\text{m}^3$ (one hour not to be exceeded more than once a year)
Carbon Monoxide	1 mg/m^3 (16)	10 mg/m^3 (8-hour average not to be exceeded more than once a year)

* There is no standard for THC. The standard for hydrocarbons less methane is 160 $\mu\text{g}/\text{m}^3$ (maximum 3-hour concentration (6 to 9 a.m.) not to be exceeded more than once a year).

The SEAS factors were developed to translate the SEAS air and water pollution release amounts into equivalent tonnages to allow gross comparisons of the impact of different scenarios. Three sets of factors were developed for weighting different effects: human health, ecological, and socio-economic. The weights were the same for the primary pollutants, so the composite tonnages calculated in this report reflect all of these effects. Using the SEAS pollutant weighting factors, an overall population indicator is developed for each AQCR with and without 10 percent electric cars. The AQCRs are then ordered in terms of the percent of change. The SEAS factors are listed in Table 1.3.

TABLE 1.3

SEAS WEIGHTING FACTORS FOR SELECTED AIR POLLUTANTS

<u>Air Pollutant</u>	<u>Pollutant Weighting Factor</u>
Carbon Monoxide (CO)	0.002
Hydrocarbons (HC)	0.022
Nitrogen Oxides (NO _x)	0.022
Sulfur Oxides (SO _x)	0.008
Total Suspended Particulates (TSP)	0.013

The formula for calculating the overall pollution indicator for an AQCR is

$$ET_k = \sum_i u_i \cdot R_{ik} \quad (1.3)$$

where

ET_k = equivalent tons in AQCR k

u_i = weighting factor for pollutant i

R_{ik} = estimated tons of pollutant i in AQCR k

The percent change in the factor for a given year provides an indication of the relative impact of 10 percent electric cars on the air pollution in the AQCRs. Those AQCRs with the largest percent reduction in the factor are the ones which would most benefit by electric cars, in terms of reduced emissions.

1.3 ASSUMPTIONS AND UNCERTAINTIES

REPS, like any forecasting model, contains within it a number of assumptions about what the important variables are to be included, what the appropriate values of the variables should be, and how the variables relate to each other. The output obviously reflects these assumptions, and should be viewed with them in mind.

An attempt is made in this section to identify the lay assumptions in REPS that could significantly affect the electric car impact analysis. As described earlier, to predict electric car impacts, the analysis basically uses three emission forecast numbers: automobile emissions, electric utility emissions, and total emissions for each AQCR and future year. The assumptions that are most important in determining these numbers are described in this section with, in some cases, alternative assumptions and their effect on the forecasts. Table 1.4, which gives urban emissions projected without electric car use for the 24 AQCRs in the year 2000, will be used as the base from which to measure the sensitivity of the assumptions.

Highway gasoline vehicle emissions estimates are based on the latest EPA exhaust emission factors--those specified in the new Mobile Source Emissions Factor report prepared by the EPA Office of Transportation and

TABLE 1.4

URBAN POLLUTION IN YEAR 2000, PERCENT TOTAL

	Conventional Auto, Percent	Electric Utility, Percent	Total, 1000 Metric Tons
TSP	4.7	5.2	3 211
SO _x	0.0	31.5	5417
NO _x	11.3	19.3	6310
THC	11.3	0.3	10534
CO	24.0	0.4	25425

Land Use Policy, March 1978.¹⁷ These factors, shown in Appendix F, supersede the AP-42 (Supplement 5) Mobile Source Emission Factors¹⁸ which were used in the original version of REPS. They are expressed as a new vehicle emission rate and a deterioration rate. They reflect the results of EPA's exhaust emission surveillance programs which measure how well vehicles perform in actual use. Data collected by the programs were analyzed to provide estimates of mean emissions by model-year vehicle in each calendar year, change in emissions with the accumulation of age, percent of vehicles complying with the standards, and the effect on emissions of vehicle parameters. These surveillance data, along with prototype vehicle test data, assembly line test data, and technical judgment, form the basis for the factors. Separate factors were produced for California and high-altitude areas to reflect separate emission and performance standards in the areas.

Using the EPA new car and deterioration emission factors, REPS calculates a composite exhaust emission factor for each AQCR and year and for different vehicle types and major pollutants: gasoline-powered cars, light-duty gasoline-powered trucks (0-8.5 GVW), heavy-duty gasoline-powered trucks, hydrocarbons, carbon monoxide, and nitrogen oxides. The composite factor, reflecting model year population and driving fraction by vehicle age, is based on a weighting of the 13 emission factors for the 13 model years. The emission factor for a given model year is calculated from the linear equation

$$C_i = a_i + b_i * M_i / 10000$$

where

C_i = exhaust emission factor in the projection year
of a model year "i" vehicle

M_i = cumulative mileage for vehicle i in projection year

a_i = new car emission rate

b_i = deterioration rate for model year i vehicle

Table 1.5 gives average composite factors by vehicle type and pollutant for California, high-altitude areas, and the rest of the country for the years 1975 and 2000. Cumulative mileage by vehicle age is based on the national travel weighting factors shown in Table 1.6.

Future vehicle kilometers traveled (vkt) in each AQCR were estimated from base year fuel use data which is stored in NEDS by county. Fuel use was converted to vkt using computed average gas mileage figures, vehicle population estimates, and travel fraction by age. Table 1.7 lists selected mileage figures used for cars and light-duty trucks. Heavy-duty gas-powered trucks were assumed to get 3.6 km/liter, and off-road gas-powered trucks were assumed to get 2.1 km/liter. Future vehicle vkt were projected assuming that they would grow in proportion to the growth in population in each AQCR.

TABLE 1.5
AVERAGE, COMPOSITE EMISSION FACTORS, GRAMS/MILE
GAS-POWERED VEHICLES

	1975			2000		
	<u>THC</u>	<u>CO</u>	<u>NO_x</u>	<u>THC</u>	<u>CO</u>	<u>NO_x</u>
California						
Cars	8.3	65.9	3.4	1.7	15.2	1.6
Light-Duty Trucks	8.4	68.7	4.1	1.7	16.0	1.7
Heavy-Duty Trucks	29.4	273.0	10.7	11.1	109.0	7.0
High-Altitude Areas						
Cars	9.7	101.0	2.4	1.7	13.6	1.6
Light-Duty Trucks	10.2	105.0	2.7	1.9	16.1	1.8
Heavy-Duty Trucks	41.0	414.0	6.9	12.0	109.0	7.0
All Other Areas						
Cars	8.1	67.1	3.7	1.7	13.6	1.6
Light-Duty Trucks	8.5	69.1	4.2	1.9	16.1	1.8
Heavy-Duty Trucks	29.7	275.0	10.8	11.1	109.0	7.0

TABLE 1.6
PERCENT OF TRAVEL BY AGE OF VEHICLE¹⁷

<u>Vehicle Age</u>	<u>Cars and Light-Duty Trucks</u>	<u>Heavy-Duty Trucks</u>
1	10.6	6.1
2	14.2	11.6
3	13.3	12.2
4	12.3	12.4
5	10.8	9.8
6	9.2	8.8
7	7.7	7.9
8	6.4	6.3
9	5.0	4.9
10	3.5	4.0
11	2.3	3.0
12	1.6	2.0
13+	3.2	11.2

TABLE 1.7
VEHICLE FLEET AVERAGE URBAN GAS MILEAGE FIGURES,
KILOMETERS/LITER

	<u>1970</u>	<u>1975</u>	<u>1980</u>	<u>1985</u>	<u>1990</u>	<u>1995</u>	<u>2000</u>
New Cars ¹⁹	5.5	5.8	7.4	10.2	10.5	10.9	11.3
New Light Trucks ²⁰	5.9	5.4	5.9	8.1	8.5	8.8	9.2

The three major highway vehicle assumptions that, if changed, would affect the output are: (1) the base year vehicle kilometers traveled which is a function of the base year fuel consumption; (2) the growth in vehicle kilometers traveled which it is assumed is equal to the growth in population; and (3) the expected new car emission control factors and deterioration rates which were provided by EPA.

Base year (1975) gasoline fuel sales for light-duty vehicles, heavy-duty vehicles, and off-highway vehicles, and diesel fuel sales for heavy-duty highway vehicles and off-highway vehicles are stored in NEDS by county. The sum of all of the country gasoline highway vehicle sales for the year which represents the 1975 contiguous United States gasoline sales is equal to 99.2 billion gallons. This corresponds exactly to the national figures in the 1975 Highway Statistics report for highway use of gasoline. A similar check for California using NEDS and the 1975 Highway Statistics showed similar accuracy. GRC did not change the Vkt growth assumption that was put in REPS by EPA.

Using population growth as an estimate for urban vkt growth, vkt was projected to increase by 21 percent by the year 2000. More rapid growth appears unlikely in view of the reportedly increasing cost and decreasing availability of gasoline, which will discourage people from driving. In addition, as urban congestion increases, the average urban travel speed will decrease, probably resulting in fewer urban miles driven per car. The OTA report of Changes in the Future Use and Characteristics of the Automobile Transportation System²¹ expects that by the year 2000, average speeds in urban areas will be 10 to 15 percent lower and motorists will encounter congested conditions up to three times as often as today.

Nevertheless, it is equally reasonable to assume that the number of automobiles driven in urban areas will increase faster than the population growth and/or that the average vehicle kilometers traveled per year per car will increase rather than stay the same, as assumed in REPS.

In fact, elsewhere in the GRC electric car impact study it was projected that light-duty vehicle travel would increase by 32 percent between 1975 and 2000.²² The OTA study forecasts a 75-percent increase in automobile travel between 1975 and 2000.

Table 1.8 shows the impact of the OTA growth assumptions. Automobile TSP emissions go from 4.7 to 6.8 percent, NO_x from 11.3 to 15.6 percent, THC from 11.3 to 15.7 percent, and CO from 24.0 to 31.6 percent. As shown in the table, the 75-percent growth assumption would increase projected automobile emissions by 46 percent and total NO_x and THC emissions by 5 percent, and CO emissions by 11 percent.

The final vehicle-related assumption, the emission factors themselves, is probably quite accurate. The vehicle emission factors, derived through actual tests, relate the standards to actual emissions. If the new vehicle standards established by the Clean Air Act Amendment of 1977 (Public Law 95-95) are postponed, or if the unavailability of unleaded gasoline forces drivers to use leaded gasoline, thereby destroying catalytic converters, then expected emissions from autos would increase somewhat. The impact on the analysis in the report would, however, probably not change significantly.

TABLE 1.8
EMISSIONS WITH OTA VKT GROWTH PROJECTIONS IN YEAR 2000,
PERCENT TOTAL

	Conventional Auto, Percent	Electric Utility, Percent	Total, 1000 Metric Tons
TSP	6.8	5.0	3281
SO _x	0.0	31.5	5417
NO _x	15.6	18.3	6637
THC	15.7	0.3	11083
CO	31.6	0.3	28240

Future electricity generation in each AQCR was projected using GRC's Recharge Capacity Projection System model (RECAPS). RECAPS is a very complex fuel-use forecasting model that uses 1976 power plant capacity and demand projections for each major electric utility company, and a power generating unit scheduling algorithm to calculate future electricity generation by fuel type and location. The model assumes the recent government power plant development policies that require the use of coal as the primary fuel, that assume all oil and gas-fired plants that can burn coal on a continuous basis do so in the future, and that require after 1985 that no new oil- or gas-fired base-load power plants will be built.

RECAPS was run for the years 1976, 1980, 1985, 1995, and 2000 to estimate yearly demand on the power plants located in the AQCRs of interest. Tables 1.9, 1.10, and 1.11 give the projected demand by AQCR and fuel type for the years 1980, 1990, and 2000, respectively. Note that demand on plants in some AQCRs decreases between 1980 and 2000. This is the result either of the addition of new plants outside the AQCR which take some of the load off those plants within the AQCR, or the result of the retirement or reduced capacity of existing plants within the AQCR.

RECAPS forecasts were based on a 1976 national power plant inventory and 1976 electric utility industry growth expectations, both in terms of total expected demand and capacity by fuel type. Tables 1.12 and 1.13 show the resulting changes expected between 1975 and 2000 in electricity generation by power plants located in the 24 urban regions and the role they play in national electricity supply.

In addition to the total electricity demand projections, there is uncertainty regarding the projected growth in nuclear power. Since 1976, there has been a renewed emphasis on conservation to reduce electricity

TABLE 1.9

1980 POWER PLANT ELECTRICITY PRODUCTION BY AQCR, 10⁶ MJ

AQCR	Total Power, 10 ⁶ MJ	Nuclear	Coal	Hydro	Oil	Gas	Other	Pumped Storage Hydro	Oil Peak	Gas Peak
24 Los Angeles	242,950	0	0	1,593	237,074	3,076	155	0	1,052	0
29 San Diego	65,998	20,372	0	0	43,782	0	0	0	1,844	0
30 San Francisco	60,163	0	0	159	59,187	0	694	0	123	0
36 Denver	26,074	0	25,717	30	310	0	0	0	16	0
43 New York	239,668	45,727	70,628	556	118,544	94	31	0	4,080	7
45 Philadelphia	137,537	46,391	68,361	0	20,978	0	94	0	1,713	0
47 Washington, DC	62,684	0	40,910	0	21,541	0	0	0	234	0
50 Miami	103,081	50,048	0	0	50,472	176	0	0	2,386	0
56 Atlanta	37,913	0	37,588	248	0	76	0	0	0	0
67 Chicago	172,485	80,810	85,323	0	5,454	362	0	0	511	25
70 St. Louis	51,390	0	51,096	0	288	0	0	0	6	0
79 Cincinnati	64,652	18,985	44,235	0	0	266	0	737	430	0
94 Kansas City	40,172	0	39,217	0	58	0	0	0	858	39
115 Baltimore	32,377	0	7,854	0	24,076	0	0	0	431	15
119 Boston	54,211	0	0	0	53,034	0	0	0	1,177	0
123 Detroit	93,237	0	71,356	0	21,554	112	0	0	143	72
131 Min.-St. Paul	42,520	0	40,463	347	0	0	0	0	1,710	0
162 Buffalo	22,454	0	22,359	94	0	0	0	0	0	0
174 Cleveland	80,633	16,167	63,167	0	1,121	0	0	0	0	0
197 Pittsburgh	192,500	27,464	164,787	0	0	0	228	0	21	0
215 Dallas	66,037	0	0	0	3,657	62,380	0	0	0	0
216 Houston	209,425	7,392	15,453	0	28,698	155,399	491	0	814	1,177
229 Seattle	10,220	0	0	4,232	2,333	0	0	0	3,655	0
239 Milwaukee	49,064	0	47,939	0	825	56	0	0	241	3

TABLE 1.10

1990 POWER PLANT ELECTRICITY PRODUCTION BY AQCR, 10⁶ MJ

AQCR	Total Power, 10 ⁶ MJ	Nuclear	Coal	Hydro	Oil	Gas	Other	Pumped Storage		
								Hydro	Oil Peak	Gas Peak
24 Los Angeles	201,635	0	0	1,629	194,138	3,299	451	0	2,119	0
29 San Diego	197,377	174,363	0	0	22,764	0	0	0	250	0
30 San Francisco	39,880	0	0	89	38,706	0	1,066	0	19	0
36 Denver	26,437	0	26,406	32	0	0	0	0	0	0
43 New York	296,639	113,508	74,522	593	94,975	0	27	4	12,976	33
45 Philadelphia	263,255	173,641	73,938	0	13,837	0	94	0	1,745	0
47 Washington, DC	85,235	0	68,615	0	16,382	0	0	0	238	0
50 Miami	204,294	141,620		0	59,249	183	0	0	3,243	0
56 Atlanta	105,989	0	105,546	277	0	165	0	0	0	0
67 Chicago	318,741	251,366	64,202	0	2,438	242	0	0	468	25
70 St. Louis	42,166	0	41,977	0	183	0	0	0	6	0
79 Cincinnati	116,800	44,262	72,459	0	0	40	0	0	38	0
94 Kansas City	46,949	0	43,727	0	217	0	0	0	2,835	169
115 Baltimore	32,049	0	9,291	0	22,317	0	0	0	439	2
119 Boston	24,427	0	0	0	24,350	0	0	0	77	0
123 Detroit	161,669	68,052	90,199	0	3,335	27	0	0	36	20
131 Min.-St. Paul	31,120	0	30,705	347	0	0	0	0	68	0
162 Buffalo	16,037	0	15,936	101	0	0	0	0	0	0
174 Cleveland	148,026	119,007	28,785	0	233	0	0	0	0	0
197 Pittsburgh	274,333	73,021	201,064	0	0	0	227	0	21	0
215 Dallas	181,841	161,693	0	0	3,846	16,302	0	0	0	0
216 Houston	316,055	175,570	91,971	0	21,943	26,572	0	0	0	0
229 Seattle	9,478	0	0	4,463	2,067	0	0	0	2,948	0
239 Milwaukee	20,891	0	20,891	0	0	0	0	0	0	0

TABLE 1.11

2000 POWER PLANT ELECTRICITY PRODUCTION BY AQCR, 10^6 MJ

AQCR	Total Power, 10^6 MJ	Nuclear	Coal	Hydro	Oil	Gas	Other	Pumped Storage Hydro	Oil Peak	Gas Peak
24 Los Angeles	190,549	0	0	1,829	176,921	5,559	1,276	11	4,951	0
29 San Diego	450,330	441,049	0	0	9,551	0	0	0	230	0
30 San Francisco	6,390	0	0	97	6,531	0	262	0	0	0
35 Denver	40,073	0	40,037	36	0	0	0	0	0	0
43 New York	443,159	232,080	83,577	710	93,332	0	47	10	33,230	172
45 Philadelphia	470,757	334,244	120,962	0	12,069	0	126	0	3,357	0
47 Washington, DC	127,000	0	112,254	0	14,269	0	0	0	458	0
50 Miami	359,037	285,894	0	0	64,456	355	0	0	8,332	0
56 Atlanta	174,100	0	173,613	317	0	170	0	0	0	0
67 Chicago	596,188	533,815	60,865	0	1,154	118	0	0	219	16
70 St. Louis	64,922	0	64,791	0	123	0	0	0	8	0
79 Cincinnati	190,806	120,092	70,714	0	0	0	0	0	0	0
94 Kansas City	81,359	0	77,931	0	128	0	0	0	2,959	340
115 Baltimore	35,511	0	15,199	0	19,466	0	0	0	844	1
119 Boston	13,879	0	0	0	13,877	0	0	0	2	0
123 Detroit	253,934	179,565	73,789	0	563	6	0	0	7	4
131 Min.-St. Paul	26,373	0	26,026	347	0	0	0	0	0	0
162 Buffalo	15,502	0	15,381	120	0	0	0	0	0	0
174 Cleveland	243,482	232,810	10,666	0	6	0	0	0	0	0
197 Pittsburgh	422,717	118,980	303,391	0	0	0	306	0	41	0
215 Dallas	507,678	493,387	0	0	4,219	10,072	0	0	0	0
216 Houston	611,400	533,327	76,077	0	1,287	709	0	0	0	0
229 Seattle	5,571	0	0	4,967	373	0	0	0	231	0
239 Milwaukee	19,990	0	19,990	0	0	0	0	0	0	0

TABLE 1.12

ELECTRICITY PRODUCTION BY FUEL TYPE IN 24 URBAN AREAS, 10^9 MJ

<u>Year</u>	<u>Total</u>	<u>Nuclear</u>	<u>Hydro</u>	<u>Coal</u>	<u>Oil</u>	<u>Gas</u>	<u>Other</u>
1975	2063	188	7	684	550	626	8
2000	5352	3505	8	1345	477	17	2

TABLE 1.13

ELECTRICITY PRODUCTION IN 24 URBAN AREAS AS A PERCENT OF
NATIONAL PRODUCTION

<u>Year</u>	<u>Total</u>	<u>Nuclear</u>	<u>Hydro</u>	<u>Coal</u>	<u>Oil</u>	<u>Gas</u>
1975	26	23	1	24	50	31
2000	19	24	1	15	38	4

demand and on alternative energy sources. However, as Tables 1.12 and 1.13 show, new fossil-fueled power plants are being sited generally away from the urban areas. Therefore it is reasonable to assume that even if new nuclear plants are replaced by fossil-fueled plants, they too would be located away from the urban areas, thereby minimizing their impact on urban air pollution. Finally, changes in the electricity demand projections affect new plant construction, and since these are assumed to be under strict emission controls, their impact on total emissions would be small.

These REPS forecasts assume that new electric utility steam generators larger than the 250 MBTU/hr generators built after 1974 would be required to meet the new source performance standards shown in Table 1.14.

TABLE 1.14

NEW EXTERNAL BOILER 1975 STANDARDS, POUNDS/MBTU

	<u>TSP</u>	<u>SO_x</u>	<u>NO_x</u>
Coal-Fired	0.1	1.2	0.7
Oil-Fired	0.1	0.8	0.3
Gas-Fired	0.1	--	0.2

REPS was run assuming several different levels of controls on future power plants. These are shown in Table 1.15. Also of significance, REPS assumes that the very strict SIP standards in Appendix E for existing power plants would be achieved. Together these controls are projected to reduce power plant emissions by the percentages shown in Table 1.15.

As the table shows, controls on new and existing power plants significantly reduce projected electric utility emissions. NO_x emissions would go up by over 160 percent, SO_x emissions by over 400 percent, and TSP emissions by over 600 percent if future controls were no better than actual controls. The forecast of total emissions in the year 2000 would go up by 18 percent, 52 percent, and 26 percent, respectively, for NO_x, SO_x, and TSP.

The final--and in fact largest--uncertainty in the REPS projections is the degree to which other urban pollution sources will be eliminated or controlled, either by relocation away from urban areas or by future regulations.

The REPS projections in this report reflect the assumption that, except for public utility growth, state sector OBERS growth will be located in AQCRs in proportion to the existing sector activity in the AQCR. This

TABLE 1.15

PROJECTED ELECTRIC UTILITY EMISSIONS
(AS A PERCENT OF EMISSIONS GIVEN EXISTING CONTROLS)

	<u>TSP</u>	<u>SO_x</u>	<u>NO_x</u>
With 1975 and 1978 NSPS and SIPS	16	24	60
With 1975 and 1978 NSPS	21	27	61
With 1975 NSPS	28	41	71

assumption is used for locating both individual emission point sources and area sources. More disaggregated OBERS growth projections could change AQCR emission projections, but would probably not change aggregated projections.

Current and future regulatory action will continue to result in major changes in emission regulations, and these in turn will affect future air pollution levels. REPS also assumes that the new source performance standards promulgated in September 1978 will be achieved for new plants built after that date. The 1978 standards are shown in Table 1.16.

The REPS projections reflect existing Federal New Source Performance Standards (NSPS) and current State Implementation Plan (SIP) regulations (see Appendix E), but they do not reflect the 1 July 1979 revisions to the SIPS that are required by the Clean Air Act amendments of 1977. These revisions will certainly affect emission regulations in all of the urban areas. It is possible to estimate the impact of those regulations having to do with non-attainment areas. The "nonattainment area" means, for any air pollutant, an area which exceeds any national ambient air quality standard for the pollutant. SIPs must include a plan to attain

TABLE 1.16
1978 ELECTRIC UTILITY NEW SOURCE PERFORMANCE STANDARDS,
POUNDS/MBTU HEAT INPUT

	<u>TSP</u>	<u>SO_x</u>	<u>NO_x</u>
Coal-Fired Plants (>250 MBTU/hr)	0.03*	0.8†	0.5
Oil-Fired Plants (>250 MBTU/hr)	0.03‡	0.8†	0.3
Gas-Fired Plants (>250 MBTU/hr)	--	--	0.2

* And a 99-percent reduction in uncontrolled emissions

† And a 90-percent reduction in uncontrolled emissions unless SOX emissions are less than 0.2 lb/MBTU

‡ And a 70-percent reduction in uncontrolled emissions

and maintain national ambient air quality standards in these areas. Therefore it is possible to estimate the change in air pollution emissions that would be necessary for this to happen. Table 1.17 shows that the REPS AQCR total emission projections for the year 2000 would drop as much as 66 percent if the nonattainment regulations are achieved. This drop will cause an increase in the percent contribution of automobiles to total emissions on the order of 10 to 20 percent.

In summary, the REPS emission forecasts are sensitive to changes in a variety of assumptions including the expected growth in vehicle kilometers traveled, the controls on major electric utility plants, and the degree to which regulations will cause primary pollution standards to be attained. Table 1.18 shows the upper and lower bounds of these assumptions.

TABLE 1.17
CHANGE IN YEAR 2000 EMISSIONS IF STANDARDS ARE ACHIEVED
(PERCENT REPS FORECASTS)

	<u>Automobile, Change in % Contribution</u>	<u>Utility, Change in % Contribution</u>	<u>Total Emissions, Percent</u>
TSP	4	5	-48
SO _x	0	0	0
NO _x	0	0	- 9
THC	23	0	-66
CO	13	0	-34

TABLE 1.18
RANGE OF TOTAL EMISSION PROJECTIONS IN YEAR 2000

	<u>Automobile, Percent Contribution</u>	<u>Utility, Percent Contribution</u>	<u>Total, 1000 Metric Tons</u>
TSP	4.6-12.9	5.0-16.2	1670-3404
SO _x	-	31.5-44.0	5420-6627
NO _x	10.9-17.1	18.3-23.6	5737-6818
THC	11.3-42.0	0.3- 0.9	3577-11084
CO	24.1-58.5	0.3- 0.6	16776-34360

The numbers indicate that electric cars would have more than a 100 percent greater impact on THC and CO emissions if OTA's VMT projections are true and if nonattainment areas can control non-auto CO emissions. If SO_x controls on utilities do no better than the NSPS controls in 1975, then the electric car SO_x negative impact projections would be 40 percent greater. The impact of the uncertainties in the NO_x and TSP numbers on the electric car impacts are less clear and probably less significant, on the order of plus or minus 10 percent, depending on the alternative assumption.

The impact analysis that follows should be viewed with these uncertainties in mind. Also, there are some differences in the percent contribution numbers for automobiles and electric utilities in the following sections when compared to the numbers in this section. In this section, the percent contribution is based on total tons emitted in the 24 AQCRs; in the following sections, percent contribution is based on a population-weighted average of the emissions in each AQCR.

2 BASELINE AIR POLLUTION PROJECTIONS

As described in Sec. 1, baseline projections of tons of emissions of the five primary air pollutants (TSP, SO_x, NO_x, THC, and CO) were made for the years 1980, 1990, and 2000 using the Regional Emissions Projection System (REPS). The original version of REPS was updated to correct certain deficiencies and to incorporate new growth projections and emission factors.

2.1 PROJECTED FUTURE EMISSIONS

Five tables summarize projected 1980, 1990, and 2000 emissions and current air quality in each of the 24 AQCRs with the largest populations. The projections reflect a variety of assumptions built into the REPS model, including OBERS and RECAP growth projections, the 1975 NEDS emission inventory, state implementation plan emission controls, and existing and projected new source performance standards. In each table, emissions for 1980, 1990, and 2000 are shown as a percent of 1975 emissions. In addition, 1975 emissions per square kilometer, 1975 emissions in million person metric tons per square kilometer, and 1975 air quality as a percent of the primary standard are shown. At the bottom of each table, population weighted averages are given.

Table 2.1 shows the projected change in total suspended particulate (TSP) emissions for each AQCR. Resultant pollutant concentrations in 1975 were above the standard in all but five AQCRs. TSP emissions are projected to increase in future years in over half of the AQCRs, and by the year 2000 all of the AQCRs except for six will have particulate concentrations above the primary standard. As will be seen in Secs. 2.1 and 2.3, automobiles and power plants are both producers of TSP, but large numbers of electric cars would improve the overall TSP pollution concentrations (see Sec. 3.1).

Table 2.2 shows the projected change in sulfur oxide (SO_x) emissions for each AQCR. In 1975, four of the 24 AQCRs had sulfur oxide concentrations which were above the primary standard; but by the year 2000, all

TABLE 2.1
PROJECTED CHANGE IN PARTICULATE EMISSIONS

					<u>Percent of 1975</u>		
	<u>AQCR</u>	<u>1975*</u>	<u>1975†</u>	<u>1975§</u>	<u>1980</u>	<u>1990</u>	<u>2000</u>
24	Los Angeles	199	3	32	102	118	135
29	San Diego	114	3	4	94	101	115
30	San Francisco	107	3	14	114	112	111
36	Denver	167	1	2	103	135	169
43	New York	115	14	255	97	96	95
45	Philadelphia	112	12	70	65	73	80
47	Washington, D.C.	67	5	16	102	112	128
50	Miami	76	1	3	88	109	138
56	Atlanta	88	2	4	120	159	202
67	Chicago	197	27	214	107	125	142
70	St. Louis	210	9	23	66	76	87
79	Cincinnati	214	16	28	29	30	35
94	Kansas City	145	6	9	90	105	119
115	Baltimore	192	4	8	109	118	128
119	Boston	113	33	127	101	97	96
123	Detroit	168	11	51	103	111	118
131	Minn-St. Paul	123	7	15	109	121	131
162	Buffalo	92	6	8	82	85	90
174	Cleveland	199	51	180	53	57	60
197	Pittsburgh	207	13	38	98	91	84
215	Dallas	153	4	13	120	170	232
216	Houston	163	5	12	124	169	222
229	Seattle	88	3	5	104	129	153
239	Milwaukee	119	14	26	60	81	68
Weighted Average		146	12	97	96	106	118

* Percent of air quality standard

† Metric tons of emissions per square kilometer

§ Million person metric tons per square kilometer

TABLE 2.2

PROJECTED CHANGE IN SULFUR OXIDE EMISSIONS

AQCR		1975*	1975†	1975‡	Percent of 1975		
					1980	1990	2000
24	Los Angeles	81	5	57	92	100	103
29	San Diego	20	2	3	115	84	61
30	San Francisco	26	3	17	104	121	140
36	Denver	34	3	4	140	152	195
43	New York	79	31	567	76	79	80
45	Philadelphia	55	30	175	56	72	83
47	Washington, D.C.	33	14	42	119	111	114
50	Miami	9	5	13	102	128	167
56	Atlanta	48	9	17	100	116	126
67	Chicago	96	45	358	88	91	89
70	St. Louis	106	69	175	35	32	37
79	Cincinnati	49	40	70	67	52	45
94	Kansas City	49	15	22	90	84	85
115	Baltimore	55	7	16	139	138	144
119	Boston	46	115	445	97	84	78
123	Detroit	85	36	163	106	96	85
131	Minn-St. Paul	126	23	45	80	81	73
162	Buffalo	64	29	40	92	80	79
174	Cleveland	121	113	396	30	25	22
197	Pittsburgh	116	58	168	95	87	81
215	Dallas	5	3	8	127	192	269
216	Houston	11	6	15	117	153	195
229	Seattle	31	7	15	31	37	43
239	Milwaukee	51	29	54	107	83	78
Weighted Average		67	31	219	87	92	98

* Percent of air quality standard

† Metric tons of emissions per square kilometer

‡ Million person metric tons per square kilometer

of the AQCRs will have SO_x concentrations less than the primary standard. As will be seen in Sec. 2.3, electric utilities are major contributors to SO_x pollution, but even with electric cars, SO_x emissions would not increase significantly so long as the stringent SO_x controls on new electric utility plants are in effect.

Nitrogen oxide (NO_x) emission projections are shown in Table 2.3. There is quite a variation in 1975 air quality; Los Angeles, Atlanta, Chicago, and Boston were above the standard. By the year 2000, three other AQCRs will have maximum NO_x concentrations less than 50 percent above the standard. Both automobiles and power plants are major NO_x producers; in most AQCRs, NO_x emissions would be reduced with electric cars.

Total hydrocarbon (THC) emission projections are shown in Table 2.4. There are no air quality standards for THC. However, there is a relationship between THC and photochemical oxidants which can be modeled using rollback to determine the effect a change in THC emissions will have on peak oxidant concentrations (see Appendix D). Therefore, Table 2.4 shows 1975 oxidant air quality as a percent of the standard and future THC emissions as a percent of 1975 emissions. Maximum THC concentrations are and will continue to be a problem in all of the AQCRs. Electric cars would help to reduce THC, and therefore help to solve the oxidant problem.

Carbon monoxide (CO) is the fifth primary pollutant. Future changes in CO emissions are shown in Table 2.5. All but three of the AQCRs had CO concentrations in 1975 in excess of the federal standard. However, by the year 2000, with improved automobile CO emission control, almost all of the AQCRs can expect major reductions in maximum CO concentrations, and 17 may even achieve the primary air quality standard.

TABLE 2.3
PROJECTED CHANGE IN NITROGEN OXIDE EMISSIONS

AQCR		1975*	1975†	1975§	Percent of 1975		
					1980	1990	2000
24	Los Angeles	153	12	127	76	76	82
29	San Diego	72	8	12	82	77	75
30	San Francisco	76	12	60	85	89	96
36	Denver	96	6	8	115	131	163
43	New York	83	58	1041	94	84	83
45	Philadelphia	98	26	153	100	95	107
47	Washington, D.C.	52	23	71	113	114	137
50	Miami	39	7	18	85	92	114
56	Atlanta	147	8	15	98	137	185
67	Chicago	109	44	354	95	97	105
70	St. Louis	65	22	55	53	47	55
79	Cincinnati	59	17	30	91	96	99
94	Kansas City	47	11	16	103	100	119
115	Baltimore	66	15	32	101	95	101
119	Boston	102	169	656	96	77	72
123	Detroit	73	37	167	100	94	92
131	Minn-St. Paul	84	22	43	100	86	83
162	Buffalo	67	17	23	110	92	92
174	Cleveland	79	45	157	113	121	136
197	Pittsburgh	83	19	55	95	97	114
215	Dallas	71	5	15	97	91	108
216	Houston	72	11	26	114	136	184
229	Seattle	82	5	11	97	98	111
239	Milwaukee	54	18	32	109	89	96
Weighted Average		90	34	313	94	92	101

* Percent of air quality standard

† Metric tons of emissions per square kilometer

§ Million person metric tons per square kilometer

TABLE 2.4

PROJECTED CHANGE IN TOTAL HYDROCARBON EMISSIONS

AQCR	1975*	1975†	1975‡	Percent of 1975		
				1980	1990	2000
24 Los Angeles	490	27	287	92	85	94
29 San Diego	233	15	21	85	70	81
30 San Francisco	245	24	120	83	65	70
36 Denver	218	10	14	96	80	88
43 New York	319	115	2066	91	82	90
45 Philadelphia	391	55	323	100	103	122
47 Washington, D.C.	282	43	131	83	65	69
50 Miami	123	12	31	99	93	109
56 Atlanta	203	12	23	88	77	86
67 Chicago	267	56	450	97	94	105
70 St. Louis	539	20	51	89	74	81
79 Cincinnati	258	24	42	101	121	162
94 Kansas City	100	15	23	93	82	88
115 Baltimore	233	34	72	89	76	83
119 Boston	190	302	1173	91	80	87
123 Detroit	321	85	382	93	84	87
131 Minn-St. Paul	144	35	70	97	95	108
162 Buffalo	253	29	40	86	71	71
174 Cleveland	282	54	188	95	95	108
197 Pittsburgh	260	15	43	86	71	73
215 Dallas	202	10	28	95	93	109
216 Houston	368	21	51	112	140	184
229 Seattle	147	11	22	89	78	86
239 Milwaukee	266	53	97	107	116	134
Weighted Average	302	62	593	93	86	97

* Percent of air quality standard

† Metric tons of emissions per square kilometer

‡ Million person metric tons per square kilometer

TABLE 2.5
PROJECTED CHANGE IN CARBON MONOXIDE EMISSIONS

AQCR		1975*	1975 ^s	1975 [†]	Percent of 1975		
					1980	1990	2000
24	Los Angeles	454	95	1007	74	38	37
29	San Diego	145	78	110	75	38	36
30	San Francisco	162	129	638	77	42	42
36	Denver	265	56	74	94	54	49
43	New York	385	410	7401	80	35	33
45	Philadelphia	207	181	1059	82	40	36
47	Washington, D.C.	201	213	645	81	37	36
50	Miami	112	59	153	96	56	56
56	Atlanta	127	57	103	84	44	46
67	Chicago	318	258	2068	98	79	86
70	St. Louis	365	98	250	84	39	36
79	Cincinnati	81	74	128	81	40	38
94	Kansas City	85	66	98	88	51	49
115	Baltimore	178	885	1902	119	132	148
119	Boston	161	1163	4514	80	35	32
123	Detroit	144	327	1472	89	55	55
131	Minn-St. Paul	103	119	236	84	44	40
162	Buffalo	118	125	174	83	48	47
174	Cleveland	247	166	582	82	44	43
197	Pittsburgh	123	69	201	82	43	41
215	Dallas	31	39	111	85	41	40
216	Houston	142	50	122	89	56	59
229	Seattle	178	52	106	86	46	45
239	Milwaukee	137	123	224	87	48	46
Weighted Average		253	252	2227	84	47	46

* Percent of air quality standard

[†] Metric tons of emissions per square kilometer

^s Million person metric tons per square kilometer

These five tables illustrate that there is a wide variation in the projected changes in emissions for the major AQCRs in the country. All AQCRs have or will have air quality which does not meet all of the standards. Nevertheless, their major pollutants and pollution sources vary. The implication of this is important in measuring the impact of electric cars on air pollution. Separate analyses have to be performed for each AQCR. This is done in Sec. 3. The remainder of Sec. 2 presents separately the baseline emission projections for conventional autos and power plants. These are the emissions affected by introduction of electric cars.

2.2 AUTOMOBILE EMISSIONS

Automobiles are major contributors to NO_x , THC, and CO emissions and, to a lesser extent, to TSP emissions. However, as a result of the Clean Air Act, major progress is being made in reducing emissions from automobiles. These new developments, as well as the projected impact of the recent (1977) amendment to the Act, are reflected in the following REPS projections (Tables 2.6 through 2.9). These projections show the percent contribution of gasoline-powered automobiles to total emissions for four out of the five primary pollutants by AQCR for the years 1975, 1980, 1990, and 2000. Since automobiles emit only minimal SO_x , no table is provided for this pollutant.

Using a weighted average, cars in 1975 produced about 12 percent of the TSP emissions in the 24 AQCRs. As Table 2.6 shows, automobiles produced TSP ranging from a low of around 2 percent to a high of over 23 percent of all TSP emissions. The contribution of automobiles to TSP emissions is projected to decline by 28 percent (from 12.3 to 8.9 percent, as measured by the population-weighted averages) between 1975 and 2000. This decline is in part due to an actual reduction in automobile emissions of about 20 percent, and to a 13 percent increase in TSP emissions from all sources during this period. In the future, approximately 75 percent of TSP auto emissions will come from tire wear.

TABLE 2.6

PERCENT CONTRIBUTION OF AUTOMOBILE EMISSIONS TO PARTICULATES

<u>AQCR</u>	<u>1975</u>	<u>1980</u>	<u>1990</u>	<u>2000</u>
24 Los Angeles	16	13	11	10
29 San Diego	15	13	11	10
30 San Francisco	22	16	15	16
36 Denver	21	18	14	12
43 New York	17	14	12	13
45 Philadelphia	8	9	7	7
47 Washington, D.C.	23	18	16	15
50 Miami	21	22	19	17
56 Atlanta	15	10	7	7
67 Chicago	3	3	2	2
70 St. Louis	5	6	5	4
79 Cincinnati	2	6	6	5
94 Kansas City	4	3	3	2
115 Baltimore	22	17	15	15
119 Boston	20	16	15	16
123 Detroit	13	10	8	8
131 Minn-St. Paul	7	5	4	4
162 Buffalo	10	10	8	8
174 Cleveland	2	3	2	2
197 Pittsburgh	3	2	2	2
215 Dallas	4	3	2	2
216 Houston	4	3	2	2
229 Seattle	9	7	5	5
239 Milwaukee	4	5	4	5
Weighted Average	12.3	10.3	9.0	8.9

TABLE 2.7

PERCENT CONTRIBUTION OF AUTOMOBILE EMISSIONS TO NITROGEN OXIDES

<u>AQCR</u>	<u>1975</u>	<u>1980</u>	<u>1990</u>	<u>2000</u>
24 Los Angeles	27	25	19	18
29 San Diego	30	26	21	22
30 San Francisco	33	27	19	19
36 Denver	19	16	13	12
43 New York	29	23	17	17
45 Philadelphia	24	18	12	11
47 Washington, D.C.	36	24	16	14
50 Miami	27	27	19	18
56 Atlanta	25	19	10	8
67 Chicago	15	12	7	7
70 St. Louis	15	21	15	13
79 Cincinnati	16	13	8	8
94 Kansas City	16	12	8	6
115 Baltimore	38	29	22	22
119 Boston	27	21	17	19
123 Detroit	27	21	14	15
131 Minn-St. Paul	17	13	10	10
162 Buffalo	25	17	13	13
174 Cleveland	14	9	6	5
197 Pittsburgh	13	10	6	5
215 Dallas	27	22	17	16
216 Houston	14	10	6	5
229 Seattle	30	15	13	12
239 Milwaukee	22	15	13	12
Weighted Average	24.6	19.9	14.2	13.8

TABLE 2.8

PERCENT CONTRIBUTION OF AUTOMOBILE EMISSIONS TO TOTAL HYDROCARBONS

<u>AQCR</u>	<u>1975</u>	<u>1980</u>	<u>1990</u>	<u>2000</u>
24 Los Angeles	32	24	13	12
29 San Diego	44	35	20	18
30 San Francisco	44	35	22	22
36 Denver	35	35	20	19
43 New York	35	26	13	12
45 Philadelphia	28	19	8	7
47 Washington, D.C.	46	38	23	23
50 Miami	36	28	14	14
56 Atlanta	42	34	21	20
67 Chicago	28	20	9	9
70 St. Louis	37	28	15	13
79 Cincinnati	28	18	7	6
94 Kansas City	28	21	12	11
115 Baltimore	40	32	18	18
119 Boston	36	27	14	13
123 Detroit	29	21	11	11
131 Minn-St. Paul	25	18	9	8
162 Buffalo	35	27	14	14
174 Cleveland	28	20	9	8
197 Pittsburgh	39	30	16	15
215 Dallas	36	27	14	13
216 Houston	18	12	5	4
229 Seattle	37	29	17	16
239 Milwaukee	18	11	5	5
Weighted Average	33.6	24.9	13.1	12.3

TABLE 2.9

PERCENT CONTRIBUTION OF AUTOMOBILE EMISSIONS TO CARBON MONOXIDE

<u>AQCR</u>	<u>1975</u>	<u>1980</u>	<u>1990</u>	<u>2000</u>
24 Los Angeles	66	56	48	50
29 San Diego	62	51	45	48
30 San Francisco	59	48	38	40
36 Denver	83	62	32	34
43 New York	74	60	50	50
45 Philadelphia	64	57	39	39
47 Washington, D.C.	72	66	49	51
50 Miami	58	51	35	36
56 Atlanta	67	60	41	40
67 Chicago	46	35	14	12
70 St. Louis	58	51	35	36
79 Cincinnati	68	61	41	41
94 Kansas City	47	39	22	21
115 Baltimore	12	7	2	2
119 Boston	72	66	51	52
123 Detroit	56	47	25	23
131 Minn-St. Paul	56	49	32	32
162 Buffalo	62	53	30	27
174 Cleveland	68	60	37	35
197 Pittsburgh	62	55	33	32
215 Dallas	65	59	45	47
216 Houston	57	49	29	27
229 Seattle	57	49	31	31
239 Milwaukee	57	50	31	30
Weighted Average	62.4	54.3	37.9	38.1

Automobiles are a major producer of NO_x in all 24 AQCRs. They produced a weighted average of 25 percent of all NO_x emissions in 1975, and are projected to produce 14 percent by the year 2000. The percent contribution of automobiles is projected to decrease in all AQCRs between 1975 and 2000. The average decrease is 44 percent. This is the result of an actual decrease in automobile emissions in the 24 AQCRs of 46 percent, as well as an increase in NO_x emissions from all other sources of 20 percent.

Automobile THC emissions come from the exhaust and crankcase, evaporation from the fuel tank and carburetor, and evaporation from the gas-handling facilities. All of these sources are included in the percent contribution estimates shown in Table 2.8. Automobiles are a major producer of THC in all AQCRs. They produce on the average 34 percent of all THC emissions, and this percent does not include THC emissions from petroleum processing and handling, other than at service stations. THC automobile emissions are projected to decrease by 60 percent from 1975 to 2000. This, coupled with a slight overall rise in THC emissions of 2 percent, means that between 1975 and 2000 the relative contribution of automobiles to THC will decrease by 63 percent (from 33 to 12 percent).

Automobiles are also major producers of CO, as shown in Table 2.9, producing more than 62 percent of CO emissions in 1975 in the 24 AQCRs. The relative contribution of automobiles to CO is decreasing such that by the year 2000 they will produce only 38 percent. The improvement between 1975 and 2000 in total tons of CO emitted by automobiles is even more impressive. There is projected to be a 75 percent reduction in tons of CO emitted by automobiles in the 24 AQCRs.

2.3 POWER PLANT EMISSIONS

Since electric cars will require that additional electricity be generated, their impact will be to increase pollution from power plants. To estimate the amount of this increase, it is first necessary to develop baseline projections of power plant emissions for the AQCRs being studied.

The quantity of emissions produced by power plants is very much a function of the type of fuel used by each plant and the emission control equipment installed at the plant. REPS, in conjunction with RECAPS, takes these factors into consideration when calculating power plant emissions.

Power plants are major contributors to NO_x and SO_x emissions and, to a lesser extent, to TSP emissions. The percent contribution figures presented in Tables 2.10 through 2.12 are for plants located in the 24 AQCRs. These plants do not necessarily produce all of the electricity used in a particular AQCR, nor is all of the electricity generated by these plants necessarily used by the AQCR in which the electricity was generated. The RECAPS model⁵ used an electricity dispatching algorithm to estimate the amount of electricity that would be generated by each power plant. Demand by fuel type for plants within each AQCR were then aggregated as estimates of future growth in electricity production by fuel type. These were used by REPS along with the existing power plant emissions inventory and federal new source performance standards to develop future power plant emissions. Section 1.3 and Appendix E describe the required control efficiencies assumed.

As shown in Table 2.10, in 1975 an average of 50 percent of all SO_x emitted in the 24 AQCRs comes from power plants. The percent varies from a low of zero percent to a high of 90 percent. There is a tremendous drop in power plant emissions between 1975 and 1980 in several of the AQCRs. This drop is due to the assumed achievement of stringent SIP standards for existing plants in those areas. Only in the AQCRs of Dallas, Houston,

TABLE 2.10

PERCENT CONTRIBUTION OF POWER PLANT EMISSIONS TO SULFUR OXIDES

<u>AQCR</u>	<u>1975</u>	<u>1980</u>	<u>1990</u>	<u>2000</u>
24 Los Angeles	58	46	38	29
29 San Diego	68	72	59	39
30 San Francisco	8	0	0	2
36 Denver	23	34	20	17
43 New York	48	22	18	15
45 Philadelphia	44	16	22	23
47 Washington, D.C.	61	65	59	58
50 Miami	66	50	34	21
56 Atlanta	83	81	78	74
67 Chicago	59	42	34	24
70 St. Louis	82	49	44	51
79 Cincinnati	90	84	75	66
94 Kansas City	77	71	66	64
115 Baltimore	18	33	21	15
119 Boston	40	36	22	14
123 Detroit	75	69	58	43
131 Minn-St. Paul	74	63	56	44
162 Buffalo	55	44	27	19
174 Cleveland	39	55	34	14
197 Pittsburgh	69	63	55	49
215 Dallas	2	1	0	0
216 Houston	2	2	1	0
229 Seattle	0	1	1	0
239 Milwaukee	79	75	57	42
Weighted Average	49.6	38.2	31.6	25.6

TABLE 2.11

PERCENT CONTRIBUTION OF POWER PLANT EMISSIONS TO NITROGEN OXIDES

<u>AQCR</u>	<u>1975</u>	<u>1980</u>	<u>1990</u>	<u>2000</u>
24 Los Angeles	32	17	20	16
29 San Diego	26	19	19	10
30 San Francisco	10	0	5	1
36 Denver	26	27	21	23
43 New York	29	26	25	23
45 Philadelphia	21	19	17	21
47 Washington, D.C.	20	35	40	46
50 Miami	38	21	21	18
56 Atlanta	31	28	46	51
67 Chicago	29	19	15	10
70 St. Louis	59	26	24	31
79 Cincinnati	46	38	39	34
94 Kansas City	33	34	34	41
115 Baltimore	10	15	14	11
119 Boston	31	30	19	12
123 Detroit	30	31	30	23
131 Minn-St. Paul	41	43	35	26
162 Buffalo	29	38	32	30
174 Cleveland	19	14	6	2
197 Pittsburgh	55	53	54	60
215 Dallas	22	19	6	3
216 Houston	22	20	5	0
229 Seattle	0	0	0	0
239 Milwaukee	31	35	20	16
Weighted Average	28.3	23.4	21.6	19.5

TABLE 2.12

PERCENT CONTRIBUTION OF POWER PLANT EMISSIONS TO PARTICULATES

<u>AQCR</u>	<u>1975</u>	<u>1980</u>	<u>1990</u>	<u>2000</u>
24 Los Angeles	13	9	6	4
29 San Diego	10	15	7	3
30 San Francisco	2	7	3	1
36 Denver	10	0	5	6
43 New York	5	8	6	5
45 Philadelphia	5	5	5	6
47 Washington, D.C.	15	18	15	16
50 Miami	12	13	10	7
56 Atlanta	15	12	14	14
67 Chicago	7	3	2	1
70 St. Louis	28	4	3	3
79 Cincinnati	70	34	21	14
94 Kansas City	17	1	4	4
115 Baltimore	1	3	2	2
119 Boston	11	11	6	3
123 Detroit	25	16	12	8
131 Minn-St. Paul	8	6	4	3
162 Buffalo	4	8	5	3
174 Cleveland	21	25	14	5
197 Pittsburgh	50	44	36	29
215 Dallas	1	1	0	0
216 Houston	2	1	0	0
229 Seattle	0	0	0	0
239 Milwaukee	46	9	35	26
Weighted Average	12.5	9.7	7.6	5.8

San Francisco, and Seattle are power plants not an important source of SO_x . There are very few power plants located in the Seattle AQCR, and most of these are hydroelectric. In Dallas and Houston, most of the power is generated from natural gas in plants which cannot burn oil on a continuous basis. San Francisco does have some oil-fired power plants, but most of their SO_x comes from chemical and commercial facilities. In all AQCRs, between 1975 and 2000 there is a tremendous drop in power plant emissions of all types including SO_x . This, of course, is due to the new stringent controls, the retirement of many existing plants, the assumption that new SIPs will be stringent, and the fact that many new power plants will be built away from AQCRs. During this same period, total SO_x emissions are projected to decrease by 25 percent. Therefore, the percent contribution of power plant SO_x emissions to total emissions will actually decrease by over 48 percent during this period.

Nitrogen oxide emissions from power plants in the 24 AQCRs make up 28 percent of all NO_x emissions in the AQCRs. In 1975 the percent ranged from a high of 59 percent in St. Louis to a low of less than one percent in Seattle. The percent contribution of power plant emissions to total NO_x are shown in Table 2.11. Their relative role is projected to decline from 28 percent in 1975 to only 19 percent in 2000. During the period from 1975 to 2000, as total NO_x emissions for all AQCRs increase by 5 percent, urban power plant NO_x emissions will decrease over 32 percent.

In 1975, power plants in the 24 AQCRs emitted approximately 12 percent of the total suspended particulate matter (TSP) emitted by all measured sources in the AQCRs. There is significant variation among the AQCRs in percent contribution of power plants. In some AQCRs only a small percent of TSP emissions come from power plants; in others the percent is as high as 50 to 60 percent. Total TSP emissions will grow by 13 percent during the period from 1975 to 2000. Urban power plant TSP emissions will decline during the period by over 70 percent.

3 IMPACT OF ELECTRIC CARS ON AIR POLLUTION

For any given level of electric car use in any AQCR, conventional car emissions will be reduced and plant emissions will be increased. The percent reduction in conventional emissions is assumed to be equal to the percent of the conventional cars replaced.* The percent increase in power plant emissions is equal to the percent increase in urban power plant throughput of each fuel type used to generate electricity. Since the fuels used to recharge electric cars might differ depending upon the number of electric cars, the air pollution impact of two electric car populations is assessed: the first is a 10 percent electric car population, and the second is a 100 percent electric car population.

The air pollution impact of electric cars for each pollutant is presented as a percent change in baseline emissions. A population weighted average of the percentage change is also shown. In addition, tables are given of projected air quality as a percent of the standard with and without electric cars for the AQCRs most affected. Finally, in Sec. 3.6 the impact of electric cars on the SEAS air pollution indicator is discussed.

3.1 ELECTRIC CAR IMPACT ON PARTICULATE EMISSIONS

For the 24 AQCRs together, TSP emissions per year are expected to increase by 400 thousand metric tons between 1975 and 2000. During this period, power plant emissions are declining by 69 percent, and automobile TSP emissions will drop by 20 percent (see Tables 2.6, 2.12, and Appendix C). Tables 3.1 and 3.2 show the resulting impact on total TSP emission of 10 percent and 100 percent electric cars.

As Table 3.1 shows, 10 percent electric cars would have relatively little impact on TSP emissions. Even with 100 percent electric cars there would be at most a 1- to 2-percent change in TSP emissions. The

* Except for TSP emissions, where 75 percent of future TSP emissions are from tire wear. These will remain with electric cars.

TABLE 3.1

PERCENT OF BASELINE EMISSIONS OF PARTICULATES WITH
10 PERCENT ELECTRIC CARS

<u>AQCR</u>	<u>1980</u>	<u>1990</u>	<u>2000</u>
24 Los Angeles	100.1	100.1	99.9
29 San Diego	100.3	100.2	99.7
30 San Francisco	100.2	99.7	99.6
36 Denver	99.6	99.8	99.8
43 New York	100.3	100.1	100.0
45 Philadelphia	100.0	100.0	100.0
47 Washington, D.C.	100.3	100.2	100.1
50 Miami	100.0	99.8	99.7
56 Atlanta	100.0	100.0	100.0
67 Chicago	100.1	100.0	100.1
70 St. Louis	99.9	100.0	100.0
79 Cincinnati	100.9	100.3	100.2
94 Kansas City	100.0	100.0	100.0
115 Baltimore	99.7	99.7	99.6
119 Boston	100.2	99.7	99.6
123 Detroit	100.3	100.2	100.1
131 Minn-St. Paul	100.1	100.1	99.9
162 Buffalo	99.8	99.8	99.8
174 Cleveland	100.7	100.1	100.0
197 Pittsburgh	101.8	101.5	100.9
215 Dallas	99.9	99.9	100.0
216 Houston	99.9	99.9	100.0
229 Seattle	99.8	99.9	99.9
239 Milwaukee	100.3	100.2	100.0
Weighted Average	100.2	100.1	99.9

TABLE 3.2

PERCENT OF BASELINE EMISSIONS OF PARTICULATES WITH
100 PERCENT ELECTRIC CARS

<u>AQCR</u>	<u>1980</u>	<u>1990</u>	<u>2000</u>
24 Los Angeles	100.9	101.1	98.9
29 San Diego	102.9	102.4	97.4
30 San Francisco	101.6	97.5	96.0
36 Denver	95.6	97.8	98.0
43 New York	103.3	100.8	99.5
45 Philadelphia	100.0	100.4	100.2
47 Washington, D.C.	102.9	102.4	101.0
50 Miami	100.1	98.4	97.3
56 Atlanta	99.7	100.1	99.7
67 Chicago	101.2	99.8	99.7
70 St. Louis	99.4	99.7	99.5
79 Cincinnati	108.8	103.2	101.9
94 Kansas City	99.5	100.1	99.7
115 Baltimore	96.8	96.6	96.3
119 Boston	101.6	96.9	96.1
123 Detroit	103.0	102.4	100.6
131 Minn-St. Paul	101.1	100.5	99.5
162 Buffalo	97.5	97.9	98.0
174 Cleveland	107.0	100.7	100.3
197 Pittsburgh	118.0	115.0	108.6
215 Dallas	99.4	99.5	99.5
216 Houston	99.5	99.5	99.5
229 Seattle	98.2	98.7	98.8
239 Milwaukee	102.5	102.4	100.1
Weighted Average	102.1	100.6	99.4

greatest positive impact would be in the Denver and Baltimore AQCRs where TSP pollution from automobiles is much greater than pollution from power plants. The greatest negative impact would be in the Pittsburgh AQCRs where power plants produce more TSP emissions than automobiles. However, even in these AQCRs an all-electric car population would only change TSP emissions by 4 to 8 percent. With 100 percent electric cars, the average decrease in air pollution concentrations weighted by population would be less one to two percent of standard in 1980 and 1990, and only 0.6 percent in 2000.

3.2 ELECTRIC CAR IMPACT ON SO_x EMISSIONS

Electric cars would cause SO_x emissions to increase since power plants are major producers of SO_x , emitting close to 50 percent of all SO_x in the 24 AQCRs in 1975. However, if the stringent controls on power plant SO_x emissions are achieved, as assumed, power plant SO_x emissions would not be the serious SO_x polluters they are today. Autos, on the other hand, produce almost no SO_x . Tables 3.3 and 3.4 show the percentage impact on SO_x emission of 10 and 100 percent electric cars. It appears that there would be about a one percent increase in SO_x with 10 percent electric cars and a 5- to 10-percent increase with 100 percent electric cars. Some AQCRs are affected more than others. The five AQCRs that would be most adversely affected are Los Angeles, New York, Minneapolis, Pittsburgh, and Detroit. All of these except Pittsburgh have current SO_x air quality within the standard. As Table 3.5 shows, with 100 percent electric cars, using rollback data from Table 2.2, there would be at most a 10-percent deterioration in SO_x air quality in these AQCRs.

TABLE 3.3

PERCENT OF BASELINE EMISSIONS OF SULFUR OXIDES WITH
10 PERCENT ELECTRIC CARS

	<u>AQCR</u>	<u>1980</u>	<u>1990</u>	<u>2000</u>
24	Los Angeles	102.1	102.5	101.1
29	San Diego	102.9	104.5	100.0
30	San Francisco	99.9	100.0	100.0
36	Denver	101.2	100.5	100.3
43	New York	100.9	101.0	101.2
45	Philadelphia	100.6	100.9	100.7
47	Washington, D.C.	102.5	102.0	101.4
50	Miami	102.1	101.1	100.5
56	Atlanta	101.5	101.1	100.7
67	Chicago	102.4	100.4	100.2
70	St. Louis	101.2	101.4	100.9
79	Cincinnati	102.6	101.6	101.5
94	Kansas City	101.9	101.1	100.6
115	Baltimore	101.0	100.3	100.1
119	Boston	101.7	100.2	100.0
123	Detroit	102.3	102.2	101.4
131	Minn-St. Paul	102.3	102.1	100.8
162	Buffalo	100.0	100.0	100.0
174	Cleveland	101.7	100.3	100.2
197	Pittsburgh	102.6	102.4	101.6
215	Dallas	100.0	100.0	100.0
216	Houston	100.0	100.0	100.0
229	Seattle	99.9	100.0	100.0
239	Milwaukee	103.0	100.5	100.2
	Weighted Average	101.4	101.1	100.7

TABLE 3.4

PERCENT OF BASELINE EMISSIONS OF SULFUR OXIDES WITH
100 PERCENT ELECTRIC CARS

<u>AQCR</u>	<u>1980</u>	<u>1990</u>	<u>2000</u>
24 Los Angeles	120.9	124.6	110.2
29 San Diego	129.1	145.3	100.2
30 San Francisco	98.6	100.0	100.0
36 Denver	111.8	104.9	103.1
43 New York	108.6	109.5	111.8
45 Philadelphia	105.9	109.0	106.7
47 Washington, D.C.	124.8	119.6	114.3
50 Miami	121.2	111.3	104.9
56 Atlanta	114.6	111.2	107.1
67 Chicago	124.4	103.8	102.2
70 St. Louis	112.4	114.4	109.1
79 Cincinnati	125.9	116.5	114.9
94 Kansas City	119.2	111.5	106.0
115 Baltimore	109.8	102.9	100.9
119 Boston	116.7	102.3	100.1
123 Detroit	122.7	122.3	113.6
131 Minn-St. Paul	123.5	120.8	107.9
162 Buffalo	99.8	100.0	100.0
174 Cleveland	116.9	103.1	102.4
197 Pittsburgh	126.4	123.7	115.5
215 Dallas	99.7	100.0	100.0
216 Houston	99.9	100.3	100.0
229 Seattle	99.2	100.1	100.0
239 Milwaukee	130.3	105.4	102.0
Weighted Average	114.5	111.0	106.9

TABLE 3.5
FIVE AQCRs WITH LARGEST INCREASE IN SO_x DUE TO
100 PERCENT ELECTRIC CARS

AQCR	SO _x Concentration Without EC, Percent of Standard			SO _x Concentration With EC, Percent of Standard		
	1980	1990	2000	1980	1990	2000
Los Angeles	74	81	84	90	101	92
New York	60	62	63	65	68	70
Minneapolis	123	121	108	125	124	99
Pittsburgh	111	102	94	140	126	109
Detroit	90	81	73	110	99	82

3.3 ELECTRIC CAR IMPACT ON NO_x EMISSIONS

Automobiles and power plants are both major producers of NO_x. In 1975 in the 24 AQCRs, each produced around 25 percent of all NO_x emissions. Replacing conventional cars with electrics would, however, only increase electricity generation in the AQCRs by an average of 25 percent in 1980, 25 percent in 1990, and 13 percent in 2000. Therefore there should be an overall reduction in NO_x emissions with electric cars. In fact, as shown in Tables 3.6 and 3.7, assuming a 10 percent electric car population, there would be about a one percent reduction in NO_x. With 100 percent electric cars, there would be an 8 percent reduction in NO_x. In some AQCRs, notably Los Angeles and Denver, the saving is even greater. Table 3.8 lists the five AQCRs where the greatest improvement would occur in projected air quality with 100 percent electric cars. Three of the five have and will continue to have a serious NO_x problem: Los Angeles, Denver, and Atlanta. Electric cars would reduce the problem, but would not be sufficient to allow the AQCRs to achieve the NO_x standard.

TABLE 3.6
PERCENT OF BASELINE EMISSIONS OF NITROGEN OXIDES WITH
10 PERCENT ELECTRIC CARS

<u>AQCR</u>	<u>1980</u>	<u>1990</u>	<u>2000</u>
24 Los Angeles	98.2	99.4	98.8
29 San Diego	98.2	99.4	97.8
30 San Francisco	97.3	98.3	98.1
36 Denver	99.4	99.2	99.3
43 New York	99.4	99.9	99.8
45 Philadelphia	99.0	99.4	99.5
47 Washington, D.C.	99.0	100.0	99.9
50 Miami	98.2	98.8	98.6
56 Atlanta	98.6	99.7	99.7
67 Chicago	99.9	99.4	99.4
70 St. Louis	98.6	99.3	99.3
79 Cincinnati	99.9	100.1	100.0
94 Kansas City	99.8	99.8	99.7
115 Baltimore	97.6	98.0	97.9
119 Boston	99.3	98.5	98.1
123 Detroit	98.9	99.7	99.3
131 Minn-St. Paul	100.4	100.3	99.4
162 Buffalo	98.3	98.7	98.7
174 Cleveland	99.5	99.5	99.5
197 Pittsburgh	101.3	101.7	101.4
215 Dallas	98.4	98.3	98.4
216 Houston	99.2	99.5	99.5
229 Seattle	99.7	98.4	98.5
239 Milwaukee	99.9	98.9	98.9
Weighted Average	99.0	99.4	99.2

TABLE 3.7

PERCENT OF BASELINE EMISSIONS OF NITROGEN OXIDES WITH
100 PERCENT ELECTRIC CARS

<u>AQCR</u>	<u>1980</u>	<u>1990</u>	<u>2000</u>
24 Los Angeles	82.4	93.6	87.8
29 San Diego	82.1	94.1	77.7
30 San Francisco	73.4	83.0	81.2
36 Denver	93.6	92.5	92.6
43 New York	94.5	99.0	97.5
45 Philadelphia	89.7	94.4	94.7
47 Washington, D.C.	89.8	99.8	99.1
50 Miami	82.2	87.6	86.3
56 Atlanta	85.8	96.8	97.0
67 Chicago	98.6	94.3	94.1
70 St. Louis	86.2	93.2	92.6
79 Cincinnati	98.8	100.6	99.7
94 Kansas City	97.6	98.1	97.3
115 Baltimore	75.9	80.3	78.6
119 Boston	93.0	84.6	81.2
123 Detroit	88.7	97.0	92.5
131 Minn-St. Paul	103.5	103.2	94.5
162 Buffalo	83.3	87.3	87.4
174 Cleveland	95.2	95.0	95.4
197 Pittsburgh	112.6	117.5	113.6
215 Dallas	83.8	83.8	84.5
216 Houston	92.4	95.3	95.1
229 Seattle	76.6	84.4	85.5
239 Milwaukee	98.7	89.3	88.6
Weighted Average	90.2	94.3	92.3

TABLE 3.8
FIVE AQCRs WITH LARGEST DECREASE IN NO_x WITH
100 PERCENT ELECTRIC CARS

	NO _x Concentration Without EC, Percent of Standard			NO _x Concentration With EC, Percent of Standard		
	1980	1990	2000	1980	1990	2000
Los Angeles	118	119	127	99	112	113
San Francisco	66	69	73	51	59	61
Seattle	80	80	90	64	70	79
Baltimore	67	63	66	53	53	54
Boston	98	81	77	92	70	64

3.4 ELECTRIC CAR IMPACT ON THC EMISSIONS

Automobiles are major producers of THC, emitting over a third of all THC emissions in the 24 AQCRs in 1975. This percent will decrease to 12 percent by the year 2000. Power plants emit less than one percent of all THC; therefore, electric cars will lower the THC emissions in all AQCRs. Tables 3.9 and 3.10 show that with 10 percent electric cars there should be a reduction in THC emissions on the order of 2 to 3 percent. With 100 percent electric cars, the reduction is on the order of 10 to 20 percent.

The five AQCRs that would have the greatest improvement in oxidant air quality with 100 percent electric cars are shown in Table 3.11. On the average, there would be a 111 percent of standard reduction in 1980, a 55 percent reduction in 1990, and a 56 percent reduction in 2000. Major reductions would occur in all AQCRs.

TABLE 3.9

PERCENT OF BASELINE EMISSIONS OF HYDROCARBONS WITH
10 PERCENT ELECTRIC CARS

<u>AQCR</u>	<u>1980</u>	<u>1990</u>	<u>2000</u>
24 Los Angeles	97.6	98.7	98.7
29 San Diego	96.4	97.9	98.1
30 San Francisco	96.4	97.6	97.7
36 Denver	96.4	97.9	97.9
43 New York	97.4	98.6	98.7
45 Philadelphia	98.1	99.1	99.2
47 Washington, D.C.	96.1	97.6	97.6
50 Miami	97.2	98.5	98.6
56 Atlanta	96.5	97.7	97.8
67 Chicago	97.9	99.0	99.1
70 St. Louis	97.2	98.5	98.6
79 Cincinnati	98.1	99.2	99.4
94 Kansas City	97.8	98.7	98.8
115 Baltimore	96.7	98.0	98.1
119 Boston	97.2	98.5	98.6
123 Detroit	97.8	98.8	98.9
131 Minn-St. Paul	98.1	99.0	99.1
162 Buffalo	97.2	98.5	98.5
174 Cleveland	98.0	99.0	99.1
197 Pittsburgh	97.0	98.3	98.4
215 Dallas	97.2	98.4	98.5
216 Houston	98.8	99.5	99.6
229 Seattle	97.0	98.2	98.3
239 Milwaukee	98.8	99.5	99.5
Weighted Average	97.4	98.6	98.7

TABLE 3.10

PERCENT OF BASELINE EMISSIONS OF HYDROCARBONS WITH
100 PERCENT ELECTRIC CARS

<u>AQCR</u>	<u>1980</u>	<u>1990</u>	<u>2000</u>
24 Los Angeles	75.8	86.7	87.3
29 San Diego	64.4	78.9	80.6
30 San Francisco	63.6	76.1	76.6
36 Denver	64.0	79.0	79.2
43 New York	73.7	86.3	87.4
45 Philadelphia	80.7	91.0	92.4
47 Washington, D.C.	61.5	75.8	75.8
50 Miami	71.9	85.3	85.9
56 Atlanta	64.5	77.3	77.7
67 Chicago	79.5	89.7	90.8
70 St. Louis	71.5	84.5	85.9
79 Cincinnati	81.0	92.1	94.1
94 Kansas City	78.2	87.4	88.2
115 Baltimore	67.3	80.4	80.5
119 Boston	72.3	85.2	86.0
123 Detroit	77.9	88.1	88.6
131 Minn-St. Paul	81.5	90.5	91.4
162 Buffalo	72.4	84.5	84.9
174 Cleveland	79.8	90.2	91.3
197 Pittsburgh	69.9	83.5	84.4
215 Dallas	72.2	84.3	85.5
216 Houston	88.0	94.8	95.7
229 Seattle	69.9	81.8	82.6
239 Milwaukee	88.2	94.5	95.1
Weighted Average	74.4	86.0	86.8

TABLE 3.11
FIVE AQCRs WITH LARGEST DECREASE IN OXIDANTS WITH
100 PERCENT ELECTRIC CARS

	<u>O_x Concentration Without EC, Percent of Standard</u>			<u>O_x Concentration With EC, Percent of Standard</u>		
	<u>1980</u>	<u>1990</u>	<u>2000</u>	<u>1980</u>	<u>1990</u>	<u>2000</u>
Los Angeles	499	416	460	341	361	402
San Francisco	204	159	171	130	121	131
Denver	208	175	193	133	138	151
Washington DC	234	182	194	144	139	147
St. Louis	479	396	434	342	335	375

3.5 ELECTRIC CAR IMPACT ON CO EMISSIONS

Cars produced 62 percent of all CO emissions in the 24 AQCRs in 1975. This percent is projected to decrease to 38 percent by the year 2000. On the other hand, power plants produce less than one percent of all CO. As shown in Tables 3.12 and 3.13, with 10 percent electric cars there would be a 4 to 5 percent reduction in CO. By replacing all conventional cars with electrics, there would be a 55 percent reduction of CO in 1980, a 38 percent reduction in 1990, and a 38 percent reduction in 2000. The greatest reduction would occur in the five AQCRs shown in Table 3.14. Their air quality would be improved substantially with electric cars, especially in Los Angeles, where automobiles produce over 50 percent of CO emissions. Without 100 percent electric cars, seven AQCRs will have a maximum CO concentration above the standard, but with 100 percent electric cars only two AQCRs would have problems: Chicago and Baltimore. These are major iron and steel producing areas with blast furnaces that give off large quantities of CO, especially if not controlled.

TABLE 3.12

PERCENT OF BASELINE EMISSIONS OF CARBON MONOXIDE WITH
10 PERCENT ELECTRIC CARS

<u>AQCR</u>	<u>1980</u>	<u>1990</u>	<u>2000</u>
24 Los Angeles	94.4	95.2	95.0
29 San Diego	94.9	95.5	95.2
30 San Francisco	95.2	96.2	96.0
36 Denver	93.8	96.8	96.6
43 New York	93.3	95.0	95.0
45 Philadelphia	94.3	96.1	96.1
47 Washington, D.C.	93.5	95.1	95.0
50 Miami	94.9	96.5	96.4
56 Atlanta	94.0	95.9	96.0
67 Chicago	96.6	98.6	98.8
70 St. Louis	94.9	96.5	96.4
79 Cincinnati	93.9	95.9	95.9
94 Kansas City	96.1	97.8	97.9
115 Baltimore	99.3	99.8	99.8
119 Boston	93.4	94.9	94.8
123 Detroit	95.3	97.5	97.7
131 Minn-St. Paul	95.1	96.9	96.8
162 Buffalo	94.7	97.0	97.3
174 Cleveland	94.0	96.3	96.5
197 Pittsburgh	94.6	96.7	96.9
215 Dallas	94.1	95.5	95.3
216 Houston	95.1	97.1	97.3
229 Seattle	95.1	96.9	96.9
239 Milwaukee	95.1	96.9	97.0
Weighted Average	94.6	96.2	96.2

TABLE 3.13

PERCENT OF BASELINE EMISSIONS OF CARBON MONOXIDE WITH
100 PERCENT ELECTRIC CARS

<u>AQCR</u>	<u>1980</u>	<u>1990</u>	<u>2000</u>
24 Los Angeles	44.5	52.2	49.9
29 San Diego	48.9	55.3	51.7
30 San Francisco	52.0	61.6	60.0
36 Denver	38.0	67.6	65.9
43 New York	32.6	50.3	50.0
45 Philadelphia	43.5	61.2	60.7
47 Washington, D.C.	34.7	51.0	49.8
50 Miami	48.9	65.2	64.2
56 Atlanta	39.8	59.1	60.1
67 Chicago	65.8	86.2	88.2
70 St. Louis	48.8	65.0	64.1
79 Cincinnati	39.2	58.9	59.2
94 Kansas City	61.1	78.4	78.9
115 Baltimore	92.5	97.6	97.9
119 Boston	34.2	49.4	48.1
123 Detroit	52.8	74.8	77.0
131 Minn-St. Paul	51.4	68.6	67.8
162 Buffalo	47.2	70.1	72.7
174 Cleveland	40.1	62.8	64.6
197 Pittsburgh	45.8	67.4	68.9
215 Dallas	40.5	55.3	53.1
216 Houston	50.8	71.2	72.5
229 Seattle	50.7	68.8	69.0
239 Milwaukee	50.5	69.5	69.7
Weighted Average	45.8	62.3	62.0

TABLE 3.14

FIVE AQCRs WITH LARGEST REDUCTION IN CARBON MONOXIDE WITH
100 PERCENT ELECTRIC CARS

	CO Concentration Without EC, Percent of Standard			CO Concentration With EC, Percent of Standard		
	1980	1990	2000	1980	1990	2000
Los Angeles	337	177	174	156	97	92
Denver	249	148	133	100	103	91
New York	308	143	133	107	76	71
St. Louis	306	150	136	154	100	90
Cleveland	205	115	112	88	76	76

On the average, 100 percent electric cars would improve CO air quality measured as a percent of standard, by 110 percent in 1980 (from 210 percent to 100 percent), 39 percent in 1990 (from 120 to 81) and 37 percent in 2000 (from 118 to 81).

3.6 IMPACT OF ELECTRIC CARS ON OVERALL POLLUTION

Using the SEAS overall air pollution indicator described in Sec. 1, it is possible to rank the 24 AQCRs in terms of the impact of 100 percent electric cars on the measures. In Table 3.15 the 24 AQCRs are ordered in terms of improvement in the indicator in 1980. Numbers are also given for the baseline pollution indicator values. This number is a weighted summation of total emission rather than air quality or emissions per person or per square kilometer. With 100 percent electric cars, the population weighted average of the indicator shows a 20 percent decrease in the factor in 1980, a 9 percent decrease in 1990, and a 10 percent decrease in 2000. The table shows that all AQCRs would improve their overall air

TABLE 3.15

CHANGE IN SEAS POLLUTION INDICATOR WITH 100 PERCENT ELECTRIC CARS

AQCR	Baseline Pollution Indicator			Change With 100 Percent EC		
	1980	1990	2000	1980	1990	2000
43 New York	58.7	49.5	51.7	-14.2	- 5.4	- 5.5
24 Los Angeles	45.3	40.7	44.2	-11.1	- 4.8	- 6.0
30 San Francisco	17.1	13.9	14.8	- 5.8	- 3.0	- 3.3
67 Chicago	52.2	51.5	56.2	- 5.5	- 3.4	- 3.6
45 Philadelphia	27.6	26.5	30.4	- 5.4	- 2.2	- 2.2
123 Detroit	24.9	21.7	21.9	- 4.7	- 1.6	- 2.0
215 Dallas	19.1	19.0	23.3	- 4.6	- 2.5	- 2.7
216 Houston	32.5	38.7	50.9	- 4.1	- 2.1	- 2.4
70 St. Louis	18.3	15.1	16.8	- 3.5	- 1.1	- 1.3
47 Washington, D.C.	11.7	9.5	10.5	- 3.4	- 1.2	- 1.4
144 Cleveland	28.4	27.7	30.4	- 3.4	- 1.9	- 2.0
50 Miami	12.6	11.8	14.0	- 3.3	- 1.6	- 1.9
119 Boston	11.9	9.5	9.6	- 2.8	- 1.5	- 1.6
115 Baltimore	18.9	19.6	21.7	- 2.6	- 1.3	- 1.5
56 Atlanta	9.4	9.7	11.8	- 2.4	- 1.0	- 1.2
229 Seattle	7.7	6.7	7.5	- 2.2	- 1.1	- 1.1
36 Denver	6.-	6.1	7.0	- 2.0	- 0.9	- 1.0
29 San Diego	5.4	4.3	4.6	- 1.6	- 0.7	- 1.0
162 Buffalo	5.9	4.8	4.8	- 1.4	- 0.6	- 0.6
131 Minn-St. Paul	12.3	11.1	11.6	- 1.4	- 0.4	- 0.8
239 Milwaukee	15.3	14.7	16.1	- 1.2	- 0.9	- 1.0
79 Cincinnati	12.8	12.9	15.1	- 1.2	- 0.4	- 0.5
94 Kansas City	9.2	8.3	9.1	- 1.1	- 0.5	- 0.6
197 Pittsburgh	24.4	21.8	22.5	+ 0.9	+ 2.3	+ 1.4
Weighted Average	31.9	28.9	31.3	- 6.4	- 2.7	- 3.0

pollution with electric cars. The benefit declines somewhat between 1980 and 2000 as cars become cleaner. But even in the year 2000, two AQCRs--San Francisco and San Diego--would reduce composite pollution by over 20 percent with 100 percent electric cars and another nine would reduce it by over 10 percent--Los Angeles, Denver, New York, Washington, D.C., Miami, Boston, Buffalo, Dallas, and Seattle.

Clearly, electric cars would reduce overall air pollution as measured by the SEAS factor. Certain urban areas would appear to benefit from electric cars more than others, and these might be singled out as possible areas for encouraged electric car use.

4 SUMMARY

4.1 INTRODUCTION

Future air pollution emissions were estimated for the 24 Air Quality Control Regions (AQCRs) having the largest populations in 1975. Separate estimates were made in tons per year for the years 1980, 1990, and 2000 for each of the five primary pollutants: total suspended particulates (TSP), sulfur oxides (SO_x), nitrogen oxides (NO_x), total hydrocarbons (THC), and carbon monoxide (CO). Emissions were projected using an improved version of the computer model called the Regional Emissions Projection System (REPS). Three possibilities were compared: a future without electric cars, a future with 10 percent electric cars, and a future with 100 percent electric cars. Particular emphasis was placed on developing accurate estimates of future power plant and conventional automobile emissions, as these are the pollution sources that would be affected by electric cars.

In addition to comparing future emissions for these scenarios, future air pollution concentrations and related air quality were also estimated and compared. Finally, a SEAS overall air pollution indicator was calculated for each AQCR and for each level of electric car use.

4.2 MAJOR FINDINGS

With respect to baseline projections without electric cars, it was found that there is a great deal of variation among the AQCRs, both in terms of current air pollution emissions and concentrations, and projected changes in the emissions and concentrations. Table 4.1 summarizes a population-weighted average of the emission and pollution concentration projections. It does not show the variation among AQCRs, but it illustrates that TSP emissions, in general, are projected to increase; SO_x will decrease through the late 1970s and early 1980s, then increase again in the 1980s; THC and NO_x will decrease through the 1980s, then begin to increase in the 1990s; and CO emissions will decline throughout

TABLE 4.1

BASELINE EMISSION AND AIR QUALITY PROJECTIONS

	Projected Emissions, Metric Tons per Square Kilometer				Projected Maximum Concentrations, Percent of Standard			
	1975	1980	1990	2000	1975	1980	1990	2000
TSP	12	11	12	14	146	139	154	170
SO _x	31	27	29	30	67	54	55	56
NO _x	34	32	31	34	90	84	82	89
THC*	62	58	53	60	302	280	262	294
CO	252	212	118	116	253	211	120	119

* Air quality is in terms of oxidant

the rest of the century. The main emission problems through the remainder of this century are TSP and THC emissions. With our new stringent SO_x, NO_x, and CO controls, major improvements can be expected in terms of controlling these pollutants.

Table 4.2 shows a population-weighted average of the percent contribution of conventional automobiles and power plants to future emissions in the 24 AQCRs. The effect of the Clean Air Act on both automobiles and power plants is evident. Percent contributions are dropping. The limited potential for improvement in air quality through use of electric cars is also evident; they can at most remove the automobile contributions of Table 4.2. Offsetting increase in power plant contributions would also be modest, since recharging 100 percent electric cars adds only 13 percent of electricity demand in power plants in the AQCRs in 2000.

TABLE 4.2

PERCENT CONTRIBUTION OF AUTOS AND POWER PLANTS TO EMISSIONS

	Contribution of Autos, Percent				Contribution of Power Plants, Percent			
	1975	1980	1990	2000	1975	1980	1990	2000
TSP	12	10	9	9	12	10	7	6
SO _x	1	0	0	0	50	38	32	26
NO _x	25	20	14	14	28	23	21	20
THC	34	25	13	12	0	0	0	0
CO	62	54	38	38	0	0	0	1

Replacing 100 percent of future conventional automobiles with electric cars would, of course, increase power plant pollution and reduce conventional car pollution. The overall impact on air pollution is a function of the individual AQCR. However, the general findings are summarized in Table 4.3. As the table shows, with 100 percent electric cars, SO_x emissions would increase, and TSP, NO_x, THC, and CO emissions would decrease.

In terms of the SEAS air pollution indicator, which is a weighted measure of total emissions, Table 4.4 summarizes the population-weighted average of the indicator with and without 100 percent electric cars. There is a 10 to 20 percent drop with 100 percent electric cars.

4.3 CONCLUSIONS

Carbon monoxide air pollution in the 24 AQCRs with the largest populations is projected by REPS to improve by over 50 percent between 1975 and 2000. During this period, SO_x and NO_x emissions will drop by 10 percent and total hydrocarbon emissions will drop by 3 percent. Total suspended particulate emissions will grow by 15 percent.

TABLE 4.3
PERCENT CHANGE IN AIR QUALITY AND EMISSIONS WITH
100 PERCENT ELECTRIC CARS

	Change in Maximum Concentrations, Percent of Standard			Change in Emissions Percent of Regional Total		
	<u>1980</u>	<u>1990</u>	<u>2000</u>	<u>1980</u>	<u>1990</u>	<u>2000</u>
TSP	+ 2.7	+ 1.0	- 0.8	+ 2.1	+ 0.6	- 0.6
SO _x	+ 9.2	+ 7.0	+ 4.4	+14.5	+11.1	+ 6.9
NO _x	- 7.1	- 3.9	- 5.8	- 9.8	- 5.7	- 7.7
THC*	-69.6	-34.2	-35.2	-25.7	-14.1	-13.3
CO	-110.1	-39.1	-37.8	-54.4	-37.9	-38.2

* Air quality is in terms of O_x

TABLE 4.4
SEAS POLLUTION INDICATOR

	<u>1980</u>	<u>1990</u>	<u>2000</u>
Indicator Without Electric Cars	31.9	28.9	31.2
Indicator With 100 Percent Electric Cars	25.5	26.2	28.3
Percent Change	-20.0	- 9.4	- 9.6

As expected, electric cars would not affect in a great way these projections--even electric cars in large numbers such as 10 percent of the total conventional car population. The impact, however, would be measurable, and it would vary from urban area to urban area. On the average, SO_x emissions would go up because of the increased activity of power plants, and NO_x , THC, and CO emissions would go down because with electrics there would be fewer conventional cars. The impact, of course, is a function of the number of electric cars. This study has facilitated the ranking of the 24 most populated urban areas according to the degree to which electric cars would benefit projected air pollution. The order differs depending upon the pollutant as well as the year, but several urban areas seem to stand out as possible candidates for electric cars. They include Los Angeles, Denver, Washington, D.C., St. Louis, Seattle, Boston, New York, and Baltimore. Clear problem areas include Detroit and Pittsburgh.

APPENDIX A

**ELECTRIC CAR ENERGY REQUIREMENTS FROM
POWER PLANTS IN AQCRs**

TABLE A.1

FUEL USE IN AUCRS TO RECHARGE 10.00PERCENT OF AVAILABLE PARS

(10**6 MJ)														
YEAR	AOCR	TOTAL	NUCLEAR	COAL	HYDRO	NAT	GAS	OTHER	PUMPED	ST OIL	PEAK	GAS	PEAK	UNKNOWN
80	24	11258.	0.	0.	0.	11258.	0.	0.	0.	0.	0.	0.	0.	0.
80	29	1834.	0.	0.	0.	1834.	0.	0.	0.	0.	0.	0.	0.	0.
80	30	4800.	0.	0.	0.	4800.	0.	0.	0.	0.	0.	0.	0.	0.
80	36	930.	0.	930.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
80	43	13443.	0.	8427.	0.	5016.	0.	0.	0.	0.	0.	0.	0.	0.
80	45	3802.	0.	3142.	0.	661.	0.	0.	0.	0.	0.	0.	0.	0.
80	47	2562.	0.	1874.	0.	674.	0.	0.	0.	0.	0.	0.	0.	0.
80	50	2171.	0.	0.	0.	2171.	0.	0.	0.	0.	0.	0.	0.	0.
80	56	688.	0.	688.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
80	67	5380.	378.	5002.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
80	70	1308.	0.	1308.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
80	79	1375.	0.	1375.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
80	94	1092.	0.	1079.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
80	115	1119.	0.	351.	0.	755.	0.	0.	0.	0.	0.	0.	0.	0.
80	119	2548.	0.	0.	0.	2548.	0.	0.	0.	0.	0.	0.	0.	0.
80	123	2724.	0.	2602.	0.	121.	0.	0.	0.	0.	0.	0.	0.	0.
80	131	1551.	0.	1551.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
80	162	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
80	174	1982.	0.	1969.	0.	13.	0.	0.	0.	0.	0.	0.	0.	0.
80	197	7510.	539.	6971.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
80	215	1861.	0.	0.	0.	27.	1834.	0.	0.	0.	0.	0.	0.	0.
80	216	2103.	0.	0.	0.	0.	2103.	0.	0.	0.	0.	0.	0.	0.
80	229	13.	0.	0.	13.	0.	0.	0.	0.	0.	0.	0.	0.	0.
80	239	1982.	0.	1982.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
TOTAL	TOTAL	74036.	917.	39249.	13.	29879.	3937.	0.	0.	0.	0.	0.	0.	0.

TABLE A.2

FUEL USE IN AQCRS TO RECHARGE 100PERCENT OF AVAILABLE PARS

(10 ⁰⁰⁰ MJ)													
YEAR	AGCR	TOTAL	NUCLEAR	COAL	HYDRO	WIND	GAS	OTHER	PUMPED	ST CIL	PEAK	GAS PEAK	UNKNOWN
90	24	12472.	0.	0.	0.	12463.	4.	0.	0.	0.	0.	0.	0.
90	29	1787.	26.	0.	0.	1762.	0.	0.	0.	0.	0.	0.	0.
90	30	1813.	0.	0.	0.	1813.	0.	0.	0.	0.	0.	0.	0.
90	36	663.	0.	663.	0.	0.	0.	0.	0.	0.	0.	0.	0.
90	43	13699.	2629.	6114.	0.	4908.	0.	0.	0.	43.	0.	0.	0.
90	45	3745.	0.	3557.	0.	188.	0.	0.	0.	0.	0.	0.	0.
90	47	3527.	0.	3301.	0.	222.	0.	0.	0.	0.	0.	0.	0.
90	50	3410.	1415.	0.	0.	2001.	0.	0.	0.	0.	0.	0.	0.
90	56	1505.	0.	1505.	0.	0.	0.	0.	0.	0.	0.	0.	0.
90	67	5054.	4348.	705.	0.	0.	0.	0.	0.	0.	0.	0.	0.
90	70	1368.	0.	1368.	0.	0.	0.	0.	0.	0.	0.	0.	0.
90	79	1595.	0.	1595.	0.	0.	0.	0.	0.	0.	0.	0.	0.
90	94	817.	0.	774.	0.	0.	0.	0.	0.	43.	0.	0.	0.
90	115	752.	0.	445.	0.	304.	0.	0.	0.	0.	0.	0.	0.
90	119	252.	0.	0.	0.	252.	0.	0.	0.	0.	0.	0.	0.
90	123	3579.	0.	3574.	0.	0.	0.	0.	0.	0.	0.	0.	0.
90	131	1133.	0.	1133.	0.	0.	0.	0.	0.	0.	0.	0.	0.
90	142	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
90	174	2629.	2364.	261.	0.	0.	0.	0.	0.	0.	0.	0.	0.
90	197	10142.	1449.	8692.	0.	0.	0.	0.	0.	0.	0.	0.	0.
90	215	30.	9.	0.	0.	0.	21.	0.	0.	0.	0.	0.	0.
90	216	2052.	0.	710.	0.	932.	402.	0.	0.	0.	0.	0.	0.
90	229	86.	0.	0.	0.	38.	0.	0.	0.	43.	0.	0.	0.
90	239	197.	0.	197.	0.	0.	0.	0.	0.	0.	0.	0.	0.
TOTAL	TOTAL	72312.	12241.	34593.	0.	20884.	428.	0.	0.	120.	0.	0.	0.

TABLE A.3

FUEL USE IN AGCHS TO RECHARGE 10.00PERCENT OF AVAILABLE FARS

(10**6 MJ)													
YEAR	AGCH	TOTAL	NUCLEAR	COAL	HYDRO	WIND	GAS	OTHER	PUMPED	ST CIL	PEAK	GAS PEAK	UNKNOWN
99	24	7991.	0.	0.	0.	6050.	612.	0.	1303.	23.	0.	0.	0.
99	29	550.	544.	0.	0.	4.	0.	0.	0.	0.	0.	0.	0.
99	30	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
99	36	732.	0.	732.	0.	0.	0.	0.	0.	1171.	0.	0.	0.
99	43	14690.	3350.	3031.	0.	7132.	0.	0.	0.	0.	0.	0.	0.
99	45	4159.	53.	4033.	0.	70.	0.	0.	0.	0.	0.	0.	0.
99	47	3826.	0.	3743.	0.	83.	0.	0.	0.	0.	0.	0.	0.
99	50	4067.	2578.	0.	0.	1489.	0.	0.	0.	0.	0.	0.	0.
99	56	1659.	0.	1659.	0.	0.	0.	0.	0.	0.	0.	0.	0.
99	67	5524.	4959.	563.	0.	0.	0.	0.	0.	0.	0.	0.	0.
99	70	1152.	0.	1152.	0.	0.	0.	0.	0.	0.	0.	0.	0.
99	79	1759.	168.	1591.	0.	0.	0.	0.	0.	0.	0.	0.	0.
99	94	766.	0.	744.	0.	0.	0.	0.	0.	19.	0.	0.	0.
99	115	621.	0.	505.	0.	113.	0.	0.	0.	0.	0.	0.	0.
99	119	15.	0.	0.	0.	15.	0.	0.	0.	0.	0.	0.	0.
99	123	3768.	1446.	2320.	0.	0.	0.	0.	0.	0.	0.	0.	0.
99	131	467.	0.	467.	0.	0.	0.	0.	0.	0.	0.	0.	0.
99	162	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
99	174	2875.	2689.	183.	0.	0.	0.	0.	0.	0.	0.	0.	0.
99	197	11126.	1597.	9529.	0.	0.	0.	0.	0.	0.	0.	0.	0.
99	215	1307.	1292.	0.	0.	0.	13.	0.	0.	0.	0.	0.	0.
99	216	2154.	1156.	996.	0.	0.	0.	0.	0.	0.	0.	0.	0.
99	229	19.	0.	0.	0.	4.	0.	0.	0.	13.	0.	0.	0.
99	239	96.	0.	96.	0.	0.	0.	0.	0.	0.	0.	0.	0.
TOTAL	TOTAL	69323.	19834.	31344.	0.	14961.	625.	0.	1303.	1226.	0.	0.	0.

TABLE A.4

FUEL USE IN A.C.M.S. TO RECHARGE 100 PERCENT OF AVAILABLE PARS

(1980 FJ)	YEAR	ANCR	TOTAL	NUCLEAR	CHAL	HYDRO	WTI	GAS	OTHER	PUMPED	ST CIL	PEAK	GAS PEAK	UNKNOWN
80	24		112584.	0.	0.	0.	712584.	0.	0.	0.	0.	0.	0.	0.
80	29		14337.	0.	0.	0.	14337.	0.	0.	0.	0.	0.	0.	0.
80	30		48000.	0.	0.	0.	48000.	0.	0.	0.	0.	0.	0.	0.
80	36		9303.	0.	9303.	0.	0.	0.	0.	0.	0.	0.	0.	0.
80	43		130427.	0.	84270.	0.	56157.	0.	0.	0.	0.	0.	0.	0.
80	45		34622.	0.	31416.	0.	6607.	0.	0.	0.	0.	0.	0.	0.
80	47		25416.	0.	18742.	0.	6742.	0.	0.	0.	0.	0.	0.	0.
80	50		21708.	0.	0.	0.	21708.	0.	0.	0.	0.	0.	0.	0.
80	50		6676.	0.	6676.	0.	0.	0.	0.	0.	0.	0.	0.	0.
80	67		53796.	5775.	50022.	0.	0.	0.	0.	0.	0.	0.	0.	0.
80	70		13679.	0.	13679.	0.	0.	0.	0.	0.	0.	0.	0.	0.
80	79		13753.	0.	13753.	0.	0.	0.	0.	0.	0.	0.	0.	0.
80	94		10421.	0.	10787.	0.	0.	0.	0.	0.	0.	0.	0.	0.
80	115		11191.	0.	3506.	0.	7551.	0.	0.	0.	0.	0.	0.	0.
80	119		25083.	0.	0.	0.	25083.	0.	0.	0.	0.	0.	0.	0.
80	123		27233.	0.	26022.	0.	1213.	0.	0.	0.	0.	0.	0.	0.
80	141		15505.	0.	15505.	0.	0.	0.	0.	0.	0.	0.	0.	0.
80	162		0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
80	174		19420.	0.	19045.	0.	135.	0.	0.	0.	0.	0.	0.	0.
80	197		75101.	5393.	69706.	0.	0.	0.	0.	0.	0.	0.	0.	0.
80	215		18607.	0.	0.	0.	270.	18337.	0.	0.	0.	0.	0.	0.
80	216		21634.	0.	0.	0.	0.	21034.	0.	0.	0.	0.	0.	0.
80	229		135.	0.	0.	135.	0.	0.	0.	0.	0.	0.	0.	0.
80	235		19420.	0.	19020.	0.	0.	0.	0.	0.	0.	0.	0.	0.
TOTAL	TOTAL		740359.	9169.	392494.	135.	592786.	39371.	0.	0.	0.	0.	0.	0.

TABLE A.5

FUEL USE IN AEC-5 TO RECHARGE 100.00 PERCENT OF AVAILABLE PARS

(10 ⁴ MJ)													
YEAR	AGE	TOTAL	NUCLEAR	COAL	HYDRO	OIL	GAS	OTHER	PUMPED	ST CIL	PEAK	GAS PEAK	UNKNOWN
90	24	120717.	0.	0.	0.	720632.	43.	0.	0.	0.	0.	0.	0.
90	24	17470.	257.	0.	0.	17615.	0.	0.	0.	0.	0.	0.	0.
90	30	14121.	0.	0.	0.	14120.	0.	0.	0.	0.	0.	0.	0.
90	30	6027.	0.	6027.	0.	0.	0.	0.	0.	0.	0.	0.	0.
90	43	136980.	26295.	61140.	0.	40083.	0.	0.	0.	428.	0.	0.	0.
90	45	37451.	0.	35572.	0.	1881.	0.	0.	0.	0.	0.	0.	0.
90	47	35273.	0.	33067.	0.	2223.	0.	0.	0.	0.	0.	0.	0.
90	50	34162.	14152.	0.	0.	20009.	0.	0.	0.	0.	0.	0.	0.
90	50	15050.	0.	15050.	0.	0.	0.	0.	0.	0.	0.	0.	0.
90	67	50437.	43482.	7055.	0.	0.	0.	0.	0.	0.	0.	0.	0.
90	70	13082.	0.	13082.	0.	0.	0.	0.	0.	0.	0.	0.	0.
90	74	15941.	0.	15941.	0.	0.	0.	0.	0.	0.	0.	0.	0.
90	94	2100.	0.	7739.	0.	0.	0.	0.	0.	420.	0.	0.	0.
90	115	7525.	0.	4447.	0.	3036.	0.	0.	0.	0.	0.	0.	0.
90	119	2523.	0.	0.	0.	2523.	0.	0.	0.	0.	0.	0.	0.
90	123	35780.	0.	35743.	0.	0.	0.	0.	0.	0.	0.	0.	0.
90	131	11330.	0.	11330.	0.	0.	0.	0.	0.	0.	0.	0.	0.
90	162	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
90	174	20205.	23044.	20205.	0.	0.	0.	0.	0.	0.	0.	0.	0.
90	197	101310.	14494.	86922.	0.	0.	0.	0.	0.	0.	0.	0.	0.
90	215	299.	86.	0.	0.	0.	214.	0.	0.	0.	0.	0.	0.
90	216	20523.	0.	7097.	0.	4321.	4019.	0.	0.	0.	0.	0.	0.
90	229	455.	0.	0.	0.	365.	0.	0.	0.	420.	0.	0.	0.
90	239	1967.	0.	1967.	0.	0.	0.	0.	0.	0.	0.	0.	0.
TOTAL	TMD	723120.	122400.	345933.	0.	540036.	4270.	0.	0.	1283.	0.	0.	0.

TABLE A.6

FUEL USE IN AIRCRAFT RECHARGE 100 PERCENT OF AVAILABLE CARS

YEAR	ACFT	TOTAL	CLARK	CLAL	HYDRU	ALL	GAS	OTHER	PUMPED ST CIL PEAK	GAS PEAK	UNKNOWN
97	24	79412.	0.	0.	0.	66505.	6121.	0.	13031.	235.	0.
98	24	5552.	5438.	0.	0.	43.	0.	0.	0.	0.	0.
99	30	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
99	36	7315.	0.	7315.	0.	0.	0.	0.	0.	11709.	0.
99	43	16592.	33505.	30308.	0.	71317.	0.	0.	0.	0.	0.
99	45	6158.	533.	40329.	0.	704.	0.	0.	0.	0.	0.
99	47	30281.	0.	37420.	0.	832.	0.	0.	0.	0.	0.
99	50	47671.	25784.	0.	0.	12686.	0.	0.	0.	0.	0.
99	50	16592.	0.	16592.	0.	0.	0.	0.	0.	0.	0.
99	67	55237.	49585.	5630.	0.	0.	0.	0.	0.	0.	0.
99	70	11517.	0.	11517.	0.	0.	0.	0.	0.	0.	0.
99	79	17505.	1685.	15810.	0.	0.	0.	0.	0.	0.	0.
99	94	7450.	0.	7443.	0.	0.	0.	0.	0.	192.	0.
99	115	620.	0.	5050.	0.	1130.	0.	0.	0.	0.	0.
99	114	100.	0.	0.	0.	149.	0.	0.	0.	0.	0.
99	123	37285.	10460.	23204.	0.	0.	0.	0.	0.	0.	0.
99	131	4671.	0.	4071.	0.	0.	0.	0.	0.	0.	0.
99	142	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
99	174	26789.	26493.	1634.	0.	0.	0.	0.	0.	0.	0.
99	197	111283.	15475.	95289.	0.	0.	0.	0.	0.	0.	0.
99	215	15073.	129204.	0.	0.	0.	128.	0.	0.	0.	0.
99	216	21540.	18559.	9980.	0.	0.	0.	0.	0.	0.	0.
99	227	100.	0.	0.	0.	43.	0.	0.	0.	128.	0.
99	239	460.	0.	460.	0.	0.	0.	0.	0.	0.	0.
TOTAL	TFC	693233.	198301.	313642.	0.	740609.	6249.	0.	13031.	12263.	0.

APPENDIX D

ELECTRICITY PRODUCTION IN AQCRs

TABLE B.1

TOTAL ELECTRICITY FUEL USE IN AQCRS WITH 10.00 PERCENT OF AVAILABLE CARS ELECTRIC

(10**6 MJ)													
YEAR	AGCH	TOTAL	NUCLEAR	COAL	HYDRU	WIND	GAS	OTHER	PUMPED	ST CIL	PEAK	GAS PEAK	UNKNOWN
80	24	254208.	0.	0.	1591.	548333.	3074.	155.	0.	1051.	0.	0.	0.
80	29	67829.	20369.	0.	0.	45613.	0.	0.	0.	1843.	0.	0.	0.
80	30	64960.	0.	0.	158.	67984.	0.	691.	0.	122.	0.	0.	0.
80	36	27002.	0.	26645.	29.	310.	0.	0.	0.	14.	0.	0.	0.
80	43	253109.	45727.	79052.	554.	723556.	94.	29.	0.	4079.	7.	0.	0.
80	45	141337.	46390.	71502.	0.	21638.	0.	94.	0.	1710.	0.	0.	0.
80	47	65245.	0.	42781.	0.	22213.	0.	0.	0.	230.	0.	0.	0.
80	50	105250.	50047.	0.	0.	52639.	173.	0.	0.	2383.	0.	0.	0.
80	56	38599.	0.	38275.	245.	0.	76.	0.	0.	0.	0.	0.	0.
80	67	177863.	81187.	90322.	0.	454.	360.	0.	0.	511.	22.	0.	0.
80	70	52494.	0.	52403.	0.	288.	0.	0.	0.	4.	0.	0.	0.
80	79	66028.	18983.	45608.	0.	0.	263.	0.	734.	428.	0.	0.	0.
80	94	41261.	0.	40293.	0.	54.	0.	0.	0.	857.	36.	0.	0.
80	115	33494.	0.	8202.	0.	28828.	0.	0.	0.	428.	14.	0.	0.
80	119	56757.	0.	0.	0.	55580.	0.	0.	0.	1174.	0.	0.	0.
80	123	95960.	0.	73954.	0.	21675.	112.	0.	0.	180.	72.	0.	0.
80	131	44070.	0.	42011.	345.	0.	0.	0.	0.	1710.	0.	0.	0.
80	162	22453.	0.	22356.	94.	0.	0.	0.	0.	0.	0.	0.	0.
80	174	82615.	16351.	65134.	0.	1133.	0.	0.	0.	0.	0.	0.	0.
80	197	200009.	28004.	171757.	0.	0.	0.	227.	0.	18.	0.	0.	0.
80	215	67895.	0.	0.	0.	1681.	64211.	0.	0.	0.	0.	0.	0.
80	216	211426.	7391.	15451.	0.	28696.	157501.	890.	0.	814.	1177.	0.	0.
80	229	10230.	0.	0.	4243.	2333.	0.	0.	0.	1654.	0.	0.	0.
80	239	51043.	0.	49920.	0.	824.	54.	0.	0.	236.	22.	0.	0.
TOTAL	744	2231429.	314448.	935667.	7260.	722631.	225916.	1585.	734.	21409.	1350.	0.	0.

TABLE B.2

TOTAL ELECTRICITY FUEL USE IN AQCRS WITH 10.00 PERCENT OF AVAILABLE CARS ELECTRIC

(10**6 MJ)												
YEAR	AQCR	TOTAL	NUCLEAR	COAL	HYDRO	Oil	GAS	OTHER	PUMPED ST	OIL PEAK	GAS PEAK	UNKNOWN
90	24	214104.	0.	0.	1627.	504600.	3302.	450.	0.	2117.	0.	0.
90	29	199161.	174388.	0.	0.	24524.	0.	0.	0.	248.	0.	0.
90	30	41690.	0.	0.	86.	46516.	0.	0.	0.	18.	0.	0.
90	36	27098.	0.	27065.	24.	0.	0.	0.	4.	0.	0.	0.
90	43	310335.	116137.	80634.	590.	90883.	0.	25.	0.	13017.	32.	0.
90	45	266999.	173639.	77494.	0.	14023.	0.	94.	0.	1742.	0.	0.
90	47	68761.	0.	71913.	0.	14602.	0.	0.	0.	238.	0.	0.
90	50	207709.	143032.	0.	0.	61246.	180.	0.	0.	3240.	0.	0.
90	56	107493.	0.	107050.	277.	0.	162.	0.	0.	0.	0.	0.
90	67	323794.	255711.	64904.	0.	5437.	241.	0.	0.	464.	22.	0.
90	70	43531.	0.	43344.	0.	180.	0.	0.	0.	4.	0.	0.
90	79	118493.	44262.	74052.	0.	0.	40.	0.	0.	36.	0.	0.
90	94	47764.	0.	44499.	0.	216.	0.	0.	0.	2876.	166.	0.
90	115	32800.	0.	9733.	0.	25620.	0.	0.	0.	436.	0.	0.
90	119	24678.	0.	0.	0.	24599.	0.	0.	0.	76.	0.	0.
90	123	165247.	68051.	93772.	0.	334.	25.	0.	0.	36.	18.	0.
90	131	52251.	0.	31637.	346.	0.	0.	0.	0.	65.	0.	0.
90	142	16034.	0.	15934.	97.	0.	0.	0.	0.	0.	0.	0.
90	174	150654.	121369.	29043.	0.	230.	0.	0.	0.	0.	0.	0.
90	197	264472.	8750.	209756.	0.	0.	0.	227.	0.	16.	0.	0.
90	215	181869.	16176.	0.	0.	1845.	16322.	0.	0.	0.	0.	0.
90	216	318107.	17554.	92679.	0.	25474.	26973.	0.	0.	0.	0.	0.
90	229	9561.	0.	0.	4460.	5105.	0.	0.	0.	2988.	0.	0.
90	234	21084.	0.	21084.	0.	0.	0.	0.	0.	0.	0.	0.
TOTAL	TOTAL	3233581.	1139068.	1094791.	7513.	545835.	47246.	796.	4.	27618.	238.	0.

TABLE B.3

TOTAL ELECTRICITY FUEL USE IN AQCRS WITH 10.00 PERCENT OF AVAILABLE CARS ELECTRIC

(10**6 MJ)												
YEAR	AQCR	TOTAL	NUCLEAR	COAL	HYDRO	WIND	GAS	OTHER	PUMPED ST	CIL PEAK	GAS PEAK	UNKNOWN
99	24	198536.	0.	0.	1829.	785969.	6170.	1274.	1314.	4973.	0.	0.
99	29	451378.	441591.	0.	0.	6555.	0.	0.	0.	227.	0.	0.
99	30	6887.	0.	0.	97.	6530.	0.	259.	0.	0.	0.	0.
99	36	40803.	0.	40767.	36.	0.	0.	0.	0.	1171.	0.	0.
99	43	457246.	235426.	86805.	709.	708462.	0.	47.	7.	33226.	169.	0.
99	45	474913.	334295.	124993.	0.	12138.	0.	122.	0.	3355.	0.	0.
99	47	130823.	0.	115994.	0.	14372.	0.	0.	0.	457.	0.	0.
99	50	363102.	288469.	0.	0.	65943.	353.	0.	0.	8330.	0.	0.
99	56	175755.	0.	175269.	317.	0.	169.	0.	0.	0.	0.	0.
99	67	601709.	538774.	61425.	0.	1152.	115.	0.	0.	216.	14.	0.
99	70	66070.	0.	65941.	0.	122.	0.	0.	0.	7.	0.	0.
99	79	192563.	120257.	72302.	0.	0.	0.	0.	0.	0.	0.	0.
99	94	82122.	0.	78073.	0.	126.	0.	0.	0.	2975.	336.	0.
99	115	36131.	0.	15705.	0.	19578.	0.	0.	0.	842.	0.	0.
99	119	13893.	0.	0.	0.	13689.	0.	0.	0.	0.	0.	0.
99	123	257702.	181010.	76106.	0.	562.	4.	0.	0.	7.	4.	0.
99	131	26837.	0.	26491.	346.	0.	0.	0.	0.	0.	0.	0.
99	142	15502.	0.	15374.	119.	0.	0.	0.	0.	0.	0.	0.
99	174	240354.	235498.	10647.	0.	4.	0.	0.	0.	0.	0.	0.
99	197	433802.	120577.	312919.	0.	0.	0.	302.	0.	40.	0.	0.
99	215	508983.	490676.	0.	0.	216.	10082.	0.	0.	0.	0.	0.
99	216	613553.	534481.	77071.	0.	1285.	706.	0.	0.	0.	0.	0.
99	229	5588.	0.	0.	4964.	375.	0.	0.	0.	243.	0.	0.
99	239	20083.	0.	20087.	0.	0.	0.	0.	0.	0.	0.	0.
TOTAL	TOTAL	5420964.	3525052.	1376572.	8417.	732277.	17599.	2085.	1321.	56072.	526.	0.

APPENDIX C

PROJECTED EMISSIONS FOR 1980, 1990, AND 2000

TABLE C.1

ELECTRIC UTILITY EMISSIONS BY AQCR WITHOUT ELECTRIC CARS,
THOUSANDS OF METRIC TONS

YEAR	AQCR	PARTICULATES	SULFUR OXIDES	NITROGEN OXIDES	THC	CARBON MONOX
80	24	13.03	106.04	72.15	7.14	6.56
90	24	9.99	96.73	84.59	5.88	5.42
99	24	7.49	76.50	75.19	5.46	5.10
80	29	3.20	17.55	11.75	0.62	2.09
90	29	1.59	10.37	10.88	0.31	1.04
99	29	0.79	5.07	5.48	0.13	0.44
80	30	3.92	0.0	0.83	0.94	0.0
90	30	1.56	0.0	9.81	0.61	0.0
99	30	0.29	2.02	2.31	0.10	0.0
80	36	0.02	19.03	23.82	0.54	1.67
90	36	0.94	11.90	20.94	0.56	1.72
99	36	1.48	13.13	28.74	0.85	2.61
80	43	13.52	68.82	184.82	4.24	8.86
90	43	10.20	59.59	160.37	3.91	8.39
99	43	8.93	50.57	146.63	4.49	9.58
80	45	4.74	32.43	59.26	0.94	2.71
90	45	5.09	55.39	51.39	0.87	2.71
99	45	6.76	67.59	69.27	1.27	4.20
80	47	5.65	65.28	55.43	1.66	4.48
90	47	5.33	55.54	65.38	1.90	5.55
99	47	6.42	55.53	89.72	2.56	7.85
80	50	3.28	59.21	29.07	0.84	1.01
90	50	3.00	49.53	30.33	1.03	1.22
99	50	2.78	40.89	32.26	1.22	1.45
80	56	4.37	115.27	35.64	0.63	2.08
90	56	6.76	129.46	80.17	1.76	5.87
99	56	8.74	132.88	121.84	2.90	9.66
80	67	14.23	261.39	126.77	1.67	26.50
90	67	11.73	220.68	100.68	1.23	20.01
99	67	8.12	149.71	75.84	1.15	18.98
80	70	3.58	201.21	51.19	0.62	2.02
90	70	2.93	165.16	42.00	0.50	1.66
99	70	4.13	219.55	61.08	0.77	2.57
80	79	16.05	223.10	60.27	0.64	2.20
90	79	10.33	154.58	65.52	1.05	3.53
99	79	8.04	119.63	58.48	1.02	3.41
80	94	0.89	101.40	40.99	1.07	2.49
90	94	3.14	88.20	39.48	1.23	2.89
99	94	3.00	85.61	56.10	2.16	5.03
80	115	0.74	19.74	13.51	0.51	0.95
90	115	0.58	12.78	11.87	0.47	0.88
99	115	0.48	9.47	10.03	0.43	0.78
80	119	3.53	36.74	44.80	1.03	1.54
90	119	1.67	19.79	23.30	0.46	0.70
99	119	0.94	11.24	13.24	0.26	0.39
80	123	13.24	183.38	78.97	1.53	4.47
90	123	10.09	138.44	72.73	1.56	5.07
99	123	7.82	92.80	54.27	1.23	4.10
80	131	3.67	82.88	68.09	0.94	3.19
90	131	2.86	75.55	47.90	0.64	2.15
99	131	2.05	53.22	34.76	0.54	1.82
80	162	1.63	48.04	28.72	0.46	1.56
90	162	0.95	25.93	20.04	0.33	1.12
99	162	0.74	18.12	19.03	0.32	1.08
80	174	60.70	169.16	62.95	1.16	3.02

Table C.1 (continued)

90	174	37.46	87.45	29.69	0.53	1.36
99	174	13.87	32.26	10.92	0.19	0.50
80	197	98.33	601.35	164.41	2.67	8.84
90	197	74.97	482.50	173.55	3.26	10.78
99	197	56.34	404.72	224.47	4.92	16.29
80	215	1.27	0.86	38.84	0.10	0.67
90	215	0.36	0.53	10.98	0.05	0.20
99	215	0.25	0.74	7.12	0.05	0.14
80	216	2.96	4.56	80.73	0.23	1.30
90	216	0.50	2.02	22.93	0.04	0.37
99	216	0.05	0.24	1.79	0.0	0.01
80	229	0.03	0.31	0.07	0.0	0.0
90	229	0.01	0.25	0.06	0.0	0.0
99	229	0.0	0.03	0.0	0.0	0.0
80	239	5.39	160.26	45.62	0.82	2.70
90	239	27.23	95.32	20.92	0.34	1.16
99	239	16.66	66.39	18.07	0.33	1.11
80		277.96	2578.00	1378.70	31.00	90.91
90		229.29	2037.67	1195.54	28.52	83.81
99		166.20	1707.90	1216.64	32.35	97.11

TABLE C.2

AUTO EMISSIONS WITHOUT ELECTRIC CARS, THOUSANDS OF METRIC TONS

YEAR	ACCR	PARTICULATES	SULFUR OXIDES	NITROGEN OXIDES	THC	CARBON MONOX
80	24	19.11	1.82	107.87	285.57	1826.85
90	24	18.06	0.0	80.36	147.06	804.61
99	24	19.02	0.0	84.48	153.75	827.27
80	29	2.81	0.26	15.87	40.52	268.79
90	29	2.66	0.0	11.82	19.99	118.39
99	29	2.80	0.0	12.43	20.88	121.72
80	30	9.05	0.86	51.08	134.41	865.08
90	30	8.55	0.0	38.05	68.75	381.01
99	30	9.01	0.0	40.01	71.86	391.74
80	36	2.69	0.25	14.17	46.52	426.39
90	36	2.75	0.0	12.85	22.88	128.71
99	36	3.11	0.0	14.55	24.84	121.28
80	43	24.17	2.30	161.04	359.68	2875.86
90	43	21.96	0.0	104.32	170.05	948.64
99	43	22.77	0.0	106.32	171.58	886.16
80	45	8.43	0.80	56.23	126.92	1004.05
90	45	7.71	0.0	36.61	61.29	332.87
99	45	7.93	0.0	37.06	61.66	308.85
80	47	5.80	0.55	38.67	85.27	690.54
90	47	5.53	0.0	26.28	41.95	238.98
99	47	6.03	0.0	28.13	44.74	234.46
80	50	5.51	0.53	36.74	74.57	656.06
90	50	6.01	0.0	28.54	37.07	259.49
99	50	6.94	0.0	32.38	41.39	269.86
80	56	3.64	0.34	24.25	58.68	432.94
90	56	3.59	0.0	17.02	32.93	154.75
99	56	4.04	0.0	18.86	36.32	157.19
80	67	11.53	1.10	76.83	176.88	1371.96
90	67	10.31	0.0	49.00	85.43	445.60
99	67	10.60	0.0	49.52	85.71	412.77
80	70	5.99	0.57	39.92	87.03	712.85
90	70	5.34	0.0	25.34	39.13	230.38
99	70	5.46	0.0	25.54	39.02	212.80
80	79	3.06	0.29	20.36	46.75	363.67
90	79	2.82	0.0	13.41	23.23	121.89
99	79	2.91	0.0	13.63	23.46	113.58
80	94	2.09	0.20	13.89	33.77	247.95
90	94	1.86	0.0	8.85	17.29	80.48
99	94	1.92	0.0	8.94	17.38	74.50
80	115	3.87	0.36	25.79	57.74	460.55
90	115	3.80	0.0	18.06	29.60	164.17
99	115	4.20	0.0	19.63	31.90	163.58
80	119	4.82	0.45	32.11	71.06	573.37
90	119	4.42	0.0	20.98	33.53	190.77
99	119	4.60	0.0	21.48	34.00	179.00
80	123	8.02	0.76	53.44	121.72	954.27
90	123	7.34	0.0	34.82	59.32	316.65
99	123	7.42	0.0	34.64	58.53	286.72
80	131	3.00	0.28	20.04	46.71	357.98
90	131	2.80	0.0	13.27	23.74	120.70
99	131	2.90	0.0	13.51	23.99	112.59
80	162	1.92	0.18	12.75	28.41	227.64
90	162	1.71	0.0	8.09	13.12	73.52
99	162	1.72	0.0	8.01	12.87	66.71
80	174	6.25	0.59	41.64	93.63	743.57

Table C.2 (continued)

90	174	5.75	0.0	27.51	45.23	248.33
99	174	5.92	0.0	27.62	45.35	230.22
80	197	4.54	0.43	30.26	67.76	540.29
90	197	4.07	0.0	19.32	31.69	175.62
99	197	4.09	0.0	19.08	31.04	159.03
80	215	6.59	0.63	43.93	101.89	784.48
90	215	6.68	0.0	31.75	56.25	288.76
99	215	7.48	0.0	34.93	61.44	291.12
80	216	5.92	0.56	39.46	90.14	704.70
90	216	6.01	0.0	28.52	48.89	259.39
99	216	6.72	0.0	31.37	53.34	261.51
80	229	3.01	0.29	20.11	47.59	359.08
90	229	2.84	0.0	13.50	24.95	122.73
99	229	3.06	0.0	14.30	26.26	119.17
80	239	3.03	0.29	20.20	46.08	360.64
90	239	2.82	0.0	13.41	22.93	121.94
99	239	3.00	0.0	14.01	23.77	116.75
80		154.84	14.71	996.64	2329.27	17809.52
90		145.37	0.0	681.49	1156.28	6328.36
99		153.63	0.0	710.42	1195.07	6120.56

TABLE C.3

TOTAL EMISSIONS BY AQCR WITHOUT ELECTRIC CARS,
THOUSANDS OF METRIC TONS

YEAR	AQCR	PARTICULATES	SULFUR OXIDES	NITROGEN OXIDES	THC	CARBON MONOX
80	24	146.07	231.58	424.03	1163.71	3283.15
90	24	168.03	251.64	428.12	1076.65	1677.34
99	24	193.00	260.45	457.71	1191.58	1648.38
80	29	21.88	24.33	61.19	113.02	524.80
90	29	23.60	17.70	57.46	93.41	263.17
99	29	26.78	12.98	55.74	107.57	252.01
80	30	56.92	63.18	189.73	366.75	1803.07
90	30	56.19	73.62	196.63	386.05	992.95
99	30	55.65	85.42	212.52	406.75	978.52
80	36	15.34	55.38	88.64	128.73	606.48
90	36	20.06	60.37	100.68	108.30	396.25
99	36	25.15	77.16	125.55	118.74	354.77
80	43	178.75	310.47	704.54	1356.80	4259.21
90	43	176.02	322.81	629.74	1227.98	1897.94
99	43	174.93	328.62	628.20	1340.82	1759.77
80	45	92.41	201.17	309.01	655.07	1774.66
90	45	102.94	255.64	296.58	676.04	856.06
99	45	112.93	294.40	331.71	805.04	782.16
80	47	32.14	100.31	160.68	219.69	1054.14
90	47	35.13	93.68	161.95	170.85	483.77
99	47	40.12	96.50	195.54	181.74	463.07
80	50	25.33	117.65	136.26	264.35	1282.99
90	50	31.41	147.70	147.97	249.65	744.67
99	50	39.76	193.09	182.10	292.49	753.56
80	56	36.40	142.07	125.28	165.04	717.98
90	56	48.48	165.13	175.66	143.80	376.28
99	56	61.46	178.38	237.39	161.41	391.26
80	67	449.54	616.58	663.87	857.33	3970.17
90	67	528.34	639.91	676.67	829.00	3210.71
99	67	598.33	627.29	729.14	826.59	3484.59
80	70	100.13	407.87	194.45	304.93	1391.57
90	70	116.11	373.38	172.12	252.19	656.79
99	70	132.72	429.39	199.35	276.52	592.16
80	79	47.75	266.80	157.05	244.74	596.88
90	79	49.39	206.71	165.95	290.68	294.58
99	79	56.47	180.11	171.66	391.62	276.61
80	94	60.10	143.07	119.92	153.69	636.00
90	94	70.45	133.36	116.20	135.90	369.57
99	94	79.61	134.45	138.26	146.25	351.41
80	115	23.33	59.73	89.33	176.11	6147.71
90	115	25.33	59.55	83.52	150.69	6844.81
99	115	27.32	61.91	88.87	163.86	7663.46
80	119	30.96	102.94	150.51	255.00	869.94
90	119	29.59	89.96	120.47	225.95	377.10
99	119	29.14	82.79	113.75	243.29	344.78
80	123	80.61	264.81	257.27	548.22	2018.86
90	123	86.60	239.30	241.57	493.75	1246.86
99	123	92.60	213.61	236.94	512.27	1250.13
80	131	58.73	132.36	157.50	250.46	734.50
90	131	64.91	134.26	136.44	246.56	382.46
99	131	70.54	120.37	131.27	278.51	348.78
80	162	19.52	110.39	76.35	102.85	430.84
90	162	20.33	95.95	63.55	84.88	245.92
99	162	21.61	94.59	63.64	85.06	244.02
80	174	246.29	306.84	459.44	661.89	1239.87

Table C.3 (continued)

90	174	263.99	255.09	490.03	461.42	666.42
99	174	278.24	229.67	553.94	523.26	650.53
80	197	225.04	961.27	312.37	221.68	990.59
90	197	208.88	879.30	318.46	183.01	524.89
99	197	193.09	318.20	376.65	188.64	494.75
80	215	214.97	143.89	202.08	166.84	1318.67
90	215	303.39	217.87	188.91	158.58	645.54
99	215	414.05	305.20	224.41	123.03	620.12
80	216	200.62	230.13	397.98	748.30	1431.24
90	216	274.79	299.94	471.97	634.13	900.72
99	216	359.31	384.18	642.09	1231.61	951.83
80	229	42.39	37.49	86.06	158.14	728.69
90	229	52.65	44.75	86.42	137.17	393.71
99	229	62.82	51.47	98.41	151.24	384.18
80	239	57.65	214.79	131.00	187.27	726.97
90	239	77.71	166.76	107.12	418.86	399.16
99	239	65.27	156.69	115.11	486.40	384.73
80		2462.86	5245.07	5654.58	9470.58	38618.95
90		2834.33	5224.38	5634.16	9235.65	24847.63
99		3210.89	5416.92	6309.92	10534.26	25425.54

APPENDIX D

RELATIONSHIP BETWEEN TOTAL HYDROCARBON EMISSIONS AND PHOTOCHEMICAL OXIDANT PEAK CONCENTRATIONS

Future oxidant peak concentrations were estimated in two ways. The first used linear rollback, and the second used the method known as Appendix J.¹⁹ Both methods incorporated estimates of current and future THC emissions and current peak oxidant concentrations. The rollback approach assumes a linear relationship between THC emissions and oxidant peak concentrations. In the Appendix J approach, the relationship is nonlinear.

The Appendix J method (see Fig. D.1) relates required THC emission control to peak oxidant concentration. To use the method to estimate future peak oxidant concentrations, it is first necessary to estimate the current level of THC emissions that would meet the standard, and then use that number and the future THC emission estimate to estimate future oxidant concentrations. Results using the two approaches were within 10 to 20 percent of each other. Rollback was chosen for use in this study for consistency, and because it was found to produce quite reliable results for Los Angeles when compared to results generated using the DIFKIN photochemical-diffusion model.¹⁷

AN-50480

Source: Appendix J of 40 CFR Part 51, The Requirements for Preparation, Adoption, and Submittal of Implementation Plans (36FR, 15486)

Figure D.1. Required THC Emission Control as a Function of PhotoChemical Oxidant Concentration

APPENDIX E

CONTROL EFFICIENCIES ASSUMED IN STUDY

See Table 1.16 for NSPS on plants constructed after 1978.

TABLE E.1

PROMULGATED AND PROPOSED FEDERAL NEW SOURCE PERFORMANCE STANDARDS
(PRE-CLEAN AIR ACT AMENDMENT OF 1977)

Source Category	SCC Code	Effective Year	Required Control Efficiency (%)				
			TSP	SO _x	NO _x	CO	HC
Steam Generators (Greater than 250 MBtu/hr)							
• Coal Fired	1-01-001-(01-02) 1-01-002-(01-05) 1-01-003-(01-06) 1-02-001-(01-02) 1-02-002-(01-05) 1-02-003-(01-06)	1975	98.0	90.0			
• Oil Fired	1-01-004-01 1-01-005-01 1-02-004-01 1-02-005-01 1-03-004-01 1-03-005-01	1975	98.0	70.0			
Carbon Black Plants							
• Channel	3-01-005-01	1983	99.0				
• Furnace with Baghouse	3-01-005-(04-05)	1979	95.0			99.9	99.85
Detergent Plants (Spray Dryer)	3-01-009-01	1979	97.12				
Explosives	3-01-010-01 3-01-010-04	1983 1983			98.5 61.6		
Nitric Acid Plants	3-01-013-(01-08)	1974			93.0		
Phthalic Anhydride (O-Oxylene)	3-01-019-03	1983					84.3
Sulfuric Acid Plants	3-01-023-(01-18)	1974		96.0			
Ammonium Nitrate Fertilizer Plants	3-01-027-02 3-01-027-03 3-01-027-05 3-01-027-06	1983 1983 1983 1983	56.6 96.8 2.5 94.4				
Sulfur Recovery Plants in Petroleum Refineries	3-01-032-(01-99)	1979		99.8			

TABLE E.1 (Cont'd.)

Source Category	SCC Code	Effective Year	Required Control Efficiency (%)				
			TSP	SO _x	NO _x	CO	HC
Sulfur Recovery Plants and Production Facilities (Non-Refinery)	3-01-032-01	1980		98.5			
	3-01-032-02	1980		97.8			
	3-01-032-03	1980		92.2			
Cotton Ginning	3-02-004-01	1983	99.9				
	3-02-004-02	1983	99.7				
	3-02-004-03	1983	99.9				
Grain Handling	3-02-005-(01-04)	1978	99.6				
	3-02-006-(01-99)						
Primary Aluminum Plants							
• Bauxite Processing	3-03-001-01	1983	98.0				
• Electrolytic	3-03-001-01	1978	97.5				
	3-03-001-02	1978	97.9				
	3-03-001-03	1978	97.4				
	3-03-001-04	1978	80.0				
	3-03-001-05	1978	33.3				
• Calcinating	3-03-002-01	1983	98.0				
By-Product Coke Oven	3-03-003-01	1980	90.0				85.0
(Ovens, Lorry Car Coolers	3-03-003-02	1980	76.6				74.8
& Chemical Recovery Plants)	3-03-003-03	1980	41.6				
	3-03-003-04	1980	61.1				
	3-03-003-05	1980	12.5				
Beehive Coke Ovens	3-03-004-01	1983	99.8				
Primary Copper Smelters							
(Roaster, Furnace, Converter)	3-03-005-(01-05)	1978	99.5				
Primary Copper Smelters							
(Ore Crushing)	3-03-005-01	1983	99.2				
Ferro-Alloy Production	3-03-006-(01-04)	1978	99.7				
	3-03-006-05	1978	99.7				
	3-03-007-01						

TABLE E.1 (Cont'd.)

Source Category	SCC Code	Effective Year	Required Control Efficiency (%)				
			TSP	SO _x	NO _x	CO	HC
Sintering Plant in Iron Steel Mills	3-03-008-03	1979	99 ⁰ W				
Iron and Steel Mills							
• Basic Oxygen Furnaces	3-03-009-03	1977	99.8				
• Electric Arc Furnaces	3-03-009-(04-05)	1977	97.4				
Primary Lead Smelters	3-03-010-(01-03)	1978	99.5				
Primary Zinc Smelters	3-03-030-(01-06)	1978	99.5	99.5			
Secondary Aluminum Smelters (Fluxing)	3-04-001-01	1983	31.0				
	3-04-001-04	1983	20.0				
Secondary Brass and Bronze Refining (Reverberatory Furnaces)	3-04-002-(05-06)	1977	98.7				
Gray Iron Foundries							
• Cupola and Reverb. Furnaces	3-04-003-(01-02)	1983	99.0				95.0
• Electric Furnaces	3-04-003-03	1979	97.0				
Secondary Lead Smelters							
• All Furnaces	3-04-004-(01-04)	1977	97.0				
• Reverberatory Furnaces	3-04-004-02	1983	95.3	97.5			
• Blast Furnaces	3-04-004-03	1983	99.9	99.4			
Asphalt Concrete Plants	3-05-002-(01-02)	1976	98.0				
Calcium Carbide	3-05-004-01	1978	99.7				
Castable Refractories	3-05-005-01	1983	94.7				
	3-05-005-02	1983	98.6				
	3-05-005-03	1983	96.8				
	3-05-005-05	1983	93.7				
Portland Cement Plants							
• Kiln	3-05-006-01	1974	99.3				
	3-05-007-01	1974	99.3				
	3-05-006-(03-05)	1974	99.8				
	3-05-007-(03-05)	1974	99.8				
• Clinker Cooler	3-05-006-02	1974	99.4				
	3-05-007-02	1974	98.3				

TABLE E.1 (Cont'd.)

Source Category	SCC Code	Effective Year	Required Control Efficiency (%)				
			TSP	SO _x	NO _x	CO	HC
Brick Manufacturing	3-05-003-01	1983	93.5				
	3-05-003-02	1983	94.1				
	3-05-003-03	1983	86.7				
Clay Products	3-05-008-01	1983	93.5				
	3-05-008-02	1983	94.1				
	3-05-008-03	1983	86.7				
	3-05-009-02	1983	91.8				
	3-05-009-03	1983	81.3				
Coal Cleaning Plants							
• Thermal Dryers	3-05-010-(01-03)	1978	99.0				
• Air Tables	3-05-010-99	1978	90.0				
Glass Manufacturing	3-05-014-01	1983	99.0				
Gypsum Manufacturing	3-05-015-(01-04)	1983	99.8				
Lime Plants (Rotary Kiln)	3-05-016-04	1978	99.8				
Petroleum Refineries							
• Process Gas Heaters	3-06-001-(01-04)	1976		99.0			
• Catalytic Regenerators	3-06-002-01	1976	93.0				
	3-06-003-01	1976	93.0				
Kraft Pulp Mills							
• Recovery Furnaces	3-07-001-04	1979	98.6				
• Smelt Dissolving Tanks	3-07-001-05	1979	85.0				
• Lime Kilns	3-07-001-06	1979	98.8				
• Fluid Bed Reactors	3-07-001-08	1983	99.9				
Surface Coatings - Auto Assembly	4-02-(001, 003-006, 008-009)-01	1983					90.0
Municipal Incinerators (Greater than 50 tons/day)	5-01-001-01	1974	98.0				
	5-02-001-01						
	5-03-001-01						
Sewage Treatment Plants (Sludge Incinerators)	5-01-005-06	1976	99.6				

TABLE E.1 (Cont'd.)

Source Category	SCC Code	Effective Year	Required Control Efficiency (%)				
			TSP	SO _x	NO _x	CO	HC
On-Site Incineration	5-01-001-01	1983	87.4				
	5-01-001-02	1983	74.8				
	5-02-001-01	1983	46.0				
	5-02-001-02	1983	74.8				
	5-02-003-01	1983	87.4				
	5-02-003-02	1983	37.0				
	5-03-001-01	1983	46.0				
	5-03-001-02	1983	74.8				
Conical Incinerators	5-01-005-05	1983	16.25				

Source: Emission Standards and Engineering Division, EPA Office of Air Quality Planning and Standards.

TABLE E.2

STATE IMPLEMENTATION PLAN EMISSION REGULATIONS, POUNDS/MBTU

State/AQCR	TSP, ²³ MBTU/hr		SO _x , ²⁴ MBTU/hr		NO _x , ²⁵ MBTU/hr	
	<250	>250	<250	>250	<250	>250
05024						
Coal	0.36	0.36	0.73	0.73	0.30	0.30
Oil	0.32	0.32	0.52	0.52	--	0.27
Gas	--	--	--	--	--	0.16
05029						
Coal	0.53	0.53	0.73	0.73	0.30	0.30
Oil	0.47	0.47	0.52	0.52	--	0.27
Gas	--	--	--	--	--	0.16
05030						
Coal	0.53	0.53	0.76	0.76	0.30	0.30
Oil	0.47	0.47	0.54	0.54	--	0.27
Gas	--	--	--	--	--	0.16
06036						
Coal	0.15	0.12	1.28	1.28	--	--
Oil	0.15	0.12	1.28	1.28	--	--
Gas	--	--	--	--	--	--
07043						
Coal	0.20	0.20	0.73	0.73	0.90	0.90
Oil	0.20	0.20	0.52	0.52	0.30	0.30
Gas	--	--	--	--	--	0.20
08045						
Coal	--	--	--	--	--	--
Oil	--	--	--	--	--	--
Gas	--	--	--	--	--	--

TABLE E.2 (continued)

<u>State/AOCR</u>	<u>TSP, ²³ MBTU/hr</u>		<u>SO_x, ²⁴ MBTU/hr</u>		<u>NO_x, ²⁵ MBTU/hr</u>	
	<u><250</u>	<u>>250</u>	<u><250</u>	<u>>250</u>	<u><250</u>	<u>>250</u>
09047						
Coal	0.06	0.05	0.83	0.83	--	0.70
Oil	0.06	0.05	0.39	0.39	--	0.30
Gas	--	--	--	--	--	0.20
10050						
Coal	--	0.10	7.67	7.67	--	--
Oil	--	0.10	7.67	7.67	--	--
Gas	--	--	--	--	--	--
11056						
Coal	0.44	0.37	4.72	4.72	--	--
Oil	0.44	0.37	4.75	4.75	--	--
Gas	--	--	--	--	--	--
14067						
Coal	0.10	0.10	1.80	1.80	--	0.90
Oil	0.10	0.10	1.00	1.00	--	0.30
Gas	--	--	--	--	--	0.30
14070						
Coal	0.19	0.10	1.80	1.80	--	0.90
Oil	0.10	0.10	1.00	1.00	--	0.30
Gas	--	--	--	--	--	0.30
15067						
Coal	0.42	0.36	3.70	2.70	--	0.70
Oil	0.42	0.36	3.70	2.70	--	0.30
Gas	--	--	--	--	--	0.20

TABLE E.2 (continued)

State/AQCR	TSP, ²³ MBTU/hr		SO _x , ²⁴ MBTU/hr		NO _x , ²⁵ MBTU/hr	
	<250	>250	<250	>250	<250	>250
15079						
Coal	0.80	0.80	3.70	2.70	--	0.70
Oil	0.80	0.80	3.70	2.70	--	0.30
Gas	--	--	--	--	--	0.20
17094						
Coal	0.35	0.28	--	1.50	--	--
Oil	0.35	0.28	--	1.50	--	--
Gas	--	--	--	--	--	--
18079						
Coal	0.32	0.26	6.70	6.00	--	--
Oil	0.32	0.26	6.70	6.00	--	--
Gas	--	--	--	--	--	--
21042						
Coal	0.10	0.06	1.57	1.57	--	--
Oil	0.10	0.06	1.05	1.05	--	--
Gas	--	--	--	--	--	--
21115						
Coal	0.10	0.06	1.57	1.57	--	--
Oil	0.10	0.06	1.05	1.05	--	--
Gas	--	--	--	--	--	--
22119						
Coal	0.12	0.12	0.55	0.55	--	--
Oil	0.12	0.12	0.55	0.55	--	--
Gas	--	--	--	--	--	--

TABLE E.2 (continued)

State/AQCR	TSP, ²³ MBTU/hr		SO _x , ²⁴ MBTU/hr		NO _x , ²⁵ MBTU/hr	
	<250	>250	<250	>250	<250	>250
23123						
Coal	0.30	0.30	2.36	2.36	--	--
Oil	0.47	0.47	1.57	1.57	--	--
Gas	--	--	--	--	--	--
24131						
Coal	0.40	0.40	4.00	1.20	--	--
Oil	0.40	0.40	2.00	1.60	--	--
Gas	--	--	--	--	--	--
26070						
Coal	0.40	0.36	3.33	3.33	--	--
Oil	0.40	0.34	2.62	2.62	--	--
Gas	--	--	--	--	--	--
26094						
Coal	0.35	0.28	--	--	--	--
Oil	0.35	0.28	--	--	--	--
Gas	--	--	--	--	--	--
31043						
Coal	0.15	0.10	0.27	0.27	--	--
Oil	0.15	0.10	0.31	0.31	--	--
Gas	--	--	--	--	--	--
31045						
Coal	0.15	0.10	0.27	0.27	--	--
Oil	0.15	0.10	0.31	0.31	--	--
Gas	--	--	--	--	--	--

TABLE E.2 (continued)

State/AQCR	TSP, ²³ MBTU/hr		SO _x , ²⁴ MBTU/hr		NO _x , ²⁵ MBTU/hr	
	<250	>250	<250	>250	<250	>250
33043						
Coal	0.60	0.60	0.20	0.20	--	--
Oil	0.10	0.10	0.40	0.40	--	--
Gas	--	--	--	--	--	--
33162						
Coal	0.60	0.60	1.40	1.40	--	--
Oil	0.10	0.10	1.15	1.15	--	--
Gas	--	--	--	--	--	--
36079						
Coal	0.20	0.15	1.70	1.70	--	0.90
Oil	0.20	0.15	1.70	1.70	--	0.30
Gas	--	--	--	--	--	0.20
36174						
Coal	0.20	0.15	3.31	2.94	--	0.90
Oil	0.20	0.15	3.31	2.94	--	0.30
Gas	--	--	--	--	--	0.20
39045						
Coal	--	--	--	--	--	--
Oil	--	--	--	--	--	--
Gas	--	--	--	--	--	--
39197						
Coal	--	--	--	--	--	--
Oil	--	--	--	--	--	--
Gas	--	--	--	--	--	--

TABLE E.2 (concluded)

<u>State/AQCR</u>	<u>TSP, ²³ MBTU/hr</u>		<u>SO_x, ²⁴ MBTU/hr</u>		<u>NO_x, ²⁵ MBTU/hr</u>	
	<u><250</u>	<u>>250</u>	<u><250</u>	<u>>250</u>	<u><250</u>	<u>>250</u>
45215						
Coal	0.30	0.30	3.00	3.00	--	--
Oil	0.10	0.10	1.05	1.05	--	--
Gas	--	--	--	--	--	--
45216						
Coal	0.30	0.30	3.00	3.00	--	--
Oil	0.10	0.10	1.05	1.05	--	--
Gas	--	--	--	--	--	--
48047						
Coal	0.29	0.23	2.64	2.64	--	--
Oil	0.29	0.23	2.64	2.64	--	--
Gas	--	--	--	--	--	--
49229						
Coal	0.20	0.20	1.50	1.50	--	--
Oil	0.16	0.16	1.50	1.50	--	--
Gas	--	--	--	--	--	--
51239						
Coal	0.15	0.15	--	--	--	--
Oil	0.15	0.15	--	--	--	--
Gas	--	--	--	--	--	--

APPENDIX F¹⁷

LIGHT- AND HEAVY-DUTY GASOLINE-POWERED VEHICLE EMISSION FACTORS

Light-Duty Automobiles

- . Areas except California and high altitudes
- . California
- . High altitudes

Light-Duty Trucks

- . Areas except California and high altitudes
- . California
- . High altitudes

Heavy-Duty Trucks

- . Areas except California and high altitudes
- . California
- . High altitudes

EXHAUST EMISSION RATES

LIGHT-DUTY VEHICLES

FOR ALL AREAS EXCEPT CALIFORNIA AND HIGH-ALTITUDE

POLLUTANT	MODEL YEAR	A (GM/MILE)	B (GM/MILE)
		NEW VEHICLE EMISSION RATE	DETERIORATION RATE (PER 10,000 MILES)
HC	PRE-1968	4.45	0.58
HC	1968-1974	2.43	0.53
HC	1975-1979	1.13	0.23
HC	1980+	0.13	0.23
CO	PRE-1968	68.30	3.06
CO	1968-1974	31.14	6.15
CO	1975-1979	18.60	2.80
CO	1980	3.00	2.30
CO	1981+	1.40	2.00
NOx	PRE-1968	3.58	0.00
NOx	1968-1972	4.43	0.00
NOx	1973-1974	2.98	0.00
NOx	1975-1976	2.42	0.08
NOx	1977-1980	1.50	0.16
NOx	1981+	0.29	0.22

The Exhaust Emission Factor is calculated from the linear equation $C = a + bY$, where C is the exhaust emission factor for a vehicle with cumulative mileage H, a and b are the factors listed in the above table, and $Y = H/10000$.

EXHAUST EMISSION RATES

LIGHT-DUTY TRUCKS: BOTH WEIGHT CATEGORIES

FOR ALL AREAS EXCEPT CALIFORNIA AND HIGH-ALTITUDE

POLLUTANT	MODEL YEAR	A (GM/MILE)	B (GM/MILE)
		NEW VEHICLE EMISSION RATE	DETERIORATION RATE (PER 10,000 MILES)
HC	PRE-1968	4.76	0.58
HC	1968-1969	3.25	0.54
HC	1970-1974	2.56	0.53
HC	1975-1978	1.92	0.46
HC	1979-1982	0.94	0.41
HC	1983+	0.31	0.23
CO	PRE-1968	70.38	3.06
CO	1968-1969	42.08	5.44
CO	1970-1974	31.48	6.15
CO	1975-1978	23.44	5.70
CO	1979-1982	14.50	5.34
CO	1983+	3.87	2.00
NOx	PRE-1968	4.16	0.00
NOx	1968-1969	4.90	0.00
NOx	1970-1972	4.59	0.00
NOx	1973-1974	3.56	0.00
NOx	1975-1978	3.62	0.00
NOx	1979-1984	1.73	0.11
NOx	1985+	0.41	0.22

The Exhaust Emission Factor is calculated from the linear equation $C = a + bY$, where C is the exhaust emission factor for a vehicle with cumulative mileage M, a and b are the factors listed in the above table, and $Y = M/10000$.

EXHAUST EMISSION RATES

HEAVY-DUTY GAS TRUCKS

FOR ALL AREAS EXCEPT CALIFORNIA AND HIGH-ALTITUDE

POLLUTANT	MODEL YEAR	A (GM/MILE)	B (GM/MILE)
		NEW VEHICLE EMISSION RATE	DETERIORATION RATE (PER 10,000 MILES)
HC	PRE-1970	23.90	0.58
HC	1970-1973	18.54	0.53
HC	1974-1978	22.02	0.53
HC	1979-1982	5.22	0.53
HC	1983+	1.46	1.06
CO	PRE-1970	272.90	3.06
CO	1970-1973	212.70	6.15
CO	1974-1978	218.80	6.15
CO	1979-1982	191.90	6.15
CO	1983+	15.38	10.54
NOx	PRE-1970	8.80	0.00
NOx	1970-1973	12.80	0.00
NOx	1974-1978	10.50	0.00
NOx	1979-1984	9.10	0.00
NOx	1985+	3.99	0.34

The Exhaust Emission Factor is calculated from the linear equation $C = a + bY$, where C is the exhaust emission factor for a vehicle with cumulative mileage M, a and b are the factors listed in the above table, and $Y = M/10000$.

EXHAUST EMISSION RATES

LIGHT-DUTY VEHICLES

FOR CALIFORNIA ONLY

POLLUTANT	MODEL YEAR	A (GB/MILE)	B (GB/MILE)
		NEW VEHICLE EMISSION RATE	DETERIORATION RATE (PER 10,000 MILES)
HC	PRE-1966	4.45	0.58
HC	1966-1974	2.00	0.70
HC	1975-1976	0.29	0.23
HC	1977+	0.15	0.23
CO	PRE-1966	68.30	3.06
CO	1966-1974	30.42	6.40
CO	1975-1976	3.80	2.33
CO	1977-1980	3.80	2.33
CO	1981+	3.00	2.00
NOx	PRE-1966	3.58	0.00
NOx	1966-1972	3.92	0.00
NOx	1973-1974	3.12	0.00
NOx	1975-1976	1.50	0.16
NOx	1977-1979	1.10	0.16
NOx	1980	0.29	0.22
NOx	1981+	0.21	0.22

The Exhaust Emission Factor is calculated from the linear equation $C = a + bY$, where C is the exhaust emission factor for a vehicle with cumulative mileage M, a and b are the factors listed in the above table, and $Y = M/10000$.

EXHAUST EMISSION RATES

LIGHT-DUTY TRUCKS: BOTH WEIGHT CATEGORIES

FOR CALIFORNIA ONLY

POLLUTANT	MODEL YEAR	A (GM/MILE)	B (GM/MILE)
		NEW VEHICLE EMISSION RATE	DETERIORATION RATE (PER 10,000 MILES)
HC	PRE-1968	4.76	0.58
HC	1968	3.25	0.54
HC	1969-1974	2.55	0.53
HC	1975-1977	1.92	0.46
HC	1978	0.29	0.23
HC	1979-1980	0.21	0.23
HC	1981+	0.15	0.23
CO	PRE-1968	70.40	3.06
CO	1968	42.10	5.44
CO	1969-1974	31.47	6.15
CO	1975-1977	23.44	5.70
CO	1978	13.70	5.34
CO	1979-1980	8.26	3.68
CO	1981+	3.80	2.00
NOx	PRE-1968	4.16	0.00
NOx	1968	4.90	0.00
NOx	1969-1972	4.58	0.00
NOx	1973-1974	3.56	0.00
NOx	1975-1977	3.09	0.06
NOx	1978	1.60	0.11
NOx	1979-1980	1.48	0.17
NOx	1981-1982	0.50	0.22
NOx	1983+	0.31	0.22

The Exhaust Emission Factor is calculated from the linear equation $C = a + bY$, where C is the exhaust emission factor for a vehicle with cumulative mileage M, a and b are the factors listed in the above table, and $Y = M/10000$.

EXHAUST EMISSION RATES

HEAVY-DUTY GAS TRUCKS

FOR CALIFORNIA ONLY

POLLUTANT	MODEL YEAR	A (GM/MILE)	B (GM/MILE)
		NEW VEHICLE EMISSION RATE	DETERIORATION RATE (PER 10,000 MILES)
HC	PRE-1969	23.90	0.58
HC	1969-1972	18.54	0.53
HC	1973-1974	22.02	0.53
HC	1975-1976	18.16	0.53
HC	1977-1979	5.22	0.53
HC	1980-1982	3.50	0.53
HC	1983+	1.46	1.06
CO	PRE-1969	272.90	3.06
CO	1969-1972	212.70	6.15
CO	1973-1974	218.80	6.15
CO	1975-1976	209.00	6.15
CO	1977-1982	191.90	6.15
CO	1983+	15.38	10.54
NOx	PRE-1969	8.80	0.00
NOx	1969-1972	12.80	0.00
NOx	1973-1974	10.50	0.00
NOx	1975-1976	7.50	0.00
NOx	1977-1979	8.04	0.00
NOx	1980-1984	6.20	0.00
NOx	1985+	3.99	0.34

The Exhaust Emission Factor is calculated from the linear equation $C = a + bY$, where C is the exhaust emission factor for a vehicle with cumulative mileage M, a and b are the factors listed in the above table, and $Y = M/10000$.

EXHAUST EMISSION RATES

LIGHT-DUTY VEHICLES

FOR HIGH-ALTITUDE AREAS ONLY

POLLUTANT	MODEL YEAR	A (GM/MILE)	B (GM/MILE)
		NEW VEHICLE EMISSION RATE	DETERIORATION RATE (PER 10,000 MILES)
HC	PRE-1968	6.03	0.55
HC	1968-1974	4.07	0.55
HC	1975-1976	1.83	0.23
HC	1977	0.70	0.23
HC	1978-1979	1.83	0.23
HC	1980	0.21	0.23
HC	1981-1983	0.21	0.23
HC	1984+	0.13	0.23
CO	PRE-1968	110.04	2.81
CO	1968-1974	76.73	4.24
CO	1975-1976	38.31	2.80
CO	1977	10.30	2.80
CO	1978-1979	38.31	2.80
CO	1980	6.18	2.30
CO	1981-1983	2.88	2.00
CO	1984+	1.40	2.00
NOx	PRE-1968	1.96	0.00
NOx	1968-1972	3.00	0.00
NOx	1973-1974	1.94	0.00
NOx	1975-1976	1.50	0.08
NOx	1977	1.90	0.16
NOx	1978-1979	1.50	0.16
NOx	1980	0.93	0.16
NOx	1981-1983	0.18	0.22
NOx	1984+	0.29	0.22

The Exhaust Emission Factor is calculated from the linear equation $C = a + bY$, where C is the exhaust emission factor for a vehicle with cumulative mileage M, a and b are the factors listed in the above table, and $Y = M/10000$.

EXHAUST EMISSION RATES

LIGHT-DUTY TRUCKS: BOTH WEIGHT CATEGORIES

FOR HIGH-ALTITUDE AREAS ONLY

POLLUTANT	MODEL YEAR	A (GM/MILE)	B (GM/MILE)
		NEW VEHICLE EMISSION RATE	DETERIORATION RATE (PER 10,000 MILES)
HC	PRE-1968	6.45	0.55
HC	1968-1969	5.00	0.55
HC	1970-1974	4.28	0.55
HC	1975-1976	3.17	0.47
HC	1977	2.80	0.47
HC	1978	3.17	0.47
HC	1979-1982	1.52	0.41
HC	1983	0.47	0.23
HC	1984+	0.31	0.23
CO	PRE-1968	113.50	2.81
CO	1968-1969	88.36	3.91
CO	1970-1974	77.58	4.24
CO	1975-1976	54.19	4.84
CO	1977	44.81	4.84
CO	1978	54.19	4.84
CO	1979-1982	29.90	5.34
CO	1983	8.00	2.00
CO	1984+	3.87	2.00
NOx	PRE-1968	2.28	0.00
NOx	1968-1969	3.13	0.00
NOx	1970-1972	3.11	0.00
NOx	1973-1974	2.35	0.00
NOx	1975-1976	2.37	0.00
NOx	1977	2.88	0.00
NOx	1978	2.37	0.00
NOx	1979-1983	1.07	0.11
NOx	1984	1.73	0.11
NOx	1985+	0.41	0.22

The Exhaust Emission Factor is calculated from the linear equation $C = a + bY$, where C is the exhaust emission factor for a vehicle with cumulative mileage M, a and b are the factors listed in the above table, and $Y = M/10000$.

EXHAUST EMISSION RATES

HEAVY-DUTY GAS TRUCKS

FOR HIGH-ALTITUDE AREAS ONLY

POLLUTANT	MODEL YEAR	A (GM/MILE)	B (GM/MILE)
		NEW VEHICLE EMISSION RATE	DETERIORATION RATE (PER 10,000 MILES)
HC	PRE-1970	32.40	0.55
HC	1970-1973	31.05	0.55
HC	1974-1978	36.77	0.55
HC	1979-1982	8.74	0.55
HC	1983	2.35	1.06
HC	1984+	1.46	1.06
CO	PRE-1970	441.50	2.81
CO	1970-1973	344.20	4.24
CO	1974-1978	353.20	4.24
CO	1979-1982	310.90	4.24
CO	1983	31.70	10.54
CO	1984+	15.38	10.54
NOx	PRE-1970	4.82	0.00
NOx	1970-1973	8.67	0.00
NOx	1974-1978	6.84	0.00
NOx	1979-1983	5.92	0.00
NOx	1984	5.64	0.00
NOx	1985+	3.99	0.34

The Exhaust Emission Factor is calculated from the linear equation $C = a + bY$, where C is the exhaust emission factor for a vehicle with cumulative mileage M, a and b are the factors listed in the above table, and $Y = M/10000$.

APPENDIX G

REPS EMISSION PROJECTIONS FOR YEAR 2000

TABLE G.1

REPS EMISSION PROJECTIONS FOR YEAR 2000

(24 AQCRs), 10³ TONS

<u>Emission Category</u>	Fuel Use,					
	<u>10⁹ MJ</u>	<u>TSP</u>	<u>SO_x</u>	<u>NO_x</u>	<u>THC</u>	<u>CO</u>
<u>Related Emissions from Point Sources</u>						
Utility						
Coal	4339	143	1469	945	21	84
Residual Oil	1297	18	211	220	9	9
Distillate Oil	229	4	28	44	2	2
Natural Gas	57	0.3	0.5	9	0	0
Industry						
Boiler Coal	1052	138	451	245	24	101
Boiler Residual Oil	985	176	341	505	15	69
Boiler Distillate Oil	594	15	95	58	5	5
Non-Boiler Combustion Residual Oil	5759	37	190	662	10	75
Non-Boiler Combustion Distillate Oil	26	1	1	5	5	5
Non-Boiler Combustion Natural Gas	6	--	5	248	16	3
Process Coal	134	12	21	5	119	84
Process Residual Oil	44	3	8	4	2	2
Process Distillate Oil	35	3	4	6	1	0
Process Natural Gas	460	11	35	22	14	29
Industry Processes Non-Fuel-Related						
Coal Mining	--	0	0	0	0	0
Oil and Gas Mining	--	0	0	0	11	0
Other Mining	--	1	0	1	12	0
Food	--	24	0	1	12	0
Pulp and Paper	--	0	0	0	0.2	0
Chemicals	--	102	167	38	638	433

TABLE G.1 (continued)

<u>Emission Category</u>	<u>Fuel Use, 10⁹ MJ</u>	<u>TSP</u>	<u>SO_x</u>	<u>NO_x</u>	<u>THC</u>	<u>CO</u>
<u>Industry Processes Non-Fuel-Related</u>						
Petroleum Refining and Handling	--	180	542	33	2114	331
Stone and Clay	--	699	434	106	217	26
Primary Metals	--	246	501	44	107	10330
Fabricated Metals	--	3	0	2	7	0
<u>Residential and Commercial Emissions</u>						
<u>Residential</u>						
Coal	45	122	30	3	8	68
Oil	908	28	56	34	8	14
Gas	3133	13	1	103	10	25
<u>Commercial</u>						
Coal	63	20	24	7	1	2
Residual Oil	762	38	248	106	7	11
Distillate Oil	669	44	38	107	6	10
Natural Gas	2162	6	2	90	6	18
<u>Transportation Emissions</u>						
<u>Highway Vehicles</u>						
Car Gasoline	2257	154	0	710	741	6129
Light Truck Gasoline	523	29	0	142	150	1291
Heavy Truck Gasoline	361	20	6	162	257	2499
Heavy Truck Diesel	524	53	216	472	51	36
Aviation	501	19	7	54	105	262
Other Transportation	912	69	159	771	375	2170
<u>Other Area Sources</u>	2626	708	455	358	4019	706
<u>Other Point Sources</u>	24	66	26	25	1026	257
<u>Miscellaneous</u>						
Gasoline Evaporation (Area Source)	--	0	0	0	454	0
Total	30487	3211	5417	6310	10534	25425

APPENDIX H

POPULATION AND INDUSTRIAL GROWTH PROJECTIONS

TABLE H.1
POPULATION AND INDUSTRIAL GROWTH PROJECTIONS

AQCR	Area, km ²	Population		Industrial Earnings	
		1975, Millions	2000, % Annual Increase	1975,* Millions	2000, % Annual Increase
24 Los Angeles	46,882†	10.6	0.84	13,900	2.35
29 San Diego	8,987†	1.4	0.84	2,400	2.35
30 San Francisco	18,117	4.9	0.84	5,900	2.35
36 Denver	13,069	1.3	1.65	1,300	3.92
43 New York	13,033	18.0	0.74	24,300	2.02
45 Philadelphia	11,875	5.8	1.42	7,900	3.37
47 Washington, D.C.	6,094	3.0	0.47	1,400	2.50
50 Miami	22,642	2.6	2.28	2,100	4.28
56 Atlanta	15,159	1.8	1.28	2,100	3.72
67 Chicago	15,765	8.0	0.38	13,200	2.10
70 St. Louis	16,941	2.5	0.30	3,700	2.26
79 Cincinnati	8,883	1.7	0.27	2,500	2.57
94 Kansas City	10,906	1.5	0.30	2,000	2.26
115 Baltimore	5,851	2.1	1.21	2,500	1.97
119 Boston	930†	3.9	0.51	4,400	1.42
123 Detroit	6,928	4.5	0.44	8,300	2.47
131 Minn-St. Paul	7,304	2.0	0.56	2,900	2.68
162 Buffalo	4,118	1.4	0.13	2,500	0.84
174 Cleveland	9,052	3.5	0.43	6,100	2.57
194 Pittsburgh	17,369	2.9	0.16	4,000	1.71
215 Dallas	39,782	2.8	1.44	3,600	3.66
216 Houston	32,233	2.4	1.44	2,900	3.66
229 Seattle	16,312	2.0	0.84	2,400	2.23
239 Milwaukee	6,794	1.8	0.76	2,900	2.66
National		213.0	0.80	192,000	2.90

* Earnings in 1976 dollars

† Approximated using planimeter; other AQCRs fall on county boundaries

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