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ENERGY & ENVIRONMENT DIVISION

EXECUTIVE SUMMARY

CALIFORNIA ENERGY SYSTEMS ASSESSMENT MODEL

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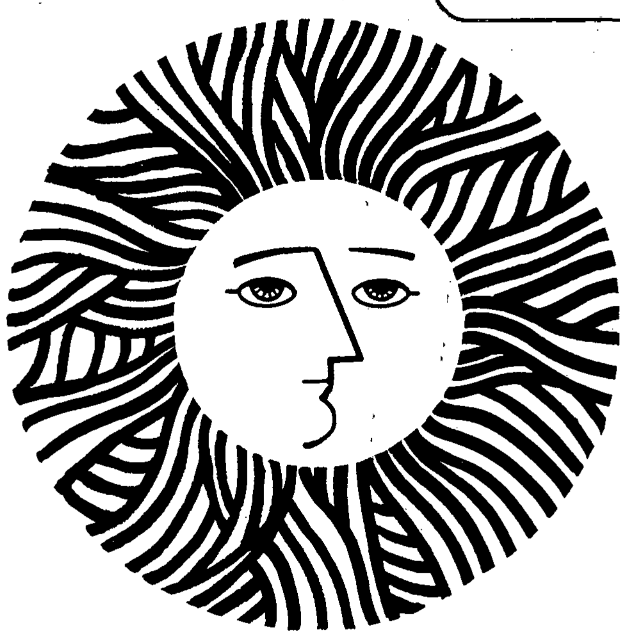

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CALIFORNIA ENERGY SYSTEMS ASSESSMENT MODEL

INTRODUCTION

The next 20 to 30 years are expected to be a period of transition from an era dependent on conventional energy sources such as oil and gas to one more dependent on unconventional supply alternatives and conservation. The California Energy Commission (CEC) and the California Air Resources Board (CARB), the sponsors of this study, are frequently required to evaluate the economic and environmental impacts of energy and nonenergy alternatives. These could involve a complex mix of technologies whose economic impacts may be beneficial by stimulating employment or may be detrimental by requiring capital beyond the means and capabilities of the financial markets. They may also produce residuals that could be harmful to the environment. The magnitude and timing of the economic and associated environmental impacts will depend on the types of energy facilities that are constructed and on the timing of their introduction into the energy system. The models and data bases prepared as part of this project will help in quantifying these impacts and aid in analyzing their degree of severity. They also will help in addressing questions of tradeoffs in different air basins.

Construction of energy facilities requires steel, cement, generating equipment, etc. that can be supplied by industries located in the state or elsewhere in the country or the rest of the world. The investment in new energy facilities will stimulate employment and output in the industries supplying these materials. The industries in turn will purchase goods and services from other supporting industries setting up a chain effect that will filter through rest of the economy. In our analysis we distinguish between the direct impacts associated with construction and operation of energy facilities and the indirect or secondary impacts associated with operation of industries supplying goods and services for energy facility construction.

The direct impacts include capital, labor, and materials required for energy facility construction and operation. Also included are residuals due to the operation of energy facilities. The indirect impacts are the labor, income and airborne emissions associated with the output of secondary industries. The direct impacts are site specific and are determined for individual air basins. The indirect impacts are determined at the state level and then disaggregated to air basins and to utility service areas.

Scope of the Study

The emphasis in this project is on developing a system of models. To demonstrate the main capability of the models, two scenarios developed by the CEC are analyzed and compared. The data used in the models are the best available. No attempt has been made to develop new data for this analysis. This report therefore summarizes the development of the models and their capabilities and limitations. The models are accounting and simulation tools that calculate impacts for given levels of supply and demand. They are not capable of forecasting energy demand or supply for California, although they can be coupled to such models to provide a more comprehensive analysis.

The models account for the economic impacts and residuals from all the supply activities but only from part of the end-use activities. The models provide a framework for evaluating the economic impacts of using 13 types of more efficient appliances in the residential and commercial sectors and the specific direct air effluents from the transportation sector. However, the end-use data provided with the models are not adequate for estimating all the end-use resource requirements. The models cannot account for capital and labor required for improving energy efficiency in the industrial, agriculture and transportation sectors.

To compare the capital requirements between the two scenarios, all the capital spent on energy supply and demand activities needs to be accounted for. The capital required for construction of energy supply facilities can be determined relatively easily if the construction costs for individual power plants, refineries, coal mines, etc. are known. The capital required for conservation is more difficult to estimate because manufactures may invest in styling changes as well as efficiency improvements.

METHODOLOGY

Figure 1 shows the analytic framework underlying the models. Energy scenarios specifying the primary energy from each type of fuel serve as the basic input for the chain of models -- a California Energy Planning Model (CEPM) and a California Input-Output (I-O) Model. The scenarios specify the energy demand by end-use sector and the amount of energy supplied by oil, gas, coal, nuclear, solar, wind, and biomass sources. This supply is in response to the energy demand by end-use sectors.

The California Energy Planning Model

The purpose of the California Energy Planning Model is to provide computational tools and data bases necessary (a) to calculate the total direct requirements for capital, manpower, and materials, and (b) to estimate the environmental residuals. These impacts are computed for each air basin and each energy facility. The model while dimensionally quite large is structurally straightforward, proceeding from a specified future energy fuel mix or energy scenario through a series of submodels to estimate resource requirements.

The CEPM translates the scenarios into the number of energy facilities of each type that would have to be constructed to meet the specified energy demand. They include stationary facilities such as coal mines, various types of power plants, oil wells, solar and wind generators, etc., as well as energy transportation and distribution facilities. End uses such as refrigeration and space conditioning are also included. The CEPM contains algorithms for determining the transportation facilities required to move the coal, oil, gas, and other energy fuels. The number of trains, pipelines, trucks, etc. are estimated on the basis of energy supply and demand by origin and destination specified in each scenario.

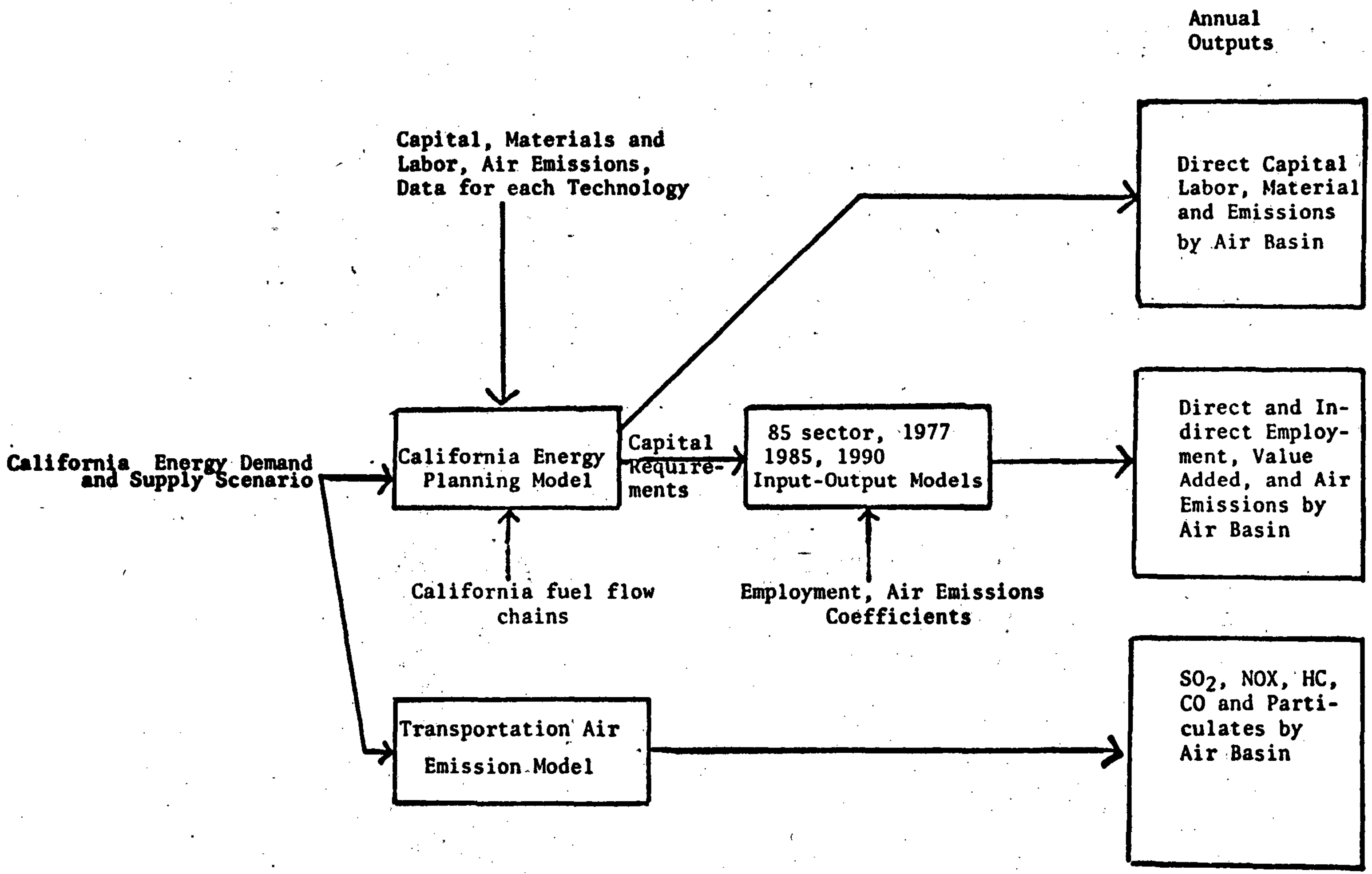

Figure II-1. — Analytical Framework of the California Energy System Assessment Model

All the energy facilities are sited by air basin. Power plants for which information is available from utility plans can be sited directly in the appropriate basin. End uses and solar and biomass facilities for which no information is available are sited by the model.

The capital and labor needed to operate and construct each type of facility are subdivided into 98 resources. Capital costs include expenditures on manpower, equipment, and materials plus taxes and utility costs. Equipment and materials costs are presented by two-digit I-O sectors. On the basis of these data, the direct capital costs and labor required to meet the prescribed energy supply are computed. The 1978 CEPM data base was augmented at LBL to include data on solar and other renewable facilities and on residential end uses. These data include estimates of labor and capital requirements only. Data on residential end uses are the costs for increasing the UECs of the appliances.

Residuals from operation of each type of facility are calculated by the CEPM. In addition, a transportation model can be used to estimate the emissions from motor vehicles. This model, which is described in a separate report [1], allows users to estimate the annual tonnage of sulfur oxides, particulates, carbon monoxide and hydrocarbons emitted into each air basin. It uses the results of CARB's emission factors model (EMFAC6) [2] to provide a quick and simple means of deriving these results while allowing the user to easily modify its energy-sensitive parameters.

The California Input-Output Model

The capital expenditures on materials, equipment and labor for all facilities calculated by the CEPM are treated as changes in final demands in the I-O model. The I-O model estimates the annual output of each industry required to meet these final demands for the next twenty years. The industrial output estimates are used in turn to calculate changes in statewide income and employment. These estimates of employment, income and output are disaggregated to air basins and service areas. Emissions of airborne pollutants are calculated for air basins from the industrial output estimates.

The 1977 U.S. Input-Output Model was derived from the 496 sector national table for 1972 prepared by the Bureau of Economic Analysis. The table was updated to 1977 and adjusted to reflect the California economy for 1977. The adjustment eliminates sectors of the national economy that are not in California such as coal mining and tobacco and eliminates purchases of goods imported into the state. The technical coefficients which reflect the production technology do not change in such an adjustment. To better reflect the state's industrial energy consumption by fuel type, we modified the technical coefficients for fuel use in the California I-O table.

The 1977 California table was projected to 1985 and 1990 on the basis of national projections made by the Bureau of Labor Statistics for those years. In deriving the coefficients for 1985 and 1990 we assumed that the California 1977 coefficients would change at the same rate as the national coefficients between 1977 and 1985 and 1990. The energy coefficients were again adjusted to reflect the forecast use of energy in California in 1985 and 1990.

D. Potential for Applications

The models can be used jointly or individually to evaluate impacts of various energy alternatives. Potential applications of these models are listed in Table 1.

Table II -2. -- Potential for Applications

	Type of Analysis	Models	Need for Additional Data
1.	Labor and Capital Requirements for Alternative Supply Scenarios	Energy Planning Model	None
2.	Labor and Capital Requirements for Alternative Demand and Supply Scenarios	Energy Planning Model	Need data if end-use technologies are to be evaluated
3.	Primary and Secondary Capital, Labor and Income Comparison	Energy Planning Model Input-Output Model	None at present except note item 2.
4.	Primary Material Reqirements of Alternative Supply Scenarios	Energy Planning Model	Need data on physical quantities of materials for solar technologies
5.	Primary and Secondary Material Requirements of Alternative Supply Scenarios	Energy Planning Model Input-Output Model	None
6.	Emissions of Air from Supply Activities and Transportation	Energy Planning Model	Need additional data for solar technologies.
7.	Secondary Industry Emissions of Alternative Supply and Demand Scenarios	Energy Planning Model Input-Output Model	None except item 2.
8.	Secondary Labor, Income and Industry Emissions due to any Economic Program.	Input-Output Model	Need to specify program in terms of its capital needs.

COMPARISON OF TWO SCENARIOS

The California Energy Commission developed two scenarios for their Second Biennial Report [3,4]. The two scenarios are the "Conventional Outlook Scenario" and the "Alternative Resources Scenario". The "Conventional Outlook" scenario is an extrapolation of current trends. It projects that several new power plants will be built in California and that the state would continue to rely heavily on fossil fuels in the future. The "Alternative Resources" scenario assumes high levels of conservation and the use of alternative sources of energy. In this section we compare the direct and indirect economic and environmental impacts of the two scenarios as an illustration of some applications of the models. The data on resource requirements and direct environmental residuals have not been revived for their relevence to California. The results are useful for comparative analysis; the absolute values may not be correct.

The conventional scenario projects the use of more fossil fuels and less renewable energy than the alternative scenario. More coal-fired power plants are built, and more coal trains and slurry pipe lines will be needed to fuel them. The conventional scenario also requires more refineries of both the high and low gasoline type. Larger amounts of electricity will be generated and distributed to end uses, requiring the construction of more transmission and distribution facilities.

The alternative scenario projects more oil from enhanced oil recovery and more electricity generation from geothermal power plants. More solar space heating and significantly larger number of cogeneration projects are constructed. At the same time it projects more use of natural gas, requiring more gas pipelines and distribution facilities.

Direct Impacts

We analyzed the direct capital and labor requirements and the sulfur oxide and particulate emissions of these scenarios as an illustration of the results from the Energy Planning Model. They are summarized in Table 2.

Table 2. -- Annual Average Direct Economic and Environmental Impacts

	Conventional Scenario		
	1979-1985	1985-1991	1992-2000
Construction			
Capital (Millions of 1978 $)	2333	3199	2534
Labor (Thousand person-years)	15.2	22.8	17.3
Emissions			
SOX (Thousand tons)	383.3	399.5	402.1
TSP (Thousand tons)	39.6	71.5	250.0
	Alternative Scenario		
	1979-1985	1985-1991	1992-2000
Construction			
Capital (Millions of 1978 $)	2985	3200	2847
Labor (Thousand person-years)	22.2	24.7	22.0
Emissions			
SOX (Thousand tons)	380.9	387.5	323.8
TSP (Thousand tons)	39.4	63.0	66.0

Labor requirements for the alternative scenario are more than for the conventional scenario by 26 percent. For the alternative scenario, they decline slightly from an annual average of roughly 22,200 person-years in 1979-1985 period to 22,000 person-years in the 1992-2000 period. In the conventional scenario, they increase slightly from 15,200 to 17,300 person-years. Labor requirements are higher during the 1986-91 period in both scenarios. These labor requirements may be compared with construction employment of 416,000 in 1978 in California [5]. The data base in the model can also be used to compare the specific labor skills that might be needed for construction and operation of these facilities.

In the alternative scenario, solar space heating and cogeneration account for 36 percent of the total labor requirements in the first period and 45 percent over all periods. In the conventional scenario, onshore primary oil recovery and refineries account for 29 percent of total labor requirements in the first period and 19 percent over all periods. This decline is due to smaller labor requirements for refinery construction and for primary oil recovery in the other periods.

In the conventional scenario electricity and gas distribution facilities require 14 percent of labor and coal power plants require 40 percent of labor from 1986 to 2000. In the alternative scenario comparable distribution facilities require 13 percent of labor and coal power plants require only 2 percent of labor from 1986-2000.

Capital requirements follow trends similar to those exhibited by labor requirements. The total capital needed for the alternative scenario over the 22 year period is $7.4 billion or 13 percent more than that needed for the conventional scenario. The direct labor intensity of this investment is also higher for this scenario -- 7.6 person-years per dollar of investment compared to 6.8 person-years in the conventional scenario, a difference of 12 percent.

Air basins 6, 4, and 1 (South Coast, San Joaquin, and S.F.Bay) will see the largest increase in labor requirements and therefore in jobs due to energy construction. Basin 6 will benefit significantly more due to higher investment in the alternative scenario. Labor intensity, defined as the ratio of person-years of effort to million dollars of capital investment, is significantly higher in basin 1 than in the other two basins in both scenarios. Again the alternative scenario has higher labor intensity, basin 1 has a ratio of 9.7, basin 6 has a ratio of 8.0, and basin 4 has a ratio of 6.3. The lower ratios in basins 4 and 6 are due to a larger penetration of conventional energy facilities. Since only alternative technologies are located in basin 1, the labor intensity is much higher.

Sulfur oxide emissions increase marginally in the conventional scenario from 383,300 tons/year to 402,100 tons/year. Forty-five percent of these emissions are located in basin 6. Emissions decline from 48 percent to 41 percent over the 20 year period. Major contributors to these emissions are oil fired power plants, refineries, and other fossil power plants. In the alternative scenario, emissions decline to 323,800 tons/year. Emissions either decline or stay the same in virtually every region in California.

In the conventional scenario, particulate emissions increase from 39,600 tons/year in 1978 to 250,000 tons/year in 2000, while in the alternative scenario they reach 66,000 tons/year. In the alternative scenario emissions decline or stay the same in all air basins except basin 8 which is the site of a coal power plant. In the conventional scenario emissions increase or stay the same in every region. The primary contributors to particulate emissions are coal-fired power plants.

Indirect Impacts

Economic Impacts

The statewide indirect impacts of the two scenarios are summarized in Table 3. In both scenarios the impacts decline between 1978 and 1991 as the level of investment in energy facilities declines; then they increase in the year 2000. The indirect impacts were computed for specific years 1978, 1985, 1991, and 2000. These are not necessarily representative of the annual average impacts for the periods surrounding these years. However the model is capable of estimating annual average impacts. Based on the investment levels in the period 1991-2000 the average annual impacts would be lower than the figures shown here although they would still be higher than in the preceding period.

Typically, one-quarter of the final demand generated by the construction activities is supplied by out-of-state sources. The value added generated is about 20 percent lower than the in-state final demand because some of the materials needed for production in California come from out of state sources. Each million dollars of total final demand supports about 20 employees.

Table 3. -- Indirect Economic Impacts of the Conventional and Alternative Energy Scenarios

	Conventional			
	1978	1985	1991	2000
Total Final Demand	2,480	2,130	2,283	3,559
In-State Final Demand	1,799	1,618	1,772	2,790
Gross Output	2,795	2,535	2,738	4,326
Value Added	1,458	1,303	1,442	2,266
Employment	53,950	44,140	43,190	68,500
	Alternative			
	1978	1985	1991	2000
Total Final Demand	2,840	2,787	2,395	3,396
In-State Final Demand	2,577	2,143	1,866	2,820
Gross Output	3,222	3,327	2,889	4,404
Value Added	1,692	1,746	1,517	2,274
Employment	62,520	57,970	45,540	69,430

Note: Values are in millions of 1978 dollars.
Employment in number of employees.

The temporal behavior of the two scenarios shows some differences. In the conventional scenario, the impacts decline by 10-20 percent between 1978 and 1985, rise slightly through 1991, and then increase by about 50 percent by the end of the decade. Impacts in the alternative scenario, which start out 20 percent higher, decline less rapidly during the first seven years, then fall to a slightly higher level than in the conventional scenario by 1991, and finally show a similar increase. By the year 2000, the indirect impacts are about the same in the two cases. Employment declines more rapidly than demand and value added as productivity increases over this period. There is little difference in the amount of employment generated per dollar of total demand between the two scenarios.

Among the sectors that show a greater than average increase in output during the 1978 to 2000 period are Lumber and Wood Products, Nonferrous Metals, Fabricated Metals Products, General Industry Machinery, and Electric Transmission and Distribution Equipment. Natural gas and electricity generation also show large increase, but crude petroleum extraction declines. In comparing the two scenarios, we see that output in the General Industry Machinery sector is much higher in the alternative scenario. Primary Iron and Steel output also increases in the alternative scenario, whereas it stays the same in the conventional. This behavior is in contrast to the Nonferrous Metals sector which shows a large growth in the conventional scenario.

The regional impacts show about the same trends as they do statewide. Of the three major air basins -- S. F. Bay Area, South Coast, and San Diego -- the latter shows the least increase, whereas the other two show similar smaller increases. This effect is smaller in the alternative scenario.

Environmental Impacts

The airborne pollutants from secondary industries are discussed in this section. Table 4 compares the emissions in the three major air basins for the two scenarios. The emissions in the alternative scenario are generally higher except for a few cases in the San Diego air basin. Sulfur oxide emissions in this basin will double by the year 2000. In general, the secondary emissions due to energy development are expected to fall somewhat by 1991 and then increase rapidly.

We cannot conclude, however, that this will lead to lower air quality. First, these quantities are small compared to the total emissions in the basins. Second, increased emissions in one sector may lead to lower emissions in another if trade-offs are required. Finally, these results are based on constant emission coefficients. Tighter standards on emissions would decrease these coefficients and could result in lower emissions than predicted by the model.

Table 4 . — Comparison of Airborne Emissions Between The Conventional and Alternative Scenarios

Carbon Monoxide (CO)
[Tons per Year]

	Conventional Scenario				Alternative Scenario			
Air Basin	1978	1985	1991	2000	1978	1985	1991	2000
S.F. Bay Area	1312	1007	996	1560	1549	1439	1162	1658
South Coast	9011	7669	7056	10227	9902	9151	7698	11663
San Diego	508	462	511	810	596	633	541	805

Oxides of Nitrogen (NOX)
[Tons per Year]

	Conventional Scenario				Alternative Scenario			
Air Basin	1978	1985	1991	2000	1978	1985	1991	2000
S.F. Bay Area	837	726	737	1167	993	1151	994	1357
South Coast	1531	1373	1380	2151	1760	1915	1658	2391
San Diego	142	156	176	275	167	221	207	296

Sulfur Oxides (SOX)
[Tons per Year]

	Conventional Scenario				Alternative Scenario			
Air Basin	1978	1985	1991	2000	1978	1985	1991	2000
S.F. Bay Area	579	484	475	732	668	709	602	835
South Coast	1157	1024	968	1419	1272	1280	1106	1623
San Diego	187	214	243	378	220	306	291	411

Total Organic Gases (TOG)
[Tons per Year]

	Conventional Scenario				Alternative Scenario			
Air Basin	1978	1985	1991	2000	1978	1985	1991	2000
S.F. Bay Area	905	746	730	1168	1028	978	796	1208
South Coast	8134	6834	6843	10895	9494	9260	7595	11331
San Diego	293	280	325	512	337	352	312	495

Total Suspended Particulates (TSP)
[Tons per Year]

	Conventional Scenario				Alternative Scenario			
Air Basin	1978	1985	1991	2000	1978	1985	1991	2000
S.F. Bay Area	637	551	554	905	812	1097	947	1217
South Coast	712	605	586	900	823	846	709	1022
San Diego	147	130	135	216	177	200	169	242

RECOMMENDATIONS FOR FUTURE RESEARCH

The set of models that are described here include the Energy Planning Model, the input-output models, and the transportation emissions model. These models will enable the CEC and CCARB to estimate economic and environmental impacts of alternative energy futures. During the course of the study we uncovered several areas where this analysis would benefit by further research. These topics are described below.

Direct Impacts: Data quality for most of the end-use energy efficiency improvements needs to be improved. On the supply side, the Bechtel model offers an internally consistent data set for capital, labor and materials requirements. A similar data base needs to be developed on the demand side. This is a more difficult task than it is for supply options since energy-using appliances are more dispersed and vary greatly in size and type. Yet, in order to quantify and compare the impact of investment in demand and supply options, a consistent engineering economic data base is essential.

In the California Energy Planning Model demand options are sited in proportion to the population of each air basin. The siting mechanism could be improved to reflect utility and CEC conservation programs in each air basin.

Indirect Impacts: Indirect impacts are estimated using California input-output tables that are based on national I-O tables, except for the energy consumption data which are California specific. The CEC is gathering data on energy consumption and industrial activity in California. The input-output tables can be improved substantially by including these new data when they become available. A second improvement would be to modify the final demand sectors to include the effects of energy conservation measures.

The present model apportions or regionalizes state level impacts using value added data for each air basin and the state. An improved method for regionalization would be to construct regional input-output tables for some of the larger and more diversified regions. Regional multipliers could then be developed separately, and regional employment impacts by skill could also be estimated using employment by occupation data and projections from the California Employment Development Department

Vulnerability Analysis: The set of models developed herein focuses on the estimated requirements and emissions from each facility. They do not address the issue of how susceptible a region would be to such impacts. Research is needed to define the carrying capacity of each region to absorb the impacts. Carrying capacity may be gauged by a set of indicators based on various economic data on industry output, industrial diversity, excess capacity, unemployment level, transportation facilities, proximity to natural resources, etc.

Least-Cost Analysis Our models can estimate costs of alternative scenarios to help determine the least-cost scenario. They can be extended to help select a least-cost scenario using computerized optimization techniques. We have constructed a least-cost model for the State of Hawaii [6] which was used with demand and supply optimization models to determine the least-cost alternatives to oil use. These models are currently being used by the Hawaii Department of Planning and Economic Development. Research is needed to develop a similar set of models for the State of California.

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