ENVIRONMENTAL QUALITY LABORATORY California Institute of Technology EQL Report No. 3

ENERGY USE IN CALIFORNIA:

Implications for the Environment

by E. J. LIST

Supported in part by the National Science Foundation,
Research Applied to National Needs (RANN),
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SUMMARY

Energy use in California in 1969 and its implications for thermal and air pollution are examined. The State is considered in terms of the energy consumed within each of the eleven designated air basins, both with respect to the source of the energy and its uses. It is shown that 94% of the energy for the State was provided by hydrocarbon fossil fuels, mainly natural gas (50% of total energy supplied) and gasoline (27% of the total). Half of the energy demand for the State was within the 9200 square miles constituting the South Coast Air Basin; 36.5% of the total demand was within Los Angeles County alone.

Air pollution emission factors characterizing each fuel source for a given use are compiled in the form of units of emittant per unit of energy. It is shown that some fuels for some purposes are inherently "dirty" energy sources and possible fuel substitutions are suggested. Emissions resulting from the combustion of fuels in 1969 are computed for each air basin. In an attempt to calculate the lowest emissions theoretically possible, that is, the residual pollution when all emitters are as clean as we know how to make them, minimum emission factors for each fuel use are given and the minimum combustion emissions determined. Possible strategies for the reduction of polluting emissions are discussed in some detail.

Ambient air heating problems (thermal pollution) from energy released within air basins are considered and the resulting possible changes in ambient air temperature are discussed.

CONCLUSIONS

1. California has become extraordinarily dependent on petroleum (44.4%) and natural gas (49%) for energy. In view of the fact the price of natural gas has been abnormally low in relation to other fuels, we can anticipate the currently publicized supply problems to lead to major increases in the cost of energy in California. The influence of the past abundance of cheap energy on the economic growth of California and the possible ramifications of future increases in energy costs should be examined.

2. An extremely large geographical imbalance in the population distribution within the State, (viz., more than 50% of the people on less than 6% of the land area forming the South Coast Air Basin) has led to a disproportionately high release of energy and associated

polluting emissions into the South Coast and San Francisco Bay Area Air Basins.

3. In view of the fact that the amount of any pollutant emitted during the combustion of any fuel is the product of the amount of fuel consumed and the emission factor (amount of emission for a unit amount of fuel) the vast quantities of fuel consumed in the South Coast and San Francisco Bay Area Air Basins far outweigh our ability to lower pollution levels by reducing emission factors. If we assume that all the fuels in these two basins are burned at the minimum emission factors that appear technologically and economically feasible, the residual pollution is still such that the promulgated ambient air quality standards cannot be satisfied. Thus, a simple policy of no growth in these two basins still leaves the areas with significant air pollution.

4. The present strategy of air pollution control agencies, namely, continually lowering the emission factors, will not attain clean air in the South Coast and San Francisco Air Basins. Furthermore, the problem is aggravated by the increasing consumption of fuel every year. However, the present strategy appears adequate to control pollution in the other air basins of California.

5. The only other policies available for air pollution control are either the reallocation of energy demands to those energy sources with zero emission factors, or the curtailment of the use of fossil fuels as an energy source. Therefore, satisfactory ambient air quality in the South Coast and Bay Area Air Basins will be attained only by replacing most of the fossil fuel consumed by near zero emission energy sources and by taking up all growth in energy consumption by near zero emission sources, or alternatively, by curtailing the use of fuels in the basin.

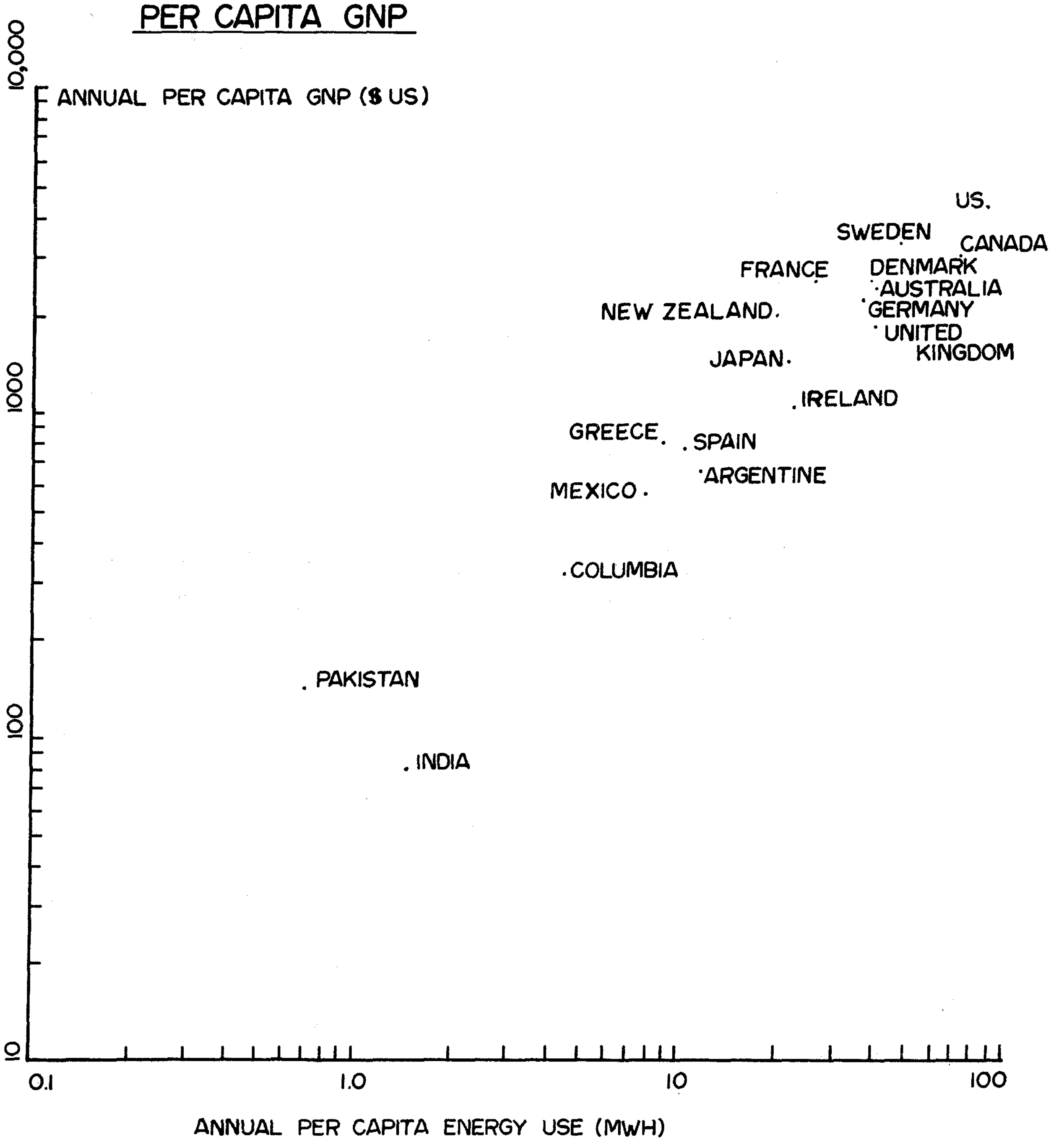
6. The only near zero emission energy source capable of accommodating the possible demand for energy at this time is nuclear-generated electric power. Hence, short of reducing the population or economic activity in these two air basins, the only way Los Angeles and San Francisco will attain ambient air quality satisfying promulgated standards is to replace fossil fuel combustion by nuclear power.

7. The South Coast and San Francisco Bay Air Basins rely on substantial electrical energy imports. By relying on generating facilities outside their air basins, and thus shifting the consequent pollution associated with the generation onto others, they can be said to be exporting their pollution.

8. The greatest energy release is in the South Coast Air Basin. It represents 1.2% of the incident solar energy on a basin-wide average. Within this basin, in the populated portion of Los Angeles County, energy release is found to be 3.7% of incident solar energy. Thermal pollution is not apparently a serious problem in California urban areas at the present time. However, a 4% growth in energy consumption maintained for the next 20 years would add temperature increments of 5-7^{O}F. on days of poor natural ventilation.

9. It is therefore apparent that if large urban societies wish to avoid chronic air pollution and thermal modification, ways must be found to encourage the development and use of non-polluting energy sources. At the same time, planning mechanisms must be adopted which keep energy release densities below the levels where problems develop such as those we are now experiencing in our major urban areas.

Figure I
CORRELATION OF PER CAPITA ENERGY AND PER CAPITA GNP



SOURCE: UNITED NATIONS YEARBOOK, 1970 (REFERENCE 1)

1. INTRODUCTION

One of the predominant factors which distinguishes modern man from his predecessors is the rate at which he utilizes energy. In this respect, the people of the United States are pioneers and will be the first to experience the problems associated with the continued and intensive use of energy. Since per capita energy usage and per capita GNP seem to be reasonably well correlated (Figure 1), we should expect the high level of economic acitivity in California to reflect a high level of energy utilization.* Thus California, and in particular southern California, should be one of the most likely places to indicate the stresses of energy use. A study of energy use in the State should therefore be rewarding in terms of indicating the kinds of problems to be faced by other areas of the world as they begin to approach the levels of affluence prevailing in California.

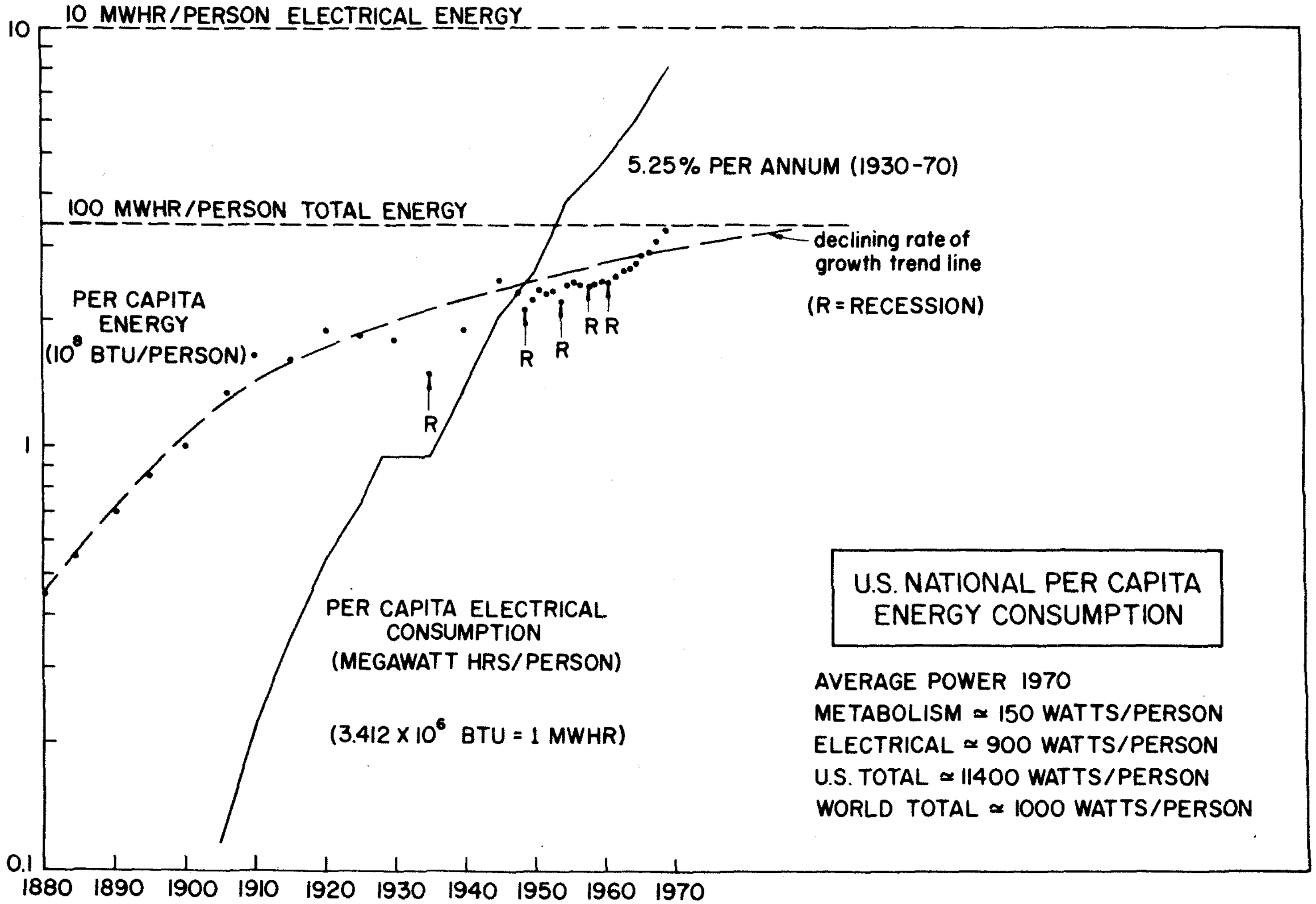
For the United States the long term rate of growth of per capita energy use appears to be slowing (Figure 2), although the last decade saw a reversal of this trend, no doubt as a result of the unprecedented eight years of continuous growth in economic activity. This growth in per capita energy use has resulted in significant rises in the levels of air pollution in our major cities since energy conversion processes generally produce some undesirable by-products which are released into the atmosphere. In addition, these conversion processes are often quite inefficient, resulting in large quantities of heat being rejected as part of the conversion process. (The conversion of fossil fuel to electricity results in the rejection of approximately two units of heat for each unit of electricity produced and transmitted to the consumer.) But, regardless of the efficiency of the conversion processes, the atmosphere is the ultimate recipient of almost all the energy used, and it is in this total heat rejection that any thermal problems will lie. Of course, the more efficient the conversion processes we use the more energy we can gainfully use for a given environmental loading.

Thermal efficiency aside, there is another aspect of what we might term the efficient use of energy which heretofore appears to have been neglected, except on an ad hoc basis. We refer to the fact that some fuels are inherently dirtier than others in a given use. For example, in an uncontrolled automobile gasoline produces almost 10 times the oxides of nitrogen per joule** than does natural gas (methane) when used as the automobile fuel. Thus the use of fuels, which in the past has been mainly determined by price and convenience, may in the future be dictated also by a pollutant index. Therefore, by restructuring the manner in which it uses energy, a society may be able to maintain its present levels of

* This is not altogether true, since Figure 1 shows some societies are definitely more energy intensive than others.

**1 joule equals 1 watt-second.

Figure 2
U.S. NATIONAL PER CAPITA ENERGY CONSUMPTION

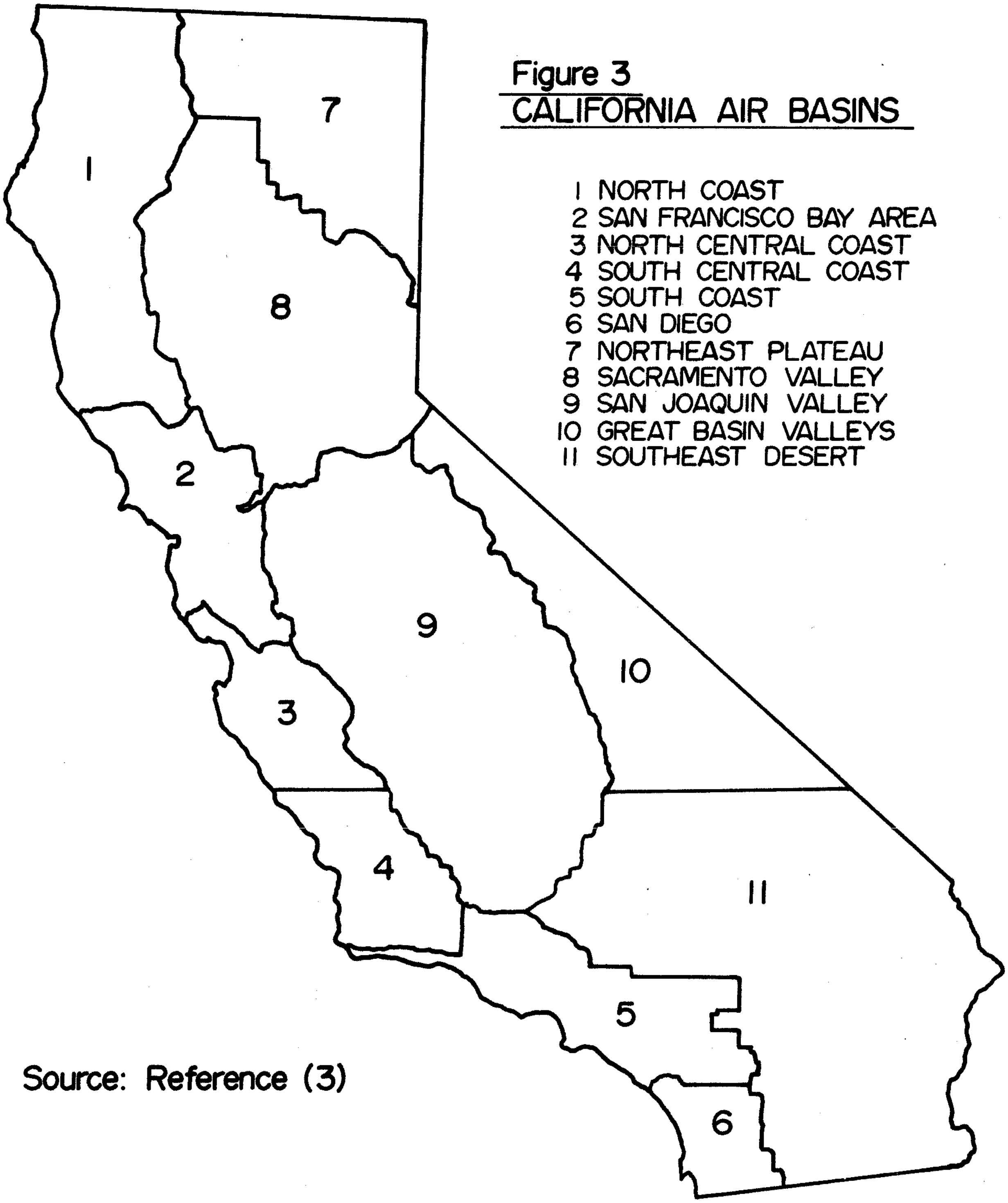


SOURCE: U.S. STATISTICAL ABSTRACTS 1954, 1970, REFERENCE (2) energy affluence while at the same time reducing pollution levels. In order to accomplish this it is necessary to identify first how the society is using energy and secondly, the pollution levels associated with the use of a given energy for a given purpose. This report is an attempt to do this for the State of California.

The report comprises three sections. The first section considers how the people of California used energy in the year 1969. The second part deals with the units of air pollution associated with each energy use and offers some comments and conclusions on the data given. Possible strategies are suggested whereby the use of energy may be modified on an interim basis in order to accomplish substantial reduction in the environmental impact. The long-term outlook for air pollution in the South Coast Air Basin is also discussed. The third section briefly discusses thermal pollution as a consequence of energy use.

Figure 3
CALIFORNIA AIR BASINS

1 NORTH COAST
2 SAN FRANCISCO BAY AREA
3 NORTH CENTRAL COAST
4 SOUTH CENTRAL COAST
5 SOUTH COAST
6 SAN DIEGO
7 NORTHEAST PLATEAU
8 SACRAMENTO VALLEY
9 SAN JOAQUIN VALLEY
10 GREAT BASIN VALLEYS
11 SOUTHEAST DESERT



Source: Reference (3)

2. AGGREGATE ENERGY CONSUMPTION WITHIN AIR BASINS

2.1 THE AIR BASINS

The State of California is large (157,000 sq. miles), and populous (20 million people), and covers several climatic zones. It was felt, therefore, that in the consideration of energy use in the State it would be desirable to subdivide the state into somewhat smaller demographic units, units that would reflect the different life styles of the people living in the various climatic zones. The State had already been subdivided into eleven air basins (Figure 3) by the State of California Air Resources Board following a directive by the State Legislature in the Mulford-Carrell Act, so these basins were chosen as the basic units for this study. They are defined in detail in the Air Resources Board publication *California Air Basins* (3)*. The criteria on which the basins were defined was meteorological and topographical, making these units ideally suited to our purposes. However, in some cases the boundaries depart quite widely from existing political boundaries, a factor of some significance as will be seen later.

Data has been collected on energy usage for all eleven of the air basins. For some basins and some types of energy usage sources of data were numerous, while for others estimates had to be made. Complete documentation of sources and methods of estimation is given for the data presented in the following tables. We begin by considering the major factors affecting the air basins as of 1969.

Table 2-1 gives the area, population, and vehicle population for each air basin, including the percentage of the State totals. It will be immediately noted that the South Coast Air Basin had almost half of the State population on less than 6% of the land area. Thus, regardless of the basin meteorology, one would expect air and thermal pollution problems to be evident first in that air basin. The three major coastal basins: Bay Area, South Coast, and San Diego, between them accounted for more than 80 per cent of the State population, and this is reflected in the relatively high population densities. These three basins are the only ones to have a population density in excess of 100 persons per square mile. The South Coast basin with 1060 persons per square mile should be compared with the Netherlands (1030) and with England (900). The U.S. National figure for comparison is 50 persons per square mile. The population density of the Great Basin Valley air basin, comprising Alpine, Mono, Inyo counties, is the lowest at 1.5 persons per square mile. This air basin, incidentally, provides 64% of the water used by the 3,000,000 people served by

* See References, page 45.

Table 2-1

Air Basin Statistics (1969)

	Air Basin	Area (1) (sq. mi.)	% Area	Population (2) (thousands)	% Pop.	Pop. Density (persons/ sq mi)	Vehicles (3)	% Vehicles	Energy density (4) GWH/sq. mi./year	Per Capita (5) Energy MWH/person
1	North Coast	15,500	9.87	206	1.04	13.3	93,830	0.93	0.8	57.0
2	San Francisco Bay	6,995	4.45	4,565	23.11	652.6	2,272,520	22.61	40.7	62.3
3	North Central Coast	5,200	3.31	384	1.94	73.8	186,730	1.86	7.8	106.0
4	South Central Coast	5,670	3.61	276	1.41	48.7	129,210	1.29	3.6	74.6
5	South Coast	9,219	5.87	9,761	49.35	1,058.7	5,047,070	50.21	60.5	57.1
6	San Diego	2,820	1.80	1,283	6.50	454.9	579,580	5.77	20.0	43.9
7	Northeast Plateau	12,900	8.21	58	0.30	4.5	27,240	0.27	0.2	45.5
8	Sacramento Valley	20,900	13.30	1,194	6.05	57.1	609,510	6.06	2.9	50.0
9	San Joaquin Valley	30,200	19.22	1,660	8.41	55.0	747,390	7.44	3.1	56.8
10	Great Basin Valley	13,900	8.85	21	0.12	1.5	9,890	0.10	0.1	48.3
11	South East Desert	33,800	21.51	345	1.76	10.2	348,080	3.46	1.1	107.5
	Total	157,104	100.00	19,753	100.00	125.7	10,051,050	100.00	7.4	59.0

Sources:
(1) Reference (3), p. 25
(2) Reference (3), p. 25
(3) Reference (4), p. 2-6
(4) See Table 2-3
(5) See Table 2-3

the Los Angeles Department of Water and Power (5). Another figure to note on Table 2-1 is the number of automobiles in the South Coast basin—more than half the vehicles in the State (4).

2.2 ENERGY CONSUMPTION WITHIN AIR BASINS

The aggregate energy consumption figures for each air basin are given in Table 2-2*; the units are those normally used for each kind of fuel. Table 2-3 is the conversion of the fuel use figures given in Table 2-2 into common units of megawatt hours (MWH). (The conversion factors used are given in Table A-1 of Appendix A.) It should be noted that these air basin figures do not include aviation fuel burned above 3500 feet, nor do they include oil used for ship bunkering except for an estimated quantity burned within the harbors of a given air basin.

The predominant feature of Table 2-3 is the fact that almost half of the energy used in California in 1969 was natural gas. Of this, almost 65% was delivered via three 30-inch diameter lines and three 34-inch diameter lines across the Arizona stateline; 14% was delivered across the Oregon stateline via one 36-inch diameter line. This means that 37% of California's energy supply is delivered by 7 pipelines. About 50% of the energy supply to the South Coast Basin comes from four gas lines.

Gasoline and natural gas together supply over 75% of the state's energy requirements. Excluding the two basins with no natural gas, the basins with lowest dependence on natural gas, namely, the North West, Sacramento Valley, and San Joaquin Valley basins, tend to make up this deficiency with hydro-electric power. Gas has probably not had the penetration in these basins in the past because of readily available hydro power.

Altogether 93.4% of the energy consumed in the state is from oil or gas hydrocarbon sources, the remaining 6.6% comprising 4.3% net electrical energy and 2.3% food. This means that the people of California are living off "capital" and not income with respect to solar energy, as is true of all industrial societies. The question may well be asked for just how long may we continue to use stored solar energy as such a large proportion of our energy consumption. In view of the low relative cost of natural gas over the last 10 years or so, we might well ask how this has influenced California's past economic growth. More important, since we can expect major increases in the cost of petroleum and gas fuels as a

*** Detailed notes on the compilation of all Tables in Section 2 are given in Appendix A.**

Table 2-2

Aggregate Energy Consumption within Each Basin (Annual, 1969)

	Air Basin	(1) Gasoline (mill. gal.)	(2) Diesel (mill. gal.)	(3) Aviation (mill. gal.)	(4) Jet Fuel (mill. gal.)	(5) LPG (mill. gal.)	(6) Residual (mill. gal.)	(7) Ref. Make Gas (mill. cu. feet)	(8) Piped Gas (mill. cu. feet)	(9) Total Elec. Use (GWH)*	(10) Elec. (Gas & Oil Produced Excluded), GWH
1	North Coast	117	16	0.70	- - - -	70	7.5	- - - -	11,295	1,302	1,070
2	San Francisco	1,920	166	7.10	87.0	16	426.0	48,400	457,295	24,898	14,693
3	North Central Coast	180	19	3.65	1.5	42	50.0	- - - -	94,733	1,960	- - - -
4	South Central Coast	120	11	1.00	1.4	33	38.4	1,000	39,876	1,289	- - - -
5	South Coast	4,050	319	40.00	128.0	51	880.0	100,140	910,237	56,184	8,310
6	San Diego	500	40	6.00	25.0	16	153.5	- - - -	82,471	5,485	689
7	Northeast Plateau	42	8	0.20	- - - -	11	- - - -	- - - -	- - - -	228	228
8	Sacramento Valley	615	77	7.50	1.5	64	3.4	- - - -	67,460	8,082	8,081
9	San Joaquin Valley	764	106	8.00	1.5	69	75.7	4,200	126,557	13,284	13,280
10	Great Basin Valley	16	2	0.20	- - - -	3	- - - -	- - - -	- - - -	229	229
11	Southeast Desert	330	28	4.00	- - - -	12	6.0	- - - -	61,322	5,035	4,000
	Total	8,654	792	78.35	245.9	387	1,662.0	153,740	1,851,246	117,973	50,580

(1) Column numbering refers to compilation details given in Appendix A
* GWH = one thousand MWH

Table 2-3

Aggregate Energy Consumption within Air Basins, 1969 (Common Units, 10^{+6} x MWH)

	Air Basin	Gasoline	Diesel	Aviation	Jet Fuel	LPG	Oil Resid.	Ref. Make	Piped Gas	Net Elec. †	People *	Total	% of State
1	North Coast	4.3	0.65	0.024	- - - -	1.88	0.34	- - - -	3.48	1.07	0.28	12.0	1.03
	%	35.4	5.4	0.2	0	15.6	2.8	- - - -	28.9	8.9	2.3	100.0	
2	San Francisco Bay	70.5	6.73	0.24	3.45	0.43	18.72	23.0	140.85	14.69	6.20	284.8	24.43
	%	24.8	2.4	0.1	1.2	0.2	6.6	8.1	49.5	5.2	2.2	100.0	
3	North Central Coast	6.6	0.77	0.12	0.058	1.13	2.20	- - - -	29.17	- - - -	0.53	40.6	3.48
	%	16.3	1.9	0.3	0.1	2.8	5.4	- - - -	72.2		1.3	100.0	
4	South Central Coast	4.4	0.45	0.034	0.055	0.89	1.69	0.5	12.28	- - - -	0.37	20.6	1.77
	%	21.3	2.2	0.2	0.3	4.3	8.1	2.3	58.9		1.8	100.0	
5	South Coast	148.6	12.93	1.36	5.07	1.37	38.14	47.5	280.4	8.3	13.55	557.2	47.80
	%	26.6	2.3	0.2	0.9	0.2	6.8	8.5	50.3	1.5	2.4	100.0	
6	San Diego	18.4	1.62	0.20	0.99	0.43	6.78	- - - -	25.40	0.69	1.74	56.3	4.83
	%	32.7	2.9	0.4	1.8	0.8	12.1	- - - -	45.2	1.2	3.1	100.0	
7	Northeast Plateau	1.5	0.32	0.007	- - - -	0.30	- - - -	- - - -	- - - -	0.23	0.09	2.5	0.21
	%	61.2	13.1	0.3	- - - -	12.2	- - - -	- - - -	- - - -	0.4	3.7	100.0	
8	Sacramento Valley	22.6	3.12	0.26	0.059	1.72	1.47	- - - -	20.78	8.08	1.63	59.7	5.13
	%	37.8	5.2	0.4	0.1	2.9	2.5	- - - -	34.8	13.5	2.7	100.0	
9	San Joaquin Valley	28.0	4.30	0.27	0.059	1.86	3.31	2.0	38.98	13.28	2.25	94.3	8.10
	%	29.7	4.6	0.3	0.1	2.0	3.5	2.1	41.3	14.1	2.4	100.0	
10	Great Basin Valley	0.6	0.08	0.007	- - - -	0.08	- - - -	- - - -	- - - -	0.23	0.03	1.0	0.09
	%	58.3	7.8	0.7	- - - -	7.8	- - - -	- - - -	- - - -	22.3	2.9	100.0	
11	Southeast Desert	12.1	1.14	0.13	- - - -	0.32	0.26	- - - -	18.89	4.00	0.47	37.1	3.05
	%	32.5	3.1	0.4	- - - -	0.9	0.1	- - - -	51.0	10.7	1.3	100.0	
	Total	317.6	32.11	2.65	9.741	10.41	72.91	73.0	570.23	50.57	27.14	1,166.1	100.00
	% of Total	27.2	2.8	0.2	0.8	0.9	6.2	6.3	49.0	4.3	2.3	100.0	

* 1.4 MWH/year = 3200 Calories/day (national average) (2)

† Note that this excludes waste heat from nuclear and geothermal power plants. In the future this must be included.

Table 2-4

Electrical Energy Production in Air Basins (GWH)*

	Air Basin	Hydro	Steam Geotherm	Steam Nuclear	Steam Oil	Steam Gas	I. C. Oil	I. C. Gas	Trash	Produced Total	Used Total	Net.	% of Used Imported	% of Produced Exported
1	North Coast	5,610	----	374	15	217	----	----	----	6,216	1,303	+4,913		
	%									5.2	1.1			79
2	San Francisco Bay	----	615	----	1,291	9,014	----	----	----	10,920	24,898	-13,978	+56	
	%									9.2	21.1			
3	North Central Coast	----	----	----	300	7,234	----	----	----	7,534	1,964	+5,570		
	%									6.3	1.7			74
4	South Central Coast	----	----	----	169	2,615	----	----	----	2,784	1,289	+1,495		
	%									2.3	1.1			54
5	South Coast	450	----	----	9,063	38,624	13	137	34	48,321	56,184	-7,863	+14	
	%									40.7	47.6			
6	San Diego	5	----	2,086	1,093	3,771	3	29	----	6,987	5,484	+1,503		
	%									5.9	4.7			21
7	Northeast Plateau	1,426	----	----	----	----	----	----	----	1,426	228	+1,198		
	%									1.2	0.2			84
8	Sacramento Valley	17,344	----	----	----	----	1	----	----	17,345	8,082	+9,263		
	%									14.6	6.8			53
9	San Joaquin Valley	14,462	----	----	----	4	----	----	----	14,466	13,286	+1,180		
	%									12.2	11.2			8
10	Great Basin Valley	1,000	----	----	----	----	----	----	----	1,000	229	+771		
	%									0.8	0.2			77
11	Southeast Desert	668	----	----	4	988	7	34	----	1,701	5,035	-3,334	+66	
	%									1.4	4.3			
	Total	40,965	615	2,460	11,935	62,467	24	200	34	118,700	117,973	+730		
	%	34.5	0.5	2.1	10.1	52.6	0.02	0.17	0.03	100	100			

* Thousands of megawatt-hours (MWH).

consequence of the well-publicized supply problems, it might well be worth studying the impact of the greatly increased fuel bills we can expect over the next few years. In fact, natural gas has had a declining real cost over the past 10 years, so that a change in sign of the derivative of the real cost versus time curve might well have a major impact on both the economy and the environment.

We now consider the energy sources in more detail. Explanatory notes on the compilation of the tables are given in Appendix A.

2.3 ELECTRICAL ENERGY PRODUCTION AND USE

Tables 2-4 and 2-5 list the production and use of electrical energy in each air basin and the state as a whole. The totals used in each basin (Table 2-5) have been incorporated into Table 2-4 to show the net export or import into each basin. As would be expected, the Bay Area and South Coast Basins are major importers. The South East Desert Basin is also an importer, principally from the Colorado River hydro-electric facilities. The other basins are all net exporters. More than one half the electrical energy used in the Bay Area is imported. This reflects the large hydro capacity owned by Pacific Gas and Electric in the Sacramento and San Joaquin Valleys, as well as their two large steam facilities at Morrow Bay and Moss Landing, both outside the basin. In this respect, we can say that these two basins in effect expect others in California to assist in carrying their environmental load. (This has been a time-honored tradition in California, e.g., Hetch-Hetchy and Owens Valley.) Natural gas is the primary source of electrical energy (53%) followed by hydro generation (35%), fuel oil (10%) and nuclear reactors (2%). The fuel plants are concentrated in the three largest air basins, the hydro-electric plants in the Sacramento and San Joaquin Valleys. The internal combustion sources are primarily gas turbines used for peaking capacity. There is one geothermal source, Pacific Gas and Electric's plant at The Geysers in northern California.

Considering the use of electrical energy (Table 2-5) it is seen that the proportions of the total electrical energy used in the Bay Area, South Coast and San Diego basins are slightly lower than the population proportions (Table 2-1), reflecting the greater direct use of gas in the urbanized areas. For the state as a whole the electrical energy used is almost evenly split 30% to each of residential, commercial and industrial users. Since the definition of what constitutes each class of consumer varies, particularly industrial and commercial consumers, these figures are only an indication of the order of magnitude of the use in each

Table 2-5

Electrical Energy Use in Air Basins (GWH)

	Air Basin		Resid.	Comm'l	Indus.	Agric.	Other	Total	% of State
1	North Coast		599	423	289	28	22	1,361	1.2
		%	44.0	31.1	21.2	2.1	1.6	100.0	
2	San Francisco Bay		6,948	8,810	7,998	171	1,601	24,898	21.1
		%	27.9	32.9	32.1	0.7	6.4	100.0	
3	North Central Coast		601	631	523	189	20	1,964	1.7
		%	30.6	32.1	26.7	9.6	1.0	100.0	
4	South Central Coast		329	381	422	116	41	1,289	1.1
		%	25.5	29.6	32.7	9.0	3.2	100.0	
5	South Coast		14,462	16,017	20,167	454	5,084	56,184	47.5
		%	25.7	28.5	35.9	0.8	9.1	100.0	
6	San Diego		1,937	3,166	199	94	88	5,484	4.6
		%	35.3	57.8	3.6	1.7	1.6	100.0	
7	Northeast Plateau		155	82	56	27	2	322	0.3
		%	48.5	25.6	17.5	8.4	0.9	100.0	
8	Sacramento Valley		3,169	1,458	2,591	440	424	8,082	6.8
		%	39.2	18.0	32.1	5.4	5.3	100.0	
9	San Joaquin		3,265	3,701	1,968	2,831	1,521	13,286	11.2
		%	24.6	27.9	14.8	21.3	11.4	100.0	
10	Great Basin		104	49	21	2	54	229	0.2
		%	45.4	21.0	9.1	0.9	23.6	100.0	
11	Southeast Desert		926	757	1,249	223	1,880	5,035	4.3
		%	18.4	15.0	24.8	4.4	37.4	100.0	
	Total		32,495	34,844	35,483	4,575	10,737	118,134	100.00
		%	27.5	29.4	30.1	3.9	9.1	100.00	
FPC (Sales to ultimate consumers), Ref (20)			33,709	36,651	39,685		1,349	111,394	

Table 2-6

Fuel Use in Electrical Energy Production (oil, thousand barrels; gas, million cubic feet)

	Air Basin	Steam Oil	Steam Gas	I. C. Oil	I. C. Gas	Total Oil for Electricity	Total Gas for Electricity
1	North Coast	32	2,918	----	----	32	2,918
2	San Francisco	3,165	93,112	----	----	3,420	93,112
3	North Central Coast	437	61,924	----	----	437	61,924
4	South Central Coast	265	25,881	----	----	265	25,881
5	South Coast	14,124	354,991	31	2,022	14,155	357,013
6	San Diego	1,667	38,729	18	414	1,685	39,143
7	Northeast Plateau	----	----	----	----	0	0
8	Sacramento Valley	----	----	2	----	2	0
9	San Joaquin Valley	----	66	----	----	----	66
10	Great Basin Valley	----	----	----	----	----	----
11	Southeast Desert	8	10,094	15	762	23	10,856
	Total	19,698	587,715	66	3,198	19,764	590,913

sector. The figures given differ from the FPC "sales to ultimate consumers" figures (20) primarily because of the way "Other" and "Agricultural" uses are defined. We have included military establishments, street and highway lighting, municipal and "in-house" use under the "Other" category.

The different patterns of activity within the basins are reflected by the differing allocations to each sector. The large farming communities in the San Joaquin Valley are shown by the high agricultural use. The less densely populated basins show a low degree of commercial and industrial activity. The highly urbanized Bay Area and South Coast show a lower residential proportion indicating the greater domestic use of gas for heating and water heating.

The use of fuels for the production of electricity is given in Table 2-6, and these figures are incorporated in the gas and fuel oil tables presented below.

2.4 NATURAL GAS

The use of natural gas in the State and air basins is shown in Table 2-7. The figures given were compiled from data provided by the gas companies (see Appendix A) and a comparison is shown with data obtained from the Bureau of Mines (19). The discrepancy of approximately 5% is probably only as accurate as the flow meters so that these data are most likely accurate to within this level. Unfortunately, a subdivision between industrial firm, commercial and residential was not available in some basins.

We see that 32% of the gas supply is used for the production of electric power and, as noted above, this represents about 53% of the electrical energy produced. Almost 58% of the gas is sold on an interruptible basis, that is, the supply is at the discretion of the supplier and reflects the difficulty he has meeting rapid shifts in demand due to the difficulty of storing large quantities of gas.

The large percentages used for power in the North and South Central Coast Basins reflects the consumption by P.G. & E's large plants at Morrow Bay and Moss Landing. Most of this gas is consumed in the summer and serves as a seasonal load leveler to match the high resale consumption in winter. The North East Plateau and Great Basin Valleys have such a low population density that the capital cost of pipelines is not warranted and gas supply is trucked LPG.

Table 2-7

Natural Gas Use in Air Basins (MMCF - millions of cubic feet)

	Air Basin	Power	Industrial Inter.	Industrial Firm	Res	Comml	Total Firm	Total Inter	Total
1	North Coast	2,918	4,232	121	2,888	1,136	4,145	7,150	11,295
	%	25.8	37.5	1.1	25.6	10.0	36.7	63.3	.6
2	San Francisco Bay	93,112	149,771	14,488	157,144	42,780	214,412	242,883	457,295
	%	20.3	32.8	3.2	34.4	9.3	46.9	53.1	24.7
3	North Central Coast	61,924	16,251	767	10,393	5,403	16,558	78,175	94,733
	%	65.4	17.1	.8	11.0	5.7	17.5	82.5	5.1
4	South Central Coast	25,881	5,869		8,126		8,126	31,750	39,876
	%	64.9	14.7		20.4		20.4	79.6	2.2
5	South Coast	357,013	165,179		388,045		388,045	522,192	910,237
	%	39.2	18.2		42.6		42.6	57.4	49.2
6	San Diego	39,143	6,571		36,757		36,757	45,714	82,471
	%	47.4	8.0		44.6		44.6	55.4	4.5
7	Northeast Plateau	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
	%								
8	Sacramento Valley	- - - -	20,989	1,390	33,511	11,570	46,471	20,989	67,460
	%		31.1	2.1	49.7	17.1	68.9	31.1	3.6
9	San Joaquin	66	66,203		60,288		60,288	66,269	126,557
	%	.1	52.3		47.6		47.6	52.4	6.8
10	Great Basin Valley	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
	%								
11	Southeast Desert	10,856	40,737		9,729		9,729	51,593	61,322
	%	17.7	66.4		15.9		15.9	84.1	3.3
	Total	590,913	475,802		784,531		784,531	1,066,715	1,851,246
	%	31.9	25.7		42.4		42.4	57.6	100
	Bureau of Mines (19)	589,531		589,750	562,127	202,946			1,948,269

2.5 PETROLEUM

From Tables 2-2 and 2-3 we see that 44.4% of the energy used in California is derived directly from petroleum products, the major proportion by far being gasoline. The sheer magnitude of some of the figures staggers the imagination. For example, in the South Coast Air Basin approximately ten million people burn more than four billion gallons of gasoline each year—over 400 gallons for every man, woman and child in southern California.

Other petroleum products are refinery gas (a by-product of the refining process used within the refineries themselves) and residual and distillate oil used for heating, transport and the production of electricity. Aviation gasoline, jet fuel and LPG are major energy sources only for somewhat specialized purposes. It should be remembered of course that the amounts of jet fuel and aviation gasoline are only those burned below 3500 feet above ground level.

The uses of fuel oils within the air basins are described in Table 2-8. The largest residual user is the South Coast Air Basin, primarily for the generation of electric power. This use for electric power is proportionately much higher than in the Bay Area. This is for two reasons: firstly, two of P.G. and E's large fuel stations are located outside the Bay Area Basin in the North and South Central Coastal basins; secondly, P.G. and E. is both a gas and an electric utility. The second factor is the more important since the total oil use including that in other basins is still substantially lower than half of that used in the South Coast. The major discrepancy in reported figures is in the refinery and industrial use of oil, for according to the Bay Area APCD (9), almost 6 million barrels of oil are used by these consumers. By comparison in the South Coast Basin only one quarter as much (1.5 million barrels) is used according to the Air Pollution Control Districts (8), (22), (23). But, the Bureau of Mines (16) claims almost 18 million barrels used for these purposes within the State of California. Mr. James Diehl* of the Bureau of Mines has stated that the figures given in the annual Fuel Oil Sales (16) take due account of interstate shipments. We can only conclude that the reports to the Air Pollution Control Districts are incomplete. The figure reported by the Bay Area district seems reasonable, while that for the South Coast Basin seems far too low.

In view of the major discrepancy between these two sets of data, we have chosen the Bureau of Mines figures as the more reliable and have reallocated the oil usage on roughly a population basis. These are the figures in parentheses in the residential, commercial and

* Personal communication.

Table 2-8

Fuel Oil Use in Air Basins (Thousands barrels)

	Air Basin	Electric Power	Res. Comml Indus & Other	Oil Co.	Bunkering	Total Residual	Military	Railroad Distillate	Vehicle Diesel	Total Distillate
1	North Coast	32	NA	- - - -				NA	342	392
			(150)*			182		(50)		
2	San Francisco Bay	3,165	2,050	3,900	800			365	3,350	3,715
			(2,300)	(3,900)	(800)	10,165		(365)		
3	North Central Coast	437	13	NA				NA	392	442
			(253)	(502)		1,190		(50)		
4	South Central Coast	265	NA	NA				NA	204	254
			(150)	(500)		915		(50)		
5	South Coast	14,156	960	584	NA		NA	NA	6,600	7,600
			(5,180)	(584)	(800)	20,720		(1,000)		
6	San Diego	1,685	2	NA	NA			NA	850	950
			(720)	(780)	(500)	3,685		(100)		
7	Northeast Plateau	0	NA	0				NA	147	197
			(0)			0		(50)		
8	Sacramento Valley	0	NA	0				NA	1,626	1,826
			(800)			800		(200)		
9	San Joaquin Valley	2	NA	NA				NA	2,320	2,520
			(1,000)	(800)		1,802		(200)		
10	Great Basin Valley	0	NA	0				NA	48	48
			(0)			0		0		
11	Southeast Desert	23	NA	0				NA	412	662
			(120)			143		(250)		
	Total	19,765	3,225	4,484						
			(10,673)	(7,064)	(2,100)	39,602		(2,265)	16,341	18,606
	Bureau of Mines (16)	19,761	10,676	7,064	25,389	62,890	15,181	10,593	16,341	26,934

* Estimates in parentheses (See Appendix A)

industrial column. Oil company usage in the Bay Area far exceeds that by oil companies in the South Coast and, on the surface, it appears that some error may be involved, especially when the refinery capacity in the South Coast Area is more than twice that in the Bay Area. However, the total refinery energy usage was cross-checked against capacity, and it appears that the Southern refineries use more refinery and natural gas to compensate for the non-use of oil.

Ship bunkering is given as estimates of that amount of oil burned in harbor. The figure for the Bay Area is a reasonable estimate from the number of ships berthing, while that for the South Coast and San Diego are probably on the low side.

2.6 ENERGY CONSUMPTION WITHIN THE STATE

The foregoing tables listed energy consumption within the air basins. However, energy is sold within California for use outside of the air basins. In particular, aircraft, ships and trains fuel here for voyages out state, and this fuel should not be regarded as energy consumed by the people of California. Obviously, it is difficult to distinguish between that used by Californians and that used nationally. A large measure of international trade with the Pacific passes through California, and energy for this purpose should hardly be judged as energy use by Californians. For these reasons the per capita energy use by Californians is about 64% of the national per capita use. However, we think that the foregoing tables give a reasonably accurate picture of energy consumed within the State.

3. AIR POLLUTION FROM ENERGY USE

3.1 EMISSION FACTORS

Air pollution emissions resulting from the combustion of fuels are normally calculated on the basis of weight or volume of emission per weight or volume of fuel. In order to compare fuels on an equal basis it seems more logical to develop emission factors on the basis of their emissions per unit of energy available in the fuel. The energy unit chosen is the kilowatt-hour (3142 B.T.U.'s), and we choose to list each fuel as having x grams of emission y when one kwh of the fuel is used for a given purpose. Emission factors stated in this way should then enable the comparison of given fuels for a given purpose on the basis of their unit emissions.

The emission factors commonly used have therefore all been converted to grams of pollutant per kilowatt hour of the fuel, using the calorific values given in Table A-1. We can therefore present the emission factors in a matrix form such as that shown in Table 3-1, which gives the grams of organic gases emitted when one kwh of the fuels labeling the rows are employed for the purposes labeling the columns. By necessity there are numerous blanks in the matrix simply because no data is available, or the fuel has never been used for that purpose. In this respect the matrix does suggest uses for fuels hitherto unconsidered, presumably from force of habit or tradition. We will consider this possibility in greater detail below.

The emission factors used in the tables were obtained from various sources, principally, Duprey (11), Los Angeles A.P.C.D. (8), Bay Area A.P.C.D. (9), Monterey-Santa Cruz A.P.C.D. (12), and U.S.P.H.S. (33), (34). The range given refers to the range of values obtained from the various data sources. This raises an interesting point. The A.P.C.D.'s give a listing of total emissions based on the emission factors measured at the source. The question is how reliable are these emission factors as an indicator of overall performance. Presumably not all sources are monitored at all times so that the emission factors measured should only be considered indicative of a possible range of values and the total emissions calculated accordingly. Thus we have elected to give a range of emission factors and later will use these to calculate a range of possible emissions.

Referring to Table 3-1 we see that the internal combustion engine is a "dirty" fuel user from the point of view of organic emissions, especially when liquid fuels are used. Since

Table 3-1

Organics from One KWH of Fuel (grams)

	Heat				Transport		Electricity	
	Res. & Comml		Indus					
Fuel	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**
Gasoline					4.80	6.67		
Diesel					1.98	2.20		
Ref. Make Gas				0.004				
Aviation Gas					6.13	6.55		
Jet Fuel					4.20	4.33		
Distillate Oil	0.027	0.045						
Residual Oil			.027	0.048			0.0388	0.0516
Piped Gas	- - - -	0.0015	0.01	0.11	0.256	0.282	0.006	0.020
LPG					0.178	0.178		

Table 3-2

Oxides of Nitrogen from One KWH of Fuel (grams)

	Heat				Transport		Electricity	
	Res. & Comml		Indus					
Fuel	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**
Gasoline					1.40	2.41		
Diesel					1.34	2.48		
Ref. Make Gas				0.22				
Aviation Gas					1.82	2.00		
Jet Fuel					0.18	0.51		
Residual Oil			0.74	0.83			0.37	1.23
Piped Gas	0.164*	0.33	0.26	0.33	0.22	0.46	0.28	2.47†
LPG					0.20	0.43		

* A kitchen range actually has the lowest emission factor, 0.086 gms/kwh.
† Exceptionally high figure from one particular power plant.

Table 3-3

Particulates from One KWH of Fuel (grams)

Fuel	Heat: Res. & Comml Low	Heat: Res. & Comml High	Heat: Indus Low	Heat: Indus High	Transport Low	Transport High	Electricity Low	Electricity High
Gasoline					0.143	0.153		
Diesel					1.23	2.06		
Ref. Make Gas			0.152	0.152				
Aviation Gas					0.150	0.150		
Jet Fuel					0.148	0.795		
Distillate Oil	0.089	0.221						
Residual Oil			0.146	0.255			0.0126	0.216
Piped Gas	0.0275	0.0293	0.0260	0.0278			0.0220	0.0232
LPG								

Table 3-4

Carbon Monoxide from One KWH of Fuel (grams)

Fuel	Heat: Res. & Comml Low	Heat: Res. & Comml High	Heat: Indus Low	Heat: Indus High	Transport Low	Transport High	Electricity Low	Electricity High
Gasoline					27.4	34.2		
Diesel					0.34	0.830		
Ref. Make Gas			0.0042	0.0042				
Aviation Gas					20.3	30.3		
Jet Fuel					0.40	1.69		
Distillate Oil	0.002	0.022						
Residual Oil			0.002	0.020			0.0004	0.002
Piped Gas	0	0.0006	0	0.0006	1.33	5.63	0	0.0006
LPG					2.56	2.56		

the emission levels are cut by an order of magnitude when gaseous fuels are employed we can only conclude that the emissions most probably result from incomplete combustion due to poor fuel air mixing with liquid fuels. The same problem does not occur where liquid fuels are consumed in a furnace where presumably the flame residence times are much longer and the mixing better.

Oxides of nitrogen levels given in Table 3-2 show that transportation processes are major producers in terms of emission per kwh of fuel used, again gaseous fuels appear to be very much lower in unit emissions.

Particulate emissions are highest from the use of diesel fuel, which comes as no surprise to those of us who have been engulfed in diesel smoke. The internal combustion engine appears to be almost the sole source of carbon monoxide, according to the emission factors of Table 3-4. The use levels for fuels for other purposes would have to be at least 100 times that of internal combustion engines to produce carbon monoxide at anything like the same level. Since gasoline alone is approximately 27% of the energy used we can see immediately that carbon monoxide is an automobile problem.

Sulfur levels are directly proportional to the sulfur content of the fuel and hence this problem is probably best solved by removing the sulfur from the fuel before combustion.

3.2 POSSIBLE FUEL SUBSTITUTIONS

We now consider how the tables given above indicate possible ways that fuel substitution could be used to reduce air pollution.

It has been noted already how the internal combustion engine is a major source of hydrocarbons, oxides of nitrogen, and carbon monoxide, when gasoline fuels are used. The obvious solution to this problem is to change to a gaseous fuel, such as the two included in the tables above. Both LPG and natural gas (methane) give order of magnitude reductions in these three pollutants. We have already seen that 27% of the fuel used is gasoline (Table 2-3) and that the methane used to produce electric power is 591 billion cubic feet (Table 2-6) representing approximately 16% of the energy in the state. (For the South Coast Air Basin these figures are 27% and 20% respectively). Since burning gasoline in power plant furnaces would not lead to any hydrocarbon or carbon monoxide emissions to speak of (because of the long flame residence times) there would be an enormous reduction in these two emissions if the automobiles burned the methane and the power plants the gasoline. Such a fuel substitution process is not without precedent: the British converted London to a smokeless fuel after the disastrous 1952 killer smog.

The switch of gaseous fuels (methane or LPG) and gasoline appears to be the only major substitution possible, simply because these two fuels are the two substantial energy sources for the State. Smaller scale optimizations would be possible but it is doubtful whether the effort would be worthwhile since only minor differences in emission factors occur. The reason the gasoline–methane/LPG switch is so desirable is the order of magnitude reduction in emission factors possible.

There is a further point worth considering in connection with the use of natural gas. We note from the tables given that the use of natural gas in power plants has almost the same emissions per kwh as the use in domestic and commercial furnaces with one major exception, oxides of nitrogen. One kwh of gas burned in a power plant produces between 0.28 and 2.4 grams of nitrogen oxides. The same kwh burned in the home produces between 0.16 and 0.33 grams. Thus, burning one kwh of natural gas in a power plant produces between approximately two and seven times the oxides of nitrogen. But, to obtain one kwh of electrical energy in the house requires the consumption of three kwh at the power plant, thus producing at least six times the oxides of nitrogen. The figure is slightly less because not all the energy from the combustion of gas is gainfully used to heat a house or the water in a hot water supply. However, the fact remains that to produce the same quantity of oxides of nitrogen the power plant would need a combustion process producing between one half and one third the oxides of nitrogen per kwh of gas, and this just does not seem possible. "Living better electrically" with "flameless cooking" is therefore only true provided the electricity is produced by nuclear or hydro-electric power plants. Apart from this argument for the direct use of gas rather than its use for the production of electricity, it is questionable in a time when fossil fuels are becoming scarcer that we can afford the luxury of wasting almost twice that which we use in the low thermal efficiency of power plants.

This argument raises an interesting question in optimality. In the short term it would seem advantageous to encourage the domestic use of gas rather than electricity, but in the long term, with the advent of clean nuclear or fusion power plants, it will be more desirable to advocate electrical power rather than gas.

Table 3-5

Oxides of Sulfur from One KWH of Fuel (grams)

Fuel	Heat: Res. & Comml Low	Heat: Res. & Comml High	Heat: Indus Low	Heat: Indus High	Transport Low	Transport High	Electricity Low	Electricity High
Gasoline					0.094	0.120		
Diesel					0.56	0.56		
Ref. Make Gas			0.05	0.05				
Aviation Gas					Negl.	Negl.		
Jet Fuel					0.179	0.179		
Distillate Oil			0.89	2.66				
Residual Oil**							0.818	2.45
Piped Gas	0.00062	0.00064	0.00062	0.00064				
LPG							0.00062	0.0015*

* anomaly
** minimum 0.5%, maximum 1.5% sulfur.

Table 3-6

Emissions from Combustion in California Air Basins in 1969 (10^6 x KGM)*

Air Basin	Organics Low	Organics High	Nitrogen Oxides Low	Nitrogen Oxides High	Particulates Low	Particulates High	Carbon Monoxide Low	Carbon Monoxide High	Oxides of Sulfur Low	Oxides of Sulfur High
North Coast	22	30	8	16	2	2	120	150	2	4
San Francisco Bay	370	500	156	325	25	38	1,940	2,430	33	77
North Central Coast	35	47	19	71	3	4	185	230	4	9
South Central Coast	23	31	11	35	2	2	122	150	3	6
South Coast	770	1,060	323	787	50	73	4,120	5,140	67	157
San Diego	100	130	39	92	6	10	510	640	10	24
Northeast Plateau	8	11	3	5	1	1	41	52	0.6	1.3
Sacramento Valley	120	160	42	73	8	12	630	785	8	16
San Joaquin Valley	145	200	57	99	11	16	780	970	12	25
Great Basin Valley	3	4	1	2	0	0	16	21	0.2	0.3
Southeast Desert	61	84	24	47	4	5	335	420	3	6
Totals	1,650	2,260	683	1,552	111	164	8,800	10,990	141	325

All figures rounded including totals
* To convert to approximate tons/day multiply by 3.

3.3 EMISSION LEVELS FROM COMBUSTION

We have developed both the energy use levels (Section 2) and emission factors per unit of energy (Section 3.1) for various uses of fuel. From these two sets of data we can compute the emission levels resulting from fuel usage in the various air basins of California.

The minimum and maximum emission factors given in Tables 3-1 through 3-5 are combined with the energy uses given in Table 2-3 to produce tables of what we consider to be the minimum and maximum emission levels for each air basin. The figures are approximate because the unit emission factors are averages, but it is felt that by giving a maximum and a minimum emission factor some feeling for the magnitude of the problem will be obtained. The A.P.C.D.'s certainly use an averaging process in the computation of emissions since the real time recording and integration of emissions from all sources does not seem feasible. We feel that although our averages may be crude, some measure of the error involved can be made by using upper and lower bounds on the emission factors.

The emissions from combustion in California in 1969 were calculated according to the above method and the detailed results are given in Tables B-1 through B-6 of Appendix B. The results are summarized in Table 3-6. The first thing we note is the spread of the results between the high and low figures resulting from the uncertainty of the emission factors employed for all the fuels. The overall uncertainty is seen to be of the order of 30% which seems a reasonable measure of the uncertainty in the measurement of emission factors and fuel consumption. The point is that although natural gas and gasoline figures are accurate to probably within 5%, it is doubtful the average emission factors used are any better than about 15-20% because the variability between pieces of equipment and the variation between peak load and low load operation, apart from differences between intermittent and continuous operation.

The emission totals are given in millions of kilograms per year and can be converted to approximate tons per day by multiplying by a factor of three. Thus we see that combustion organics alone are of the order of 5000 to 6800 tons per day in the State and between 2300 and 3200 tons per day the South Coast Air Basin. This can be compared with total hydrocarbon emissions computed by the Los Angeles A.P.C.D. for Los Angeles County alone of 2500 tons/day.

From Tables B-1 through B-6 of Appendix B we note that gasoline combustion is responsible for about 94% of combustion organics, 52% of the oxides of nitrogen, 29% of combustion particulates, and 99% of the carbon monoxide. We can therefore outline any worthwhile control program as requiring the following measures:

(1) Removal of carbon monoxide from automobiles.
(2) Removal of hydrocarbons from automobiles.
(3) Removal of oxides of nitrogen from automobiles and non-vehiclular combustion sources.
(4) Removal of organics from evaporative non-vehicular sources (untabulated here).

Not surprisingly, this is precisely the strategy currently being pursued.

3.4 MINIMUM EMISSIONS FROM COMBUSTION

It is of importance to compute the minimum possible combustion emissions in the State, and in particular the South Coast Air Basin, since this will give an indication of the best air quality we can reasonably expect. Obviously, people will be more receptive to air pollution control measures if they know the utility of them. We should therefore give some attention to the air quality that it is possible to attain without major societal dislocations.

We have already given the fuel usage for various purposes and also the unit emission factors for various pollutants when the fuel is used for a stated purpose. Suppose that for fuel j we use E_j units of energy and that associated with this use e_{ij} units of pollutant i are produced per unit of fuel. Then the total amount of pollutant i, P_i, is given by

$$P_i = \sum_j E_j e_{ij} + S_i$$

where S_i are the emissions of i from non-energy production sources, for example, the evaporation of solvents, or non-combustion gasoline emissions. Now, for given non-combustion emissions, S_i, we minimize P_i, the amount of pollutant i, by one or more of three possible measures:

(a) reduction of the emission factors e_{ij},
(b) reallocation of the total energy demand to the E_j with lowest emission factors,
(c) reduction in energy use E_j.

Current anti-pollution control measures have all employed (a). But, due to the limits on technology, e_{ij} can only be made so small. Suppose they can be reduced to k_{ij}, then

$$\text{minimum } (P_i) = \sum_j E_j k_{ij} + S_i$$

However, it is an undisputed fact that energy demands have maintained an almost monotonic growth. This means that to make any progress at all in the reduction of P_i the e_{ij} must be driven toward k_{ij} (the best attainable emission factors) at a rate faster than the growth rate in energy use. When the k_{ij} are attained the pollutants will then grow at the rate of energy use unless strategy (b) or (c) is followed, in which case further reductions in total pollutants are possible. Thus, it is reasonably obvious that in the long run plan (a), reducing the emission factors alone, is not the best way to attain cleaner air since any gains will ultimately be consumed by the growth in energy consumption, and yet this is precisely the policy employed by virtually all air pollution control agencies. The California Air Resources Board has followed this scheme for the entire time it has been in existence. The Environmental Protection Agency has done exactly the same, although it is encouraging to see there are some indications that EPA intends strategy (b) and (c) to be considered as part of the plans States must use to attain promulgated ambient air quality standards (37).

We now employ the simple reasoning above to calculate what we consider to be the lowest attainable combustion emissions in the South Coast Air Basin for 1975, without using plan (b) or (c), i.e., no reduction in the growth of energy consumption and no substitution of fuels for those with a lower emission factors. We assume that the rate of growth of energy consumption is maintained at 4% and at the same time the emission factors are reduced to the minimum technically possible. The important fact to recognize is that these will be the lowest emission levels ever attainable without the reallocation of existing energy sources or a shift to nuclear power or some other non-polluting source. If no such reallocation or replacement occurs but the growth alone is taken up by non-polluting sources these calculated levels will be the air quality the South Coast Basin must continue to live with. Should the growth not be taken up by non-polluting energy sources then these minimum levels will be only a transient minimum and the air quality will again deteriorate as the use of energy continues to rise.

We can easily compute these minimum combustion emission* levels for 1975 by multiplying fuel usage figures by a 4% per annum growth rate and using emission factors that in our judgement are probably the best that can be obtained by this date. For automobiles these are emission levels given by the EPA under the Clean Air Act Amendments of 1970. For combustion processes they are the minimum emission factors for a given fuel from those listed in Tables 3-1 through 3-5. Thus we assume, for example, that power plants will ultimately be modified to the point where their emissions per kwh of gas

* It must be remembered that the emission levels quoted here are for combustion processes alone. To these figures must be added all the organics and particulates from non-combustion processes. This will be the topic of another report.

Table 3-7

Predicted Possible Minimum Combustion Emissions - South Coast Air Basin 1975 (10^6 x KGM)

Fuel	Gasoline	Diesel	Aviation	Jet Fuel	Residual Oil Utility	Residual Oil Other	Distillate	Ref. Make Gas	Firm	Natural Gas Inter.	Utility	Total Fuel (MWH x 10^6) / Total Emissions (KGM x 10^6)	Total Emissions (tons/day)
Consumed 1969 (MWH x 10^6)	149	13	1.4	5.1	26	12	13	48	120	51	110	547	
Consumed 1975 (4% annual growth)	189	16	1.7	6.5	33	15	17	60	152	65	140	695	
Emissions													
Organics	(0.188)*	(0.188)	(6.13)	(4.20)	(0.039)	(0.027)	(0.033)	(0.004)	(Negl)	(0.01)	(0.006)		
1969	713	26	8.3	21	1.0	0.3	0.4	0.2		0.5	0.7	772	2,330
1975	36	3	10	27	1.3	0.4	0.6	0.2		0.6	0.8	80	200
Nitrogen Oxides	(0.164)*	(0.164)	(1.82)	(0.18)	(0.164)	(0.74)	(0.13)	(0.22)	(0.164)	(0.26)	(0.164)		
1969	275	17	2.5	0.9	10	8.9	1.7	10	20	13	63	422	1,275
1975	31	2.6	3.1	1.2	5.4	11	2.1	13	25	17	23	134	243
Carbon Monoxide	(1.93)*	(0.34)	(30)	(0.4)	(0.002)	(0.002)	(0.002)	(0.004)	(0.0006)	(0.0006)			
1969	4,070	4.4	41	2.0				0.2	0.1			4,120	12,440
1975	364	5.6	52	2.6				0.3	0.1			424	1,266
Particulates	(0.143)	(0.143)	(0.15)	(0.15)	(0.13)	(0.15)	(0.09)	(0.015)	(0.028)	(0.026)	(0.022)		
1969	21	16	0.2	0.8	0.3	1.8	1.2	0.7	3.3	1.3	2.4	49	150
1975	27	2.3	0.3	1.0	0.4	2.3	1.5	0.9	4.2	1.7	3.1	44	130
Sulfur Oxides	(0.094)	(0.56)	(Negl)	(0.18)	(0.82)	(0.82)	(0.89)	(0.05)	(0.0006)	(0.0006)	(0.0006)		
1969	14	7		0.9	21	10	12	2.4	0.1		0.1	67	203
1975	18	9		1.2	27	13	15	3.0	0.1		0.1	86	215

* EPA 1976 Tail Pipe Emission Standards (39)
Emission factors in parentheses.

or oil consumed are as low as domestic gas appliances.* We also assume that diesel vehicles are reduced to the same levels as automobiles and all other sources, in general minor, remain the same.

From Table 3-7 we see that combustion organics and carbon monoxide are reduced to approximately 10% of 1969 levels; oxides of nitrogen to 20% of 1969 levels. There is no debate that such reductions would have a very significant effect on air quality. But, as stated above this gain could only be maintained by assuring that *every* new energy source within the basin had zero emissions. At the present time this means nuclear power. There is obviously no hope of satisfying the Federal Ambient Air Quality Standards (37) without wholesale replacement of fossil fuels by nuclear power. The figures given in Table 3-7 represent the result of almost utopian assumptions in respect to what can be hoped for in emission reduction from combustion. As noted above, combustion processes are not the sole sources of hydrocarbons and particulates and therefore to keep the air quality that these emission figures represent, severe controls on the growth of evaporation of fuels and solvents would be necessary. As an indication of the order of magnitude of these evaporative problems consider the possible sources of gasoline evaporation, in comparison to exhaust emissions as shown in Table 3-8. We see that the non-combustion emissions could amount to as much as three times the tailpipe emissions!

Thus, the essential point, which cannot be emphasized too strongly, is that the energy supply, if permitted to grow at all, must do so in non-polluting ways. We have almost attained the point where our fossil fuel energy demands are so large that they have surpassed our ability to reduce the unit emission factors. We have therefore reached the fossil fuel carrying capacity of the South Coast Air Basin—if we want reasonably clean air.

The possibilities of further gains in air quality, over and above those given above, should be considered also. Fuel substitutions were considered previously in Section 3.2 and it was shown there that one major shift that could occur was the transposition of gasoline and natural gas/LPG. However, the effect of this substitution becomes inconsequential when the emission factors for both become the same, which will be the case in 1976 when all automobiles must satisfy the EPA tailpipe emissions standards (39).

Thus, the only major substitution worth considering is the replacement of fossil fuels, wherever possible, by nuclear power. In view of the well-publicized impending fossil fuel supply crisis this seems eminently reasonable and it will occur as the shortage of fossil

* These are in line with EPA standards of performance for steam generators (38).

Table 3-8

Relative Magnitude of Tailpipe Hydrocarbon Emissions and Other Losses of Gasoline for South Coast Air Basin Consumption in 1975 (estimated as 5100 million gallons.)

Filling Service Station (2)	3.3	-	5.2	gms/gallon
Filling Automobile Tank (2)	7.5	-	8.0	"
Evaporation Losses (3)	6.5	-	13.0	"
Total Losses (4)	17.3	-	26.2	gms/gallon
	260	-	390	tons/day
Exhaust (0.5 gms/mile (1) at 15 miles/gallon)			7.5	gms/gallon
			= 113	tons/day

(1) EPA emission standard
(2) Reference (11)
(3) Estimated accumulated losses in storage, spillage representing ¼ to ½% loss
(4) Represents 0.6 - 1% total losses, according to Reference (17) losses are of order of 1%

fuel results in higher prices, making nuclear power even more competitive. Of course, this is not the only factor which will make the substitution of nuclear power more attractive. The fact that fossil fuel plants will more than likely no longer be permitted in the air basin means there is no longer any advantage from shorter transmission lines to fossil plants. The other major factor is the increasingly stringent emission controls being placed on fossil-fueled steam generators (38). These controls must raise the cost of fossil plants closer to that for nuclear plants.

It therefore seems that the process of demanding lower and lower emission factors for fuels is one way of accomplishing strategy (b) above. As the cost of the control measures required to attain the lower emission factors rises, the reallocation of fuel usage occurs naturally as a consequence. The question is, should we invent direct incentives to accomplish the same ends faster?

The final plan, (c), will probably take the longest to find acceptance. The idea that a society should voluntarily restrain its energy demands appears somewhat new to democratic societies in peace time. Many nations have had energy "rationing" in effect during time of war, and some still have "power cuts" or "brown outs" as a consequence of incompetent planning. But generally speaking, we have come to accept the ready availability of energy to be our rightful due. Has the time come when our society should rethink its priorities? We have already accepted the fact (well, most of us) that we can no longer use land, air and water in any that pleases us when our decisions could have an impact on the rest of society. Is the same now true of energy?

4. THERMAL PROBLEMS FROM ENERGY USE

In view of the large concentration of the State's energy use in the South Coast Air Basin (50%), we thought it of interest to compare the release of this energy with the incident solar energy. From Table 2-3 we see that the total energy release in the basin was 557 million megawatt hours (MWH). By comparison, the incident solar energy on an annual average basis* over the 9219-square-mile basin is 46,000 million MWH. The artificial energy release therefore represents 1.2% of the incident solar energy. It would not appear that the basin as a whole is going to suffer any untoward heating problems. However, a 4% growth rate for 25 years would see this figure raised to over 3% of the incident solar energy. Another point is the fact that the energy is not released uniformly over the basin. To see how the clustering of people within the basin affects the result we consider Los Angeles County, or rather the populated portion of it, represented by that area not in designated National Forest (7).

Table 4-1 gives the energy released in Los Angeles County. The area of release has been taken as that section of the County not included within designated forest area. We see that the energy released was already 3.7% of the estimated incident solar energy. A 4% per annum growth rate maintained for 25 years will see this figure raised to almost 10% of the incident solar energy. Thus, while we could well argue whether the energy is released over 1500 square miles or 2500 square miles, in the long run the question is irrelevant, since growth within the County simply means the 10% figure will be attained sooner or later.

The figures above are somewhat lower than those calculated by Lees (35) and lead to average rates of energy release that would not be reached until 20 years after Lees' predictions. Thus, his computations for the rate increase in mean temperature in Los Angeles Basin are just shifted by 20 years. According to Lees' model and our energy figures, we can expect a current mean temperature increase of something around $2^{O}F$ from the residual heat of our energy use. The actual temperature rise depends on the height of the temperature inversion and the wind speed. The 4% growth rate in total energy for the basin would lead to about $5\text{-}7^{O}F$ rise in 20 years.

The conclusion we reach from this rough analysis is that although the current release of energy averaged over the whole South Coast Air Basin is no great cause for concern, the concentration of energy release within Los Angeles County should give us reason to pause and consider rates of growth within the County. As Figure 2, Section 1, shows, population

* 450 $cal/cm^2 \cdot day = 5.0 \times 10^6$ $MWh/mile^2$.

Table 4-1

Energy Released in Los Angeles County 1969

Source	Millions	Millions MWH/Year
Combustion		
Gasoline	2,920 gallons	107.1
Diesel	55 gallons	2.2
Aviation Gas	40 gallons	1.4
Jet Fuel	120 gallons	4.8
Residual Oil	551 gallons	24.2
Natural Gas	726,000 cu. ft.	223.6
Ref. Gas	100,000 cu. ft.	47.5
Electricity (millions MWH)		
Oil	7.4	
Gas	25.0	
	36.4	
Total Used	41.2	
Thermal (1)	4.8	4.8
People	1.4 MWH/person	9.8
Total Los Angeles County		425.4×10^6 MWH/year
Incident Solar Energy (2) on 2300 sq. Miles (3)		$11{,}500 \times 10^6$ MWH/year
Energy As Fraction of Incident Solar		3.7%

(1) Imports plus hydroelectric

(2) 5.0×10^6 MWH/Sq. mile/year

(3) Non-forested area (7)

growth in itself is not the problem–it is the per capita rise in energy consumption. If we are to avoid possible severe environmental problems of heating within the Los Angeles Basin area we will have to shift to electrical energy sources located outside the basin so that the waste heat produced is not a loading on the basin.

In view of the fact that the Los Angeles area is by far the most intensive energy user in the State, and it is at least 20-25 years before thermal problems become serious there, we can conclude that other areas of California probably do not have to worry about this particular problem at this time.

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APPENDIX A

NOTES PERTAINING TO TABLES IN SECTION 2

The two major tasks in the compilation of the tables given in Section 2 was the identification of data sources and then obtaining the data from those sources. The following numbers in parentheses refer to the column numbering on the headings of Table 2-2.

(1) GASOLINE

The total gasoline consumed in the State is available from Highway Statistics (15) but the consumption in counties or air basins is not available directly since each gasoline distributor pays the fuel use tax directly to the State Board of Equalization. Distributors, naturally enough, are unwilling to disclose individual gas station sales. The figures listed in Table 2-2 are therefore obtained by apportioning the State total as obtained from *Highway Statistics* (15) among the counties in accordance with the figures given by the State Controller (6) for the disbursement of Highway Users Tax under Section 2106. This apportionment allocates $0.01040 per gallon of the fuel use tax and hence the disbursements listed in Statement No. 39 of the *Controller's Annual Report* (6) can be related to gallons of fuel. There is a small discrepancy between the totals obtained from this calculation and the totals as given in the *Highway Statistics*(15), and this has been adjusted by a simple scaling of all the county totals. Where a county is split between two air basins the county total has been split according to the vehicle distribution given by Downing and Stoddard (4). No distinction was made between on- and off-highway usage.

(2) DIESEL

Total diesel figures, Table 2-8, were obtained from the U.S. Bureau of Mines *Annual Mineral Survey* (16), and cross checked with the LPG internal combustion usage listed in the same source and the total "other fuel" figures given in *Highway Statistics* (15) as well as with the Board of Equalization figures (17). The vehicle portion of the total was allocated to air basins on the basis of the proportionate number of trucks registered in that air basin obtained from the *California County Fact Book* (7). This method of allocating the vehicle usage of diesel fuel resulted in a much larger apportionment to Los Angeles County than that listed in the L.A. APCD *Profile* (8) but approximately the same as that in the Bay Area *Emissions Inventory* (9). In view of the major level of economic activity in the South Coast basin the figures given here are felt to be the most reasonable. The railroad portion of Table 2-8 was allocated on the basis of a rough arbitrary weighting dependent on the population served by the railroad and the length of railroad track in a basin.

(3) (4) AVIATION FUELS

The gallons of aviation gasoline consumed as listed in Table 2-2 are derived from the known usage of gasoline by a plane in climbing to 3500 feet and in landing. For example, a four-engine gasoline-powered plane uses an average 117 gallons to land and take off; detailed figures are given in *Compilation of Air Pollutant Emission Factors* (11). These factors, combined with known traffic statistics from the Los Angeles APCD (8), the Bay Area APCD (9), and the Monterey-Santa Cruz APCD (12), and coupled with statistics of plane ownership in each county (7), enable a rough assessment of the amount of aviation gasoline burned to 3500 feet.

Jet fuel figures are known for the three air pollution control districts mentioned above and these coupled with population figures in other air basins give a rough assessment of the amount of traffic and therefore fuel burned. Military fueling is not included.

(5) (7) LPG AND REFINERY MAKE GAS

LPG figures as given in Table 2-2 were derived from the total figures obtained from the Bureau of Mines (16), (21). Establishing the sales by air basin was impossible as the LPG gas market is a very competitive one. Discussions with sales executives of Calgas Corporation and Petrolane, two major California suppliers, lead to the somewhat arbitrary allocations shown and they should be taken only as indicative. However, the statewide totals are relatively accurate.

Refinery make gas was obtained for the South Coast Air Basin and San Francisco Air Basin from the figures given in the respective Los Angeles APCD (8) and Bay Area APCD (9) emission inventories, and was extended to the whole basin and other basins on the basis of the known refinery capacities in the respective basins (10). Details are given in Table A-3.

(6) FUEL OILS

A primary source of data on fuel oil consumption is the Bureau of Mines (16), which gives a listing of total fuel oil sales, including diesel oil for the entire state. These are the figures listed across the bottom line of Table 2-8. Several comments are in order on the compilation of this chart. The electric power production figures are very accurate as they are taken from the month by month reports made by the utilities to the Federal Power Commission for each operating power plant. The figures for residential, commercial and industrial usage of residual and distillate oil given in the table are those obtained from the air pollution districts concerned (8), (9), (12), (22), (23), (24). The discrepancies have already been commented on.

(8) NATURAL GAS

The usage of natural gas in the State and air basins is shown in detail in Table 2-7. There are three major utilities in California: San Diego Gas and Electric, Pacific Lighting Service (through its subsidiaries Southern California Gas Company and Southern Counties Gas Company) in the southern part of the State and Pacific Gas and Electric in the north. SDG&E is confined almost entirely to the San Diego Air Basin and hence sales in that basin were obtained from the company annual report (26). Pacific Lighting Service (27) had already broken down their gas sales into each air basin. Pacific Gas and Electric kindly provided a company document (28) subdividing their sales by category and county, and since in the northern region of the State the air basins generally follow the prexisting county boundaries this data was readily related to air basins. The gas sales to steam power plants were also obtained from the Federal Power Commission (20) and agreed with the previous data with very minor discrepancies. The total gas utilization data was also checked with the Bureau of Mines (19) data and agreed to within 5% which is probably only the accuracy of the flow meters anyhow. Thus the gas data is probably the most accurate of the study.

(9) ELECTRICAL ENERGY USE

The use of electrical energy in the State is described in detail in Table 2-5. The categories given are those supplied by the utilities and the definitions of what comprises a commercial versus an industrial establishment probably varies with the utility. The "other" category listed includes such uses as street and highway lighting, in plant use, military use, and the like. The totals given show a small discrepancy with the FPC sales to ultimate consumers except in this "other" category, which probably results from differences in the description of consumers.

The figures were compiled from a variety of sources, the primary two being data provided by SCE (29) and PG&E (30). Other utilities operations are essentially confined to one air basin and hence the data was available from their annual reports to the Federal Power Commission (31) or data provided the author by the utility. Pacific Gas and Electric "wheels" energy for the U.S. Bureau of Reclamation and the delivery of this energy is described in their annual report to the Federal Power Commission (32).

In the South Coast Air Basin, where county lines do not coincide with the air basin boundaries, the energy was divided according to the population distribution. In the North Coast and Northeast Plateau Air Basins, the consumption for Del Norte, Siskiyou and Modoc counties was obtained from Pacific Power and Light (36) directly.

In the Southeast Desert Air Basin, the energy provided by California Pacific Utilities to the city of Needles was not obtained but estimated from that known for similar towns in the Imperial Valley. The error introduced by this estimate is probably quite small relative to the total consumption in California. A large portion of the electrical energy consumed in the basin is obtained from Glen Canyon and Hoover dams and is used by the Metropolitan Water Districts of California for aqueduct pumping.

(10) ELECTRICAL ENERGY PRODUCTION

The production of electrical energy within the State is described in Table 2-4. The data was extracted from the FPC Form 4 monthly data sheets (1) which provide the following information for each class of utilities: type of generating plant, fuel used, and power produced. The results are therefore as accurate as the data provided to the FPC by the utilities. The totals of gas and oil used are given in Table 2-6 and incorporated into Tables 2-7 and 2-8. The electrical energy produced from hydro, geothermal, and nuclear power is incorporated into Table 2-3.

Table A-1

Calorific Values of Fuels

Fuel				
Gasoline	1 Barrel	=	1.541	MWH
Diesel	1 Barrel	=	1.703	MWH
Aviation Gas	1 Barrel	=	1.480	MWH
Jet Fuel	1 Barrel	=	1.665	MWH
LPG	1 Barrel	=	1.131	MWH
Residual Oil	1 Barrel	=	1.841	MWH
Distillate Oil	1 Barrel	=	1.705	MWH
Ref. Make Gas	1 Million cu. ft.	=	475	MWH
Piped Gas	1 Million cu. ft.	=	308	MWH

Source: Reference (14)

People 1.4 MWH/yr/person = 3200 Calories/day/person

Table A-2

Aviation within Air Basins

	Air Basin	Planes	Gas (Thous. Gall.)	Jet Fuel (Thous. Gall.)
1	North Coast	355	700	----
2	San Francisco	3,182	7,100	87,000
3	North Central Coast	368	3,650	1,460
4	South Central Coast	235	1,000	1,400
5	South Coast	6,367	40,000	128,000
6	San Diego	1,097	6,000	25,000
7	Northeast Plateau	95	200	----
8	Sacramento Valley	1,571	7,500	1,500
9	San Joaquin Valley	1,586	8,000	1,500
10	Great Basin Valley	90	200	----
11	South East Desert	847	4,000	----
	Totals	15,793	78,350	245,860

Table A-3

Refinery Make Gas

	Air Basin	Refinery Capacity (bbl/day)	Gasoline Output (bbl/day)	Refinery Make Gas MMCF
2	San Francisco	660,400	442,000	48,400
4	South Central Coast	42,000	4,200	1,000
5	South Coast	758,800	406,000	100,140
9	San Joaquin Valley	109,850	38,000	4,200
	Totals	1,571,050	890,200	153,740

APPENDIX B

EMISSION LEVELS FROM FUEL COMBUSTION IN CALIFORNIA IN 1969

The following tables give the emission levels from fuel usage from each energy source listed in Table 2-2. The results are summarized in Table 3-6.

Table B-1

Emissions of Organics in California in 1969, (Millions of Kilograms or Thousands of Long Tons). Fuel Consumed in Millions of MWH in Parentheses

Emissions are In Thousand Tons	Gasoline	Diesel Fuel	Aviation Gas	Jet Fuel	Residual Oil Power	Residual Oil Other	Distillate Oil	Ref. Make Gas	Natural Gas Firm	Natural Gas Inter. *	Natural Gas Utility	Total Fuel	Min. Total Emissions	Max. Total Emissions
Min. Emission Factor	4.80	1.98	6.13	4.20	.0388	.0272	.0331	.004	Negl.	.01	.006			
Max. Emission Factor	6.67	2.2	6.55	4.33	.0516	.0408	.0445		.0015	.0108	.020			
1 North Coast	(4.3)	(0.65)	(0.02)	- - - -	(0.06)	(0.28)	(0.67)	- - - -	(1.28)	(1.30)	(0.90)	(9.46)		
Min. Emission	20.6	1.29	0.12	- - - -	0.002	0.008	0.022	- - - -	Negl.	0.013	0.005		22.1	
Max. Emission	28.7	1.43	0.13	- - - -	0.003	0.011	0.030		0.002	0.014	0.018			30.3
2 San Francisco Bay	(70.5)	(6.73)	(0.24)	(3.45)	(5.83)	(12.89)	(6.33)	(23.0)	(66.04)	(46.13)	(28.68)	(269.82)		
Min. Emission	338.4	13.33	1.47	14.49	0.226	0.350	0.210	0.092	Negl.	0.461	0.172		369.2	
Max. Emission	470.2	14.81	1.57	14.94	0.301	0.526	0.282		0.099	0.498	0.574			503.8
3 North Central Coast	(6.6)	(0.77)	(0.12)	(0.058)	(0.81)	(1.39)	(0.75)	- - - -	(5.10)	(5.01)	(19.07)	(39.68)		
Min. Emission	31.7	1.52	0.74	0.24	0.032	0.038	0.025	- - - -	Negl.	0.050	0.115		34.5	
Max. Emission	44.0	1.69	0.78	0.25	0.042	0.057	0.033		0.007	0.054	0.382			47.3
4 South Central Coast	(4.4)	(0.45)	(0.03)	(0.055)	(0.49)	(1.20)	(0.43)	(0.5)	(2.50)	(1.81)	(7.97)	(19.83)		
Min. Emission	21.1	0.89	0.18	0.23	0.019	0.033	0.014	0.002	Negl.	0.018	0.048		22.5	
Max. Emission	29.4	0.99	0.20	0.24	0.025	0.049	0.019		0.004	0.020	0.159			31.1
5 South Coast	(148.6)	(12.93)	(1.36)	(5.07)	(26.06)	(12.08)	(12.96)	(47.5)	(119.52)	(50.88)	(109.96)	(546.92)		
Min. Emission	713.3	25.60	8.34	21.29	1.011	0.328	0.429	0.190	Negl.	0.509	0.660		771.6	
Max. Emission	991.2	28.45	8.91	21.95	1.345	0.493	0.577		0.179	0.549	2.199			1,056.1
6 San Diego	(18.4)	(1.62)	(0.20)	(0.99)	(3.10)	(3.68)	(1.62)	- - - -	(11.32)	(2.02)	(12.06)	(55.01)		
Min. Emission	88.3	3.21	1.23	4.16	0.120	0.100	0.054	- - - -	Negl.	0.020	0.072		97.3	
Max. Emission	122.7	3.56	1.31	4.29	0.160	0.150	0.072		0.017	0.022	0.241			132.5
7 Northeast Plateau	(1.5)	(0.32)	(0.01)	- - - -	- - - -	- - - -	(0.34)	- - - -	- - - -	- - - -	- - - -	(2.17)		
Min. Emission	7.2	0.63	0.06	- - - -	- - - -	- - - -	0.011	- - - -	- - - -	- - - -	- - - -		7.9	
Max. Emission	10.0	0.70	0.07	- - - -	- - - -	- - - -	0.015		- - - -	- - - -	- - - -			10.8
8 Sacramento Valley	(22.6)	(3.12)	(0.26)	(0.059)	- - - -	(1.47)	(3.11)	- - - -	(14.31)	(6.46)	- - - -	(51.39)		
Min. Emission	108.5	6.18	1.59	0.25	- - - -	0.040	0.103	- - - -	Negl.	0.065	- - - -		116.7	
Max. Emission	150.7	6.86	1.70	0.25	- - - -	0.060	0.139		0.021	0.070	- - - -			159.8
9 San Joaquin Valley	(28.0)	(4.30)	(0.27)	(0.059)	- - - -	(3.31)	(4.30)	(2.0)	(18.57)	(20.39)	(0.02)	(81.22)		
Min. Emission	134.4	8.51	1.65	0.25	- - - -	0.090	0.142	0.008	Negl.	0.204	Negl.		145.2	
Max. Emission	186.8	9.46	1.77	0.25	- - - -	0.135	0.191		0.028	0.220	Negl.			198.9
10 Great Basin Valley	(0.6)	(0.08)	(0.01)	- - - -	- - - -	- - - -	(0.09)	- - - -	- - - -	- - - -	- - - -	(0.77)		
Min. Emission	2.9	0.16	0.06	- - - -	- - - -	- - - -	0.003	- - - -	- - - -	- - - -	- - - -		3.1	
Max. Emission	4.0	0.18	0.07	- - - -	- - - -	- - - -	0.004		- - - -	- - - -	- - - -			4.3
11 Southeast Desert	(12.1)	(1.14)	(0.13)	- - - -	(0.04)	(0.22)	(1.13)	- - - -	(3.00)	(12.55)	(3.34)	(33.65)		
Min. Emission	58.1	2.26	0.80	- - - -	0.002	0.006	0.037	- - - -	Negl.	0.126	0.020		61.4	
Max. Emission	80.7	2.51	0.85	- - - -	0.002	0.009	0.050		0.005	0.136	0.067			84.3
Total Fuel	(317.6)	(32.11)	(2.65)	(9.74)	(36.39)	(36.52)	(31.72)	(73.0)	(241.64)	(146.55)	(182.00)	(1,109.92)		
Min. Total Emissions	1,524.5	63.58	16.24	40.91	1.412	0.993	1.050	0.292	Negl.	1.466	1.092		1,651.5	
Max. Total Emissions	2,118.4	70.64	17.36	42.17	1.878	1.490	1.412		0.362	1.583	3.640			2,259.2

* Excluding Utility Use

Table B-2

Emissions of Oxides of Nitrogen in California in 1969, (Millions of Kilograms or Thousands of Long Tons). Fuel Consumed in Millions of MWH in Parentheses.

Emissions are in Thousand Tons.	Gasoline	Diesel Fuel	Aviation Gas	Jet Fuel	Residual Oil		Distillate Oil	Ref. Make Gas	Natural Gas			Total Fuel	Min. Total Emissions	Max. Total Emissions
					Power	Other			Firm	Inter. *	Utility			
Min. Emission Factor	1.40	1.34	1.82	.18	.370	0.74	.127		.164	.26	0.280			
Max. Emission Factor	2.41	2.98	2.00	.511	1.23	.830	.83	.220	.330	.331	2.47			
1 North Coast	(4.3)	(0.65)	(0.024)	- - - -	(0.06)	(0.28)	(0.67)	- - - -	(1.28)	(1.30)	(0.90)	(9.46)		
Min. Emission	6.0	0.87	0.04	- - - -	0.02	0.21	0.09	- - - -	0.21	0.34	0.25		8.0	
Max. Emission	10.4	1.61	0.05	- - - -	0.07	0.23	0.56	- - - -	0.42	0.43	2.22			16.0
2 San Francisco Bay	(70.5)	(6.73)	(0.24)	(3.45)	(5.83)	(12.89)	(6.33)	(23.0)	(66.04)	(46.13)	(28.68)	(269.82)		
Min. Emission	98.0	9.02	0.44	.621	2.15	9.50	0.80		10.83	11.99	8.00		156.0	
Max. Emission	169.9	16.6	0.50	1.763	7.17	10.70	5.25	5.06	21.8	15.27	70.84			325.0
3 North Central Coast	(6.6)	(0.77)	(0.12)	(0.058)	(0.81)	(1.39)	(0.75)	- - - -	(5.10)	(5.01)	(19.07)	(39.68)		
Min. Emission	9.2	1.03	0.22	0.010	0.30	1.03	0.10		0.84	1.30	5.33		19.2	
Max. Emission	15.9	1.91	0.24	.030	1.00	1.15	0.62	- - - -	1.68	1.66	47.10			71.3
4 South Central Coast	(4.4)	(0.45)	(0.034)	(0.055)	(0.49)	(1.20)	(0.43)	(0.5)	(2.50)	(1.81)	(7.97)	(19.83)		
Min. Emission	6.1	0.60	0.06	.010	0.18	0.89	0.05		0.41	0.47	2.23		11.2	
Max. Emission	10.6	1.11	0.07	.028	0.60	1.00	0.36	0.11	0.83	0.60	19.69			35.0
5 South Coast	(148.6)	(12.93)	(1.36)	(5.07)	(26.06)	(12.08)	(12.96)	(47.5)	(119.52)	(50.88)	(109.96)	(546.92)		
Min. Emission	208	17.33	2.48	.912	9.64	8.90	1.65		19.60	13.23	30.8		323.0	
Max. Emission	358	32.10	2.72	2.591	32.06	10.03	10.76	10.45	39.50	16.84	271.60			786.7
6 San Diego	(18.4)	(1.62)	(0.20)	(0.99)	(3.10)	(3.68)	(1.62)	- - - -	(11.32)	(2.02)	(12.06)	(55.01)		
Min. Emission	25.8	2.17	0.36	.178	1.15	2.71	0.21		1.86	0.53	3.37		38.5	
Max. Emission	44.3	4.00	0.40	.506	3.81	3.05	1.34	- - - -	3.73	0.67	29.79			91.6
7 Northeast Plateau	(1.5)	(0.32)	(0.007)	- - - -	- - - -	- - - -	(0.34)	- - - -	- - - -	- - - -	- - - -	(2.17)		
Min. Emission	2.1	.43	0.01	- - - -	- - - -	- - - -	(0.04)		- - - -	- - - -	- - - -		2.6	
Max. Emission	3.6	0.79	0.01	- - - -	- - - -	- - - -	0.28	- - - -	- - - -	- - - -	- - - -			4.7
8 Sacramento Valley	(22.6)	(3.12)	(0.26)	(0.059)	- - - -	(1.47)	(3.11)	- - - -	(14.31)	(6.46)	- - - -	(51.39)		
Min. Emission	31.6	4.18	0.47	.011	- - - -	1.08	0.39		2.35	1.68	- - - -		41.9	
Max. Emission	54.5	7.75	0.52	.030	- - - -	1.22	2.58	- - - -	4.73	2.14	- - - -			73.4
9 San Joaquin Valley	(28.0)	(4.30)	(0.27)	(0.059)	- - - -	(3.31)	(4.30)	(2.0)	(18.57)	(20.39)	(0.02)	(81.22)		
Min. Emission	39.2	5.76	0.49	.011	- - - -	2.44	0.55		3.04	5.30	0.01		57.2	
Max. Emission	67.5	10.70	0.54	0.30	- - - -	2.75	3.57	.44	6.13	6.75	0.05			98.8
10 Great Basin Valley	(0.6)	(0.08)	(0.007)	- - - -	- - - -	- - - -	(0.08)	- - - -	- - - -	- - - -	- - - -	(0.77)		
Min. Emission	0.8	.11	0.01	- - - -	- - - -	- - - -	0.01		- - - -	- - - -	- - - -		0.9	
Max. Emission	1.5	0.25	0.01	- - - -	- - - -	- - - -	0.07	- - - -	- - - -	- - - -	- - - -			2.0
11 Southeast Desert	(12.1)	(1.14)	(0.13)	- - - -	(0.04)	(0.22)	(1.13)	- - - -	(3.00)	(12.55)	(3.34)	(33.65)		
Min. Emission	17.0	1.53	0.24	- - - -	0.02	0.16	0.14		0.49	3.26	0.94		23.7	
Max. Emission	29.2	2.48	0.26	- - - -	0.05	0.18	0.94	- - - -	1.00	4.15	8.25			46.7
Total Fuel	(317.6)	(32.11)	(2.65)	(9.74)	(36.39)	(36.52)	(31.72)	(73.0)	(241.64)	(146.55)	(182.00)	(1,109.92)		
Min. Total Emissions	444.0	43.03	4.82	1.75	13.46	26.92	4.03		39.63	38.10	51.0		682.9	
Max. Total Emissions	765.4	79.50	5.30	4.98	44.76	30.31	26.33	16.06	79.80	48.51	449.54			1550.5

* Excluding Utility Use

Table B-3

Emissions of Particulates in California in 1969, (Millions of Kilograms or Thousands of Long Tons). Fuel Consumed in Millions of MWH in Parentheses

		Gasoline Gasoline	Diesel Fuel	Aviation Gas	Jet Fuel	Residual Oil Power	Residual Oil Other	Distillate Oil	Ref. Make Gas	Natural Gas Firm	Natural Gas Inter. *	Natural Gas Utility	Total Fuel	Min. Total Emissions	Max. Total Emissions
	Min. Emission Factor	.143	.123		.148	.0126	.146	.0889		.0275	.0260	.0220			
	Max. Emission Factor	.153	2.06	.150	.795	.216	.255	.221	.0152	.0293	.0278	.0232			
1	North Coast	(4.3)	(0.65)	(0.02)	- - - -	(0.06)	(0.28)	(0.67)	- - - -	(1.28)	(1.30)	(0.90)	(9.46)		
	Min. Emission	0.62	0.80		- - - -	0.001	0.041	0.060		0.035	0.034	0.020		1.61	
	Max. Emission	0.66	1.34	0.003	- - - -	0.013	0.071	0.148	- - - -	0.038	0.036	0.021			2.33
2	San Francisco Bay	(70.5)	(6.73)	(0.24)	(3.45)	(5.83)	(12.89)	(6.33)	(23.0)	(66.04)	(46.13)	(28.68)	(269.82)		
	Min. Emission	10.08	8.28		0.511	0.073	1.882	0.563		1.816	1.199	0.631		25.42	
	Max. Emission	10.79	13.86	0.036	2.743	1.259	3.287	1.399	0.350	1.935	1.282	0.665			37.61
3	North Central Coast	(6.6)	(0.77)	(0.12)	(0.058)	(0.81)	(1.39)	(0.75)	- - - -	(5.10)	(5.01)	(19.07)	(39.68)		
	Min. Emission	0.94	0.95		0.009	0.010	0.203	0.067		0.140	0.130	0.420		2.89	
	Max. Emission	1.01	1.59	0.018	0.046	0.175	0.355	0.166	- - - -	0.149	0.139	0.442			4.09
4	South Central Coast	(4.4)	(0.45)	(0.03)	(0.055)	(0.49)	(1.20)	(0.43)	(0.5)	(2.50)	(1.81)	(7.97)	(19.83)		
	Min. Emission	0.63	0.55		0.008	0.006	0.175	0.038		0.069	0.047	0.175		1.71	
	Max. Emission	0.67	0.93	0.004	0.043	0.106	0.306	0.095	0.008	0.073	0.050	0.185			2.47
5	South Coast	(148.6)	(12.93)	(1.36)	(5.07)	(26.06)	(12.08)	(12.96)	(47.5)	(119.52)	(50.88)	(109.96)	(546.92)		
	Min. Emission	21.25	15.91		0.750	0.328	1.764	1.152		3.287	1.323	2.419		49.11	
	Max. Emission	22.74	26.63	0.204	4.030	5.269	3.081	2.864	0.722	3.502	1.415	2.551			73.37
6	San Diego	(18.4)	(1.62)	(0.20)	(0.99)	(3.10)	(3.68)	(1.62)	- - - -	(11.32)	(2.02)	(12.06)	(55.01)		
	Min. Emission	2.63	1.99		0.146	0.039	0.537	0.144		0.311	0.053	0.265		6.15	
	Max. Emission	2.81	3.34	0.030	0.787	0.669	0.938	0.358	- - - -	0.332	0.056	0.280			9.60
7	Northeast Plateau	(1.5)	(0.32)	(0.01)	- - - -	- - - -	- - - -	(0.34)	- - - -	- - - -	- - - -	- - - -	(2.17)		
	Min. Emission	0.22	0.39		- - - -	- - - -	- - - -	0.030		- - - -	- - - -	- - - -		0.64	
	Max. Emission	0.23	0.66	0.002	- - - -	- - - -	- - - -	0.075	- - - -	- - - -	- - - -	- - - -			0.96
8	Sacramento Valley	(22.6)	(3.12)	(0.26)	(0.059)	- - - -	(1.47)	(3.11)	- - - -	(14.31)	(6.46)	- - - -	(51.39)		
	Min. Emission	3.23	3.84		0.009	- - - -	0.215	0.277		0.394	0.168	- - - -		8.17	
	Max. Emission	3.46	6.43	0.039	0.047	- - - -	0.375	0.687	- - - -	0.419	0.180	- - - -			11.64
9	San Joaquin Valley	(28.0)	(4.30)	(0.27)	(0.059)	- - - -	(3.31)	(4.30)	(2.0)	(18.57)	(20.39)	(0.02)	(81.22)		
	Min. Emission	4.00	5.29		0.009	- - - -	0.483	0.382		0.511	0.530	Negl.		11.28	
	Max. Emission	4.28	8.86	0.041	0.047	- - - -	0.844	0.950	0.030	0.544	0.567	Negl.			16.16
10	Great Basin Valley	(0.6)	(0.08)	(0.01)	- - - -	- - - -	- - - -	(0.08)	- - - -	- - - -	- - - -	- - - -	(0.77)		
	Min. Emission	0.09	0.10		- - - -	- - - -	- - - -	0.007		- - - -	- - - -	- - - -		0.20	
	Max. Emission	0.09	0.16	0.002	- - - -	- - - -	- - - -	0.018	- - - -	- - - -	- - - -	- - - -			0.27
11	Southeast Desert	(12.1)	(1.14)	(0.13)	- - - -	(0.04)	(0.22)	(1.13)	- - - -	(3.00)	(12.55)	(3.34)	(33.65)		
	Min. Emission	1.73	1.40		- - - -	Negl.	0.032	0.100		0.082	0.326	0.074		3.76	
	Max. Emission	1.85	2.35	0.019	- - - -	0.009	0.056	0.250	- - - -	0.088	0.349	0.078			5.05
	Total Fuel	(317.6)	(32.11)	(2.65)	(9.74)	(36.39)	(36.52)	(31.72)	(73.0)	(241.64)	(146.55)	(182.00)	(1,109.92)		
	Min. Total Emissions	45.42	39.50		1.442	0.459	5.332	2.820		6.645	3.810	4.004		110.94	
	Max. Total Emissions	48.59	66.15	0.398	7.743	7.860	9.313	7.010	1.110	7.080	4.074	4.222			163.55

* Excluding Utility Use

Table B-4

Emissions of Carbon Monoxide in California in 1969, (Millions of Kilograms or Thousands of Long Tons). Fuel Consumed in Millions of MWH in Parentheses

		Gasoline	Diesel Fuel	Aviation Gas	Jet Fuel	Residual Oil Power	Residual Oil Other	Distillate Oil	Ref. Make Gas	Natural Gas Firm	Natural Gas Inter. *	Utility	Total Fuel	Min. Total Emissions	Max. Total Emissions
	Min. Emission Factor	27.4	.34	30.3	.40	.002	.002	.002	.00424	.0006	.0006	Negl.			
	Max. Emission Factor	34.2	.830		1.69	.00408	.0204	.0222				.0006			
1	North Coast	(4.3)	(0.65)	(0.02)	----	(0.06)	(0.28)	(0.67)	----	(1.28)	(1.30)	(0.90)	(9.46)		
	Min. Emission	118	0.22	0.61	----	Negl.	0.001	0.001	----	0.001	0.001	Negl.		118.8	
	Max. Emission	147	0.54		----	Negl.	0.006	0.015				0.001			148.2
2	San Francisco Bay	(70.5)	(6.73)	(0.24)	(3.45)	(5.83)	(12.89)	(6.33)	(23.0)	(66.04)	(46.13)	(28.68)	(269.82)		
	Min. Emission	1,932	2.29	7.27	1.38	0.012	0.026	0.013	0.098	0.040	0.028	Negl.		1,943.2	
	Max. Emission	2,411	5.59		5.83	0.024	0.263	0.140				0.017			2,430.3
3	North Central Coast	(6.6)	(0.77)	(0.12)	(0.058)	(0.81)	(1.39)	(0.75)	----	(5.10)	(5.01)	(19.07)	(39.68)		
	Min. Emission	181	0.26	3.64	0.02	0.002	0.003	0.001	----	0.003	0.003	Negl.		184.9	
	Max. Emission	226	0.64		0.10	0.003	0.028	0.017				0.011			230.4
4	South Central Coast	(4.4)	(0.45)	(0.03)	(0.055)	(0.49)	(1.20)	(0.43)	(0.5)	(2.50)	(1.81)	(7.97)	(19.83)		
	Min. Emission	121	0.15	0.91	0.02	0.001	0.002	0.001	0.002	0.001	0.001	Negl.		122.1	
	Max. Emission	150	0.37		0.09	0.002	0.025	0.009				0.005			151.4
5	South Coast	(148.6)	(12.93)	(1.36)	(5.07)	(26.06)	(12.08)	(12.96)	(47.5)	(119.52)	(50.88)	(109.96)	(546.92)		
	Min. Emission	4,072	4.40	41.21	2.03	0.052	0.024	0.026	0.201	0.072	0.030	Negl.		4,120.1	
	Max. Emission	5,082	10.73		8.57	0.106	0.246	0.288				0.066			5,143.5
6	San Diego	(18.4)	(1.62)	(0.20)	(0.99)	(3.10)	(3.68)	(1.62)	----	(11.32)	(2.02)	(12.06)	(55.01)		
	Min. Emission	504	0.55	6.06	0.39	0.006	0.007	0.003	----	0.007	0.001	Negl.		511.0	
	Max. Emission	629	134		1.67	0.013	0.075	0.036				0.007			638.2
7	Northeast Plateau	(1.5)	(0.32)	(0.01)	----	----	----	(0.34)	----	----	----	----	(2.17)		
	Min. Emission	41	0.11	0.30	----	----	----	0.001	----	----	----	----		41.4	
	Max. Emission	51	0.26		----	----	----	0.008				----			51.6
8	Sacramento Valley	(22.6)	(3.12)	(0.26)	(0.059)	----	(1.47)	(3.11)	----	(14.31)	(6.46)	----	(51.39)		
	Min. Emission	619	1.06	7.88	0.03	----	0.003	0.006	----	0.008	0.004	----		628.0	
	Max. Emission	773	2.59		0.10	----	0.030	0.069				----			783.7
9	San Joaquin Valley	(28.0)	(4.30)	(0.27)	(0.059)	----	(3.31)	(4.30)	(2.0)	(18.57)	(20.39)	(0.02)	(81.22)		
	Min. Emission	767	1.46	8.18	0.03	----	0.007	0.009	0.009	0.011	0.012	Negl.		776.7	
	Max. Emission	958	3.57		0.10	----	0.068	0.095				Negl.			970.1
10	Great Basin Valley	(0.6)	(0.08)	(0.01)	----	----	----	(0.08)	----	----	----	----	(0.77)		
	Min. Emission	16	0.03	0.30	----	----	----	Negl.	----	----	----	----		16.3	
	Max. Emission	21	0.07		----	----	----	0.002				----			21.4
11	Southeast Desert	(12.1)	(1.14)	(0.13)	----	(0.04)	(0.22)	(1.13)	----	(3.00)	(12.55)	(3.34)	(33.65)		
	Min. Emission	331	0.39	3.94	----	Negl.	Negl.	0.002	----	0.002	0.008	Negl.		335.4	
	Max. Emission	414	0.95		----	Negl.	0.004	0.025				0.002			418.9
	Total Fuel	(317.6)	(32.11)	(2.65)	(9.74)	(36.39)	(36.52)	(31.72)	(73.0)	(241.64)	(146.55)	(182.00)	(1,109.92)		
	Min. Total Emissions	8,702	10.92	80.30	3.90	0.073	0.073	0.063	0.310	0.145	0.088	Negl.		8,797.9	
	Max. Total Emissions	10,862	26.65		16.46	0.148	0.745	0.704				0.109			10,987.7

* Excluding Utility Use

Table B-5

Emissions of Oxides of Sulfur in California in 1969, (Millions of Kilograms or Thousands of Long Tons). Fuel Consumed in Millions of MWH in Parentheses

		Gasoline	Diesel Fuel	Aviation Gas	Jet Fuel	Residual Oil † Power	Residual Oil † Other	Distillate Oil	Ref. Make Gas	Natural Gas Firm	Natural Gas Inter. *	Natural Gas Utility	Total Fuel	Min. Total Emissions	Max. Total Emissions
	Min. Emission Factor	.0936	.56	Negl.	.179	.818	.818	.89	.05	.000618	.000618	.000618			
	Max. Emission Factor	.120				2.45	2.45	2.66		.00064	.00064	.001545			
1	North Coast	(4.3)	(0.65)	(0.02)	----	(0.06)	(0.28)	(0.67)	----	(1.28)	(1.30)	(0.90)	(9.46)		
	Min. Emission	0.40	0.36	Negl.	----	0.05	0.23	0.60	----	0.001	0.001	Negl.		1.64	
	Max. Emission	0.52				0.15	0.69	1.78		0.001	0.001	0.001			3.50
2	San Francisco Bay	(70.5)	(6.73)	(0.24)	(3.45)	(5.83)	(12.89)	(6.33)	(23.0)	(66.04)	(46.13)	(28.68)	(269.82)		
	Min. Emission	6.60	3.77	Negl.	0.618	4.77	10.54	5.63	1.15	0.041	0.029	0.018		33.17	
	Max. Emission	8.46				14.28	31.58	16.84		0.042	0.030	0.044			76.81
3	North Central Coast	(6.6)	(0.77)	(0.12)	(0.058)	(0.81)	(1.39)	(0.75)	----	(5.10)	(5.01)	(19.07)	(39.68)		
	Min. Emission	0.62	0.43	Negl.	0.010	0.66	1.14	0.67	----	0.003	0.003	0.012		3.55	
	Max. Emission	0.79				1.98	3.40	2.00		0.003	0.003	0.030			8.65
4	South Central Coast	(4.4)	(0.45)	(0.03)	(0.055)	(0.49)	(1.20)	(0.43)	(0.5)	(2.50)	(1.81)	(7.97)	(19.83)		
	Min. Emission	0.41	0.25	Negl.	0.010	0.40	0.98	0.38	0.03	0.001	0.001	0.005		2.47	
	Max. Emission	0.53				1.20	2.94	1.14		0.002	0.001	0.012			6.12
5	South Coast	(148.6)	(12.93)	(1.36)	(5.07)	(26.06)	(12.08)	(12.96)	(47.5)	(119.52)	(50.88)	(109.96)	(546.92)		
	Min. Emission	13.91	7.24	Negl.	0.908	21.32	9.88	11.53	2.37	0.074	0.031	0.068		67.33	
	Max. Emission	17.83				63.85	29.59	34.47		0.077	0.033	0.170			156.54
6	San Diego	(18.4)	(1.62)	(0.20)	(0.99)	(3.10)	(3.68)	(1.62)	----	(11.32)	(2.02)	(12.06)	(55.01)		
	Min. Emission	1.72	0.91	Negl.	0.177	2.54	3.01	1.44	----	0.007	0.001	0.007		9.81	
	Max. Emission	2.21				7.60	9.02	4.31		0.007	0.001	0.019			24.25
7	Northeast Plateau	(1.5)	(0.32)	(0.01)	----	----	----	(0.34)	----	----	----	----	(2.17)		
	Min. Emission	0.14	0.18	Negl.	----	----	----	0.30	----	----	----	----		0.62	
	Max. Emission	0.18				----	----	0.91		----	----	----			1.27
8	Sacramento Valley	(22.6)	(3.12)	(0.26)	(0.059)	----	(1.47)	(3.11)	----	(14.31)	(6.46)	----	(51.39)		
	Min. Emission	2.12	1.75	Negl.	0.010	----	1.20	2.77	----	0.009	0.004	----		7.86	
	Max. Emission	2.71				----	3.60	8.27		0.009	0.004	----			16.35
9	San Joaquin Valley	(28.0)	(4.30)	(0.27)	(0.059)	----	(3.31)	(4.30)	(2.0)	(18.57)	(20.39)	(0.02)	(81.22)		
	Min. Emission	2.62	2.41	Negl.	0.010	----	2.71	3.83	0.10	0.011	0.013	Negl.		11.70	
	Max. Emission	3.36				----	8.11	11.44		0.012	0.013	Negl.			25.45
10	Great Basin Valley	(0.6)	(0.08)	(0.01)	----	----	----	(0.08)	----	----	----	----	(0.77)		
	Min. Emission	0.06	0.04	Negl.	----	----	----	0.07	----	----	----	----		0.17	
	Max. Emission	0.07				----	----	0.21		----	----	----			0.32
11	Southeast Desert	(12.1)	(1.14)	(0.13)	----	(0.04)	(0.22)	(1.13)	----	(3.00)	(12.55)	(3.34)	(33.65)		
	Min. Emission	1.13	0.64	Negl.	----	0.03	0.18	1.01	----	0.002	0.008	0.002		3.00	
	Max. Emission	1.45				0.10	0.54	3.01		0.002	0.008	0.005			5.76
	Total Fuel	(317.6)	(32.11	(2.65)	(9.74)	(36.39)	(36.52)	(31.72)	(73.0)	(241.64)	(146.55)	(182.00)	(1,109.92)		
	Min. Total Emissions	29.73	17.98	Negl.	1.743	29.77	29.87	28.23	3.65	0.149	0.091	0.112		141.32	
	Max. Total Emissions	38.11		Negl.		89.16	89.47	84.38		0.155	0.094	0.281			325.02

* Excluding Utility Use

† Min. Sulfur Content = .5% Max. S = 1.5%

ABOUT THE AUTHOR:

E. John List is assistant professor of environmental engineering science at the California Institute of Technology and a charter staff member of the Environmental Quality Laboratory. A native of New Zealand, he is a graduate of the University of Auckland in engineering and mathematics. After taking his PhD in applied mechanics at Caltech in 1965, he was a lecturer at the University of Auckland before joining the Caltech faculty in 1969.

ABOUT EQL:

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

Front Cover: Areas Served With Gas By Utilities
Back Cover: Electric Service Areas

Maps Courtesy of California State Public Utilities Commission


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