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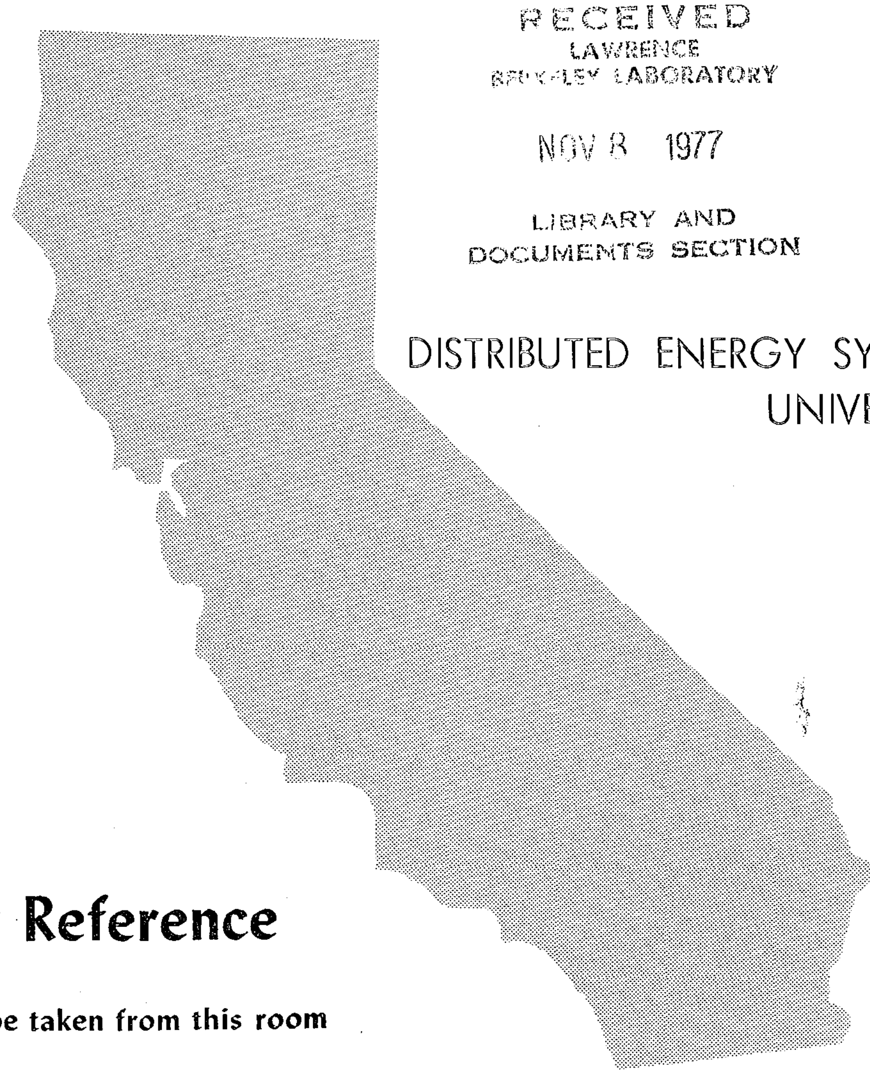
DISTRIBUTED ENERGY SYSTEMS IN CALIFORNIA'S FUTURE:

A PRELIMINARY REPORT
VOLUME 1



DISTRIBUTED ENERGY SYSTEMS STUDY GROUP
UNIVERSITY OF CALIFORNIA

SEPTEMBER 1977

LAWRENCE BERKELEY LABORATORY

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DISTRIBUTED TECHNOLOGIES PROJECT
INTERIM REPORT OF THE CALIFORNIA STUDY

A Collaborative Project Between Lawrence Livermore Laboratory, Lawrence Berkeley Laboratory and The University of California

Work carried out under the auspices of the U.S. Energy Research and Development Administration

CHAPTER I
SUMMARY

During the Winter of 1977 a group of faculty and staff from the University of California (primarily Berkeley and Davis) and from two ERDA National Laboratories (Lawrence Livermore Laboratory and Lawrence Berkeley Laboratory) became intrigued by the prospects for alternative energy futures based on renewable energy forms. A major stimulus to this interest was the work of Amory Lovins, especially his article in Foreign Affairs and his more detailed report presented at the Symposium on Future Strategies for Energy Development, held in the fall of 1976 at Oak Ridge, Tennessee, under the sponsorship of Oak Ridge Associated Universities. At the same time that interest was developing in California, there were several inquiries to ERDA, most notably a request from Senator Henry Jackson, to provide commentary on the implications of Lovins' work.

Out of this interest grew several ERDA-supported distributed technology projects, one of which is the California study. This project was structured during the winter of 1977, and formal work began in the summer of 1977. This interim report thus represents the results of two months of effort on an eight-month study.

In approaching the issue of distributed technologies, it was clear from the outset that it was desirable to look for approaches which differed from those usually used. There was a feeling among many of the persons involved in the initial discussions that most present methodologies for energy analysis tend to be too narrow in concept. One often-repeated

Such a decision was debated and defeated when the H-bomb was proposed. A negative decision was made in the U.S. on the supersonic transport and, only recently, for freon aerosol propellants. Constraints on nuclear energy systems have been debated for a number of years, and the final outcome remains far from clear.

Related to this theme is a belief that energy will for some time continue to be a major issue for our society. The relation of energy and specific supply technologies to well-being, the costs as well as the benefits, will be a focus of on-going debate. In addition, the pressures associated with the transition from reliance upon depleting oil and gas to other energy forms will be extraordinarily great for the U.S. and for the world. While there are many routes which might be taken, there are no assured solutions. Further, there are many potential paths which carry with them the possibility for extreme dislocation. Thus, efforts to develop improved understanding of energy alternatives are highly justified.

Another theme is a belief that local considerations are likely to prove increasingly important in the determination of national energy strategies. It was this perception which led to the decision to focus upon California as a site for a case study.

California is a particularly appropriate region for selection. New ideas have often become visible in California before they became national themes. Examples include clean air standards, protection of environmental values (e.g., the coastline), establishment of legislation to control energy system siting, etc.

To explore future alternatives is to place one in a position of being almost certainly wrong. Yet the rewards of improved foresight can be immense. To view the world too narrowly is a de facto decision to forego the insights which might be gleaned from analysis. C.P. Snow was referring to this in his analysis of the classic confrontation between Lindemann and Tizard prior to the Battle of Britain over the emphasis to be placed on radar (radar was probably the critical determining factor in Britain's victory): "Often, ... a phrase from one of the old Icelandic sagas kept nagging at my mind. It was: 'Snorri was the wisest man in Iceland who had not the gift of foresight'" (Snow, 1962). Through analysis of some unusual (by conventional standards) energy futures for California, we hope to illuminate options open to the United States and the world and perhaps provide some much-needed foresight.

1.1 ASSUMPTIONS

We have focused our attention on the development of distributed energy systems. These are related to what Amory Lovins has called "soft" technologies. Since many problems or issues can be evaluated only in comparison with alternative choices, we include as well discussion of alternative "hard" systems. The criteria we have used in defining distributed systems, adapted from those suggested by Lovins (1977), are that the technologies be:

- o Renewable
- o Environmentally benign
- o Local
- o Subject to graceful failure
- o Foolproof
- o Flexible
- o Comprehensible
- o Matched in energy quality

Renewable. An energy system should draw upon the continuous flows of energy in the earth's environment. A less strict statement of this criterion is that the duration of availability of supply must be considered in making a commitment to any energy technology. Thus we may decide to draw upon an exhaustible fuel for a certain transition period, but we should be aware of the temporary nature of such source and should plan our investments in such a way to ease the eventual transition to renewable energy sources.

Environmentally benign. This criterion seems simple, but its application is difficult. Because different energy delivery options have different types of environmental impacts rather than simply different intensities of the same impacts, the evaluation of relative impact depends partly upon value systems. Thus the successful application of this criterion is linked strongly to the next.

Local. An energy system should draw upon energy sources in the immediate vicinity of the energy demand to be provided. This facilitates but does not assure local control of the energy system. By local control the energy consumers participate in deciding such questions as how much energy is required and with what reliability it must be delivered.

Application of this criterion also leads to putting the environmental impacts of energy systems in the local environment of those receiving the benefits of the energy . Thus local citizens decide what type and what degree of environmental impact they are willing to accept in return for the benefits of energy delivery.

Fails gracefully. When an element of the energy system fails, the system should respond with a graceful readjustment, perhaps by shedding some function or subregion of service. The system should not come crashing down upon failure of one element. This criterion is clearly of importance in designing electric grid systems but is also useful in analyzing other energy technologies. This criterion is strongly linked to the next.

Foolproof. The system should not be highly sensitive to either normal human error or to malevolent actions by a few individuals. To the degree that a technology requires perfect knowledge and judgment on the part of its operators or requires fences and security patrols to prevent access to the system by unauthorized persons (those considered by the operators of the system to have less than perfect knowledge and judgment), that technology fails to meet this criterion.

Flexible. The system should be amenable to subsequent modification to meet changes in the energy demands to be served or in the energy sources available. This criterion reduces the adverse consequences of the inevitable poor decisions that will sometimes be made in planning energy systems. Thus this criterion allows both for the human fallibility of planners and for the fundamental unpredictability of future consumer preference.

Comprehensible. The interested public should be capable of understanding the major features of a technology sufficiently well to participate in decisions concerning its use. It is not required that the public should be able to design and build the system themselves, but rather that they understand the consequences of the use of the technology sufficiently well to make informed decisions as to whether they want to use it. If a technology is so complex that the public, even the informed and interested public, must depend upon the opinions of a few experts in evaluating it, then that technology does not meet this criterion.

Matched in energy quality. The thermodynamic quality of the energy source should match the requirements of the function to be provided. Thus a high-temperature heat source should not be used if a low-temperature source will suffice. This criterion can be related to some of the other ideas discussed above. One linking concept is the aesthetics of design. Supposedly the more closely the energy qualities of source and requirement are matched, the more pleasing the system design.

It will be noted that a variety of environmental and social criteria are embedded among the foregoing criteria. In selecting these criteria as a focus of attention, we have assumed that environmental and social characteristics of technologies will be important among criteria for selection of alternative energy systems. Our assumption regarding the importance of environmental and social criteria is justified by the fact that the relation between energy and well-being is two-sided. The application of energy as a productive input to the economy, yielding desired goods and services, contributes to well-being; the environmental and social costs of getting and using energy subtract from it. At some level of energy use, and for a given mix of technologies for energy supply, further increases in energy supply will produce incremental social and environmental costs greater than the incremental gains to well-being; that is, growth in energy use begins to do more harm than good. Because of perceptions of externalities, under some circumstances society may choose to pay more (in strictly economic terms) for a more benign energy source than for a less benign one. Similarly, society may opt for selecting particular short-term and transition energy sources to facilitate the transition to a longer-term energy future built on more benign and sustainable sources and efficient end use. The fact that the relation between energy and well-being is two-sided places environmental and social impacts at the heart of the energy predicament rather than on the periphery.

Nowhere among this set of criteria do the terms 'cost' or 'economics' appear. This omission stems not only from our initial, fundamental assumption regarding the importance of environmental and social criteria, but also from a conviction that all technologies which have the potential to play a major role on a time scale of 50 years have prospective costs which overlap each other. That is to say, advocates of each technology present optimistic numbers which show their own approach to be economically best. In subsequent analyses we will explore economics of alternative systems. We do not, however, believe that analysis of distributed energy systems should concentrate initially upon costs.

There are other arguments which might support the decision to allow economic factors to play only a small role in the first phase of the study. These arguments derive from the increasingly often expressed viewpoint by some economists and others that our society is entering a stage in which major decisions will be made on the basis of considerations ranging far beyond economics (Heilbroner, Business Civilization in Decline; Daniel Bell, The Coming of Post-Industrial Society; J.K. Galbraith, Money and the Affluent Society; etc.).

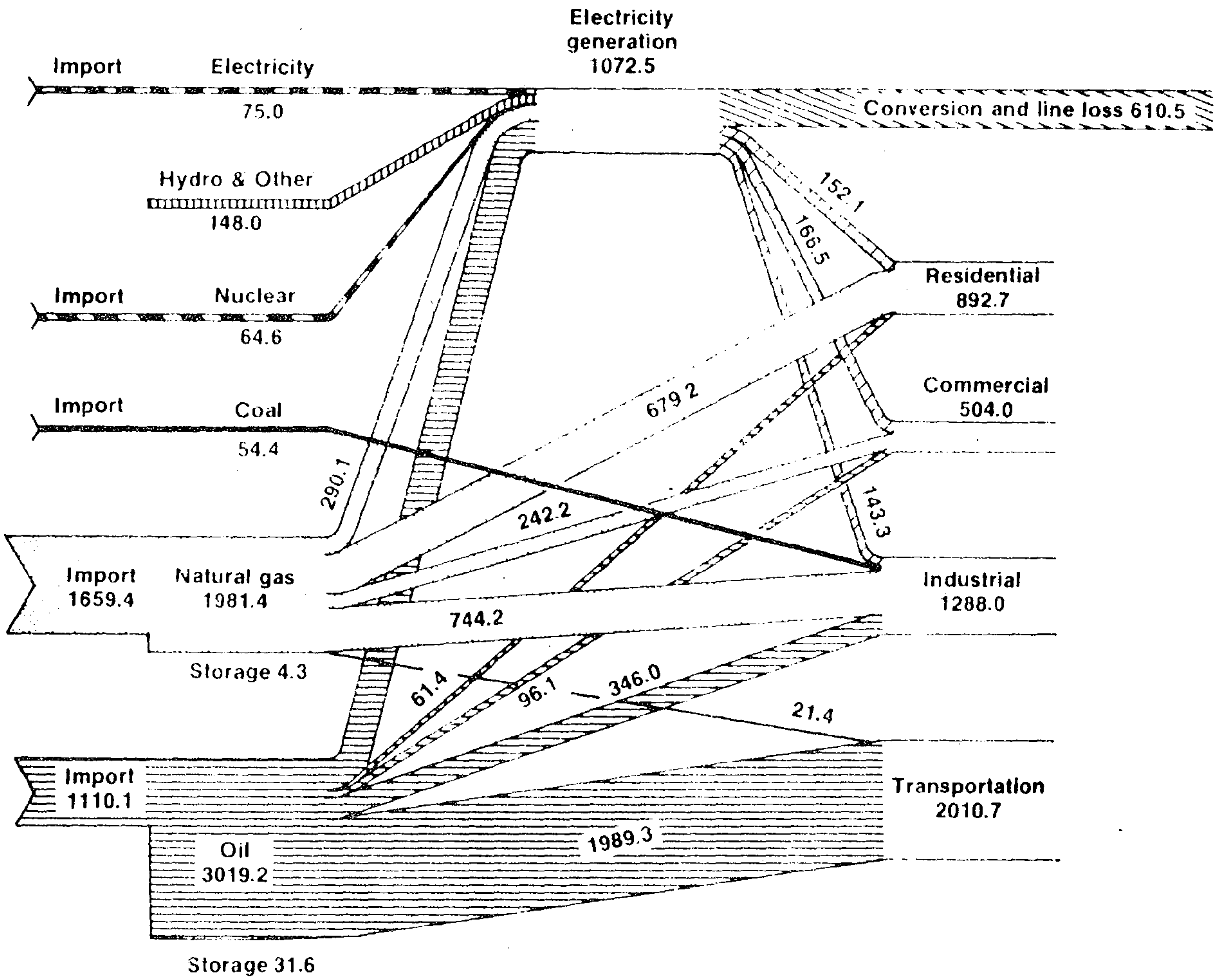
In setting out to assess issues and problems in the development of energy systems based on the foregoing criteria, we have begun to do the following things: 1) assess the California setting in which development of the energy system will take place (Chapter IV); 2) analyze availability of renewable resources and provide a preliminary matching of those resources to demands, as inferred from assumed projections of population and the economy (Chapters V, VI, and XI); and 3) analyze an array of environmental and social factors that bear on implementation of alternative energy systems (Chapter VII and Volume 2).

1.2 THE CALIFORNIA SETTING

California is the nation's most populous state. Viewed in terms of energy use, California would rank as the ninth "nation" in the world. This energy supplies the eighth largest economy in the world and the most affluent economy. California may properly be thought of as the prototypical example of the "post-industrial society," i.e., a society experiencing the changes characteristic of the most advanced social and industrial systems. The society is dominated by high technology, rapid expansion of the service sector, utilization of extensive knowledge generation and transmission facilities, and increased resources for and vulnerability to change.

The patterns of energy supply and use in California differ from national averages in important ways. These are reviewed in Chapter IV and are summarized here. On a per-capita basis, California uses only 85 percent as much energy as the national average. Transportation energy use is 8 percent greater than the U.S. average. Residential sector energy use is 68 percent of the U.S. average, a difference which results from the unusually mild climate. Industrial sector use is 65 percent of the U.S. average on a per-capita basis as a result of the dominance of the service sector. The overall supply balance situation in California is summarized in Figure I-1.

The shift to emphasis on the service sector has been going on in California for many decades. Related to the emphasis on the service sector is a need to import manufactured goods. Manufactured-good imports are offset to a large degree by agricultural exports and entertainment and recreation. Manufacturing industries do use less energy in California than the U.S. average. For every 1000 kilowatt-hours of energy used, California produces $158 of value added as compared to only $94 for the nation as a whole. The largest single industry in the state in terms of energy is agriculture, which uses directly about 5 percent of the energy in the state (and several times as much when indirect energy is included). Agriculture also uses about 85 percent of all the water in the state.



Source: Los Alamos Scientific Laboratory (1975)

Figure I-1. Energy Sources and Uses in California—1975 (10^{12} Btu)

(This figure also appears in Chapter IV—Figure IV-1.)

In recent years the California energy supply situation has shifted strikingly. At the turn of the century, California was a major producer and consumer of oil and coal. Coal is no longer produced, and oil and gas production is declining rapidly. By 1975 the total energy use in the state was 6500 trillion Btu/year. Of this, only 44 percent was produced internally, with 32 percent coming from other states and 24 percent from foreign sources. The state relies heavily on oil and gas, with oil presently providing 62 percent of the total energy and gas providing 31 percent.

Among the many energy issues facing the state are: expansion of nuclear energy systems; strategies for importing gas as liquid or through pipelines; policy on importing oil both for local use and for transshipment to other states; tradeoffs between energy supply expansion and conservation; the environmental implications of additional energy use, particularly in coastal areas; and the land use implications of expanding energy systems.

To assist in addressing energy issues, California has taken major steps in restructuring its institutions. The California Energy Resources Conservation and Development Commission was established in 1975 and has authority over siting of electricity plants and standards for energy conservation, as well as responsibility in other areas. The Energy Commission must interact with over a dozen other agencies having authority of one sort or another in the energy area, especially including the Public Utilities Commission, the Air Resources Board, and the Coastal Zone Commission. Special interest groups are numerous and influential in California. These cover the full spectrum from industry groups through environmental lobbying and litigating groups. Sensitivity over the environmental implications of energy development is particularly high in California and has given rise to many confrontations. Among the most interesting recent situations have been the debates over a nuclear moritorium, over siting of liquified natural gas terminal facilities, over oil terminals in the environmentally polluted South Coast air basin, and over rate reform in utility pricing practice.

1.3 THE CALIFORNIA ENERGY RESOURCE BASE

A major objective of this study is to explore the prospects for operating an advanced society primarily upon renewable resources. The resource base within the state must be characterized in order to permit evaluation of the resource limits. The resource base analysis can proceed from two different perspectives: the total theoretically available resource and the amount of resource which might reasonably be utilized. The approach taken here is to assess reasonable upper bounds on energy resources. In so doing we have tried to make conservative assumptions, in the sense that new technologies or approaches could expand the resources considerably beyond those developed here.

The solar insolation falling upon California is more than ample to meet virtually any energy need. Taking a typical insolation level of 1370 Btu/ft^2/day, insolation into California is 2,450,000 trillion Btu/yr (regional variation within the state amounts to about 30%). This is 350 times the fossil energy presently used. Practical considerations limit the actual resource considerably. Table I-1 summarizes our estimates of the likely limits. The details of the estimates are presented in Chapter V. Practical conversion efficiencies from biological processes are about 1 percent of insolation which still allows for abundant energy. Water and land constraints are critical. About 10-15 million acre-feet of water are required to produce 1000 trillion Btu/year from biomass. The total utilizable water resource in California is about 40 million acre-feet per year, the bulk of which is committed to agriculture. The 4000 trillion Btu estimated from these numbers must be scaled down by about an order of magnitude due to other claims on water. The final estimate of 570-710 trillion Btu includes municipal solid and liquid waste, agricultural residue, etc.

California has an extensive coast line, and the kelp growing offshore provides a major potential resource. Analyses were performed for kelp farming of 10,000 and 20,000 square miles of ocean, leading to ranges of resource of 460-920 trillion Btu/year.

Table I-1

Summary of California Energy Resource Estimates for the Year 2025

Resource	Annual Energy, 10^{12} Btu		
	Heat	Electricity or Mechanical	Fuels
Solar Energy	immense	immense	
Biomass, Land			570-710
Biomass, Ocean			460-920
Wind		2400-9400	
Geothermal	34000	670	
Hydroelectric		230	
Ocean Energy		Nil	
Fossil Fuels			Nil

This table also appears in Chapter V—Table V-13.)

The wind energy resource base was estimated at 2400-9400 trillion Btu/year, the uncertainty due to poor data. Constraints on land use and technical inability to use low-velocity wind may combine with environmental/aesthetic limitations to make this upper limit difficult to achieve.

Geothermal energy may be a rich indigenous resource for the state. Estimates of the maximum potential resource go as high as 20,000 megawatts of electricity, corresponding to about 670 trillion Btu per year. Whether this resource can be extensively developed and whether it will last for long periods is unknown.

Solar power for building heating and cooling and for electricity generation has no practical resource limit. The effective limitation is based upon other claims on land, which are discussed below.

The fossil resource base of California is declining, and there is no possibility of meeting a significant portion of the state's energy needs in the next century. Fossil fuels will, however, continue to be available at some costs, and we have assumed these will be used to meet needs for petrochemical feedstocks, lubricants, and waxes and greases.

1.4 OUTCOME ANALYSIS—CALIFORNIA IN 2025

Initial analyses balancing demand against supply for the year 2025 have been made. The demand analysis was based upon the National Academy of Sciences' Demand/Conservation (1977) report developed by the Committee on Nuclear and Alternative Energy Strategies (CONAES) scaled to California population assumptions and modified in some other regards (especially in the transportation sector). Key demographic and economic assumptions are summarized in Table I-2. These procedures have several major consequences; it is assumed that in the year 2025: 1) population of the state will have nearly doubled from its 1975 level, 2) Gross State Product will have nearly quadrupled from its 1975 level, and 3) the structure of the economy is not significantly changed. In addition it is assumed that there is vigorous emphasis on energy conservation, and technologies used are essentially the present state-of-the-art. The analysis is developed in detail in Chapter VI and summarized here in Table I-3. Energy use is divided into electricity, high- and low-temperature, and liquid fuels. Because of a severe liquid fuels problem which developed in the supply/demand integration, a secondary analysis was carried out in which transportation was modified by using electrically-fuelled vehicles for urban transport. The demands with liquid-fuelled vehicles are shown in line f) and with electric urban transit in line g). The electric urban transit assumption decreases liquid fuels requirements at the expense of increasing the demand for electricity.

The results of the analysis can be totalled in terms of energy delivered to final demand or of equivalent primary energy. To estimate equivalent primary energy, we multiply the electricity needs by a factor of three (corresponding to 33% conversion efficiency) and add the other needs. There are considerable ambiguities in this process, especially for comparison with a centralized supply system in which liquid fuels and gas are prepared by conversion of coal or oil shale—with conversion efficiencies of 60 percent and below. The results are summarized in Table I-4, which also scales them to the U.S. (This comparison is not strictly legitimate but may prove useful because of the similarity to many of U.S. total numbers.)

Table I-2

Economic/Demographic Assumptions

	1975	1980	1990	2000	2010	2025
GNP, 10^9\$ [1]	1499	1713	2141	2570	2998	3640
U.S. Population [2]	214	223	245	263	279	305
GNP/capita, 10^3\$	7.00	7.68	8.74	9.77	10.75	11.93
California Population [3]	21.2	22.6	26.1	29.3	32.8	38.6
GSP, 10^9\$ [4]	148	174	228	286	353	460

[1] CONAES "2% linear" GNP growth (1977)

[2] CONAES population projection (1977)

[3] California Department of Finance D-100 Series (1974)

[4] Gross State Product = (GNP/capita) x (Population of California)

(This table also appears in Chapter VI—Table VI-1.)

Table I-3

End-Use Energy (2025)
trillion Btu/year

	1975[6]		A				B			
	Elec-tric	Non-Elec-tric	Elec-tric	Heat <350°F	Heat >350°F	Liquids	Elec-tric	Heat <350°F	Heat >350°F	Liquids
a) Agriculture[1]	36	167	114	13	---	153	114	13	---	153
b) Other industry[1]	140	1100	416	1273	742	---	516	1579	913	
(Paper)			(66)	(195)	(39)		(79)	(234)	(47)	
c) Transportation[2]	---	2100	---	---	---	2110	---	---	---	2910
d) Commercial[3]	140	225	174	132	---	---	225	171	---	---
e) Residential[4]	190	675	167	287	---	---	183	317	---	---
f) Total	506	4266	871	1705	742	2264	1038	2080	913	3063
g) Transportation (electric urban transit)[5] (replaces line c)			790			870	890	---	---	1230
Total (all sectors) (with electric urban transit) using line g) instead of line c)			1661	1705	742	1024	1928	2080	913	1383

Note: Petrochemical feedstocks and lubricants are to be provided from heavy oils here.

(1) Table VI-5,6
(2) Table VI-8
(3) Table VI-3
(4) Table VI-2
(5) Table VI-9,10
(6) California Energy Commission (1975)

(This table also appears in Chapter VI—Table VI-12.)

Table I-4

Energy Use Totals (trillion Btu)

	1975		A		B	
	Delivered Energy	Primary Energy	Delivered Energy	Primary[a] Energy	Delivered Energy	Primary[b] Energy
Liquid-fuelled transport	4772	5784	5582	7324	7094	9170
Electric urban transit	--	--	5132	8454	6304	10160
			Results Scaled to U.S. (quadrillion Btu)			
California scaled to U.S.						
Liquid-fuelled transport	--	--	44	58	56	73
Electric urban transit	--	--	41	67	50	81

[a]Results are calculated assuming electricity is produced with a conversion efficiency of 33 percent and other fuels with 100 percent. This procedure leads to slight disagreement with actual results for 1975.

[b]California results are scaled according to the ratio of populations in 2025 of U.S. (305 million) to California (38.5 million).

These energy needs were then matched with centralized and distributed supplies. The balance for the distributed cases is shown in Table I-5. The procedure used in developing this table is described in detail in Chapter VI. Because of liquid fuels shortages, only the electric urban transport case is considered. The procedure uses biomass to meet liquid fuels needs. On-site solar is used for residential, commercial and agricultural low-temperature needs. Solar-driven cogeneration is used for those industries where it appears appropriate to provide both low- and high-temperature heat, together with some electricity. Geothermal and hydro-power are used almost to the limit. On-site solar electric power is used to meet the remaining electricity needs.

In each case energy storage is assumed which is adequate to provide seasonal averaging. (An analysis of a prototype city under the assumption of short-term rather than long-term averaging has also been carried out and is included in Chapter XI.)

Table I-6 presents a supply/demand balance for a centralized energy system. In this case liquid fuels are assumed supplied by conversion from oil shale or coal. Electrical needs are met using nuclear power, coal and hydro-power. The problems associated with each of these components of the energy system are considerable but are not addressed here, since the focus of this initial phase of the work is on distributed systems.

The analysis leads to certain observations, which may require modification through subsequent work. Subject to the reservation that these may be modified, we summarize our tentative observations here:

- The supply/demand balance presented here required that considerable care be paid to energy conservation. This attention is essential in the distributed cases because of the need to utilize all available liquid fuels. Imperatives toward conservation in the centralized case are of a very different kind; this area has not been addressed in our work.
- The analysis does suggest that an advanced post-industrial state can, at least on technical grounds, be operated using indigenous renewable resources for a population nearly twice the present size and an economy nearly four times the present size.

Table I-5

Supply/Demand Balance Distributed Cases
(trillion Btu)

	A				B			
		Heat				Heat		
	Electricity	<350°F	>350°F	Liquid	Electricity	<350°F	>350°F	Liquid
Biomass[1]								
Waste				480				480
Tree Farm				100				200
Kelp				444				703
On-Site								
Solar Residential/ Commercial/Agricultural		432				501		
Cogeneration[2]								
Conventional	146	195	39		175	234	47	
Geothermal[3]	327				512[4]			
Hydroelectric[5]	136				136			
Wind[6]	666				666			
On-Site								
Solar[7]								
Cogeneration								
High-Temperature	39		259		53		352	
Low-Temperature	162	1078			202	1345		
Solar-Electric[8]	629				700			
Total	2105	1705	298	1024	2442	2080	399	1383

Note: Petrochemical feedstocks and lubricants are obtained from heavy oils and are not included here.

[1] Table V-7

[2] 183 kWh/10^6 Btu heat, see Appendix 4

[3] 13 GW, 85% capacity factor = 96 x 10^9 kWh = 327 trillion Btu

[4] 20 GW, 85% capacity factor = 150 x 10^9 kWh = 512 trillion Btu

[5] 9.2 GW, 50% capacity factor = 40 x 10^9 kWh = 136 trillion Btu

[6] 65 GW, 34% capacity factor = 195 x 10^9 kWh = 666 trillion Btu

[7] Cogeneration sized to meet all low-temperature heat (350°F) and high-temperature (350°F) heat in chemicals, food, asphalt and 40% of other industries. Typical design gives .15 Btu as electricity for each Btu of heat (McDonnell Douglas Corporation, 1977).

[8] 84 GW, 25% capacity factor = 184 x 10^9 kWh = 629 trillion Btu
94 GW, 25% capacity factor - 205 x 10^9 kWh - 700 trillion Btu

(This table also appears in Chapter VI—Table VI-13.)

Table I-6

Supply/Demand Balance Centralized Cases
(trillion Btu)

	A				B			
	Electricity	Heat <350°F	Heat >350°F	Liquid	Electricity	Heat <350°F	Heat >350°F	Liquid
Synthetic Liquids				2163				3063
Synthetic Gas								
Cogenerated Fuel[1]	534		860		591		453	
Cogenerated Heat			824				883	
Other Industry			147				363	
Geothermal[2]	327				327			
Hydroelectric[3]	136				136			
Central Station	4				5			
Coal or Nuclear	1182				1490			
Total	2020		1831		2366		2199	3063

[1]See Appendix 4

[2]13 GW, 85% capacity factor = 96 x 10^9 kWh - 327 trillion Btu

[3]9.2 GW, 50% capacity factor = 40 x 10^9 kWh = 136 trillion Btu

[4]62 GW, 65% capacity factor = 353 x 10^9 kWh = 1204 trillion Btu

[5]77 GW, 65% capacity factor = 459 x 10^9 kWh = 1566 trillion Btu

(This table also appears in Chapter VI—Table VI-15.)

- The land use implications of both centralized and distributed systems are considerable. For distributed, renewable systems special processes relate to the needs of industry for process heat and electricity. Should all the solar process heat and electricity producing facilities be located adjacent to the industry they serve, about 25 percent of the urban land in California would be required.
- The environmental impacts of the distributed systems appear less than those of centralized systems, from many different perspectives (Chapter X).
- System reliability (Chapter VII, XVIII) questions are fundamentally different in distributed energy systems and in systems based on fossil energy forms. Renewable resources fluctuate in their availability due to weather, etc. Reliability of energy can be achieved only through averaging. This averaging can occur in space (through energy storage) or in time (through interconnection). New approaches to and attitudes toward reliability of energy systems may be required for systems based predominantly upon renewable energy forms.
- The inclusion of relatively small quantities of fossil-based energy forms can considerably ease the difficulties of a distributed energy system. Attention to hybrid systems may prove important.

1.5 ISSUES

The analyses which have led to these observations are incomplete. A few of the more important limitations are enumerated here. Pathways to the future described have not yet been explored; economic analysis has not been carried out; embodied energy in imports and exports from California has not been considered; sensitivity of analysis to major changes in energy supply and use technologies have not been undertaken; no vulnerability/resilience analysis has been carried out; the social meaning of the crude, quantitative index of amenity has not been assessed. Our assumptions regarding both supply and demand technology will be reexamined. There are some inconsistencies in the technological assumptions. Thus, the use of kelp as a source of liquid fuel draws upon an undeveloped, highly speculative technology of unknown environmental impact. We could equally well have addressed the liquid fuels problem using hydrogen produced by electrolysis. A careful analysis of individual industries may provide choices which will ease the need for high-temperature process heat, and so on.

Technical characterization of potential outcomes for California in the year 2025 has emphasized engineering aspects. Yet public and private choices for the future will depend in large measure on social and environmental considerations as well. The primary objective of the entire study is to contribute to development of insight into long-term consequences of choices that may be made in the near future. Few choices can be made in isolation. We seek insight into how choices in energy impact on society generally and, conversely, how choices in other matters might impact on development of the energy system. We believe that the greatest contributions we can make will come from exploration of pathways to the future. On the other hand, the development of new methods for exploring pathways is slow and difficult. No one of us has the scope, depth and experience to handle that task alone. We have developed a working group of social scientists and natural scientists. At this stage of development the processes of interaction within the project are as important to us as the results. We began working together three months ago; our efforts to date reflect our separate origins. Integration of our various perspectives into a systematic study of pathways to the future lies ahead. Some themes for the next stage of the work include:

- o Technical issues
- o Environmental issues—an initial framework has been developed so that environmental impacts of very different energy technologies can be systematically compared (Chapter X). The intent is to assure that major issues are not overlooked because no methodology exists for addressing them quantitatively or because existing information is deficient.
- o Land use—all patterns of development of energy systems will have serious impacts on land use, but the impacts of different systems vary greatly. Distributed systems place the problems largely in the hands of local institutions, which developed in very different circumstances to meet very different needs. For distributed systems the environmental and social costs reside at or near the site of the benefits; for centralized systems the impacts of supply technologies are removed geographically from the place where the benefits are received. Institutions are required for overriding local interests in one place for the sake of benefits elsewhere. The impacts on institutions, exercise of political power, and values and expectations of the public are very different. We are studying quantitative aspects of alternative land use patterns (Chapter XII) and institutions and processes for making land use decisions (Chapter XI).
- o Organization—in fundamental ways technology _is_ organization, and it is a basic mistake to regard technology as hardware alone. Not until people are organized to use the hardware for some end does equipment become technology. Different technologies have different imperatives for organization, both for initial production and response and control by government. We are concerned with organizational implications of alternative energy technologies, analysis of alternative modes for governmental control or direction of development of the energy system (Chapter XV) and factors that affect the innovativeness of small business in adapting to alternative technologies (Chapter XVI).

o People—the future development of the energy system will be influenced not only by policies and practices of organizations, both public and private, but also by the private choices and behavior of people. Most social change in fact stems from private choices. We attempt to understand better the behavior of people, both as key actors in organizations related to use of energy and as private consumers, and also the influences that information, ideas, expectations, values and beliefs have on behavior, in order to understand better how those factors bear on alternative choices for development of the energy system and vice versa (Chapters XIII and XIV).

o Economics—we have deliberately set aside economic analysis in order to emphasize technical, environmental and other social factors. Major questions which will need to be addressed include: 1) what are economic factors that bear on development of demand for energy and how are these likely to shape future development? 2) how are increasing costs and scarcity of energy likely to affect the structure of the future economy? 3) How can we estimate aggregate costs of development of alternative energy systems?

1.6 KEY OBSERVATIONS

Out of the work done to date, four central observations emerge. These observations are, we believe, central to all work relating to the evaluation and assessment of distributed energy systems and their comparison with centralized systems.

1) The environmental impacts of certain of the "soft" technologies—notably increased end-use efficiency, active and passive solar heating and cooling with individual building or neighborhood units; fuel production from biomass in the form of wastes, and dispersed on-site wind generators—will prove markedly smaller than those of virtually all the traditional "hard" technologies, as well as smaller than those of the more centralized technologies for harnessing renewables (Chapter X).

The conclusion is preliminary, but review of the structure of the argument makes the conclusion appear to be robust—not likely to be invalidated by modification of the more detailed assessments of specific technologies.

2) Energy/land conflicts and tradeoffs will become increasingly severe. The problem is important for all energy systems. Both the specific impacts and the institutional implications are very different for distributed as compared with centralized systems.

3) Energy systems based on renewable resources will require new attitudes toward stability of energy supply. Unlike fossil fuels, renewable resources must include storage as an intrinsic part of the system.

4) Organizational or institutional problems and conflicts are major considerations in all pathways of development of the energy system.

1.7 CAVEATS AND A REQUEST FOR COMMENTS

We have noted previously and note frequently again later in this report that we are reporting interim results. We are aware of many—though we expect far from all—of the defects in it. The selection of end states was tentative and is subject to modification. The selection of both distributed and centralized energy supplies was made with knowledge of the technological, environmental and institutional difficulties associated with some of them. The scoping of institutional issues is also tentative. The next phase of our work will include changes in assumptions, greater depth of analysis, and more attention to issues relating to the process of transition to alternative futures.

We would appreciate constructive comments on any aspect of the work included in this report—including especially suggestions for changes in assumptions or focus and suggestions as to promising alternative directions for investigation.

REFERENCES

Amory Lovins, Soft Energy Paths—Toward a Durable Peace, Ballinger Press, 1977.

National Academy of Sciences, Demand/Conservation Panel Report of the Committee on Nuclear and Alternative Energy Strategies (CONAES), draft report to be released approximately November, 1977.

C.P. Snow, Science and Government, 1962.

CHAPTER II
INTRODUCTION

"Lovins" energy scenarios are attracting increasing attention among a wide circle of disparate groups in the U.S. and other industrialized countries. Based on the writings of Amory B. Lovins and others, such scenarios are intended by their authors to encompass a wide set of objectives. On one level they are aimed at portraying the technical/engineering feasibility of employing an alternative set of energy technologies to satisfy future energy demands. On another level, they provide the basis for a formidable assault on current strategies being employed to offer the nation substitutes for oil and natural gas. And finally, they present the case for inserting a variety of environmental and societal considerations into the energy determination of national energy goals and priorities many of which have not been seriously considered heretofore in governmental energy planning.

At the most fundamental level, however, Lovins' work is inducing a fundamental reassessment of the structural parameters and criteria for long-term development of the U.S. system of production, distribution and end-use consumption of energy. In effect, a new conceptual framework is being developed for priorities for decision-structures and criteria for the choice of technologies.

While many terms have been suggested to characterize Lovins' work—"decentralization," "distributed," "small-scale," "soft"—none are sufficiently suggestive of either the radical nature of the blueprint or the vastly enlarged societal domain into which energy systems decisions are placed in its formulation. To quote Lovins:

> The second path (Lovins' model) combines a prompt and serious commitment to efficient use of energy, rapid development of renewable energy sources matched in scale and in energy quality to end-use needs, and special transitional fossil-fuel technologies. <u>This path, a whole greater than the sum of its parts, diverges radically from incremental past practices to pursue long-term goals</u>. (emphasis added) (Lovins, 1977)

In substance, Lovins' primary intention is to provoke us into an examination of fundamentals regarding our view of the role of energy in its relationship to society and thus to explore new bases for evaluating possible modes for national energy system development.

Lovins' model is presented in a bare-bones fashion. Its purpose is to encourage the process (going on in this study among others) of trying to define new models. Over a period of time such models can gain acceptability but only if they are more successful than their competitors in offering acceptable approaches to solving some of the central energy problems of the country.

This interpretation of Lovins' work has been somewhat obscured by the tenor of the discussion and commentary elicited in reaction to Lovins' writings (U.S. Congress, 1975; 1976). In part, this reaction stems from the manner in which Lovins has decided to couch his own arguments and theses. Faced with the difficult task of attracting the attention of both his policy analyst peers and policy-makers in government and industry, Lovins has (as is customary for all those who wish to cast themselves in the role of heretics) pushed the conventional model of "centralized high technologies" to its limit in order to call attention to the points at which it may break down. Lovins sharpens the discussion by arguing that there is a mutual exclusivity between the conventional path or model and his own, thereby establishing the entire issue as one requiring immediate attention.

Lovins' articles are highly controversial. They deserve discussion. However, to pose the issue in terms of a confrontation between two opposing paths—one of which we know a great deal about and one of which still exists as only a "quantitative vehicle for ideas"—places an unfair burden on the new entry. This is evident in the attacks on Lovins' soft technology futures. The reactions demonstrate the risks of trying to move too quickly from a new conceptual framework for thinking about energy system development to a specific "solution" strategy. As with any major change in paradigms affecting important areas of societal concern, an initial period of assimilation and exposition is required. The present work is a step in that process.

REFERENCES

Amory Lovins, Soft Energy Paths—Toward a Durable Peace, Ballinger Press, 1977.

U.S. Congress, Committee on Interior and Insular Affairs, U.S. Energy Resources, A Review as of 1972 (and references herein), Serials 93-40 and 92-75, 1975.

U.S. Congress, U.S. Senate, Interior Committee, Joint Hearings before the Select Committee on Small Business and the Committee on Inerior and Insular Affairs, Serials 94-47 and 92-137, December 9, 1976.

CHAPTER III
THE ENERGY PREDICAMENT

3.1 CHANGING REALIZATIONS

It is safe to say that if the optimistic expectations of a few years back that the U.S. and other industrialized countries would be able to substitute alternative energy forms for oil and natural gas in the late 80's or early 90's were still shared by government officials and energy analysts, most of the present work would be regarded as little more than an academic exercise. However, the past few years have seen a broad-based retreat from this optimistic position. Today there is a general consensus among most energy experts that the tasks of developing and placing in operation a set of alternative supply technologies will take considerably longer, will entail much higher monetary investments and will result in much more extensive environmental and societal impacts than had been anticipated a few years ago when the broad outlines of ERDA's current R&D strategy were being formulated.

The significance for U.S. policymakers of this recognition is that the sheer scale of the energy undertaking will inevitably result in a situation in which decisions affecting the choice of future energy technologies can no longer be divorced and treated in isolation from other societal goals and aspirations. For example, extending high priority to breeder reactor technology inevitably implies certain kinds of problems vis-a-vis proliferation of nuclear materials. Likewise, the decision to emphasize technologies for generating electricity through central station facilities carries with it implications with respect to the centralization of energy decision-making processes.

While the degree of interdependence between energy R&D strategy decisions and broad social objectives varies, we all understand that our daily lives will be powerfully affected by decisions taken with respect to energy R&D policy. This collective realization has served as a major stimulant for the creation of a favorable environment for putting forth new approaches to the nation's (and the world's) energy problems. We identify three implications as they relate to energy planning and assessment.

3.1.1 Access

The first is that the processes by which future U.S. energy choices are assessed must assure that probable developments and impacts on a broad range of social criteria will be assessed and factored into energy decisions. It is increasingly required that the design of energy systems must follow from our understanding of what we wish our pattern of energy end uses to be. This requisition tends to shift the emphasis in energy system planning away from the producer perspective to that of the user. It also acknowledges that it is not really possible to divorce the value systems of those laying out the R&D options from what they propose.

3.1.2 Implementation Analysis

Interdependence implies that the decision structure utilized in constructing alternative energy R&D strategies cannot be separated from implementation analysis. There is much to suggest that decision tools currently used in assessing energy R&D strategies implicitly acknowledge this interrelationship between decisions and implementation by restricting the alternatives examined to those which are consistent with our present energy system infrastructure. Most analyses to date assume continuation of the current private sector and utility control structure of energy production, distribution, and end use. Given the magnitude of the energy problems facing the nation and the world, however, new approaches may be essential. For just as we find it necessary to consider a broader set of social criteria with respect to technical energy R&D decisions, there is a need to examine new infrastructure arrangements not tied to the maintenance of what already exists. Basic to those considerations are the organizational arrangements making up the energy industry and its relationship with decision-making agencies within government.

3.1.3 The Political Dimension

The political dimension is the third major implication of interdependence. New constituencies favoring particular technological solutions are increasingly influencing energy programs. Differences in the impact of alternatives in their effects on the poor, on organized labor, and on industrial profits also mean that we can expect pressures to relate energy R&D policies and programs to special interest groups.

In much energy R&D planning, more attention is paid to the future economic environment into which the proposed alternative energy supply technologies are supposed to fit than to the political environment which will affect the public acceptance of such technologies when they are ready to be put into operation. This occurred with the SST and to a large extent with light water reactors. Breeder reactors offer another demonstration of the failure to take account of the political environment. Political unacceptability of many of the environmental and control aspects of high technology energy supplies will increasingly be the determining element in limiting their utilization.

3.2 THE EFFECTS OF PROLONGED CRISIS

Should the energy crisis in the U.S. and throughout the world significantly worsen within the next decade and beyond (i.e., should shortages begin to develop in fossil fuels or prices reach levels where substantial hardships are imposed on significant parts of the world's population), it is likely that increasingly radical approaches will be seriously considered by responsible governments. What distinguishes the energy crisis in the U.S. up to now from the real crisis of the 30's depression or war-time situations is the lack of significantly perceived deprivation on the part of a large segment of the public. (Except for the '73 embargo, the crisis has in fact been an "energy experts' crisis.")

This situation could change rapidly. For example, repetition of area-specific stoppages such as happened during the 1976-77 winter season in the East and Mid-West could reoccur because of the inherent difficulties associated with insuring an equitable allocation of resources in the presence of limited total supplies.

Seen in this light, current perspectives concerning the opportunities for alternative modes of future development of the nation's energy system is likely to undergo a number of important modifications.

Traditional views of the future assume that the country will have the time to proceed to modify our energy system in a somewhat orderly and systematic fashion from its current heavy dependence on oil and natural gas to one of dependence on essentially inexhaustible resources. Lovins' article in Foreign Affairs, for example, deals with a transition strategy which moves away from a dependence on the use of coal to a "soft technology" future. Similarly, coal is viewed by ERDA plans as the primary transition fuel, with breeder reactors, fusion and solar-electric seen as the ultimate inexhaustibles. In both scenarios, however, less attention is paid to the details of the transition than to the outcome. On the other hand, the ability of the nation to respond to sudden oil shortages in the 1985-2000 period without major economic and political disruption has become the nation's and the world's major concern. The accelerated reactor construction programs in Germany, France and Japan are evidence of this, as is President Carter's energy conservation and coal-replacement programs.

3.3 CONSTITUENCIES, SOCIAL GOALS AND ENERGY SYSTEMS

For the greater parts of its existence, the actors involved in making decisions on how energy was produced, distributed and consumed in the United States could count on almost a total lack of interest among the public and legislative bodies. Such behavior was not due to any great faith in the institutions that determined policy in these areas. Energy was simply cheap, plentiful, out-of-sight and out-of-mind. These conditions no longer hold. The onset of the environmental movement, the focus on energy facility siting, concern for the risks associated with nuclear power, and urban pollution generated by automobiles have all combined to make apparent that ill-advised energy decisions could pose a threat to all. As a result of this recognition, energy decision-makers at every level became increasingly accountable to larger numbers of government agencies and public interest organizations.

Until recently, the relationships between the energy industry, i.e., oil companies, utilities, manufacturers of energy production and conversion and consuming equipment, and environmental interests, had settled down more or less to one in which most decisions are preceded by lengthy proceedings followed by hard bargaining sessions. Such a procedure represents a tacit recognition on both sides that power to influence the final outcome is shared. More importantly it acknowledges that while each side will continue to articulate opposing points of view, each side also recognizes the basic validity of the others position —to wit, we must provide energy to meet any and all reasonable demands but at a minimal cost to the environment.

More recently energy decisions have become the focus of a new set of interest groups. Because the source of interest of the groups emanates from the espousal of a broad set of social goals and values applicable to a wide range of individual-society interactions, the attack of these groups on the existing energy system in the U.S. is much more pervasive. Decisions and choices affecting what is or not included in such energy systems must follow, these groups maintain, from their relationship to certain societal outcomes. Energy must serve to support the desired social structure and not vice versa.

All energy strategies should take into account contingencies and how contingency planning relates to long-term outcomes. In most current planning, only a limited amount of attention is being paid to the implications of short-term options in terms of the eventual technological structure of the nation's overall energy system. But current government initiatives being considered in these and other areas to resolve these near-term problems will have pronounced effects on the flexibility of policy-makers at a later date to influence the longer-term form of energy production, delivery and consumption. This situation may be aggravated if evidence of energy cutoff becomes an increasingly important component of energy system decisions.

CHAPTER IV
THE CALIFORNIA SETTING

If California were a country it would rank ninth in the world in total energy consumed, following the United States as a whole, U.S.S.R., China, Japan, Germany, United Kingdom, France, and Canada (Bradshaw, 1977). This energy supplies the eighth largest economy in the world, and one of the most affluent. In this chapter we review this existing energy system and point out a number of important characteristics of the California setting. As will be shown, California is now increasingly dependent upon other states and nations for its energy even though it uses less energy on a per capita basis than the nation as a whole. The large energy industries play an important part in the California economy, being among the most concentrated of all industries. Government is heavily involved in the California energy industry through some 20 state agencies with regulatory or policy control. Finally, it will be shown that the state's energy system as a whole is affected by a broad social context unique to the state, one that may be described as an "advanced industrial society," which is at the cutting edge of social and economic development. This social development has important implications for the state's ability to implement a distributed energy future.

4.1 RECENT TRENDS IN ENERGY SUPPLY

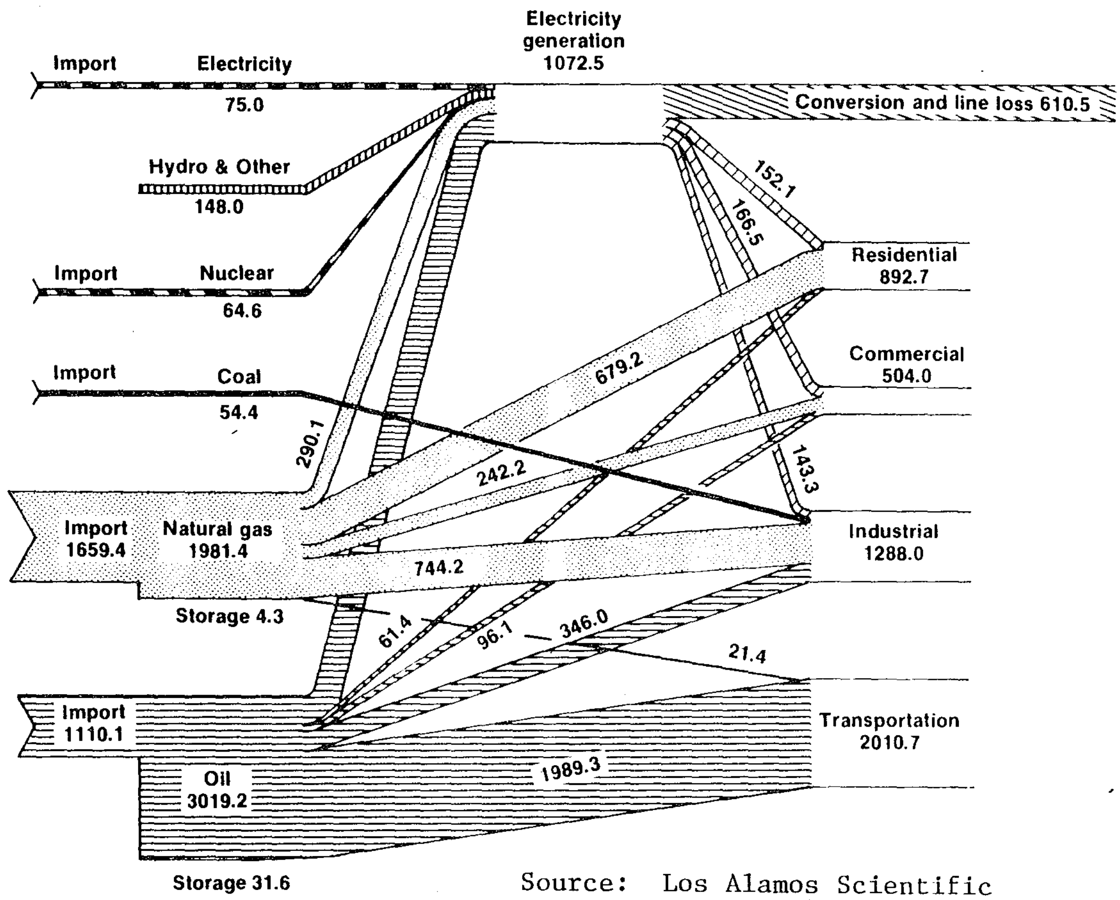
Uses of all major energy forms have been increasing in California over the past decades; however, the steady growth of the past has been disrupted by several recent changes. The most important of these changes is that, faced with a growing shortage of in-state fuel supply, California is now looking for out-of-state fuel sources. This section will show the recent energy supply trends for the major sources of energy for California. This section is largely based on the report, Impacts of Future Coal Use in California by the Lawrence Berkeley Laboratory (Siri, 1977).

4.1.1 General Trends

California depends largely on fossil fuels for its energy, especially oil and gas (Figure IV-1). The historical trend has been for California to import fuel in increasing amounts, because of diminishing in-state supplies of gas and oil. "In fact California has not been self sufficient in terms of energy supply and demand balances of these two fuels since the late 1940's" (State Energy Commission, 1977). Table IV-1 shows the energy supply to California and the percentage supplied in state. As can be seen, California is increasingly dependent on out-of-state and foreign imports of energy to meet demand.

4.1.2 Oil Trends

Prior to the 1930's California was a major oil exporting state. However, the state's oil production peaked in 1953 at one million barrels a day. New discoveries and the use of secondary recovery methods, which allowed recovery of more oil from depleted fields, caused production to peak again at about a million barrels a day in the 1968-70 period (Schwartz, 1976). Table IV-2 summarizes the supply and demand for oil in the past fifteen years. The recent decline in California oil production is due mainly to depletion of the old oil-producing fields. In addition, the U.S. Department of Interior and the California State Lands Commission imposed moratoria on development of offshore petroleum leases in the Santa Barbara Channel following the 1969 oil spill there. These moratoria have only recently been lifted, and new conditions (much stricter than pre-1969) have been imposed on offshore oil and gas development. In 1975 the Department of Interior auctioned offshore leases on more tracts off Los Angeles and south of the Channel Islands. Along with these newly permitted development activities, the much increased price for "new" oil appears to be halting the decline in production of California oil, and a slight increase occurred in 1976. Table IV-2 also shows the increase of the use of foreign imports to make up for the depleted in-state supply.



Source: Los Alamos Scientific Laboratory (1975)

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Figure IV-1. Energy Sources and Uses in California—1975 (10^{12} Btu)

Table IV-1

Primary Energy Supply to California (10^{12} Btu)[a]

	1960	1965	1970	1975
Petroleum	2210	2386	2951	3161
Natural Gas	1454	1934	2363	1987
Hydroelectric[b]	174	324	472	645
Geothermal[b]	0	3	6	32
Nuclear[b]	0	3	31	61
LPG	42	49	66	69
Coal	52	57	93	162
Total	3932	4756	5982	6117
Total In-state Resources	2468	2814	3272	2542
Percent In-state Resources	63	59	55	42

[a]Source: Siri, 1977.

[b]Converted to primary energy equivalent using 10,000 Btu/kWh.

Table IV-2

California Petroleum Sources and Sales[a]

	1960[b]	1965[b]	1970[b]	1975[c]
Crude Oil Sources—in 10^6 barrels/yr, (10^{12} Btu/yr)				
California	300 (1740)	313 (1814)	379 (2197)	296 (1717)
Other States	17 (97)	25 (144)	74 (432)	60 (348)
Foreign Imports	64 (373)	74 (428)	55 (322)	189 (1096)
Total	381 (2210)	412 (2386)	508 (2951)	545 (3161)
Oil Sales—in 10^{12} Btu/yr				
Gasoline	752	934	1153	1244
Jet Fuel	137	275	411	351
Distillate	163	214	236	292
Residual	500	431	421	809
Other	411	459	560	336
Total	1963	2313	2781	3032

[a]The difference between the supply and sales is mainly due to refinery and transport losses, and miscellaneous product imports and sales. Source: Siri, 1977.

[b]Schwartz, 1976

[c]Stanford Research Institute, 1973.

4.1.3 Natural Gas

Natural gas production in California (see Table IV-3) has paralleled oil production. Production of wet gas, which is that produced in fields in association with oil, has declined precipitously since 1969 as the oil fields of Southern California and the San Joaquin Valley have been depleted. Production of dry gas, which comes from fields with only gas reserves, has also declined. The explanation of this, however, lies not so much with resource limits as with the policy of Pacific Gas and Electric, the only major buyer for this gas in the Sacramento Valley and Delta areas. PG&E reserves this gas to meet peak demands and treats it as a form of energy storage. During 1975 California dry gas production was only 48 percent of production capacity.

The most significant trend in the supply of natural gas since 1973 has been the increasing magnitude of curtailments of interstate deliveries. Curtailments began in the nation in the 1970-71 season, when about 0.2 trillion cubic feet (Tcf) of natural gas (out of 20 Tcf) were curtailed in the U.S. interstate market. Curtailments have risen in the nation in approximately a linear fashion since 1970, with annual curtailments reaching about 4 Tcf (or almost 20% of natural gas supply) in the 1976-77 season (CPUC, 1975). California has experienced a similar increase in natural gas curtailments of its supplies from the Southwest: 5 percent in 1973; 9 percent in 1974; 14 percent in 1975; and 18 percent in 1976. The 18 percent curtailment of natural gas from the Southwest in 1976 represented a curtailment of about 9 percent of the total gas supply to California. As such, California has experienced reductions in natural gas supply that are only about half of the reductions felt by the rest of the nation. However, the effects of these reductions in natural gas supply have been significant in California, especially because the gas has generally been replaced by oil, whose emissions during combustion are significantly greater than those of natural gas. The environmental problems that California faces, and especially the air pollution problems in selected air basins within the state, are significantly aggravated by the natural gas curtailments to the state.

Table IV-3

California Natural Gas Sources and End Uses[a]

	1960	1965	1970	1975
Sources—Marketed Production—in $10^9 ft^3$ (10^{12} Btu)				
California	515	644	642	368
Canadian	0	151	294	365
Southwestern U.S.	838	1004	1262	1159
Total	1353(1454)	1799(1934)	2198(2363)	1892(1987)
End Uses—in 10^{12} Btu				
Residential	394	526	594	664
Commercial	117	176	226	205
Industrial	342	412	615	557
Electrical Generation	348	530	684	295
Miscellaneous[b]	264	278	230	235
Total[c]	1465	1922	2349	1956

[a]Source: Siri, 1977.

[b]This category includes production and processing use, transportation, chemical feedstocks and other miscellaneous uses.

[c]The slight mismatch of total supply and demand is due to rounding errors, and to different data sources.

4.1.4 Electrical Energy Trends

In 1960, the two major sources for electrical energy for California were natural gas-fired generation and hydroelectric generation, as shown in Table IV-4. Hydroelectricity increased over the fifteen-year period 1960 through 1975, while natural gas use peaked in 1970, then declined by nearly 60 percent in the last five years. This decline in availability of gas has been made up primarily by residual fuel oil. During this period both geothermal and nuclear power plants were constructed and placed in operation in California. However, by 1962 it was necessary for California to import electrical energy and power from out-of-state sources, primarily from the Bonneville Power Administration in the Pacific Northwest. By 1970, imported electrical energy accounted for 10 percent of the supply, most of which came from the Bonneville Power Administration, (shown as 'Transfers' in Table IV-4) and the remainder from coal-fired facilities in the Southwest partially owned by two southern California utilities. By 1975, imported electrical energy was 22 percent of the total California use.

4.1.5 Other Fuels

Two other fuels contribute to California energy supply. Liquified Petroleum Gas (LPG) and Coal, as shown in Table IV-5. LPG production and consumption has grown about 3 percent per year, although for 1975 the supply level shown may be an underestimate, since refinery production of LPG apparently has not been included. Coal supply has been nearly constant for the past 15 years. The coal imported into California has been mainly high-Btu, low-sulfur metallurgical grade coal for coking use in steel making (California Energy Commission, 1976). More recently, there has been some coal used as fuel for cement making. Another source, not shown in the tables, is wood, which between 1960 and 1970 (the last year for which we have data) produced between 15 and 18 x 10^{12} Btu per year (Siri, 1977).

Table IV-4

Electrical Energy Generation and Sales for California (10^9 kWh)

	1960[a]	1965[a]	1970[a]	1975[b]
Generation				
Hydroelectric	17.4	30.5	37.9	40.7
Natural Gas	31.7	51.6	67.4	27.3
Fuel Oil	14.6	10.4	13.0	48.3
Geothermal	0	0.3	0.6	3.2
Nuclear	0	0.3	3.1	6.1
Total (in-state)	63.7	93.1	122.0	125.6
Transfers	—	1.9	9.3	23.8
Coal (out-of-state)	—	—	3.7	10.7
Total Generation	63.7	95.0	135.0	160.1
Sales (end use)				
Residential	19.8	23.0	34.6	43.5
Commercial	14.0	30.0	48.3	40.9
Industrial	22.1	29.7	39.1	44.8
Other	0.3	0.4	1.1	16.2
Total Sales	56.2	83.1	123.1	145.4

[a] Stanford Research Institute, 1973.

[b] California Energy Commission, 1976.

[c] The difference between generation and sales is predominantly due to transmission losses.

Source: Siri, 1977.

Table IV-5

Miscellaneous Energy Sources and Uses 10^{12} Btu

	1960	1965	1970	1975
LPG—Supply[a]	42	49	66	69[b]
LPG—Uses[a]				
Residential, Commercial	18	24	25	c
Industrial	5	1	7	c
Transportation	4	3	3	c
Miscellaneous	15	21	31	c
Coal—Supply[d]	52	57	56	55[e]
Coal—Uses	The predominant use is coking coal for steel production.[a,d] Since 1970, a small amount has been used for fuel in cement plants.			

[a]Schwartz, 1976.

[b]California Energy Commission, 1976

[c]Data incomplete.

[d]Schwartz, 1976.

[e]Lawrence Berkeley Laboratory estimate based on past trend and an evaluation of end uses.

Source: Siri, 1977.

4.1.6 Non-Energy Imports and Exports

Since California does little primary steel and metals processing, much of the energy consumed in California comes into the state already embedded in processed goods. This indirect use of energy is probably substantial, although we do not have a good estimate of just how large it is. We think California exports relatively less energy in processed goods, although the amount exported in processed agricultural goods is not trivial. These indirect transfers of energy between California and other regions deserve considerable intensive study.

4.2 PATTERNS OF ENERGY USE

The use of energy in California differs markedly from the nation as a whole due to a number of factors including the state's warmer climate, a different industrial structure, and other differences in its social structure. It is important that California not be treated as a microcosm of the entire nation because substantial policy mistakes might result. In this section we will present some data on the differences in California energy use from that of the nation as a whole. More detailed analysis is being prepared through data in the functional use data base at LBL.*

In general, Californians consumed only 85 percent as much energy as the national average on a per capita basis. Estimates show that the average Californian in 1975 used about 281 million Btu's energy per year while the rate for the nation as a whole was 330 million Btu's per year (California Energy Commission, 1977). On a per capita basis data from 1972 are available for three broad sectors, and are presented in Table IV-6.

Table IV-6

Energy Use Per Capita, 1972 (10^6Btu)

	California	United States
Residential and Commercial	61.8	91.0
Transportation	96.3	89.1
Industrial	63.1	96.7

Source: Bradshaw, 1977.

*The data for this file are being assembled under Federal Energy Administration contract. Lawrence Berkeley Laboratory now has the data, but they are not yet processed.

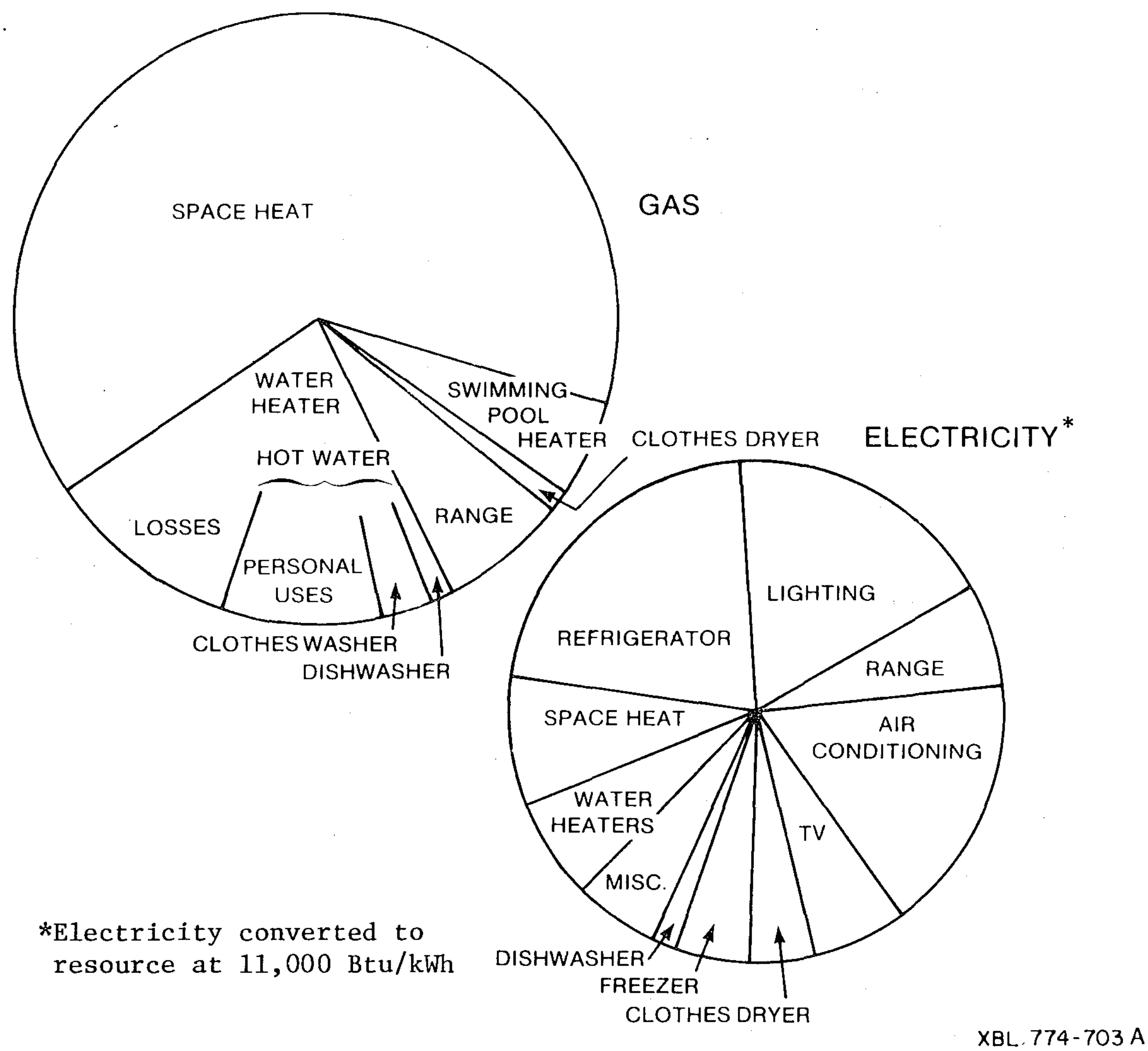
4.2.1 Residential and Commercial

Since California has a warmer climate than most of the rest of the nation, the lower energy use for residential and commercial heating and lighting is not surprising. Figure IV-2 shows the distribution of gas and electricity use in the residential sector for California. Gas provides the dominant means of space heating, although use of electricity may be increasing with estimates of between 15 and 50 percent of new houses being heated in this manner (California Energy Commission, 1977). Furthermore, the housing stock in California is especially poorly insulated with some 2-4 million housing units requiring initial or additional insulation. In addition, housing uses energy indirectly through the water which must be pumped from northern California to serve the bulk of the population in the southern part of the state.

In the commercial sector much less is known about energy consumption. In 1970 California had about 2,500 million square feet of commercial floor space allocated as follows (Ahern, 1975):

Type of space	Million square feet
Retail stores	525
Schools	525
Office buildings	500
Public buildings	400
Hospitals	200
Hotels	200
Garages	150

Lighting (and the resulting cooling requirements) account for the largest amount of energy use in this sector. Over 20 billion kilowatt-hours per year, or about 50 percent of the commercial sector's electricity use goes to lighting. California uses more lighting than the rest of the country per square foot of office space. Nationally, the lighting load is estimated at 7.1 $kwh/ft^2/year$ while the comparable figure for California is 10.5 (California Energy Commission, 1977).



*Electricity converted to resource at 11,000 Btu/kWh

Figure IV-2. California Residential Energy Use

4.2.2 Transportation

The transportation sector is the largest energy user in California, accounting for about 44 percent of the total. Gasoline constitutes the largest porportion of this with about 234 million barrels in 1975. Jet fuel added another 56 million barrels while distillate (including diesel) and residual oil accounted for 34 and 36 million barrels respectively (Ahern, 1975).

4.2.3 Energy Use and the California Economy

The single largest industry in California is agriculture, and estimates show that about 5 percent of the total energy used in California in 1972 went to agriculture(Servinka, 1975). The largest category of energy use is for various field operations and the processing of crops as shown in Table IV-7. Over a quarter of all energy use was in the form of fertilizers and irrigation, with fertilizers accounting for 14.9 percent and irrigation 13.1 percent of the total. Although more recent data are not available, these data suffice to show that California's agriculture is a major user of energy, and comparative data may show that the type of agriculture found in California—specialized and highly mechanized—is more energy intensive than agriculture found in the rest of the country.

Water movement is especially important in California agriculture with its heavy reliance on irrigation. In total, agriculture uses about 85 percent of all water in the state (California Energy Commission, 1977).

In manufacturing, California industry uses less energy per capita than in the nation (Figure IV-3). In part this is due to fewer persons working in industry. Overall, the state has about 85 percent of the national employment rate in manufacturing. However energy use in California by this sector is only 65 percent of the national level. The reasons for this low energy use include the mix of industries in California, which includes few large energy users such as steel manufacturing. Data from the 1972 Census of Manufactures were used to compute the relation between energy used for heat and power and the value added by manufacture. For every thousand kilowatt-hour equivalent of energy used in industry, California

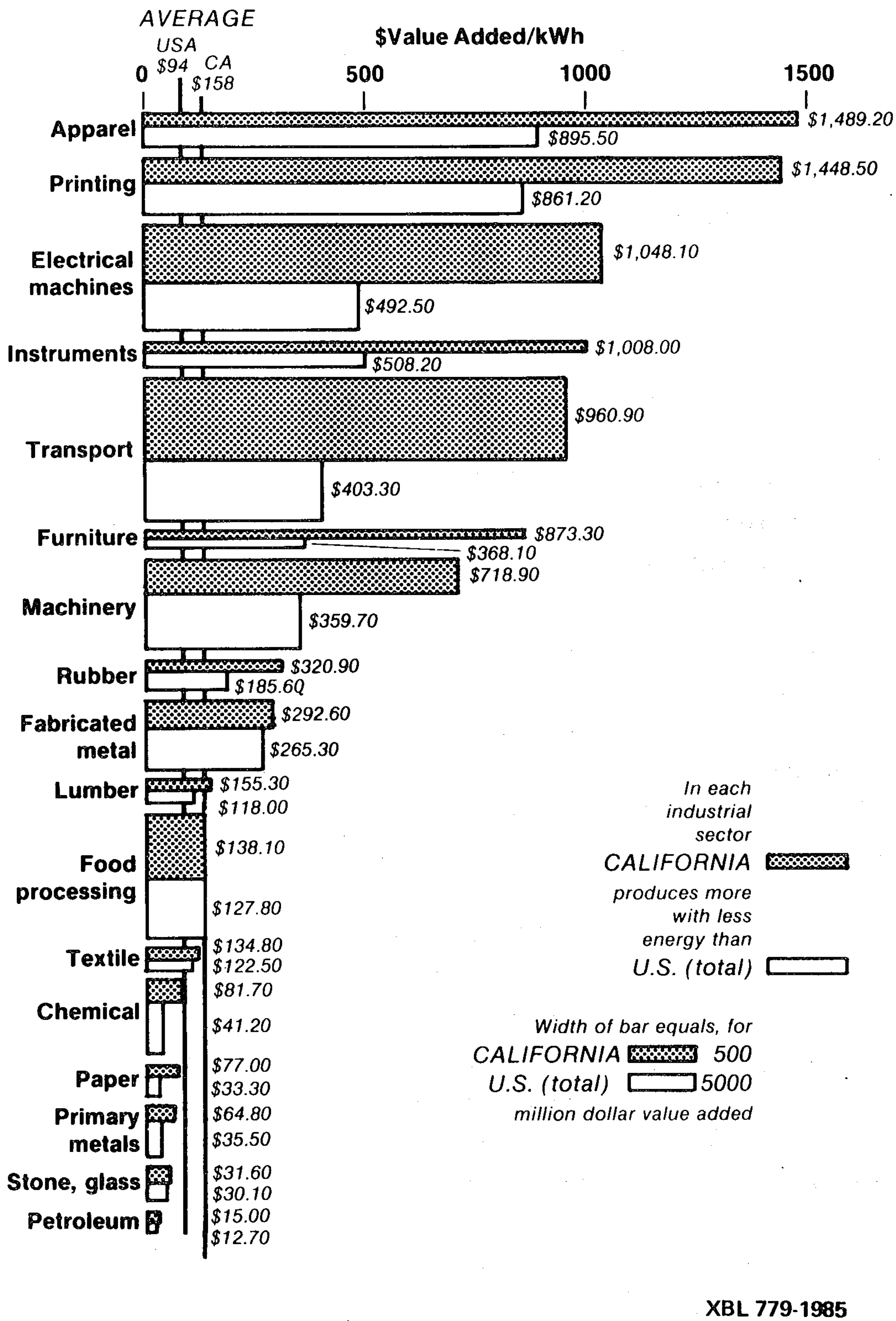


Figure IV-3. Dollars Value Added by Manufacture per Thousand Kilowatt-Hours of Energy Used for Heat and Manufacture, 1971

Table IV-7

Energy Use in California Agriculture—1972 (10^{12} Btu)

	Natural Gas	Electricity	Diesel Fuel	Gasoline	Other Fuels	Total	Percent
Field Operations and Processing							
Field crops	36.48	1.58	13.50	2.41	0.23	54.20	23.7
Vegetables	16.60	1.22	5.43	3.10	0.42	26.77	11.7
Fruits and Nuts	12.71	1.40	3.66	1.56	0.31	19.65	8.6
Livestock	10.71	4.98	6.50	0.97	1.15	24.32	10.6
Irrigation	4.06	24.48	0.92	0.06	0.42	29.93	13.1
Fertilizers	30.57	1.98	0.95	0.44	0.10	34.03	14.9
Forest protection	--	0.14	8.40	0.85	0.09	9.48	4.1
Greenhouses	10.27	0.28	--	--	--	10.56	4.6
Aircraft	--	--	0.15	0.20	1.11	1.46	0.6
Vehicles (farm use)	--	--	1.46	14.60	--	16.07	7.0
Other use	--	--	--	--	2.24	2.24	1.0
Total	121.41	36.07	40.96	24.19	6.08	228.71	

Source: Servinka (1975)

produced $158 value added compared to only $94 in the nation as a whole. Thus California industry appears to be over 50 percent more efficient in converting energy into economic value. California's particular mix of industries favors this finding. However, when data are examined for each of the major manufacturing sectors for which data are available, California is again found to produce more value added in each sector than does the nation for each unit of energy consumed. Thus, while the mix within the sectors is undoubtedly important, the data suggest that something more is occurring to produce this uniformly consistent finding of greater productivity in energy use (Bradshaw, 1977).

4.2.4 Cost of Energy in the California Economy

Energy accounts for a total expenditure by California individuals and businesses of $11.5 billion (1972) and by 1990 about 48 billion dollars (1974 dollars) in new capital will be required for construction of energy related facilities. Averaged over 15 years, this amount is about 14 percent of the 1974 Gross Private Capital Formation in California (Sathaye, 1977). The place of energy systems in the California economy, thus, looms very large and expensive.

However, Californians are not faced with the high costs of energy that other parts of the nation are. A recent survey of 25 major cities in the nation shows that the utility bills of California cities are less than of any other state, and that during the last fiscal year they rose only half as much as the national average. The study, done by the California Public Utilities Commission, reported that despite increased costs of energy and the drought, monthly bills in Los Angeles, San Francisco and San Diego rose only $2.08 while national increases averaged $4.25. San Francisco averaged the lowest bill, $29.38, with San Diego ranked fourth and Los Angeles ranked fifth. New York City had the highest typical bill—$77.29 (L.A. Times, July 28, 1977). Thus, the bottom line for much of the economic impact of energy in California is that it remains relatively less expensive than in most of the rest of the country.

4.3 THE INSTITUTIONAL STRUCTURE OF THE ENERGY INDUSTRY

The energy industry in California is one of extreme concentration of power and supply in the hands of several very large companies. California energy industries rank as some of the largest corporations in the nation, and their worldwide operations involve the state in complex relations with entities outside of the state. Thus, in order to understand the nature of the problems involved in a transition to a decentralized energy future, it is imperative that more be learned about these firms and their operations.

In California 95 percent of all electrical energy is delivered by three public utilities (Council on Energy and Resources, 1975). Pacific Gas and Electric is the largest of these, employing 24,580 persons and having revenues of 2.65 billion dollars in 1976. This ranks PG&E tenth largest among the industrial and utility firms in the state. Southern California Edison had revenues of 1.82 billion dollars, ranking it fifteenth largest among the state's industrial and utility firms. San Diego Gas and Electric and the Sacramento Municipal Utility District are the other large utility firms (L.A. Times, May 15, 1977). Power generation is also carried out by 16 smaller units including the California Department of Water Resources, the Imperial Irrigation District, the Glendale Public Service Department, the Pasadena Water and Power Department, and the Bureau of Reclamation (FEA, 1977).

Yet it is the size of PG&E which remains the dominant fact in the California utility business. PG&E is the second largest utility in the United States, and ranks about 80th among all industrial corporations in the Fortune 500.

California has experienced considerably above average rates of population growth since statehood, but of particular importance is the rapid recent growth which has meant that many more industrial facilities are new. We have no comparative data on this now, but we know that 17 percent of the state's rated electrical generating capacity (5,827 out of 34,724 MWe) was installed between 1970 and 1976 (FEA, 1977).

Because of its natural resources, California is able to generate a large amount of hydroelectricity. On the other hand, California has not yet become as dependent upon nuclear power as have other large industrial states. For example, in rated capacity, California is only 4 percent nuclear while the nation is 9 percent. Among the ten largest industrial states, Illinois has the largest proportion of nuclear capacity (22%) followed by Pennsylvania (14%), New York (14%), New Jersey (13%), Massachusetts (10%), and Texas, Indiana, and Ohio with none (FEA, 1977). This lack of large existing nuclear capacity in California gives the state extra opportunities to consider distributed energy options.

Other energy-related companies besides utilities play a large role in the California economy. In a ranking of the top 100 California corporations, oil companies occupied the top four positions, and the sixth. The largest in order are: Standard Oil, Atlantic Richfield, Union Oil and Occidental Petroleum, with Getty Oil in sixth place. In total, these five large oil companies headquartered in California had sales of $43.6 billion and employed 31,390 persons in California alone (L.A. Times, May 15, 1977).

While there are many other energy-related companies in California, further analysis will be required to identify them and their importance. In summary, however the role of the energy industry in California remains large. As reported by the LBL Analysis of the California Energy Industry,

> In relation to the overall California economy, the present energy industry accounts for about 1.4 percent of nonagricultural employment, and provides about 3.5 percent of the Gross State Product. Wages in the California energy industry run about 1 percent higher than for the national energy industry, while the work week is about 2 percent shorter. In terms of labor intensity the energy sectors range from 4.7 to 14.3 employees per million dollars output whereas the median for all industries is 27.5. Because the energy sectors are presently among the lowest twenty percent in labor intensity, large changes in output from these sectors are required before significant changes in the level of employment are felt (Sathaye, 1977).

4.4 THE GOVERNMENTAL STRUCTURE FOR ENERGY DECISION MAKING

Energy decisions in California are embedded in an extremely complex institutional structure which includes a myriad of agencies, legislative committees, public interest groups, and powerful individuals. Currently this structure is confused by the immaturity of key institutional actors, technical uncertainty, and deep politicized rifts over proper energy strategies. This confusion may not differ qualitatively from that experienced elsewhere, but the actual sources of dissensus are particular to California, and interesting to the extent that they will perturb the future development of energy policy.

The main State agencies involved in energy matters are the California Energy Commission and the California Public Utilities Commission. The Energy Commission is a relatively new organization which has swallowed up the institutional "turf" of many pre-existing agencies. The Commission:

- has primary responsibility for preparing the forecasts of electrical supply and demand;
- has primary jurisdiction over thermal plant siting;
- has the power to establish conservation measures such as appliance efficiency standards and building insulation standards;
- is instructed to develop and coordinate a program of R&D; and
- is instructed to develop contingency plans for energy shortage situations.

"The Commission has the 'exclusive power to certify all sites' [for thermal power plants], and such a certificate is 'in lieu of any permit, certificate or similar document required by any state, local or regional agency or any federal agency to the extent permitted by law.'" This differs from the former practice of issuing certificates from a large number of individual agencies. On the other hand, there are still a number of real overlaps and continuing institutional tension.

This may be especially true vis-a-vis the state PUC, which previously had responsibility for plant siting and forecasting. The PUC does retain jurisdiction over utility rates. Currently this dispute, such as it is, is focused on gas siting and regulation, and in particular on the question of who decides on LNG siting—a very controversial problem in California presently.

Clustered around the Energy Commission and the state PUC are a large number of divisions, located administratively within the California Resource Agency, which have their own expertise and veto power to the energy problem. These include:

The Air Resources Board
The California Coastal Zone Conservation Commission
The Colorado River Board of California
Department of Conservation
Department of Fish and Game
Department of Water Resources
Geothermal Resources Board
Reclamation Board
San Francisco Bay Conservation and Development Commission
Solid Waste Management Board
State Lands Commission
Water Resources Control Board

Among these departments the Air Resources Board, the Coastal Commission, the State Water Resources Control Board, and the Department of Water Resources may play especially important roles in energy planning. The Air Resources Board has responsibility for limiting emissions from stationary and mobile sources, including power plants and automobiles. ARB rulings may greatly constrain certain energy options (like coal), although The Commission does not concede that the ARB rules must apply. In the <u>1977 Biennial Report</u>, the Commission said:

> Facilities subject to the Commission's certification authority may have to comply with standards promulgated by state and local air pollution agencies; whether they must is a complex question of law which is currently unresolved (California Energy Commission, 1977).

Since water resources are limited in California for cooling purposes, there is a large incentive for locating plants along the coast. This, however, conflicts with a strong public interest in preserving the coast for recreational purposes. The Coastal Commission is explicitly charged to mediate this problem, which means that it will be involved in energy planning for some time to come. Likewise the State Water Resources Control Board, the agency charged with administration of the State's inland water resources, will also affect energy planning by limiting the amount of water available for inland power plants.

The Department of Water Resources is important for another reason. It is charged with the development of the State's water resources, and as such uses more energy (for its pumps) than any other single energy consumer in the state. All of the Department's contracts for energy supply terminate in 1983, and it is currently looking at a number of options for meeting its demands; these include the construction of its own power plants.

4.4.1 The State Legislature

California's legislative system is bicameral, resembling in many ways the U.S. Congress. The basic difference is that the committee system is de-emphasized in California, which means that responsibility for legislation tends to focus more on individuals. The seniority system is also less important. The result is that energy policy may be more heavily influenced by particular individuals than it would be on the federal level. Nevertheless, there are at least 18 committees in the Senate and Assembly which share some responsibility for energy matters.

In years past energy policy in the Assembly was dominated by Charles Warren, now head of the U.S. Council on Environmental Quality. Warren chaired the Assembly Committee on Resources, Land Use, and Energy, which became the locus of energy policy decision-making. Warren originated the Warren-Alquist Act which created the Energy Commission and chaired the important Assembly hearings on Proposition 15, the nuclear safety initiative voted down in 1976. Apparently no one has replaced Warren to date; instead his responsibilities have been split up among a number of legislators. It can be argued that much of the excitement has gone out of energy discussions at the legislative level—most of the questions being reformist in nature—and that this accounts for the lack of assertive leadership.

In the Senate energy planning appears to be dominated by Senator Alquist, Chairperson of the Public Utilities, Transit and Energy Committee, and Senator Dills, Chairperson of the Government Organization Committee. In general the Senate has been the more conservative body, and has tended to leave the initiative in energy matters to the Assembly. This was certainly true in the case of the three nuclear bills passed in the wake of Proposition 15, although this may have been due to Warren's influence.

The Governor is a "wild card" in state energy policy. Experience indicates that if the Governor is interested, he can have considerable impact on deliberations elsewhere. This can happen either through direct personal intervention or through the manipulation of the Office of Planning and Research, a non-specialized research agency serving the Governor. Beyond these avenues, of course, the Governor has considerable impact on energy policy through his appointments to the Energy Commission and other interested agencies. Indeed, Governor Brown may have opportunity to appoint two new commissioners (out of five total) to the Energy Commission in the near future.

4.4.2 Federal Relations

Obviously California does not make energy decisions in a vacuum; Federal actions have considerable impact. This federal activity has been experienced through a multitude of agencies. Significant consolidation of federal activity will occur with the establishment of the Department of Energy, and the regional office of that Department will become an important actor in the California energy scene. The actual role of this regional office is yet unknown. Suffice to say that tension between federal and state planning is of considerable concern, and that there is a considerable resentment when policies come into conflict.

4.4.3 Special Interest Groups

Arrayed about the governmental institutions are a large number of activist groups representing a diverse California-based constituency which attempt to influence energy decision-making (and non-decision-making). These groups support very different types of energy policy, and are often in direct or indirect conflict with each other. Groups which have been identified as important in energy matters include (Council on Energy Resources, 1975):

American Gas Association
American Nuclear Energy Council
American Petroleum Institute
Atomic Industrial Forum
California Council for Environmental and Economic Balance
California Tomorrow
Center for Law in the Public Interest
Citizen's Action League
Conservation Coordinators (California Coastal Alliance)
Environmental Defense Fund
Environmental Policy Center
Friends of the Earth
Get Oil Out
Independent Petroleum Association of America
National Association of Electric Companies
National Coal Association
Natural Resources Defense Council
Pacific Legal Foundation
People's Lobby
Planning and Conservation League
Sierra Club
Toward Utility Rate Normalization

The static analysis developed here of necessity reveals little of the real flows of power and influence that would be important to a transition to a distributed energy system. What is required is a dynamic description. Such analysis should certainly examine the importance to the current California energy policy environment of the campaign of June of 1976 following which California voters voted down Proposition 15, a measure which would have almost certainly shut down nuclear power in the State had it passed. It did not although the three nuclear bills passed by the legislature in its wake have much the same effect. The story of how these events took place in spring of 1976 would be an excellent way to approach the dynamic interaction of the many relevant energy policy actors in California.

4.5 THE BROADER SOCIAL CONTEXT

The object of this section is to summarize a large amount of background material about the larger social environment in California relevant to the process of implementing alternatives to the current energy system.

In general, California may be thought of as a prototypical "advanced industrial society," that is, a society which is experiencing many of the changes characteristic of the most advanced social and economic developments in the world today (Bradshaw, 1976). Many of these changes are ones in which California has been leading the nation for some time with other areas following California by several years to several decades. These developments have been variously described by other scholars as the "post-industrial society," the "technotronic society," or the "new industrial state" (Bell, 1973; Brzezinski, 1970; Galbraith, 1967) but all agree that a new type of social and economic structure is evolving in some modern societies. By the criteria of these authors, California is the largest area in the nation which most closely matches the types of changes pictured as advanced- or post-industrialism (LaPorte, 1976).

The energy implications of four components of advanced industrialism will be discussed: the domination of high technology, the rapid expansion of the service sector, the utilization of extensive knowledge generation and transmission facilities, and increased resources for and vulnerability to change.

4.5.1 The Domination of High Technology

In California society virtually every sector is dominated by the most sophisticated technology available. With 10 percent of the national population, California has more engineers than any other state, including 30 percent of the nation's aerospace engineers. Its agriculture is acknowledged as the most technologically sophisticated and specialized. In local government, California cities are more likely than others to use computers. In gross terms, the economy is marked by especially strong high technology electronics and aerospace industries instead of steel and heavy machinery. The importance of high technology industries in the California economy is massive, yet they were hardly known fifty years ago. For example, television was invented in San Francisco just 50 years ago and the transistor after World War II. The modern aerospace industry could hardly have been imagined 50 years ago. From this experience it is hard to imagine what technologies will dominate the California economy 50 years from now, although it is probably that the future will be marked by even more change than the past.

Data shows that most rapidly growing sectors of the California economy are dominated by the development of new technologies, the use of highly trained employees, and little use of energy. Table IV-8 shows for a selected number of industrial sectors their rate of growth in employment between 1960 and 1970, the proportion of college graduates employed, and their per capita energy use. As can be seen, the rapidly growing sectors tend to have high educational levels and low energy consumption. From data such as these it may be suggested that the growth of the economy in the future may come through technologies which substitute knowledge for energy. In fact, the implications of the development of a high technology economy is the use of increasingly sophisticated and complex forms of conceptual and scientific knowledge which do not rely on vast amounts of raw energy to achieve intended results. In sum, it may be difficult to predict the specific character of the industrial structure of California in the future, but it is reasonable to anticipate greater than average growth in the high technology sectors with consequent demands for more knowledge and less energy.

4.5.2 The Service-Welfare Society

A second characteristic of the advanced industrial society which has great implications for the energy demands of the future is the fantastic growth in California of the service sector, especially its professional component, and the institution of massive government funded welfare programs.

The growth of service sector employment has come largely at the expense of agricultural employment rather than a decline in manufacturing

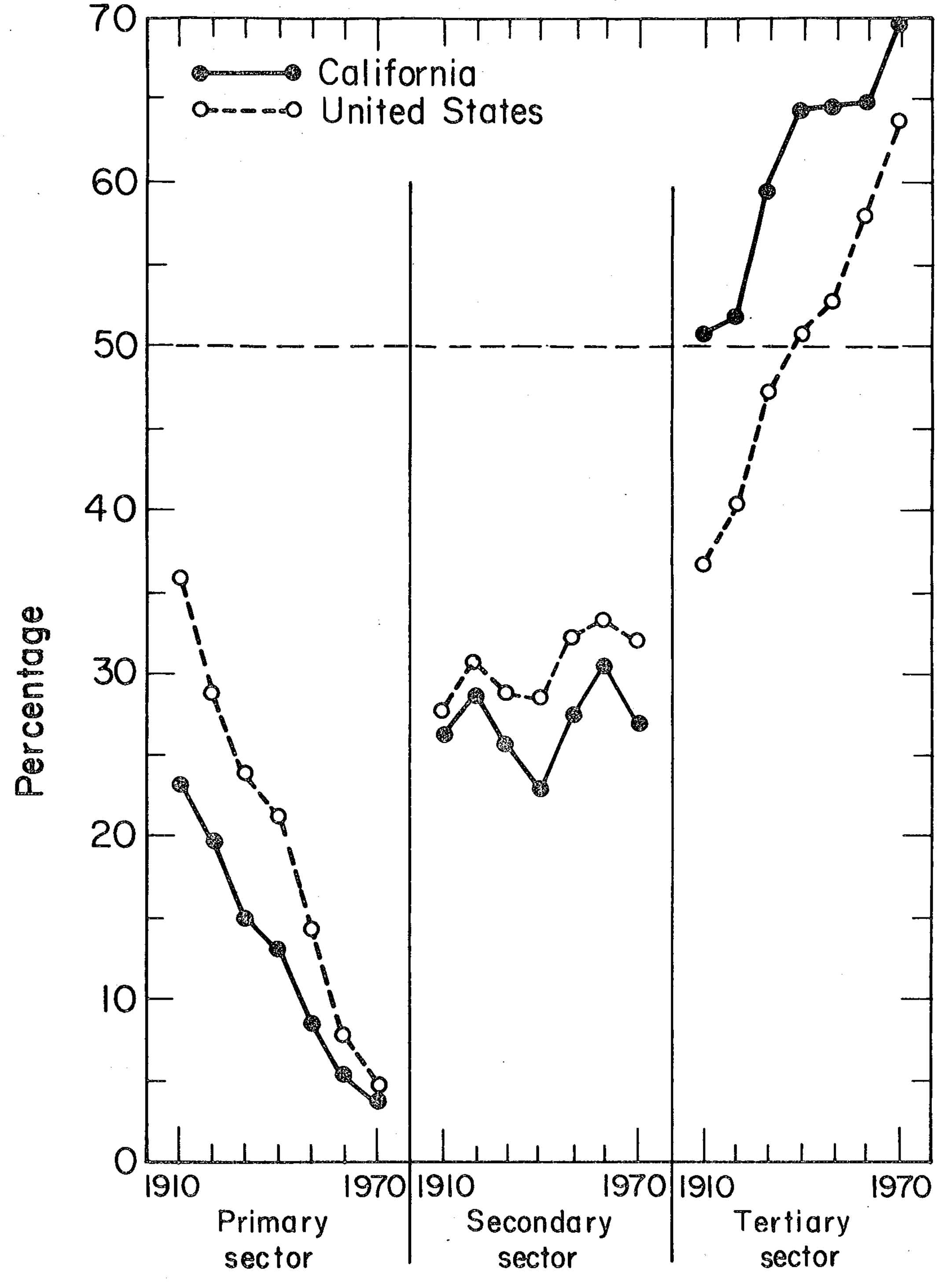
Table IV-8

The Preliminary Figures on the Relation Between California Industry Employment Growth Rates Between 1960-1970, Proportion Industry Work Force Having 4 or More Years College and Million Btu per Employee Selected Industries

Growth 1960-1970		Percent 4+ yrs. college	Million Btu per employee, 1971
2,244.7	Electronic Computers	34.7	123.0
82.4	Optical & Health Supply	17.0	311.8
67.9	Ordinance	23.2	159.9
67.9	Total, Professional	53.9	98.7
63.6	Business Services	23.4	323.6
55.2	Radio, TV	21.0	99.7
45.3	Communication	11.1	200.4
38.7	Textile	5.2	276.1
38.1	Machinery	10.3	191.1
37.3	Insurance	27.4	189.4
33.7	Public Administration	16.0	136.7
33.5	Rubber	8.7	420.1
31.6	Trade	6.3	222.9
29.9	Paper	8.4	1943.6
29.4	Electrical Machinery	17.4	169.1
29.1	Motor Vehicles	5.7	356.2
22.5	Scientific Instruments	19.1	268.9
20.8	Repair Services	2.8	327.4
20.7	Mining	9.9	4031.0
20.0	Utilities	8.0	36402.7
15.7	Printing	12.4	86.1
13.6	Chemicals	21.7	2098.7
13.4	Transport	4.1	1287.3
8.6	Apparel	7.3	69.3
3.0	Furniture	3.9	146.5
1.3	Primary Metal	5.6	358.2
0.5	Construction	3.9	345.5
-0.3	Air Craft Manufacture	18.5	116.5
-6.7	Leather	4.4	99.4
-10.9	Stone, Glass, Clay	7.0	2116.0
-22.0	Food Processing	6.4	697.4
-22.7	Agriculture	4.1	443.4
-26.5	Fabricated Metal	6.3	285.7
-27.1	Lumber	3.1	420.4
-30.1	Petroleum	20.0	133546.8
-66.2	Household Appliance	7.4	204.6

as shown in Figure IV-4. Often post-industrialism is measured by employment in services exceeding 50 percent. By this standard the nation became post-industrial in 1940 but California was already post-industrial by 1910 (LaPorte, 1977). Since service employment is less energy intensive than manufacturing (the former is generally considered commercial while the latter is industrial) the growth of the service sector promises substantially greater energy flexibility. On the other hand, much less is known about the energy requirements of this component. One of the shifts associated with the growth of the service sector is a change in broad social values. The values of the industrial society emphasize rationality and routine while the values of the service society emphasize interpersonal relations, subjectivity, and spontaneity. These values have found their way into the social structure of California on an experimental basis in many of the alternative type communities found in the state. Schwartz in studying many of these communes to discover their energy-frugal lifestyles, reported that perhaps 12,000 persons in Mendocino County live in alternative, low energy consuming "back-to-the-land" movement style housing. Another 3,000 persons are estimated in Nevada County, and similarly large numbers of persons are probably found in other rural areas. Schwartz concludes that "the importance of the experimenters with new ways of living exceeds their relative numbers... they are demonstrating that more frugal living is not only possible but can be satisfying" (1977). Furthermore, Stanford Research Institute estimated that 4-5 million Americans are living lives fully committed to the concept of voluntary simplicity which involves "simplification of externals, insistence on living as naturally as possible, a preference for smallness, concern with personal growth, and self-sufficiency." The Governor of the State frequently voices the "small is beautiful" theme even though many parts of the society are particularly large in scale (L.A. Times, Feb. 28, 1977).

This set of values is paralleled by another rooted in the affluence of California. With per capita personal income of $6555 in 1975, $721 above the national average (U.S. Bureau of the Census, 1977), Californians have long had more money to spend and have developed a lifestyle based on energy demanding pursuits. For example, over one-third of all



Source: LaPorte (1977)

Figure IV-4. Percent Employment by Industrial Sector in California and United States, 1910-1970 power boats registered in the nation are in California, and 18 percent of all private aircraft are located in the state. Recreational vehicles have received their most enthusiastic reception in the California market. These and other energy-consuming features of the California lifestyle have an important primary impact on the economy, found in the exceptional importance of tourism, especially for the rural areas of the state. Furthermore, they are not likely to be easily abandoned by many people in the society including those who aspire for them.

Finally, the emphasis on welfare in the state is evidenced by data that California spends 15 percent of total state and local government expenditures for welfare, and this amounts to the third highest rate of payment by state and local governments for public welfare (Bradshaw & LaPorte, 1976). Additionally, California has about one in six children in the state on Aid to Families with Dependent Children. At present there is increased pressure to increase medical coverage and state contributions for education. These expanded social programs may compete with public funds needed for energy needs. On the other hand, the state has been troubled by persisting unemployment, averaging about 2 percentage points above the national rate over the last 25 years.* It is clear that the employment implications of any energy program will receive highest political scrutiny.

4.5.3 Education and Research Capability

An advanced industrial society is knowledge intensive, having an extensive educational system for the transmission of knowledge and a large research effort for the generation of new knowledge (Bradshaw, 1976). Both of these capacities are especially important for the development of an alternative, decentralized energy system.

*Computed from data in the California Statistical Abstract and the U.S. Statistical Abstract.

California is among the top states in the nation in terms of the proportion of college educated adults and the proportion of young persons attending college. Estimates have been made that 80 percent of California's high school graduates attend a college somewhere. Furthermore, about three and a half million Californians were involved in 1974 in non-degree educational efforts such as adult school, extension, and private training schools. Combined with degree enrollment, this means that one out of three persons over the age of 18 is active in some form of education in California (Salner, 1977).

A decentralized energy strategy will require the diffusion of a great deal of information to large numbers of persons. It appears that the existing educational resources of California may be beneficial for this purpose. In addition, efforts are underway for the establishment of a California energy extension service which will specifically handle energy related information.

The extensive research effort of California will be used to facilitate technological developments for a decentralized energy strategy. Already there has been a number of developments in the state which are applicable. For example, considerable energy savings are promised by alterations on electric motors which increase their efficiency. In lighting, greater efficiencies have been promised. And, solar applications are being developed experimentally as, for example, at the ERDA experimental solar power plant to be built near Barstow.

4.5.4 Propensity to Change

There are several characteristics of the California experience which increase the chances that change might be able to take place.

1. Population-related factors. The state's population growth has been the most rapid long-term growth of any country in the world, Japan and Israel not excepted. We do not know if this growth is going to continue or not, although there are reasons to suspect that California will grow at a rate much closer to the national average during the next 50 years.

Nonetheless, continued high population mobility will bring many new people with new ideas into the state.

A change is taking place in the rate with which different parts of the state are growing, however. The central cities such as San Francisco and Los Angeles have actually declined in population during the last several decades. Since 1970, for the first time, the rural regions of the state have grown at a rate considerably above that of the urban ones. Much of this growth is not the extension of urban areas into adjacent areas, but the leap frogging of growth to rural regions. This is due to desires for a rural lifestyle and to increasing rural opportunities.

2. Flexibility. The knowledge intensive industries in California are new and innovative, and they have more flexibility to move into new areas compared to the large firms. Furthermore, as will be discussed in Chapter V, the abundant natural resources in California provide for flexibility in developing alternative energy systems. There are few areas of the earth with such opportunities.

3. Diversity. California is exceptional in the diversity of its industry, having some of the traditional old industrial structure as well as the new. In addition, there is acknowledged diversity in lifestyle in California, ranging from traditional to every form of alternative experimental style imaginable. More than just hippies and communes, the California experience is diverse with communities trying to limit growth and use solar energy. This diversity is really a form of unplanned social experimentation which can provide information about the character of future energy alternatives (Schwartz, 1977).

4. Change is valued. An important value in California is change in and of itself. More than in other areas California public opinion responds to change and does not rely heavily on tradition. The willingness to promote experimentation is high in the state, and survey data is likely to support this statement.

5. Export. Although California imports amounts of energy, the state is a large exporter of many other products which gives it a good position in the inter-state and international balance of trade. The large tourist

industry as well as exports of agricultural products, computers, aircraft and the like are made possible because of the limited availability of similar products elsewhere and the important position of California at the western edge of the country.

6. <u>Governmental innovation.</u> In most states the government is a block to innovation while in California the government is more likely to support and initiate changes. Comparative research has shown that California has the most innovative and the most professional state government in the nation. Today that is supported by the state government interest in energy programs and in the Governor's aspirations to make the state the national leader in solar research and development.

REFERENCES

William Ahern et al., Energy Alternatives for California: Paths to the Future, Rand Corporation, Santa Monica, Report R-1993-CSA/RA, p. 196, 1975.

Daniel Bell, The Coming of Post-Industrial Society, Basic Books, New York, 1973.

Ted Bradshaw and Todd LaPorte, California's Recent Development: Questions about an Advanced Industrial Society, Institute of Governmental Studies, University of California, unpublished, April 22, 1976.

Ted K. Bradshaw, "Differences in Energy Consumption: California and the Nation," California Data Brief, Volume 1, Number 1, April 1977.

Ted K. Bradshaw, "New Issues for California, the World's Most Advanced Industrial Development," paper read at the meetings of the Pacific Sociological Association, 1976.

Zbigniew Brzezinski, Between Two Ages: America's Role in the Technotronic Era, Viking Press, New York, 1970.

California Energy Resources Conservation and Development Commission (ERCDC), California Energy Trends and Choices, 1977 Biennial Report, Volume 1, 1977.

California Energy Resources Conservation and Development Commission (ERCDC), Quarterly Fuel and Energy Summary, Volume 1, Number 4, 1976.

California Public Utilities Commission (CPUC), Ten-Year Natural Gas Forecast, 1975.

Council on Energy Resources, Energy Policy in California: A Directory, University of California, Berkeley, October 1975.

Federal Energy Administration, Inventory of Power Plants in the United States, June 1977.

John Kenneth Galbraith, The New Industrial State, Houghton Mifflin, New York, 1967.

Todd LaPorte and Ted Bradshaw, "Advanced Industrial California: Employment Patterns," California Data Brief, Volume 1, Number 4, July 1977.

Todd LaPorte and C.J. Abrams, "Alternative Patterns of Post-Industria: The Californian Experience," in Leon Lindberg, ed., Politics and the Future of Industrial Society, David McKay Company, New York, 1976.

Marcial Salner, "Education Beyond High School; California's Resources," California Data Brief, Volume 1, Number 3, June 1977.

REFERENCES (continued)

Jayant Sathaye _et al._, Lawrence Berkeley Laboratory, _Analysis of the California Energy Industry_, p. xvi, January 1977.

Seymour I. Schwartz, _Energy-Conserving Lifestyles_, (report to the California Energy Resources Conservation and Development Commission), University of California, Davis, p. 141, 1977.

S.I. Schwartz and G.D. Simon, _Potential Coal Use in California: An Analysis of the Dimensions of the Problem_, Institute of Governmental Affairs, University of California, Davis, Preliminary Report, October 1976.

V. Servinka _et al._, "Methods Used in Determining Energy Flows in California Agriculture," _Transactions of the ASAE_, Volume 18, Number 2, p. 246 ff, 1975.

W.E. Siri, _Impacts of Future Coal Use in California_, Interim Regional Report, Lawrence Berkeley Laboratory, July 1977.

Stanford Research Institute, _Meeting California's Energy Requirements, 1975-2000_, Menlo Park, May 1973.

U.S. Bureau of the Census, _Statistical Abstract_, 1977.

CHAPTER V
ENERGY RESOURCES FOR CALIFORNIA'S FUTURE

5.1 INTRODUCTION

In the previous chapter we traced the evolution of the California energy system over the past fifty years to its present state. Before embarking on an exploration of some of the paths this evolution might take over the next fifty years, we must assess the type and size of the energy resources that will be available for California's use over this period. These resource characteristics will establish certain constraints on the future paths. However within these broad constraints there will be great flexibility for Californians to decide which resources they wish to develop and how they wish this development to occur.

We consider in this chapter only the technical limits of what can be achieved with each potential resource. Thus we will explicitly examine resource size and land and water requirements, leading to a summary of resource estimates (Table V-13). Some indication will be given of those resource characteristics that lead to environmental, social, or institutional limits to utilization. However analysis of such non-technical limits to resource utilization must be done within the context of an entire energy system, including the institutions responsible for developing and delivering the energy.

In analyzing these energy resources we make conservative assumptions about the capabilities of future technologies for resource utilization. While important advances in some of these technologies will certainly occur, we cannot know just how they will change our abilities. The assumed energy delivery systems require only applications of existing technology; they represent the lower bound of future capabilities.

We distinguish between different energy forms in our analysis of these energy resources. While there is already some potential in our present energy system for substitution of different fuel types (e.g., switching from oil to coal in power plants), and our capabilities for substitution will no doubt increase in the future, we believe that there will always be an intrinsic advantage in using certain energy forms for certain applications. Thus we consider it an important goal for future energy systems to be able to match approximately the mix of energy forms most desired by final consumers.

Just as important as the form of the delivered energy is the time variation in its availability and the dependability of its supply. These characteristics of energy resources must be carefully considered in judging the overall performance and reliability of a hypothetical energy system for the State. In this phase of the study we have developed only partial information on these important characteristics (Chapter VII).

5.2 BIOMASS

5.2.1 Sources and Uses of Biomass

Biomass is the term used for organic matter which is a form of stored solar energy. Biomass can be burned to provide heat, burned to drive a steam-electric powerplant, or can be converted to the liquid and gaseous fuels that are valuable energy forms for many applications. We will emphasize the latter use of biomass in our discussion here. The techniques to convert biomass to these fuels are relatively well developed. The biomass for this conversion to fuels can be obtained in waste materials (municipal solid waste, agricultural wastes, etc.) or can be grown specifically as an energy crop. The total amount of biomass that theoretically could be grown in California is immense. However, the amount that actually can be produced turns out to be quite limited.

In the following pages we have estimated the energy potential for biomass from organic waste resources, land-based energy plantations, and kelp farms in the ocean. Water appears to be a limiting factor in developing land-based energy plantations. The last component of our biomass estimate is rather speculative in that operation has never been demonstrated successfully except at small scale. After estimating the amount of biomass available from each of these sources, we estimate the total amount of fuel (in the form of methanol) that could be obtained from the conversion of this biomass.

5.2.2 Biomass Waste Resources

What energy can be made available from projected future sources of organic wastes in California? Most of these wastes are already being collected and disposed of without utilizing their energy potential (municipal solid wastes, sewage, feedlot wastes and some timber wastes). Exploiting these waste resources will not displace existing land uses and will provide a solution to waste disposal problems in urban areas. Existing biomass resources are listed in Table V-1, and an estimate of the potential biomass resource base from seven waste categories is provided. These estimates assume that the total waste

Table V-1

Total Quantity and Energy Content of Biomass Resources in California, 1975

	Quantity (million dry tons)	Heat Content[4] (million Btu's/ dry ton)	Total Btu Content (10^{12} Btu)
Municipal Solid Waste[1]	14.0	13.3	186
Municipal Sewerage Waste[2]	.7	19.8	14
Agricultural Industry Residue[1]	2.1	17.6	37
Agricultural Field Residue[1]	8.6	17.6	151
Dairy and Feedlot Manures[1]	3.6	17.0	61
Lumbermill Residues[3]	2.0	16.0	32
Timber Harvesting Residues[3]	4.5	16.0	72
Other Timber and Wood Residue[3]	6.9	16.0	110
TOTAL	42.7	14.7	663

[1] Stanford Research Institute (1976)

- o Municipal Solid Waste (MSW) - assumes moisture content of 25 percent. Total MSW estimate in SRI report is 18.6 million wet tons.
- o Agricultural industry, agricultural field residues and dairy and feedlot manures include current amounts of each waste sold, used as animal feed or returned to the soil as digestion residues and can be used for the same purposes.

[2] Assumes .20 dry pounds of sewage wastes per capita per day (.08 lb fecal matter, .12 lb dry urine salts and a population of 21 million persons).

[3] Groncki (1976).

- o Lumber mill residues do not include residues currently used for fuel or by pulp industry.
- o Other timber and wood residue include orchard prunings, conifer thinnings and dead and dying trees.

[4] Sources for heat content:

- o Solid wastes - State Solid Waste Management Board (1977). (One ton of wet solid wastes with a moisture content of 25 percent has an energy equivaluence of 10 x 10^6 Btu.)
- o Municipal sewage wastes, agricultural residues and feedlot wastes - Portola Institute (1974).
- o Wood residues - Groncki (1977).

resource is available for collection.* In fact, municipal solid wastes, sewage wastes, feedlot wastes and most timber residues are currently collected and disposed of at a cost to the public or private operators. Those sources which are already collected account for approximately 75 percent of the energy content of wastes in the state. Thus the assumption of nearly 100 percent collectibility is plausible.

Projections of the 1975 waste resource base to 2025 are presented in Table V-2. The simple methodologies used to derive these projections are provided in the footnotes of the table. The projections assume among other things a constant amount of waste per capita. This may be unrealistic if the state's population embarks upon a conservation/ recycle-oriented lifestyle over the next 50 years. It also assumes that lumber mills do not improve their efficiency of wood use.

5.2.3 Energy Farms

In this section we estimate the maximum amount of energy which can be produced in California on conventional energy farms, by which we mean the raising of crops whose primary value is their energy content and which can be grown and harvested by well-established methods (including timber harvesting).

We proceed by examining in turn the constraints which limit plant growth. Photosynthesis is a complex process which stores solar energy (primarily in the form of glucose) and consumes water, carbon dioxide and soil nutrients. If any of these is in short supply relative to the others, it becomes a constraint on plant growth. In addition the process is sensitive to temperature and many plants are killed by frost; thus, biomass production depends on the length of the growing season.

The theoretical upper limit on the efficiency with which land plants may store solar energy has been variously estimated (Loomis, 1965; Bassham, 1977) to be 5.3 and 6.5 percent. The average annual solar energy per unit area varies little over the state (less than 30 percent) from a

*Sewage waste potential has been reduced by 10 percent to account for methane capacity already used by sewage treatment plants for heating. Lumber mill residues exclude wastes already being used for fuel or in the pulp industry. Agricultural wastes include wastes currently returned to the soil, sold or used as cattle feed as the residue from the digestion process can be used for these same purposes.

Table V-2

Energy Content of Biomass Resources in California, 2025

	Quantity (10^6 tons)	Heat Content (10^6 Btu's/ dry ton)	Total BTU Content (10^{12} Btu)
Municipal Solid Waste[a]	25.7	13.3	390
Municipal Sewerage Waste[a]	1.3	19.8	26
Agricultural Industry Residue[b]	3.0	17.6	053
Agricultural Fiel Residue[b]	13.8	17.6	243
Dairy and Feedlot Manures[c]	4.4	17.0	75
Lumber Mill Residues[d]	2.5	16.0	40
Timber Harvesting Residues[d]	5.6	16.0	90
Other Timber and Wood Residues[d]	8.6	16.0	138
TOTAL	64.9	14.7	1055

[a] 1975 figures increased by ratio of population in 2025 to population in 1975.

[b] Agriculture residues increased by ratio of projected crop values (in constant dollars) in 2025 to crop values in 1975.

[c] 1975 figures increased by ratio of projected 2025 livestock population to 1975 livestock population.

[d] 1975 figures increased by ratio of projected 2025 timber production to 1975 timber production.

Source for projections: (U.S. Department of Commerce, 1972) mean of 2.54 x 10^{-5} quad/acre/year. The theoretical maximum efficiency then implies the storage of 1.35 x 10^{-6} quad/acre/year as biomass. Actual solar conversion efficiencies for various plants range from about one percent for sugar beets, sorghum and eucalyptus to about 0.057 percent for mature forests. Cultivated crops achieve at most one-fifth of the theoretical maximum, due to constraints imposed by growing season, leaf display, carbon dioxide supply, and the fact that most crops are grown to optimize fruit or grain yield rather than total biomass (Loomis, 1963).

Since the total land area of California is 100 million acres, the theoretical maximum biomass storage is enormous; even taking efficiencies typical of cultivated crops the potential is still large. On the other hand, the efficiencies of naturally-growing plants are much smaller than for cultivated crops. From this one concludes that the crucial question is how much of California's land area contains sufficient moisture and nutrients and a long enough growing season to produce an appreciable amount of biomass.

The most critical constraint in California turns out to be the availability of water. Table V-3 summarizes the land and water requirements for various crops. Table V-4 summarizes the origins and disposition of the water resources in California, and Table V-5 summarizes the supply and demand in 1972 and as projected to 2025 (Department of Water Resources, 1974). The projection of demand to 2025 is a linear extrapolation of a Department of Water Resources projection to the year 2020. The projected agricultural demand is based on a state population given by the D-100 projection (see Chapter VI) and conservative assumptions about agricultural productivity and exports.

The implications of these two tables are clear. The projected net demand in 2025 exceeds the projected dependable supply by some four million acre-feet and equals the total utilizable resource. This means that even in non-drought years water will be in short supply in 2025 and that one cannot plan to grow biomass on irrigated farms.

Without the ability to irrigate, one is unlikely to improve greatly on the naturally-occurring plant species, which are adapted to the existing patterns of rainfall. Table V-6 details the amount of biomass which can be grown by managing and harvesting these plants wherever possible. For an estimate of the maximum potential, we assume that all hardwood forests

Table V-3

Land and Water Requirements for Biomass Crops

Crop	Yield (dry ton/ acre)	Irrigation (ft of water)	Required for 1 Quad	
			Land (10^6 acres)	Water (10^6 acre-ft/yr)
Eucalyptus	13-22[2)]	3.5[2)]	3.6-6.1	13-21
Alfalfa	13[3)]	2-4^{10}[1)]	6.1	12-24
Sorghum	16[3)]	2^{10}[1)]	5.0	10
Sugar Beet	15[3)]	3-4.5^{10}[1)]	5.3	16-24
Corn	6[3)]	1-2^{10}[1)]	13	12-26

1) California Department of Water Resources (1974)

2) D.J. Aalo (1977)

3) J.A. Bassham (1977)

Table V-4

Balance Sheet of California Water Resources (1972)
(10^6 acre-ft/yr)

	Income	Debits	
Average Annual Rainfall	200		
Evaporation & Transpiration (excluding irrigated crops)		129.2	
Total Runoff			70.8
Imports (Colorado River)	4.4		
Inflow from Oregon	1.4		
Wild & Scenic Rivers		17.8	
Salinity Repulsion		3.4	
Outflow to Nevada		1.2	
Use Not Possible (remote, floods, etc.)		13.6	
Total Non-usable Water Resource			-30.2
Total Utilizable Water Resource			40.6

Source: California Department of Water Resources (1974c)

Table V-5

California Water Supply and Demand, 1972 and 2025
(10^6 acre-ft/yr)

DEMAND[a]			SUPPLY		
Use	1972	2025	Source	1972	2025
Urban	5.04	10.2	Local Water Projects	9.3	9.8
Agricultural	31.7	36.4	Imports (local agencies)	2.5	1.7
Power Plant Cooling	.04	.4[b]	Ground Water	5.2	5.6
Recreation, Fish, Wildlife	.66	.85	Central Valley Project	7.3	9.2
TOTAL	37.4	47.8	Other Federal Projects	5.1	5.3
			State Water Project	1.2	4.5
			Waste Reclamation	.2	.4
			Desalting	--	.2
NET DEMAND[c]	31.0	40.4	TOTAL DEPENDABLE SUPPLY	30.7	36.4

Source: California Department of Water Resources (1974c)

[a]Extrapolated from 2020 to 2025.

[b]DWR estimate based on an assumed fivefold increase in electric power generation.

[c]Corrected for water re-use.

Table V-6

California Biomass Farming Potential

CALIFORNIA LAND				BIOMASS FARMS		
Cover Type	Area[a] (10^6 acres)	Projected Uses: Type	Projected Uses: Area[a] (10^6 acres)	Area (10^6 acres)	Assumed yield (dry ton/acre)	Annual output 10^{12} Btu
Coniferous forest[b]	20.4	Commercial	16.0			
		Non-commercial	4.8	4.8	0.13[c]	
		Reserve	1.4			
Pinon-Juniper[d]	2.7			2.7	0.13[c]	12
Grass & Forbes	9.8			<2[e]	.07[f]-.15[g]	<3
South Desert Shrub	24.4			--		
Urban & Industrial	2.3			--		
Water	1.4			--		
Hardwood Forest	10.2	Commercial	1.3	1.3[h]	1.2[i]-5[j]	19-83
		Non-commercial	2.8	2.8[h]	0.68[k]-5[j]	24-100
Chaparal & Mountain Brush	10.2			3.75[l]	2.0[m]	50
North Desert Shrub	5.3			--		
Cultivated & Pasture	13.6	Irrigated crops	10.3[n]	.57[o]	13-22[p]	90-160
		Dry crops	.6[f]	--		
Barren	1.2					
TOTALS	101.5					200-490

[a]Disagreements between area figures in these two columns reflect differences in land category definitions.

[b]Biomass resources obtained from thinning in new commercial forests and removing dead and dying trees in existing forests are included in the previous estimates of waste biomass availability (Table V-2).

[c]Assumes 140-year rotation (Groncki, 1977).

Footnotes to Table V-6 (continued)

[d]Environmentally fragile

[e]Estimated acreage mechanically harvestable (Brigg, 1977)

[f]Brigg (1977)

[g]Heady (1977)

[h]Source of acreage estimates: Groncki (1977)

[i]Assumes 40-year rotation (Groncki, 1977)

[j]Assuming coppice farming (Aalo, 1977)

[k]Assumes 90-year rotation (Groncki, 1977)

[l]Groncki (1977)

[m]Assumes 20-year rotation (Groncki, 1977)

[n]Projected agricultural cropland based on D-100 population projections and conservative assumptions about agriculture (Department of Water Resources, 1974).

[o]The acreage which could be irrigated assuming reclamation of 20 percent of the urban water use in 2025.

[p]Yield estimates for intensively cultivated eucalyptus (Henry, 1977).

(including those now commercially harvested) are cut down and converted to wood forms (Henry, 1977). However, we assume that the presently commercial coniferous forest remains being used for lumber, and only the presently non-commercial coniferous forests are converted to energy farms. We also assume that 20 percent of municipal (and industrial) waste water is reclaimed and used to irrigate a biomass crop, which is taken to be eucalyptus (Aalo, 1977). These activities will require substantial fertilizer (0.1-0.2 million tons nitrogen, 0.02-0.03 million tons phosphorus, and 0.1-0.2 million tons potassium for the acreage and the yields quoted.) There is more than enough cropland available for this. Henry (1977) asserts that 50 percent of municipal water is consumed and another 20-30 percent is necessary to carry off dissolved salts. Possibly some of the consumption might be reduced by urban conservation measures. If 80 percent of urban water could be reclaimed for biomass farms it would result in an additional 0.3-0.5 quad of biomass annually above the amount listed in Table V-5 and would entail a concomitant fourfold increase in fertilizer usage.

To produce more than this amount of energy, biomass farming would have to compete with food-growing agriculture for land and water. Table V-3 shows that this competition is severe. To produce one quad of additional biomass would require some 10-15 million acre-feet of water. If this were diverted to biomass farming, it would require a substantial (25-30%) reduction in the amount of irrigated cropland. Moreover, part of the biomass produced in food production is agricultural waste which is utilizable for energy production and therefore the net gain in energy production would be somewhat less than one quad, depending on the nature of the displaced crops.

It is also possible to consider relaxing the environmental constraint reserving some 17 million acre-feet of water for wild and scenic rivers. To irrigate the 2.1 million acres of crop and pastureland in Table V-6 not projected as cropland and biomass farms would require some 8 million acre-feet of this water. Again, biomass and food agriculture would be in competition for this land and water. If it were used entirely for biomass farming, it would produce an additional 0.3-0.6 quads annually; if for food agriculture, less than half as much.

We conclude that the potential for conventional biomass farming (including forest management) is from 0.2 to 0.5 quads annually, that the upper estimate involves forest management practices which are not benign, and that a large expansion of this potential by irrigated agriculture incurs major environmental costs (dams on wild and scenic rivers), economic costs (greatly reduced food production) or both.

5.2.4 Ocean Kelp Farming

Reliance on waste resources and land-based energy plantations yields only 1200 to 1500 x 10^{12} Btu of biomass. We will find in Chapter VI that demand for fuels exceeds this amount. Thus we have explored the potential for kelp farms off the coast of California. Ocean-based kelp farming is attractive for two reasons. First, kelp is highly efficient in converting sunlight into stored energy (2%) (Budhraja, 1976). Second, water and land are removed as constraints.

However, kelp farming remains an unproven technology in comparison to the preceeding methods of producing biomass. Although preliminary feasibility studies have been completed, no large-scale project has demonstrated the feasibility of kelp farming. We have examined two scales of kelp plants for California, a moderate program totaling 6.4 x 10^6 acres of ocean (10,000 square miles) and a large program totaling 12.8 x 10^6 acres of ocean (20,000 square miles). Assuming kelp can attain a 1.25 percent efficiency of photosynthesis and assuming daily insolation of 1300 Btu/square feet, these two schemes would yield 1.55 and 3.09 quads of biomass, respectively.

An examination of the site problems and institutional constraints in implementing this program has not been attempted at this time. The program would require floating kelp beds 100-150 feet below the water secured to the ocean floor by weights and moorings. Individual kelp farms would range in size from 100 to 200 square miles apiece.

5.2.5 Conversion to Fuels

Table V-7 shows the conversion of the potential biomass sources identified above into liquid fuel. This is not the only possible use of_biomass, it could be burned directly for heat or to generate electricity. However our energy demand estimates in Chapter VI below will show the biomass to be most useful in the form of a high quality fuel, such as methanol. Thus we assume all biomass is so converted. Our figures assume no improvement in conversion technologies from present demonstrations. Enzymatic conversion or other techniques may significantly improve conversion efficiencies in the future.

When converted to liquid fuels, the quantities of biomass from land energy farms and waste yield only 0.6 to 0.7 quads. When methanol from ocean kelp is added, the total amount of liquid fuels available to California from biomass is found to be in the range of .8 to 1.3 quads of liquid fuels. In Figure V-1, we have provided a map of California, specifying the location of biomass resources in the state.

Table V-7

Fuels from Biomass, 2025
(10^{15} Btu)

	Btu Content (10^{15})	Conversion[1] Efficiency	Yield (methanol) 10^{12} Btu
Biomass Waste Resources	1.055	.45	480
Tree Farms	.200 - .490	.45	90-221
Kelp Farms (Ocean)	1.55 - 3.09	.18	278-545
TOTAL	2.810-4.64		848-1246

[1]For biomass wastes and tree farms we assume an overall efficiency of 45 percent by two processes: Pyrolysis of biomass to produce gas converted to methanol using water-shift conversion process, and digestion of waste to methane and conversion into methanol. For kelp farms we assume that energy inputs equal to 20 percent of the energy value of the kelp is expended in maintaining the kelp farmland and collecting and preparing the kelp for digestion. We further assume digestion of kelp at 60 percent efficiency and final conversion to methanol at 45 percent efficiency (Dickson, 1976).

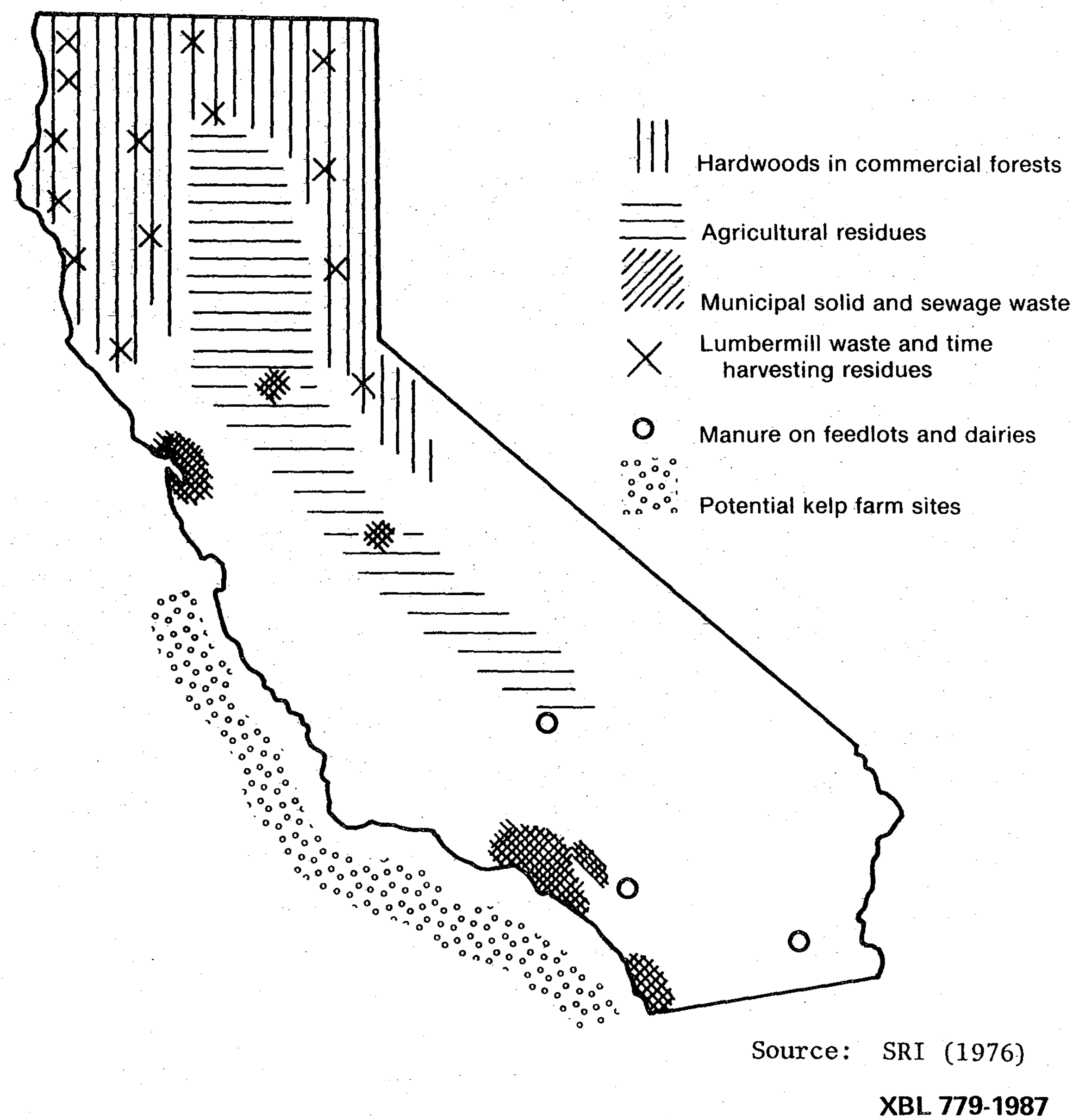


Figure V-1. Location of Biomass Resources in California

5.3 SOLAR ENERGY

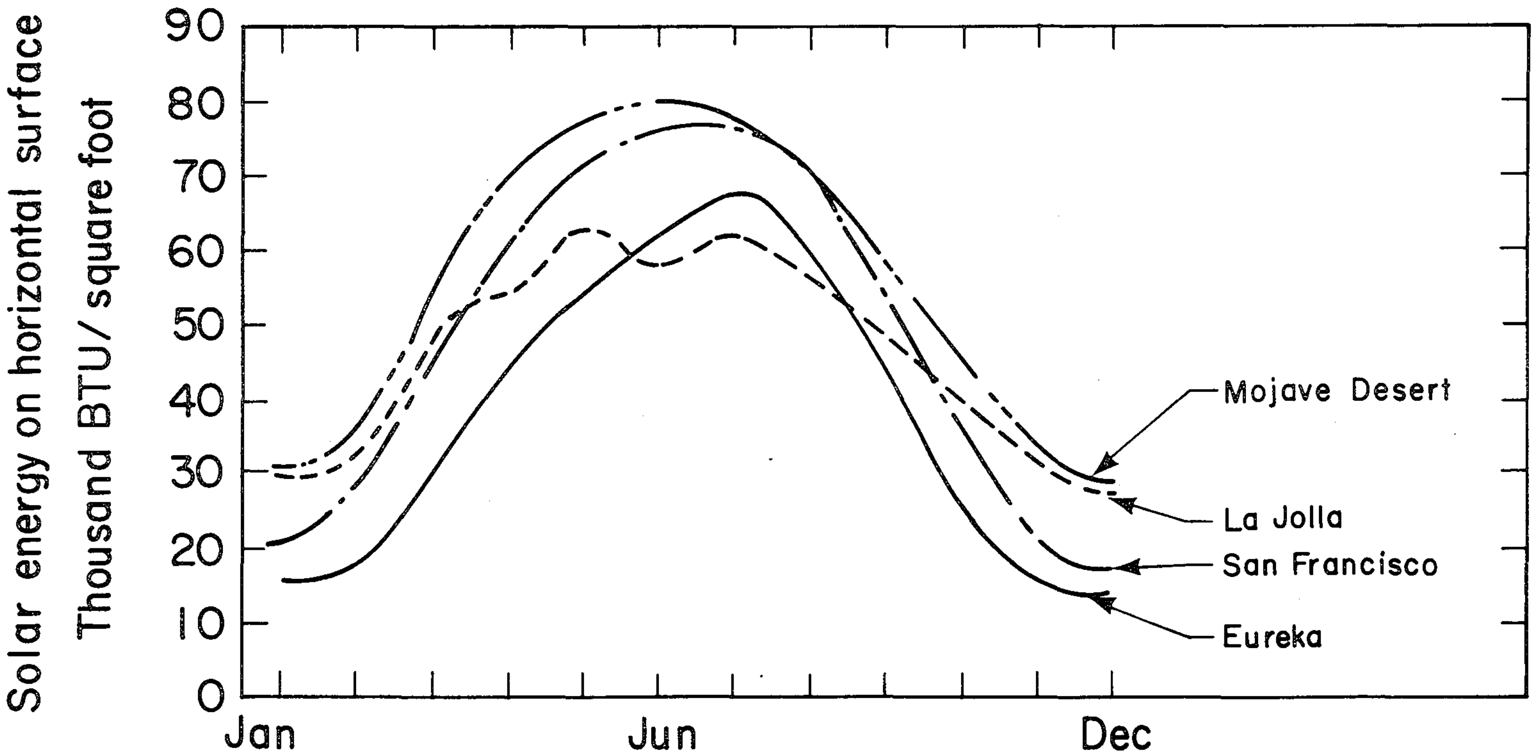
5.3.1 Characteristics of the Resource

California has a plentiful solar resource, average insolation (solar radiation) in the state being somewhat higher than in most of the Nation. However, California also has a diversity in its solar resource because of the many climatic zones in the state. Insolation in the Mojave Desert is nearly as high as any U.S. location, while insolation in the northwestern corner of the state is nearly as low as anywhere in the U.S. The annual pattern of insolation at several locations in the state is shown in Figure V-2.

There is even greater variation between regions of California in the dependability of the solar resource. This has important consequences for the reliability of systems incorporating solar energy, and for the requirements for storage of energy or backup sources of energy. Figure V-3 shows the average number of occurrences per heating season (October through March) of cloudy periods of various durations. It is seen that the frequency of occurrence of single days of cloudiness does not vary greatly among the populated coastal regions of the state (about 15 occurrences per heating season). However periods of five successive days of cloudiness are ten times more likely in the northernmost than in the southernmost parts of the state.

The total amount of solar energy falling on the state is immense in comparison with the amounts that might be used by humankind. If we take as a typical vlaue for the average daily insolation 1300 Btu/ft^2, then the total amount of energy falling on the land area of the state each year is 2400 quads. This is about 500 times the energy demand of the state in the year 2025 estimated in Chapter VI.

We do not attempt to estimate the maximum energy obtainable from each of the solar energy technologies. Instead, in each of these cases we estimate the physical characteristics of the systems required to



Source: Berdahl (1977)

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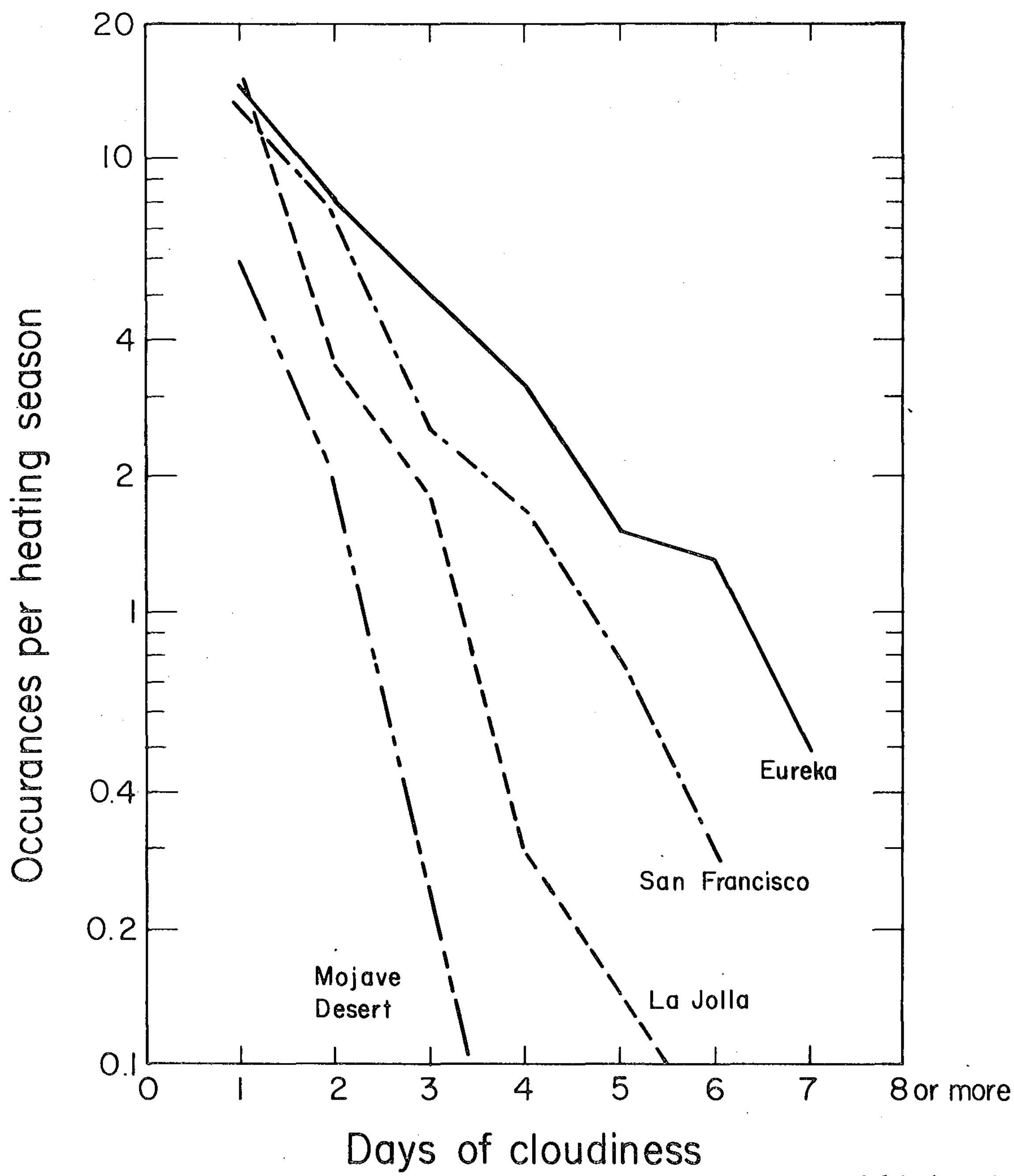
Figure V-2. Annual Variation of the Solar Energy Falling on a Horizontal Surface for Four Locations in California. The annual totals in thousand Btu/ft^2 are Mojave Desert 664, San Francisco 576, La Jolla 548, and Eureka 454.



Source: Berdahl (1977)

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Figure V-3. Frequency of Occurrence of Periods of Cloudiness of Various Durations in Four Locations in California. The heating season is taken to be October through March, and the criterion for a cloudy day is that insolation received is less than 40 percent of the insolation at the top of the earth's atmosphere.

provide annually a certain amount of energy: 0.1 quad (10^{14} Btu) of useful energy. Note that 0.1 quad of useful energy from a solar system may displace a requirement for 0.15 to 0.3 quads of fossil fuel, depending upon the efficiency with which that fuel would be used. The physical characteristics of the solar systems will be generally expressed here as a certain number of square feet of collector area, and sometimes also as a requirement for an amount of dedicated land area. This allows some conception of the practical limits to our utilization of solar energy in California.

5.3.2 Solar Water Heating

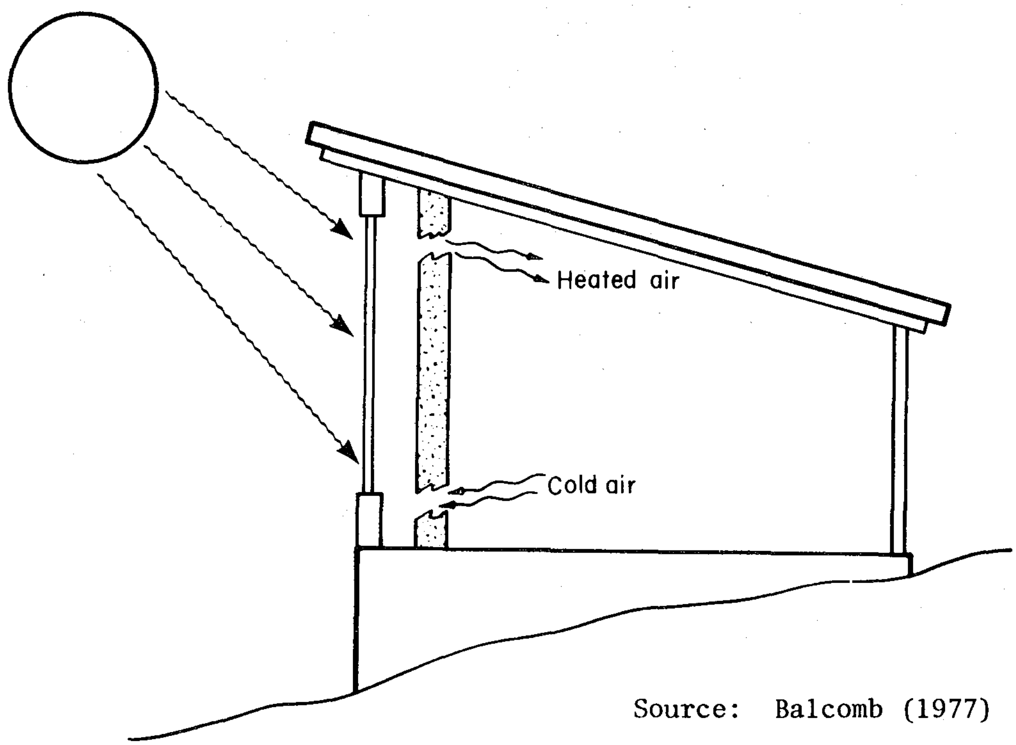
Hot water (temperatures less than 212°F) is required for residential, commercial, and industrial applications. Direct collection of solar heat could provide for all of these requirements. We analyze here only the use of solar energy for heating residential hot water, but the resulting estimate of the collector area required and land required to provide a unit of useful energy can be extended to the other applications.

There are many possible configurations of solar water heaters. Each has certain advantages. Here we consider a system with a flat-plate collector with a pumped liquid coolant (Balcomb, 1976). Such systems are now generally designed to provide only 50-75 percent of the hot water requirement of a residence, backup providing the balance. For the year 2025 we assume the design goal will be to approach 100 percent solar operation. This requires a larger collector area and a larger storage volume than present systems for the same delivered quantity of useful energy. We assume four days of storage is provided, and the area of collector is correspondingly increased. Typical values of collector area and storage volume per person might be 40 ft^2 of collector and 80 gallons of storage. Such a system, because it is sized to provide adequate heat for harsh conditions, will be oversized for average operation and thus will operate at an annual average efficiency of only about 20 percent, rather than the 50 percent typical of systems designed to provide only some of the water heating load.

From the above considerations, we can estimate the collector area required to provide 0.1 quads of useful energy annually. With an annual efficiency of 20 percent, and a typical value of insolation for mid-California, the area of solar collector required would be 830 million ft^2. This may or may not also require any land area. For most applications of solar water heating, the area required for collectors can be obtained on the roof of the building. However for some industrial applications and in high density urban areas this may not be possible, and in these cases about 2 billion ft^2 (75 square miles) of land would be required for each 0.1 quad of delivered useful energy.

5.3.3 Passive Solar Heating of Buildings

In passive solar design, the entire building serves as the solar collector and storage (Anderson, 1977). This can be considered either to be energy-conserving design, or to be a particularly simple form of solar heating. Here we will treat it as the latter and estimate the useful heat collected by the building. There are many different types of passive solar systems, and an important concept in passive design is to match carefully the design of the building to the particular site it will occupy. However for our analysis here we will consider only one type of design: the Trombe wall (Figure V-4). The performance of this system has been simulated for 29 various climates (Balcomb, 1977). We use these simulations to estimate the potential contribution of passive solar heating of buildings in California. For the densely populated areas of California (excluding the deserts and high mountains) the percentage of building heat provided by the Trombe wall ranges from 99.9 percent in Los Angeles to about 56 percent in the northern part of the state (data for this simulation actually from Medford, Oregon). The useful solar heating per square foot of south facing window ranges from 70,000 Btu/year to about 43,000 Btu/year. In the southern part of the state these systems can provide 100 percent of the requirement with good reliability. However in the northern part, either backup or extremely large additional heat storage is required because of the occurrence of



Source: Balcomb (1977)

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Figure V-4. Trombe Wall Type of Solar Passive Heating of a Building. The sunlight through the south-facing windows heats a massive concrete wall. The wall then provides heat as needed to the building by a combination of radiation and convection.

periods of 8 or more cloudy days. For a house in Los Angeles with 1500 ft^2 of floor area, the annual useful heat provided by a Trombe wall would be about 13 million Btu. Thus about 8 million passive solar homes would provide 0.1 quads of useful solar energy.

5.3.4 Solar District Heating

Densely populated urban areas present special problems for the use of solar energy. Available roof areas may not suffice for the area of solar collectors required to meet the loads in some locations. Of the various systems that might be used to deal with this situation, we analyze one: solar district heating with neighborhood solar collection and storage, and incineration of municipal solid waste for backup. The basic design approach is to use active solar systems (collectors plus storage) to meet the neighborhood heat load for residential and commercial building space and water heating. This concept will be developed in more detail in Chapter VI. Here we summarize the collector and storage requirements for a given quantity of delivered useful energy.

We stipulate that in San Francisco a neighborhood solar district heating system would provide enough storage for five days of hot water demand plus one day of storage for the space heat requirements at peak heating conditions (35^oF all day). In Los Angeles we stipulate four days of storage for the hot water demand plus storage for one day of space heat requirements at peak (40^oF all day). With these stipulations each square foot of collector in the San Francisco system will provide annually about 0.16 million Btu of useful heat, and each square foot of collector in the Los Angeles system about 0.19 million Btu. Thus 0.1 quads of useful annual delivered energy will require 525 to 625 million ft^2 of collector and about 45 to 60 square miles of land area. If each district system serves the needs for both commercial and residential heating requirements of 1000 persons, then each system requires on the order of 50,000 to 80,000 square feet of collector and three to five acres of land or roof-top area with good solar exposure. (In

San Francisco, the most densely populated California city, the present average density is 1000 persons per 40 acres.) About 10,000 such district systems would provide 0.1 quad of useful energy annually.

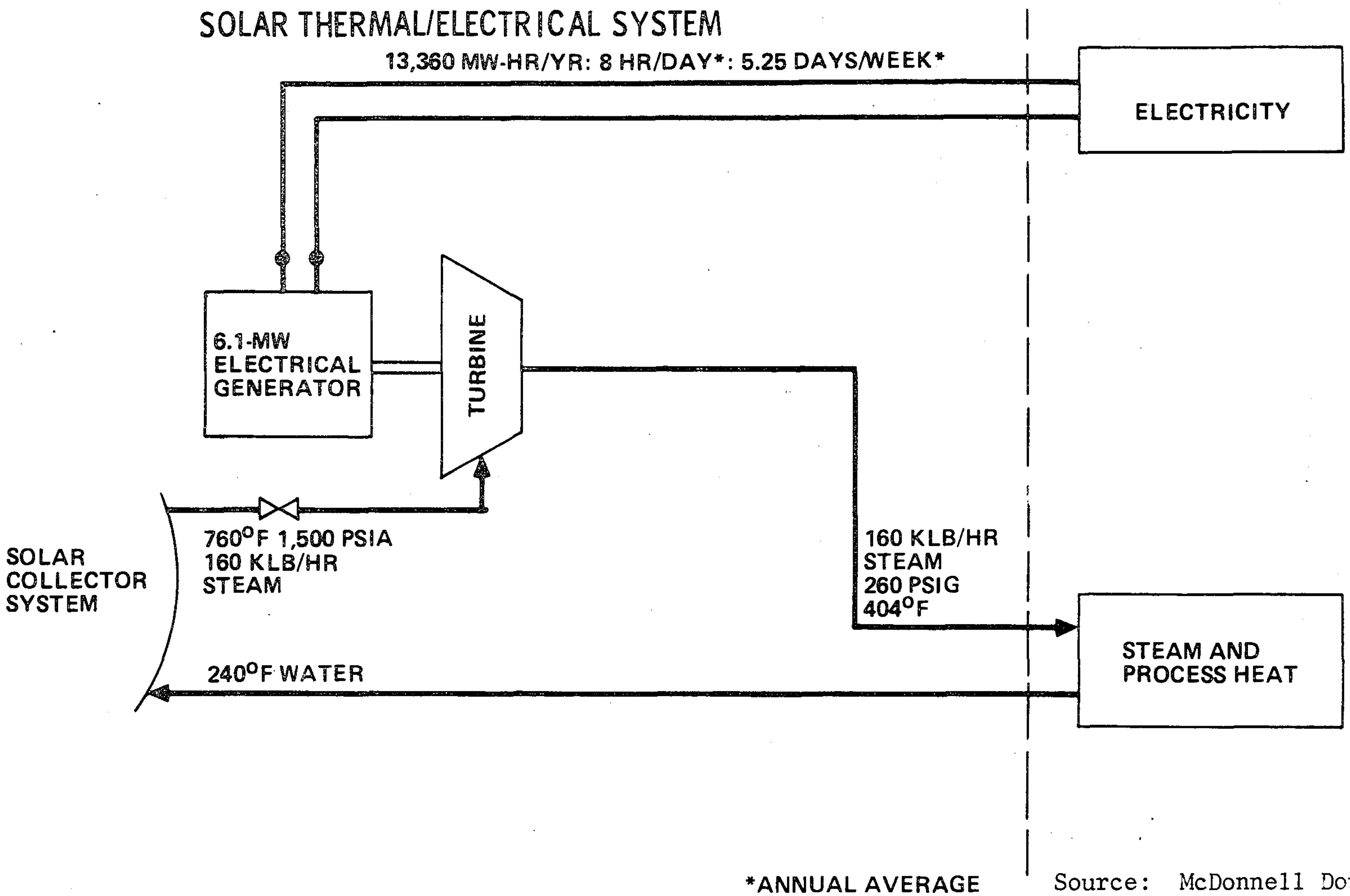
5.3.5 Solar Industrial Process Heat and Cogeneration

Industries require large amounts of heat in the form of steam or hot air at temperatures between 212°F and 350°F. These requirements can be provided by concentrating solar collectors and high temperature storage systems. Some industries also require heat at temperatures above 350°F. Solar collectors can provide some of this heat requirement as well, but at the highest temperatures (about 1000°F) the technical problems of heat collection and storage are severe.

Steam generated in solar collectors to provide for these heat requirements can be run through a turbine and thus generate electricity before going to the process requiring moderate temperature heat. For some industries the relative demands for heat and electricity match the mixes of electricity and heat production possible in such solar cogeneration systems. However in other industries the relative demands are not appropriate and either excess electricity or excess heat must be sold or otherwise disposed of.

The concentrating and sun-tracking collectors used in such systems can be highly efficient. However they utilize only the light coming directly from the sun, and are not able to take advantage of the diffuse light from the sky (as can flat-plate collectors). Thus the resource available for these solar systems is somewhat smaller and less dependable than for the low-temperature systems considered above.

A typical industrial solar cogeneration system for an industry (McDonnell Douglas, 1976) might collect heat at 760°F and use this to generate electricity. The exhaust steam from the turbine, at 404°F, would then be used for process heat (see Figure V-5). Such a system might generate about 38 kWh of electricity for each million Btu of process



Source: McDonnell Douglas (1976)

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Figure V-5. Total Energy Systems: Industrial Applications of Solar Energy heat delivered. About 44 square miles of land adjacent to industrial sites would be required by solar cogeneration systems to provide 0.1 quad of heat plus electricity (McDonnell-Douglas, 1977).

5.3.6 Other Solar Technologies

Many other solar energy technologies are under active development and will probably be available for wide utilization before the year 2025. That we have not included them in the analyses above does not indicate any judgment on our part that such technologies will not be successfully developed or will not be advantageous relative to those technologies we have considered. For example, low-cost photovoltaics may become important for on-site electricity generation, but their land requirements will not be significantly different from the land requirements estimated above for solar cogeneration. Indeed, photovoltaics may also ultimately be used in a cogeneration scheme, with waste heat from photovoltaic cells being used for industrial processes.

5.4 HYDROELECTRIC AND PUMPED STORAGE RESOURCES

Hydroelectric power comprises, after oil-fueled generation, the second largest source of electicity in California. Its 7.2 GW of installed capacity and 39,191 GW-hrs of annual output (in 1975) comprised over one fifth of all generating capacity and one quarter of power output in California (U.S. Department of Commerce, 1976).

The impacts of the current drought in California have had a small impact on available hydroelectric generating capacity but a substantial impact on power generation: 1977's estimated output is 40 percent of the 1975 (pre-drought) level (Sathaye, 1977).

Three areas of potential new conventional hydroelectric (rather than pumped storage) capacity are: 1) rerating existing facilities by rebuilding turbines or adding additional ones; 2) building additional large projects; 3) installing small hydroplants (rated output less than 25 GW-hrs) in new and/or existing dams. We summarize here various estimates of this potential new capacity in California.

The potential capacity at new large dams (excluding protected areas, such as parks and wild and scenic rivers), is approximately 6.9 GWe. The rated annual output is 12,500 GW-hrs per year (California Department of Water Resources, 1974). However, under 1977 drought conditions the expected output is 40 percent of the rated annual output or 5,000 GW-hrs.

The Federal Power Commission (1976) finds 9.3 GWe of potential capacity (including some rerating of existing facilities). Rated annual output is 27,600 GW-hrs per year (11,000 GW-hrs under present drought conditions).

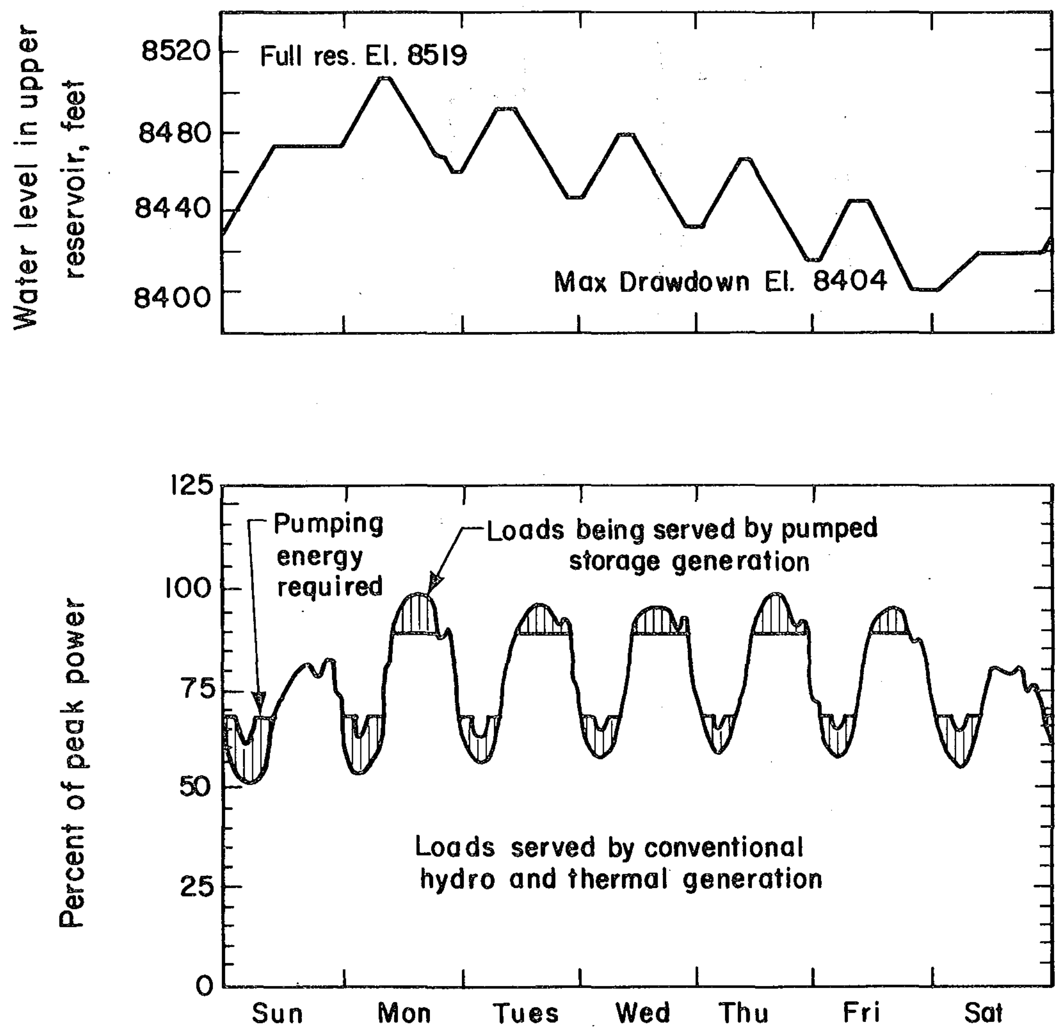
A separate survey of small hydroelectric sites (California Department of Water Resources, 1976) finds over 0.2 GWe of potential capacity at small sites already in existence, with a total rated output of almost 1,000 GW-hrs per year. This survey covers only 10 percent of water agencies and the question of potential power production at new small dam sites was not addressed.

Combining the existing hydroelectric capacity, the Federal Power Commission estimate of potential new capacity, and the results of the survey of small sites, we find an estimated annual output of 67,790 GW-hrs (0.23×10^{12} Btu).

Hydroelectric power, once used to meet baseload demand in California, is now almost exclusively used for daily and seasonal peak loads (subject to downstream water flow constraints). The ultimate example of the application of hydro to meet peak power requirements is pumped storage, in which off-peak power is "converted" to peak power, with an approximately 70-75 percent conversion efficiency. In a pumped hydroelectric storage facility off-peak power is used to pump water from a lower to an upper reservoir; during the peak a turbine is driven by water from the upper reservoir to generate electricity. A variant of typical pumped storage operation (pumping and power generation on a diurnal cycle with up to 12 hours power production) is the weekly cycle (illustrated in Figure V-6). By limiting power generation to eight hours each weekday, the upper reservoir can be drawn down gradually over five days and refilled through pumping at the weekly (as well as daily) off-peak periods on the weekend (Federal Power Commission, 1975). The choice of operating mode (daily versus weekly cycle) is a tradeoff between larger reservoir capacity (with attendant environmental impacts) and the ability to utilize power during the weekend off-peaks. If the baseload is provided by a very capital-intensive, low operating cost system such as nuclear or wind power, the ability to utilize a smaller system for more hours of the pumping is economically attractive.

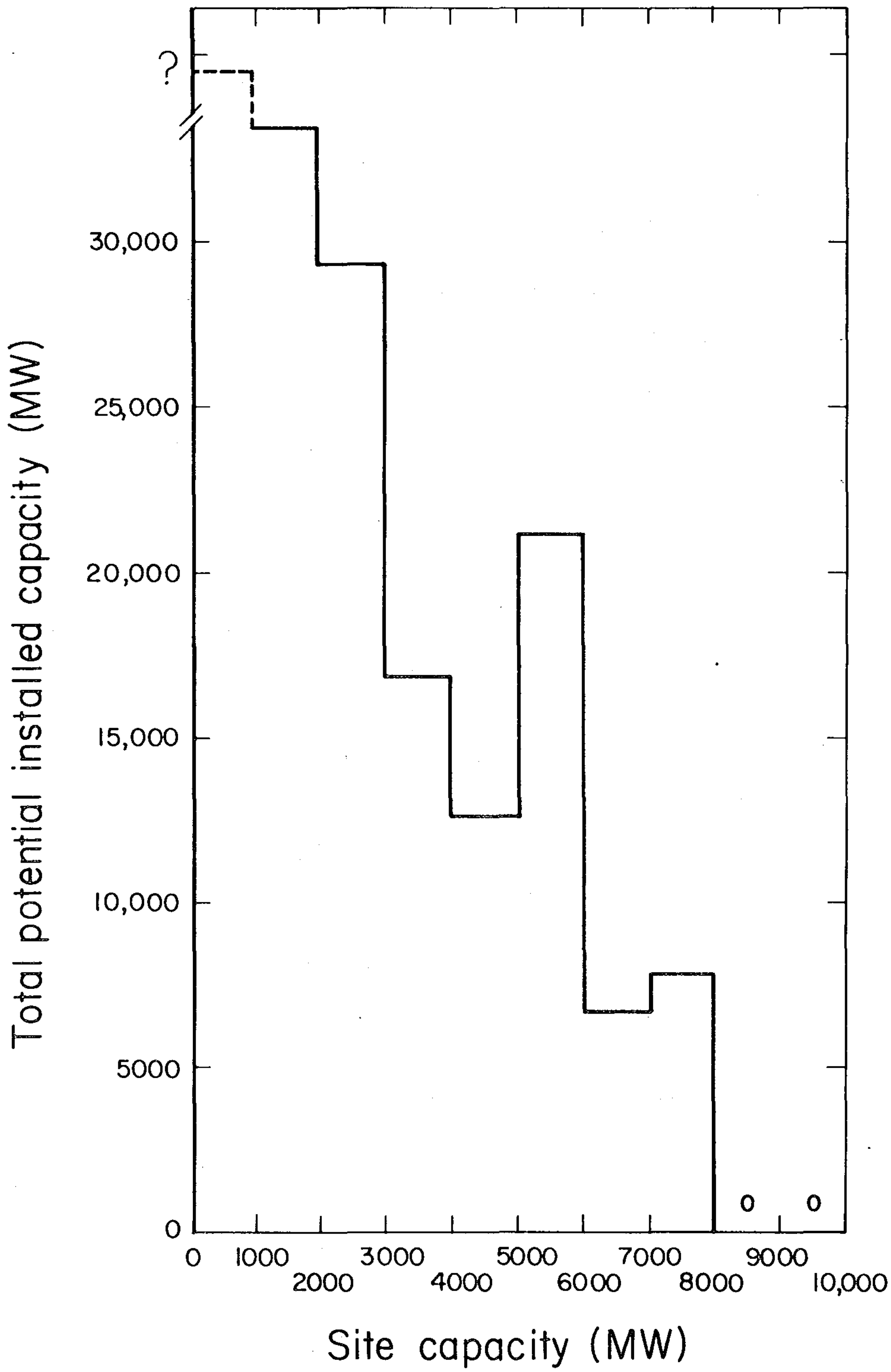
The Federal Power Commission (1975) has estimated the total potential pumped storage in California (based on twelve hours continuous output at rated capacity) at 128 GWe, excluding projects on the Eel River, currently protected, and two projects in which current water contracts preclude pumped storage. Development of this potential would require hundreds of facilities on almost every river or sizable stream in California. One key FPC selection criterion was project size; in order to limit the number of sites to be surveyed, they excluded those of less than one GWe capacity. Figure V-7 shows that pumped storage potential is greatest for the smaller plant sizes studied. It suggests the existence of substantial potential capacity in the less-than-gigawatt plant size range.

A potential limiting factor on pumped storage potential is the attendant water requirement. The total water requirement for the fully-implemented 128 GWe pumped storage system is 1.5 million acre-feet (AF).



Source: Federal Power Commission (1975)

Figure V-6. Typical Summer Weekly System Load Curve for the Pacific Southwest



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Source: Federal Power Commission (1975)

Figure V-7. Site Capacity (MW)

1.3 million AF is usable storage and the balance, 4,000 AF per site, is the assumed minimum dead storage capacity in the upper and lower reservoirs. This is only a small increment to the reservoir storage in an average year (at May 1) of over 25 million AF (Sathaye, 1977). It is also small in comparison to California's total surface runoff of 55 million AF (California Department of Water Resources, 1974).

An additional water impact is the requirement of make-up water to replace evaporation and seepage from the one hundred (upper and lower) reservoirs in the pumped storage system. The surface area of project reservoirs (excluding those in which the drawdown of ten feet or less suggests that an existing large reservoir is being used) is approximately 21,000 acres. At typical losses of three feet per year, system evaporative losses are about 63,000 acre-feet. Seepage losses are approximately 5 percent of total capacity or 75,000 acre-feet per year (J. Vayder, 1977). Total make-up requirements are thus approximately 138,000 acre-feet per year or 9 percent of system storage capacity. By comparison in 1977, a drought year, the Central Valley agricultural surface water supply alone is over 9 million acre-feet, nearly two orders of magnitude larger than the water losses from a 128 GWe pumped storage system. This suggests that water availability is not an impediment to pumped storage implementation on any feasible scale.

5.5 GEOTHERMAL ENERGY

California has a large geothermal potential and already has the only operating geothermal power plant in the U.S. (at The Geysers in northern California). Further, much of the geothermal R&D being conducted in the U.S. is directed toward development of California resources. Thus there is good reason to anticipate the availability of significant amounts of geothermal power in the state in the future. However, there are also a number of factors that make this less than certain to occur. First, the technical problems in using the bulk of the geothermal resource are significant. The Geysers field appears to be unique in that it provides a high quality dry steam which can be used directly to drive turbines. The other geothermal resources in the state provide hot pressurized water, a much more difficult resource to utilize. Second, the environmental issues surrounding the use of geothermal power have not been resolved. There are potentially important environmental impacts from geothermal development, and these have yet to be dealt with by legislation. Third, the duration of the geothermal resources is unknown. Some resource areas may be almost renewable resources if they are properly managed. However other resource areas may be rather quickly exhausted if there is no renewal of their heat content by heat flow from deep underground.

Table V-8 and Figure V-8 summarize the location and estimates of energy potential of the known geothermal resource areas in California, as compiled by the U.S. Geological Survey. Maximum potential from these geothermal sources has been estimated at 30 gigawatts of electrical generating capacity. A very large amount of energy, 34 quads, could be used for non-electric, direct-heat applications (ERCDC, 1977). However these resources are generally not located at sites of demand for direct heat, so use of this heat would require bringing industry to the resource. PG&E currently operates a facility at The Geysers, with 502 MWe of generating capacity, and has filed plans to increase generating capacity at this location to 2600 MWe by 1995.

An additional constraint on the maximum development of electrical generating capacity from geothermal sources should be noted: in several locations, including the very promising Imperial Valley Region, adequate

Table V-8

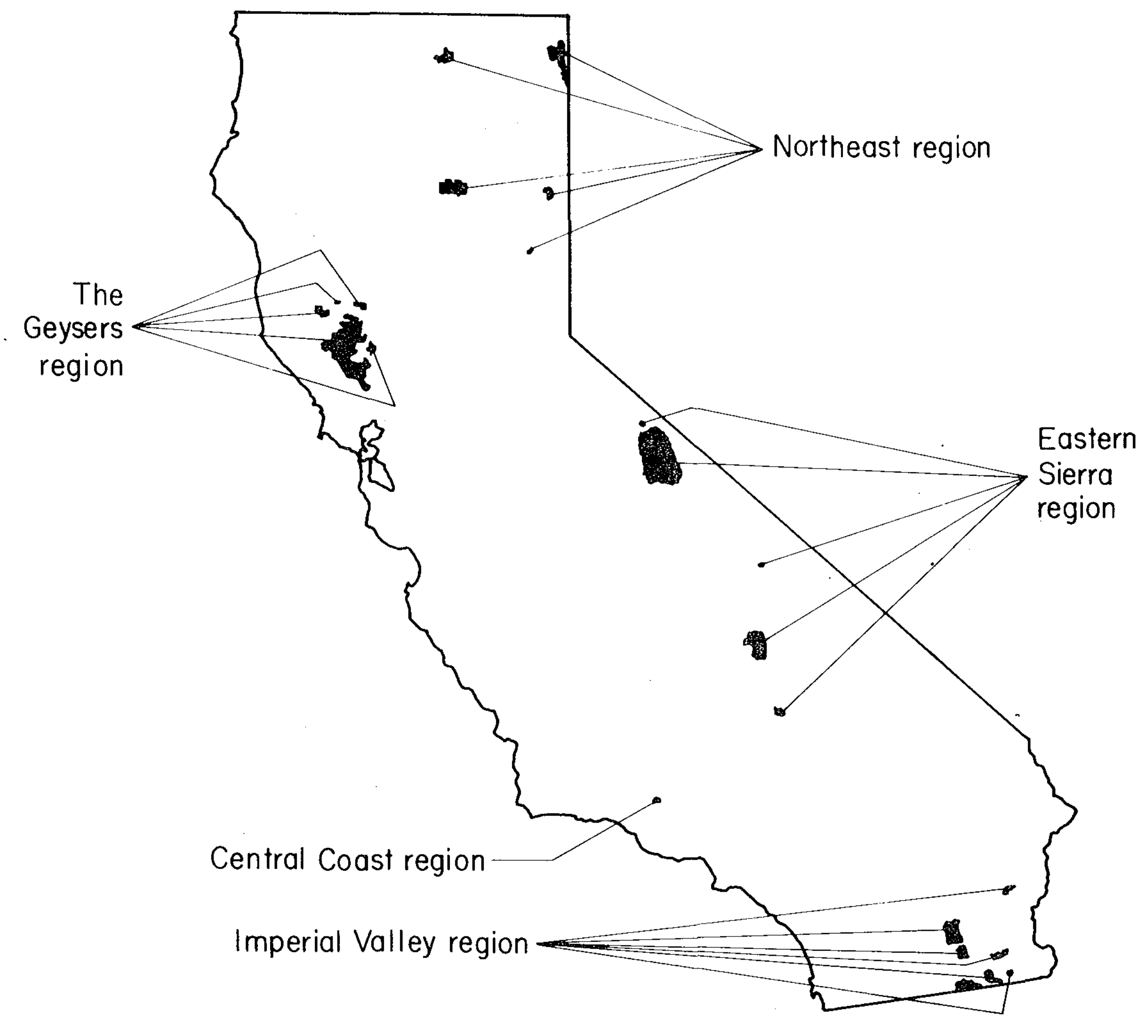
Identified Potential of Geothermal Resource Areas[a]

Location/KGRA	Estimated Reservoir Temperature, °C	Electric Energy Potential MWe for 30 years
The Geysers Region		
Geysers-Calistoga	240-135	1993
Knoxville	150	(c)
Little Horse Mtn.	150	(c)
Lovelady Ridge	140	(c)
Witter Springs	140	(c)
		1993
Imperial Valley Region		
Brawley	200	333
Dunes	135	(c)
East Mesa	180-160	487
Ford Dry Lake	(b)	(b)
Glamis	135	(c)
Heber	190	973
Salton Sea	340	2786
		4579
Eastern Sierra Region		
Bodie	(b)	(b)
Coso Hot Springs	220	4533
Mono Long Valley	220	6083
Randsburg	125	(c)
Saline Valley	(b)	(b)
		10,616
Northeast Region		
Beckwourth Peak	(b)	(b)
Glass Mountain	(b)	(b)
Lake City-Surprise Valley	175	2123
Lassen	210	133
Wendel-Amedee	140	(c)
		2256
Central Coast Region		
Sespe Hot Springs	155	(c)

(a) Source: Jet Propulsion Laboratory, (1976)

(b) No data available.

(c) Temperature too low for commercial power generation but may be valuable for nonelectric application.



Source: Jet Propulsion Laboratory (1976)

Figure V-8. Locations of California Known Geothermal Resource Areas (KGRA's) water for power plant cooling may not be available, and the scarcity of this particular resource may in 2025 constitute the limiting factor on geothermal development. If the full potential of 30 GWe were developed, this would provide about 670 x 10^{12} Btu of electrical energy.

Direct utilization of geothermal hot water and steam both from the major fields and from smaller sites shows great promise. A variety of uses have been proposed, and utilization in the canning industry is under particularly active development (Davey, 1977). Such direct utilization will probably be limited by the problems of siting such industries at the locations of geothermal resources. In general, geothermal steam and hot water are appropriate for all industrial process heat applications in the temperature ranges available and constitute a supply source of increasing current interest to industries now dependent on natural gas.

5.6 RENEWABLE OCEAN ENERGY RESOURCES

5.6.1 Potential Ocean Sources

The potential ocean energy sources considered here are tides, waves, thermal gradients, currents and salinity gradients. Energy sources which are not considered in this section include ocean-grown biomass (kelp farms), off-shore oil, gas, geothermal and wind resources. Off-shore geothermal energy may be an appreciable resource which has not yet been adequately surveyed. This section utilizes information contained in an assessment of California's ocean energy resources by Dr. Walter Schmitt of the Institute of Marine Resources, Scripps Institution of Oceanography (Schmitt, 1977).

Estimates of the size of effective ocean energy resources are highly dependent on assumptions about the technology for energy extraction. For example, an estimate of energy available from ocean thermal gradients depends on the minimum water temperature difference required for operation of such a facility. Hence in addition to surveying the available physical resources, the feasibility of technologies must also be discussed.

No demonstrated technologies are now available which are likely to permit appreciable energy extraction from the ocean near California. Since we have adopted a policy of conservative assumptions in this first phase study about the availability of technologies, no contribution from ocean power sources is included the hypothetical supply systems formulated in Chapter VI.

However, if appropriate technological advances occur, the energy flux contained in ocean waves and the salinity gradient of waste water discharges could supply appreciable energy. Table V-9 summarizes the findings for each of the resources considered.

5.6.2 Tidal Energy

Only two tidal power electricity generating stations have been built (Gray, 1972). One is located on the Rance River in France and has been in commercial operation since 1968. A small experimental tidal power

Table V-9

Potential of Various Ocean Energy Resources for California

Energy Source	Energy Potential in California	State of Required Technology
Tides	Small	Developed.
Waves	Large (10,000 MW approx.)	Experimental devices under development.
Thermal Gradients	None	Undergoing rapid development.
Currents	None	Speculative designs.
Salinity Gradients	Moderate	Concepts under development. Implementation very uncertain.

plant of 400 KW installed capacity has been built at Kislaya Guba on the Barents Sea, in the Soviet Union. Over twenty other sites with large potential for tidal power have been studied in detail. Only three of these sites are located in the U.S.A.: two are on Cook Inlet, Alaska, and one is at Passamaquoddy Bay, Maine.

An appropriate site is necessary for development of tidal power. On the open ocean the tidal height range is only about 60 centimeters. Shoaling effects increase this range in coastal regions by up to a factor of four. The funneling action of a converging estuary may amplify the tidal range even more. In certain bays or estuaries with a certain basin length, resonance effects can occur, amplifying the tidal amplitude by a factor of about four. An example of these effects can be found in the Bay of Fundy, located between Nova Scotia and New Brunswick, Canada, where tides occur with a mean range in height of 11 meters and a maximum of 16 meters. Favorable sites have a large tidal range and large surface area of enclosed water and require a short dam to isolate the basin from the ocean.

No sites in California have been identified by proponents for the development of tidal power. However, the nearby head of the Gulf of California is a possible site for such an installation. Tidal amplitudes are small (approximately 1.5 meters) along the California coast and none of the larger bays concentrate tidal energy. The construction of ocean basins for use as water energy storage devices has been proposed as an adjunct to intermittent energy sources such as wave power. These storage basins could also provide some energy from tides. In summary, tidal power is not expected to make an appreciable contribution to California's energy supply.

5.6.3 Wave Energy

Wave energy is generated from wind energy which in turn is derived from solar energy. The energy in waves occurs in several forms. One of these is the gravitational potential energy of the raised water at the wave crest. Another is the kinetic energy of forward motion of the wave. A third is the kinetic energy of the local motion of the water in a wave zone.

No large-scale wave energy conversion systems have been built. Engineering is in the invention, study, design and experimentation stages. The only operating wave power machines are small models used to power marine navigational aids. A variety of designs have been proposed for wave machines, but very few have ever been operated. In Japan a large number of wave-powered buoys and navigational aids of maximum power up to one kilowatt have been in use for some years.

The average power in ocean waves is considerable and is larger at higher latitudes. For the winter months, power levels greater than 50 KW per meter are generated by waves off the coast of Northern California. Year round values for Southern California and summer power levels off Northern California are much less. These power values are expressed as the energy flux per meter through a line perpendicular to the mean direction of wave motion. To estimate the power available off the Northern California coast we consider a single line of wave energy converters. The average power per year is taken as 20 kW per meter. The length is approximately 500 kilometers. The average power across the line is 10,000 MW. The conversion efficiency of wave energy devices has been variously estimated to be in the range of 10 to 80 percent.

Estimates both of available power in the waves and of conversion efficiency are unreliable. Nevertheless, it is clear that wave power off the coast of California has considerable energy potential. It is not necessary to restrict consideration to a single line of wave converters parallel to the coast. Waves grow in height and period with the strength and duration of the wind. Hence, lines of wave generators must be spaced some distance apart, to permit partial regeneration of the waves by the wind. It has been suggested that 50 kilometers might be a suitable spacing for such lines of wave converters; the power available per string, with such an arrangement would be about one quarter of the free ocean wave power (Isaacs, 1976). Assuming an energy conversion efficiency of one third, twelve strings of converters spaced 50 km apart would generate an average of 10,000 MW. This represents an arbitrary choice of parameters, the total available energy is dependent on the area of ocean utilized.

5.6.4 Ocean Thermal Gradients

The difference in temperature between the surface waters of the ocean (warmed by the sun) and the cold deep ocean waters is a potential source of energy. In the presently favored design for ocean thermal gradient power production, warm water taken from the surface layers of the sea is pumped through an evaporator containing a working fluid in a closed Rankine cycle system. The vaporized working fluid drives a gas turbine to provide electric power output. After passing through the turbine, the vapor is condensed by cold water drawn from deep in the ocean and is then pumped back to the evaporator for reuse. Ammonia is most often considered as the working fluid in the cycle but propane is a possible alternative.

Ocean thermal energy conversion requires an appropriate site. The present designs of ocean thermal energy systems are intended for operation with approximately 20^{o} C difference in water temperature and will not function at temperature differences smaller than this. Such temperature differences between surface water and deep water are not available near the coast of California. The surface waters are not very warm and subject to seasonal cooling. Depths suitable for cold water intake are not available close to shore, especially not under the only pool of seasonally warm water available near the State, in the Southern California Bight. Operation at decreasing temperature differences rapidly becomes uneconomical, and it seems unlikely that ocean thermal gradients will contribute energy supplies to California.

5.6.5 Ocean Currents

Electricity generation powered by ocean currents has been proposed for sites off the east coast of Florida. Even for this exceptionally favorable area, power generation requires development of technology and has not been shown to be economical. The Florida current contains a wide band of water with speeds between one and two meters per second.

A wide, persistent current with speeds in the range of only centimeters per second moves from north to south, parallel to the California coast. A nearshore countercurrent develops occasionally. No natural channels or passages heighten the speed of this general flow. Since the power in the water current is proportional to the cube of the velocity, large-scale energy extraction from ocean currents near California is considered impractical.

5.6.6 Salinity Gradients

Theoretically energy may be obtained by mixing fresh and salt waters. The difference in salinity between fresh water and seawater can support a pressure differential across a membrane equal to that of a water column of about 240 meters height. Dilution of one cubic meter per second of fresh water in a large volume of sea water will theoretically generate one Megawatt of power. This could perhaps be converted to electrical power with an efficiency of 15 to 50 percent. In some suggested schemes, fresh water flows into sea water through a semipermeable membrane which prevents the salt from crossing.

No technique for generation of power from salinity gradients that can be applied on a large scale has yet been demonstrated. A number of schemes have been suggested. Practical utilization of salinity power must await a lengthy and uncertain process of invention, engineering development and reduction in component costs. Major problems to be overcome include construction of large, robust, cheap semipermeable membranes and effective coupling of the hydrostatic potential energy to an electric power generator.

The embryonic state of development of this resource and uncertainty about the potential for practical utilization exclude this power source from consideration in this study. Furthermore, no likely sources of large quantities of fresh water seem to be available. A possible water supply might consist of waste water from California's cities. About one half of the fresh water supplied to cities reappears as waste water, still low in salinity. After some treatment, this water might become available for salinity power generation. If salinity power becomes economical, it may lend itself to decentralized power generation, utilizing many available small water supplies.

5.7 WIND ENERGY

5.7.1 Characteristics of the Resource

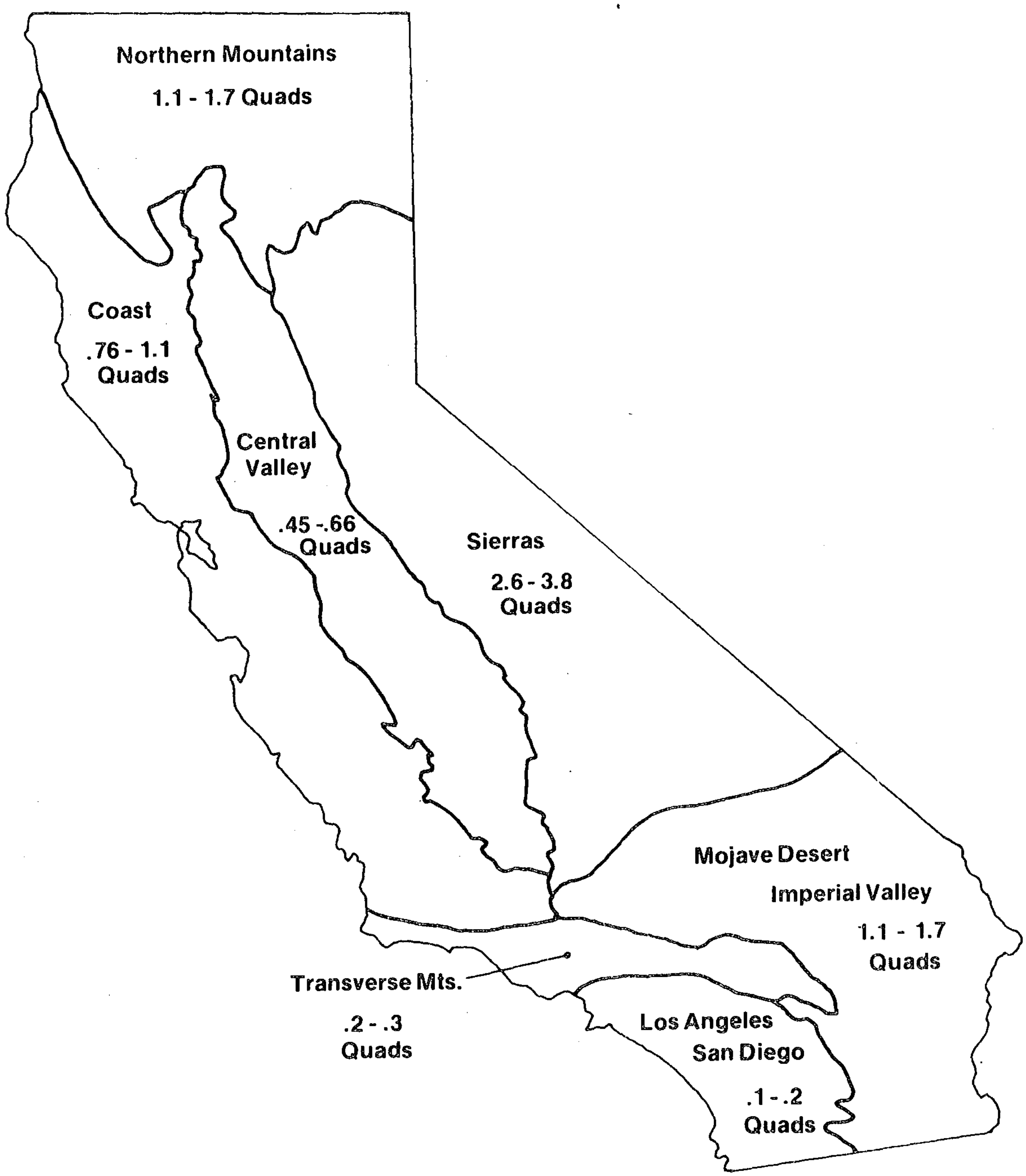
The energy available from wind varies with the cube of its speed. This implies a tremendous amplification of the variability that characterizes the resource. The wind speed one day may be twice that of the following day. However, because of the cubic variation, the energy obtainable at that site from the wind differs by a factor of eight between the two days. Thus wind energy is highly variable with time, and is not predictable. It varies even more widely than solar energy.

Secondly, the wind speed varies widely between sites. The regional wind speed varies between regions (i.e., between San Francisco and Los Angeles) and also varies locally because of deflection and concentration of wind by hills, valleys, etc. Again, because power goes with the cube of speed, the available wind energy will differ greatly (factors of ten or more) between sites, even sites in the same locale. Thus the siting of wind machines is much more critical than the siting of solar systems.

5.7.2 Maximum Available Energy

The estimate here is intended as a statement of physical possibility only; accordingly, we set aside temporarily questions of land use and economics and assume that all of the land area of California is covered with a network of optimally-spaced windmills. This would space wind mills with a separation of about ten times the diameter of each wind mill. About 6 percent of the land area would be actually occupied by windmills—about twice the amount now occupied by urban and built-up areas.

Wind energy depends greatly upon terrain. This dependence has been handled in an approximate way by dividing the state up into several regions by terrain and estimating the wind resource for each. Table V-10 presents this estimate for the seven regions shown in Figure V-9. For the mountainous regions, no good data exists and the estimates are based on general weather maps. Therefore the mountain estimates are much more uncertain than those for the other regions.



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Source:

Figure V-9. California Wind Energy Resources

The average power extracted by a windmill increases with the height of the windmill. However the exact manner in which it increases depends on the surrounding terrain and is not known. Table V-10 assumes windmills of 100 meter height and gives estimates assuming two plausible functional

Table V-10

California Wind Energy, by Region

Region	Annual Average Wind Power Flux (W/m^2)	Annual Average Energy (quads) 10m Tower	Annual Average Energy (quads) 100m Tower
Coast	94	.28	.76-1.1
Central Valley	83	.17	.45-.66
Los Angeles/San Diego	48	.04	.1-.2
Mojave Desert/Imperial Valley	160	.43	1.1-1.7
Northern California	187	.42	1.1-1.7
Sierras	255	.95	2.6-3.8
Transverse Mountains	121	.07	.2-.3
Total		2.4	6.3-9.4

Source: Klems (1977)

dependences on height (Klems, 1977). The two estimates give some idea of the range of uncertainty involved in extrapolating the weather station data. Over flat terrain the lower estimate is more likely to be correct.

Bearing in mind these assumptions and qualifications, one sees from Table V-10 that the maximum amount of energy extractable from the wind annually is 6.3 - 9.4 quads for high windmills.

5.7.3 Typical Supply Systems

Let us consider two alternative systems for delivering one quad of electricity (10^{15}Btu) annually from the wind, one centralized and one dispersed.

The characteristics of the centralized system are clear. To maximize the wind power one selects high windmill towers and locates them in the areas of highest wind power; hence the system consists of large windmills located in mountainous regions, particularly the high Sierras. Each windmill consists of a two-bladed propellor 360 feet in diameter mounted on a tower 330 feet high; its rated capacity is 3.5 megawatts. To generate one quad annually requires between 25,000 and 48,000 such windmills. The windmills would be spaced at least 0.6 miles apart and would extend over an area of between 10,000 and 19,400 sq. mi., (i.e., over about half of the Sierra Nevada).

Let us suppose the distinguishing characteristic of the dispersed wind system to be that the windmills are not remotely sited; that is, that they are located in the first four regions in Table V-10. Then they might be on the average about 50 feet high, 60 feet in diameter, and spaced every 600 feet. Again the available land area is covered by a forest of windmills. To produce one quad of energy would require about 6 million such windmills. In designing a diversified system there is an important tradeoff between windmill diameter and spacing: to avoid interference between windmills they must be spaced at least 10 diameters apart. Thus one can build larger windmills spaced farther apart or smaller ones spaced closer. The total area required by the array of windmills remains the same.

5.7.4 Time Variation and Dependability

Wind energy at a given site varies quickly (over minutes), daily, and with the seasons. The rapid variation causes certain technical (and generally soluble) problems of connecting to an electrical grid. The daily variation can be accommodated by, for example, pumped hydroelectric storage. The variations over periods of weeks to months may cause problems of dependability of delivered energy. The peak in wind energy does not occur in the same season at all sites. For example in the San Francisco area wind energy is highest in the summer months (Coty, 1977), but on the northern coast of California wind energy is highest in the winter and spring. This diversity in the timing of the wind resource may be crucial to the successful operation of energy systems employing wind energy for a significant portion of the electrical generation. This subject will be analyzed further in Chapter VI.

5.8 FOSSIL FUEL RESOURCES

California has significant fossil fuel resources in the form of oil and gas, but has very little coal. While coal has been mined here in the past, California is not even included in most listings of states in the U.S. with coal resources. The few resources of coal in California are small and of poor quality, so it is unlikely that coal will be used to any significant extent unless it is imported from outside the state.

The story is much different with oil and gas. California has long been a major producer of oil and gas. The California fields represented major discoveries at one time. However as discussed in Chapter IV, the production from these fields has been declining. It is possible that advanced methods of recovery could allow production of the remaining oil and gas in these California fields at sufficient levels to be of importance to the state for several decades. Estimates of the potentially recoverable crude oil and heavy crude oil (more difficult to extract) are shown in Tables V-11 and V-12. One forecast of future California oil production is shown in Figure V-10. Production schedules are shown corresponding to three possible sizes of the ultimately recoverable resource. This is only one of many possible forecasts, and the suggested schedule of development may not prove feasible. Nevertheless it indicates that little California oil will probably remain in 2025 under present development policies. Only by a dedicated program of resource recovery, and by a strict program of conservation, will any significant amounts of California oil and gas be available in 2025. Still, if the appropriate policies are established, some part of the resource could be reserved and used as a feedstock for the chemical industry long after 2025.

Table V-11

Estimates of California's Conventional Crude Oil Supply[e]

Source	Origin of Data Base: Date Reported	Proven Reserves (billions of bbl)	Additional Recoverables (billions of bbl)	Estimated Undiscovered	Total Recoverable (quads)
National Petroleum Council, 1973	NPC Oil-in-Place 1/1/71	3.984[a]	2.004[a]	16.2[b]	126
California Resource Agency, 1973	Calif. Div. Oil and Gas 1/1/71	5.2	0.95	9.59	90
California Coastal Zone Conservation Comm. (draft), 1974	NPC Oil-in-Place; Calif. Div. Oil and Gas 1/1/71	6.1	22.4	30.4	336
LLL, 1976	NPC Oil-in-Place 1/1/71	3.557[a]	8.7	21.9	195
USGS, 1975	USGS 1/1/75	3.557[a]	1.849	Onshore 6.68 Offshore 2.85 Sum of means 9.53[c]	85
				6-13.9[d]	65-110

[a]API reserve data as of 1/1/71 (3.984) and 1/1/75 (3.557).

[b]Using 23.3% average recovery (NPC, 1973 estimate).

[c]To 200-m depth offshore; these values are derived by subtracting Oregon and Washington contribution from undiscovered Pacific Coast State Estimates. This should properly not be done, but the error introduced by so doing is probably small.

[d]95-5% percentiles.

[e]Reproduced from Borg (1976).

Table V-12

An Estimate of California Heavy Oil Resources (billions of bbl)[a,d]

API[e] Gravity	Remaining Oil-In-Place, 1975[b]	Potentially Additional Recoverable 1975	Potentially Additional Recoverable 1985	Overall Recovery Factor Assumed to be Realized by 1985
°20-15	14	4[c]	9	70%
°15-10	30	4	14	50%
°10-7	3	0	1	33%
Total	47	8	24	55%

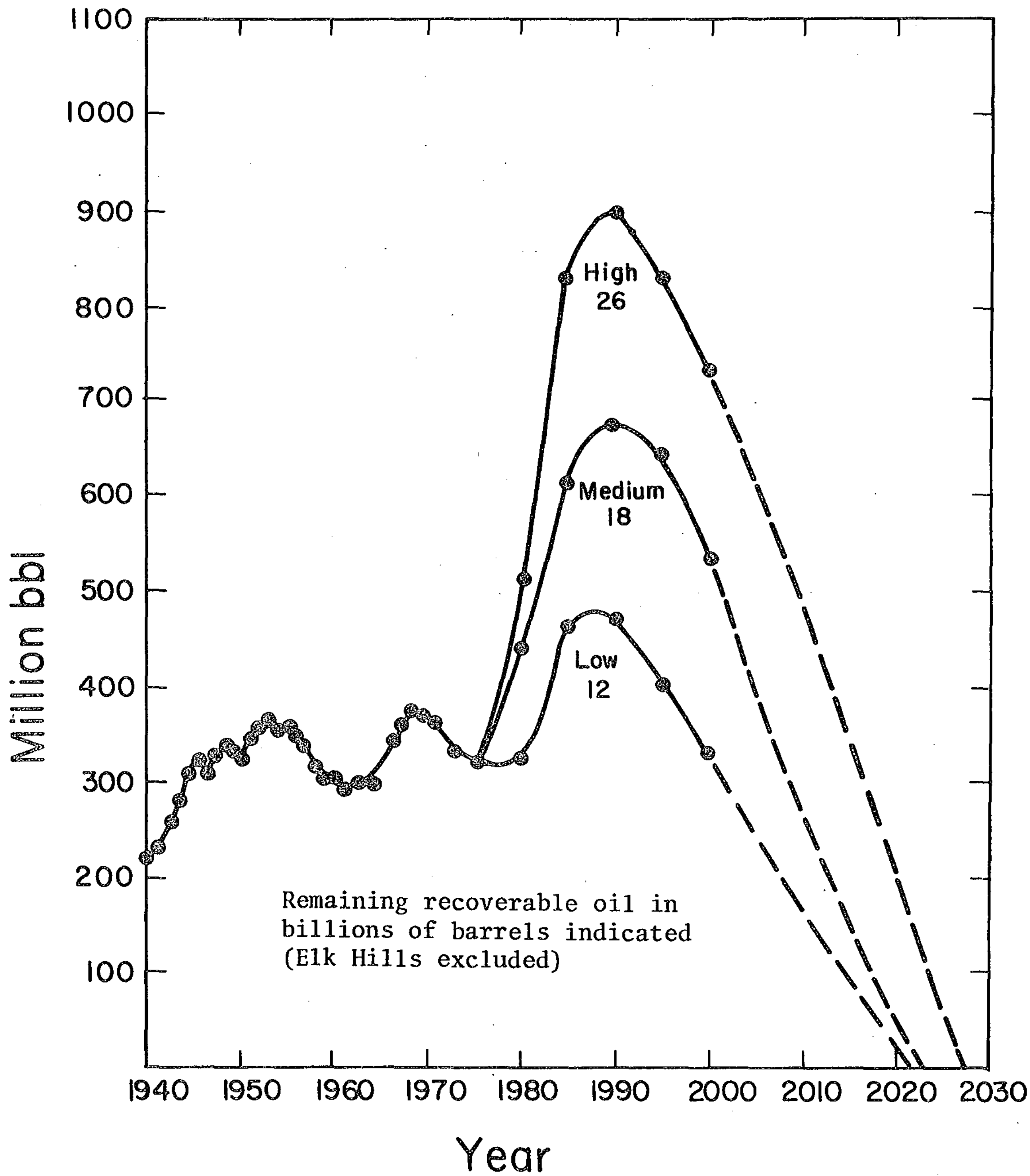
a Leighton (1976)

b May be high by 20-30 percent due to thinning on field margins.

c Possibly up to 4 x 10^9 bbl are already included in California research estimates (Leighton, 1976)

d Table reproduced from Borg (1976)

e API gravity is a measure of the heaviness of crude oil. Higher values of API gravity correspond to lighter oils that have a greater yield of the more valueable light products such as naptha. Mideastern crude oils are usually in the range °31-35.



XBL 779-1997

Source: Nehring (1975)

Figure V-10. California Oil Production

5.9 SUMMARY OF RESOURCE ASSESSMENTS

The analyses in the above sections have shown that California will have significant amounts of energy available from its own resources in the year 2025. The above estimates, because they are conservative in their assumptions about future technological capabilities, are a useful starting point for long-range energy planning. These estimates are summarized in Table V-13. However it is not sufficient to simply add the total annual amounts of energy available from the above resources and try to conclude whether there is enough energy for California's needs. The people and institutions that will determine which resources are used and how they are developed were not considered in developing these estimates. These resource assessments are without meaning until they are brought into the context of policies for their development. Further, the form of the energy, the time variation of its supply, and its dependability must all be considered in the context of specific energy delivery systems in order to assess the adequacy of these resources for California's future energy demands.

In the next chapter we will formulate estimates of the energy demands in California in the year 2025 and develop several hypothetical systems to meet the demands with the resources considered in this chapter and with other energy resources outside the State.

Table V-13

Summary of California Energy Resource Estimates for the Year 2025

Resource	Annual Energy, 10^{12} Btu		
	Heat	Electricity or Mechanical	Fuels
Solar Energy	immense	immense	
Biomass, Land			570–710
Biomass, Ocean			460–920
Wind		2400–9400	
Geothermal	34000	670	
Hydroelectric		230	
Ocean Energy		Nil	
Fossil Fuels			Nil

REFERENCES

D.J. Aalo and R.E. Inman, Intensive Silviculture as a Source of Energy-Fibre in California, Mitre Corporation, report to California ERCDC, 1977.

Bruce Anderson and Michael Riordan, The Solar Home Book, Chesire Books, Harrisville, New Hampshire, 1977.

J. Douglas Balcom, Pacific Regional Solar Heating Handbook, available from U.S. Superintendant of Documents, November 1976.

J. Douglas Balcomb, Passive Solar Heating of Buildings, Los Alamos Scientific Laboratory, Report LA-UR-77-1162, 1977.

J.A. Bassham, Lawrence Berkeley Laboratory, LBL-4844, 1977.

Paul Berdahl et al., California Solar Data Manual, Lawrence Berkeley Laboratory, Draft, January 1977.

I.Y. Borg, Randolph Stone and Kenneth P. Puchlik, Oil, Gas, Uranium and Thorium: Supply and Depletion, UCRL-52180, Lawrence Livermore Laboratory, December 24, 1976.

Darwyn Brigg, USDA Soil Conservation Service, 2728 Chiles Road, Davis, California, (916) 758-2000, personal communication, 1977.

V.S. Budhraja et al., Ocean Food and Energy Farm Project, Subtask No. 6: Systems Analysis, Volume 1, Integrated Sciences Corporation, Santa Monica, 1976.

California Department of Water Resources (DWR), "Hydroelectric Energy Potential in California," Bulletin 194, March 1974a.

California DWR, "Vegetative Water Use in California, 1974," Bulletin 13-3, 1974b.

California DWR, "The California Water Plan: Outlook in 1974," Bulletin 160-74, November 1974c.

California DWR, Preliminary Office Report: Small Hydroelectric Sites Survey, August 1976.

California Energy Resources Conservation and Development Commission (ERCDC), 1977.

California Department of Finance, Population Projection for California Counties—1975-2020, Report 74 P-2, June 1974.

U.Coty, Principal Investigator, Wind Energy Mission Analysis, Final Report, LR 2761, Lockheed-California Company, Burbank, California, Contract AT(04-3)-105 (ERDA), 1977.

James V. Davey, Survey Report: Study of Information/Education Discussions with Private Industries and Public Institutions on the Direct-Heat Utilization of Geothermal Energy, Lawrence Berkeley Laboratory, LBL-5988, March 1977.

REFERENCES (continued)

Edward M. Dickson et al., Impacts of Synthetic Liquid Fuel Development, Volume II, Stanford Research Institute, 1976.

Federal Power Commision, Bureau of Power, Potential Pumped Storage Projects in the Pacific Southwest, 1975.

Federal Power Commission, Hydroelectric Power Resources of the U.S.: Developed and Undeveloped, U.S. Government Printing Office, January 1976.

T.J. Gray and O.K. Gashus, Tidal Power, Plenum Press, New York, 1972.

Al Groncki, USDA, Figures presented at the Conference on Energy from Wood, sponsored by CERCDC, Sacramento, July 1976.

Al Groncki, USDA, personal communication, 1977.

Harold Heady, University of California, Berkeley, (415) 642-7125, personal communication.

J.F. Henry et al., Economics of Energy Crops on Specific Northern California Marginal Crop Lands, InterTechnology/Solar Corporation, Warrenton, Virginia, 1977.

John D. Isaacs et al., "Utilization of the Energy from Ocean Waves," in Waves and Salinity Gradient Energy Conversion Workshop Proceedings, ERDA Report No. COO-2941-1, May 1976.

Jet Propulsion Laboratory, Geothermal Energy Resources in California: Status Report, for ERCDC, pp. 2-11, June 1976.

J.H. Klems, A California Wind Energy Resource, to be published in 1977.

A.J. Leighton, "Monograph on Alternate Fuel Resources," F.J. Hendel, ed., Am. Inst. of Aeronautics and Astronautics, Volume 20, 1976.

R.S. Loomis and P.A. Gerakis, "Productivity of Agricultural Eco-Systems," Photosynthesis and Productivity in Different Environments, International Biological Program, Volume 3, Cambridge University Press, 1975.

R.S. Loomis and W.A. Williams, "Maximum Crop Productivity: An Estimate," Crop Science, 3:67, 1963.

McDonnell-Douglas Astronautics Company, Industrial Applications of Solar Total Energy, Final Report, Volume I, Summary, April 1977.

National Petroleum Council, U.S. Energy Outlook: Oil and Gas Availability, 1973.

R. Nehring, Oil and Gas Supplies for California: Past and Future, Rand Corporation, Report R-1850-CSA/RF, 1975.

Portola Institute, Energy Primer: Solar, Water, Wind and Biofuels, 1974.

Jayant Sathaye et al., Effects of the Drought on California Electricity Supply and Demand, LBL-6356, June 1977.

REFERENCES (continued)

Walter Schmitt, Marine Energy Prospects for California, personal communication, 1977; derived from Cheryl L. Wick and Walter R. Schmitt, "Prospects for Renewable Energy from the Sea," Marine Technical Society Journal, in press.

State Solid Waste Management Board, Bay Area Solid Waste Management Project, Phase 1, February 1977.

U.S. Department of Commerce, Social and Economic Statistics Administration and the U.S. Department of Agriculture, 1972 OBERS Projections, Volume I, 1972.

U.S. Department of Commerce, Social and Economic Statistics Administration, Statistical Abstract of the U.S., 1976.

U.S. Energy Resources Development Administration, California Energy Trends and Choices, Volume 5, Status of Alternative Energy Technologies, 1977 Biennial Report of the State Energy Commission, 1977.

J. Vayder, personal communication, 1977.

CHAPTER VI

ALTERNATIVE ENERGY FUTURES FOR CALIFORNIA—FIRST CUT ANALYSIS

In this chapter we begin the task of characterizing alternative energy futures for California. The approach is through specifying outcomes or end states for California in a single year—2025—and meeting the energy requirements through distributed and centralized energy supply. Through this procedure it becomes possible to better understand some of the most important features of a distributed energy future. As we have noted several times earlier, the results are tentative and will be extended through further work.

Even in this early work, however, several key observations emerge:

- From a technical point of view it does appear feasible for a complex post-industrial society such as California to operate on renewable, largely distributed energy systems, even for a greatly expanded population and expanded economic activity per capita.
- All possible future energy systems involve major problems of land use. For centralized systems the costs are geographically separated from the benefits; for distributed systems costs and benefits are associated geographically.
- Concepts of system reliability are fundamentally different in systems relying predominantly upon renewable energy forms than they are for fossil or other non-renewable forms. Energy storage plays a key role in the performance of "flux" energy sources.

6.1 ASSUMPTIONS

As a means for thinking about distributed futures, we have begun with a set of assumptions and have explored some of the implications of these assumptions. The intent in choosing the particular assumptions was to explore a certain boundary situation. They key starting point assumptions were, qualitatively, the following:

1) An end point would be chosen sufficiently far out in time that industrial and commercial infrastructure would be replaced. This corresponds approximately to the end of the transition period to a soft path (Lovins, 1977).
2) Amenity levels involving direct use of energy by consumers (e.g. space heating) would be maintained at levels approximating those of 1975. "Amenity" is measured in certain aggregated numbers.
3) Economic growth would continue, though at a reduced rate. The service sector would grow faster than manufacturing (OBERS, 1972). The structure of the manufacturing sector is unchanged.
4) Every possible effort would be made to avoid imports of energy to California. We endeavor to make California self-sufficient in energy.
5) In the distributed outcome, maximum emphasis would be placed on renewable energy resources and on on-site energy systems.
6) Technological assumptions would be conservative. That is, only existing or virtually existing technologies would be utilized.
7) In the distributed outcome, every effort would be made to satisfy the criteria for soft energy systems as specified by Amory Lovins (1977).

These assumptions provide severe constraints. There are also innumerable questions of interpretation as one applies these ground rules to a specific situation. There are many ways of relaxing the constraints which affect the outcomes substantially. We reiterate that the intent of this initial effort was to gain experience with types of energy futures very different than those normallly investigated and warn readers against drawing unwarranted conclusions from this particular analysis.

In order to allow the analysis to proceed rapidly, we elected to draw heavily upon existing work. In the energy use analysis, the major source was the work of the Demand/Conservation Panel of the National Adademy Committee on Nuclear and Alternative Energy Strategies (CONAES, 1977). This Panel report was developed by a broadly constituted group which worked together over a period of two years. At this stage of analysis we do not seek to add to the discussion and analysis of their assumptions and methods. We have drawn primarily upon two energy demand analyses for the United States developed by the CONAES D/C Panel. These results were then translated to the California context. Some of the major assumptions of the CONAES D/C Panel report were:

1) Outcomes were analyzed primarily for the year 2010.
2) No major technological changes were assumed.
3) Economic growth is linear, reaching twice present GNP by 2010.
4) Energy use is primarily price-driven. Price assumptions are four times present levels (A scenario) and two times present levels (B scenario) in 2010, rising linearly.
5) Modest but continued population growth is assumed (0.7% per annum).
6) Amenity levels are maintained at current levels.

In applying the CONAES D/C Panel results to California, a population growth rate for California was used which was selected by the California Energy Commission (CEC) for their analyses (D-100 series). This uses the same birth rate used by CONAES but also assumes significant migration into the state, and thus the California population is an increasing fraction of the U.S. population. Some Key Economic/Demographic assumptions are shown in Table VI-1. The population assumptions are discussed in more detail in the next section.

Important fundamental assumptions are implicit in the explicit assumptions listed in Table VI-1. Many factors likely to be important are omitted. Among the most important provisions are these:

- No major shifts in the market basket of goods and services are permitted.
- The industrial sector output mix is changed only slightly from the present mix.

Table VI-1

Economic/Demographic Assumptions

	1975	1980	1990	2000	2010	2025
GNP, 10^9\$[1]	1499	1713	2141	2570	2998	3640
U.S. Population[2]	214	223	245	263	279	305
GNP/capita, 10^3\$	7.00	7.68	8.74	9.77	10.75	11.93
California Population[3]	21.2	22.6	26.1	29.3	32.8	38.6
GSP, 10^9\$[4]	148	174	228	286	353	460

1 CONAES "2% linear" GNP growth (1977)

2 CONAES population projection (1977)

3 California Department of Finance D-100 Series (1974)

4 Gross State Product = (GNP/capita) x (Population of California)

- Embodied energy imported to and exported from California is ignored.
- Advanced technologies which may well become commercial are not included.
- Analysis of the implications of long-term energy storage is omitted.
- Changes in social values, expectations, taste, behavior, etc. are excluded.

Of all the omissions, this last may well be most important from the point of view of developing satisfactorally distributed technology futures. For example, relatively small changes in attitudes toward system reliability could have profound impacts on the costs of distributed energy systems.

6.1.1 Population Assumptions

The size of the future populations of the U.S. and of California are unpredictable. The U.S. fertility rate (the average number of children per woman) has varied from about 6 in the middle of the 19th century to about 2.1 at the depth of the Great Depression, to almost 4 in the post-World War II baby boom, to the present historically low value of 1.8. A fertility rate of 2.1, if maintained, would lead to zero population growth. While the present low rate is at least partially a consequence of the availability of new and very effective techniques of birth control, a continuation of the present fertility rate will occur only if people choose to use these techniques; that is, if they continue to desire smaller families than people have desired in the past. As these future attitudes are unknowable, the future population growth is also unknowable.

The future population of California will also depend upon the rate of migration into the state. Migration into the state has been as high as 357,000 persons in 1963 and as low as 16,000 in 1970. By 1974 the migration rate had increased again to about 100,000. It is unknown if this migration rate will continue into the future. The magnitude of illegal immigration from Mexico is unknown.

The above uncertainties in population growth would have been a severe problem for this study if our objective were prediction. However our task is analysis of future energy alternatives, and for this we require only a plausible scenario of future population growth. Of course, we must also be alert to any conclusions of our study that are sensitive to total population size. Such sensitivity might come about through natural resource limitations, for example water shortages, or through limited availability of land.

The California Department of Finance has developed a set of population projections for California with various assumptions as to fertility rate and rate of migration into the State (1974). Projections based on fertility rates of 2.8, 2.5 and 2.1 are labeled C, D and E, respectively. The projections are further labeled by the migration rate assumed, in thousands of persons per year. The projection adopted by the Department of Finance as a baseline is the D-100 projection, which assumes a constant fertility rate of 2.5 and a constant migration rate of 100,000 per year. This projection has also been adopted by the California ERCDC as a baseline for their energy supply and demand projections.

If we were to select the population projection we consider most likely according to present trends, we would probably choose a projection based upon a fertility rate of about 2.0 and a small but non-zero migration rate. However, because detailed demographic projections already exist for the D-100 projection and because we wish to facilitate comparison of our results with those of other energy supply and demand projections for California, we have used the D-100 projection throughout this study.

The Department of Finance has run the D-100 projection on a county basis through the year 2020. We have extended these county population projections to the year 2025 and present the results in Appendix 5 this volume. The projected total population for the State in the year 2025 is 38,581,000. This is an increase by a factor of 1.82 over the population of the State in 1975.

The age distribution of the population of California in this projection is given to sufficient accuracy by the age distribution in the U.S. under the same assumption of a constant fertility rate of 2.5 (Bureau of the Census, 1967). This age distribution is given in Table VI-2. The median age in this distribution is 32.1, a slight increase from the present median age of 28.

Table VI-2

Age Distribution of U.S. Population
(D Series, Year 2015)

Age	Percentage
0-5	8.6
5-9	8.2
10-14	7.8
15-19	7.5
20-24	7.4
25-29	7.5
30-34	7.3
35-39	6.6
40-44	5.9
45-49	5.6
50-54	6.2
55-59	5.9
60-64	5.0
65-69	4.0
70-74	2.7
75 and above	3.8

Source: California Department of Finance (1974)

6.2 OBSERVATIONS

The primary observation from the results developed in this chapter is that it appears to be technically possible to devise a future for California based upon a transition to renewable resources. This future is predicated upon the explicit assumptions discussed above, plus a large number of implicit assumptions, most of which should be clear from the discussion of the chapter supplemented by reference material (such as the CONAES D/C report). The outcomes developed in this chapter will be expanded considerably in future work and will probably be changed. There are many implications of the outcomes which require much greater examination. We are, for example, aware of the need to perform economic analyses and to relate technical specifications to economic factors. Pathways to alternative outcomes need exploration in detail. A start on this process has been made and is discussed in Chapter VII and in the material included in Volume 2.

Two important additional observations have emerged from the work reported in this chapter. These are:

- o Energy sources based upon renewable (flux) sources are intrinsically fluctuating sources. Reliability can be achieved only through averaging in space and/or time. Regardless of how much averaging is included, there will be occasional instances of outage.
- o Flux sources trade energy for land. Siting of flux sources places energy in competition with other demands upon land. This competition is likely to be severe.

6.3 POSSIBLE END STATES IN 2025

We consider four possible configurations for the California energy system in the year 2025. The parameters which distinguish among these various states are the centralization of the supply system and the end-use demand levels considered. We separate the conservation aspect of soft energy systems from the supply side characteristics of diversity, renewability, flexibility, etc. The motivation for this separation is to examine the extent to which conservation is coupled to the soft or distributed technologies. Conversely we examine low demand configurations with conventional centralized supply to determine the extent to which conservation can mitigate adverse impacts of these technologies. Unfolding the soft versus hard debate along these axes provides a broader context in which to make comparisons.

The numerical sum of demands for various kinds of energy is determined by the end-use amenity provided, conversion efficiency and the supply system used. A classic example of the intermingling of these phenomena is the passive solar design of buildings. Balcomb (1977) has estimated that for a southern California climate passive design can provide essentially all heating requirements with no other energy inputs to the building. It would be misleading accounting, however, to say that this is a zero-demand end use and thus not include the solar energy heating a passive building in our energy accounts. Rather we shall adopt the convention that end-use amenities characterize demands. Thus when, for example, solar energy provides for a certain end use, we will include in our accounts as a solar energy contribution the amount of energy that otherwise would have been consumed at the point of end use.

In the following sections we develop estimates for energy demand in individual sectors of the economy—residential, commercial, industrial and transportation. We develop these estimates for two levels of final demand, designated the "A" and "B" cases. (For the transportation sector an additional two cases are developed which emphasize electric urban transport. This secondary analysis was required by problems which emerge in providing sufficient liquid fuels.) These demands are then integrated with available energy supplies from distributed and largely renewable resources and from non-renewable energy forms. The implications of the resulting cases are then examined in a preliminary way in terms of their implications for California.

6.3.1 Residential Sector

Very detailed data are available on residential energy use in California, particularly on electrical use. The data in this sector allow an accurate thermodynamic matching of end use to energy supply. In particular, the end uses of low thermodynamic quality (space conditioning and water heating) can be separated from those of higher quality (appliances, lighting). The end-use requirements for 2025 can be easily specified in terms of a constant level of amenity compared to 1975. This means roughly 400 square feet of living space per capita, 20 gallons of hot water per capita per day and access to the standard appliances.

Each of these amenities can only be translated into an energy demand with further demographic specification. The energy requirements for space conditioning are a function of housing type (single-family dwelling, multi-unit or mobile home). Appliance populations are determined by the number of households rather than the number of people, so the absolute total of refrigerators, etc. depends upon demographic assumptions concerning household size. In recent years household size has declined. In 1975 the average California household had three people. We adopt the CONAES assumption of 2.4 persons per household.

Space conditioning energy demands are a function of housing mix and the geographical distribution of that housing. The current California state building code requires an average of 9 Btu/ft^2/degree day for heating. This is averaged over climates and housing types. We use this number for our baseline and apply the CONAES thermal integrity coefficients to project future requirements. For cooling loads we rely upon very detailed data produced by the California Energy Commission (CEC). They identify four cooling zones in the state. Electricity requirements per household in the hottest zone are 4100 kWh per year; in the coolest zone this falls to 530 kWh. These data specify the 1975 demand. By 1995

CEC projects the average requirement will drop to around 50 percent of the base case. Thus even with population and household growth, technical efficiency will keep air conditioning requirements roughly constant. This means that the weather-sensitive loads which now cause the summer peak requirement for electricity will probably decline in relative importance.

Table VI-3 summarizes residential sector energy demands. The 1975 baseline data comes from LBL (1976). The appliance loads will be supplied by electricity in all scenarios. These constitute roughly 40 percent of the sectoral demand. Even if some of the 2025 saturations were increased, the impact on total requirements would be small. For low-quality energy needs, which are roughly 60 percent of the total, solar technologies are available. In the area of water heating, however, significant demand for backup could occur on a regional basis if storage is inadequate. Electric resistance is the most plausible backup source. If storage of hot water is limited to a day or two and in the event that the entire state were covered by clouds for three days or longer, the demand from 16 million water heaters could be as much as 16,000 MW of power. This assumes a moderate diversity with an average of 1 kW per household. To smooth this requirement out would involve control technology that would cycle the load more efficiently. We assume enough storage is included so that no backup is required.

6.3.2 Commercial Sector

Data concerning the stock of commercial buildings and their pattern of energy use are available in considerably less detail than in the residential sector. Therefore all studies of this sector rely upon averages which do not tell much about the range of variation in end-use efficiencies and amenities. Those data which are available show that lighting is the largest single end use in commercial buildings. The other major amenities which consume the largest amount of energy are space heating and hot water, followed by air conditioning.

The CONAES Demand/Conservation Panel modeled the conservation impact on this sector in terms of a decreasing energy intensity. The

Table VI-3

Residential Sector Demand

	1975 Average Unit Energy Use[1]	1975 Appliance Saturation	2025 Appliance Saturation	CONAES Energy Intensity (% of 1975) A	CONAES Energy Intensity (% of 1975) B	Annual Energy Use 2025 (10^{12} Btu) A	Annual Energy Use 2025 (10^{12} Btu) B
<u>Low Quality Energy</u>							
Space Heat[2]	9 Btu/ft^2/dd		100	.60	.75	96.0	115.0
Air Conditioning[3]	530 kWh - 4100 kWh		50			27.0	27.0
Water Heating	4000 kWh		100	.75	.80	164.0	175.0
<u>High Quality Energy</u>							
Refrigerators	1130 kWh	115	115	.50	.50	38.0	38.0
Freezers	1400 kWh	22	22	.50	.50	8.0	8.0
Cooking	1200 kWh	36	100	.75	.80	49.0	53.0
Lighting	1130 kWh	100	100	.60	.70	37.0	43.0
Color TV	420 kWh	75	100	.60	.70	13.7	16.0
Dishwasher	250 kWh	36	50	.60	.70	4.1	4.7
Clothes Washer	70 kWh	70	70	.60	.70	1.5	1.7
Clothes Dryer	950 kWh	29	30	.60	.70	9.3	10.9
Miscellaneous	195 kWh	100	100	.60	.70	6.3	7.4
TOTAL						453.9	499.7

[1] Energy use per household (LBL, 1976)

[2] See Appendix 1

[3] See Appendix 2

1975 new buildings were normalized to 1.0 and the energy use per square foot in subsequent years declined to 40 percent and 60 percent of this in the two lowest demand scenarios. Energy intensity is an aggregate or average concept, and no effort was made to separate the various end-use efficiency changes that underly the changes in total average energy use. The CONAES assumptions are consistent with studies of the impact of the new ASHRAE* standards.

Summarized in Table IV-4 are the commercial sector energy use for 1975 and calculated energy intensities for our two 2025 demand levels. These data are given on a per-square-foot basis. Total sectoral demand requires a projection of future commercial floorspace. There are several ways to do this. First, one might assume that the per capita floorspace remains invariant from 1975 to 2025. In 1975 there was just over 3 billion square feet of floorspace for a population of 21.2 million. This gives a ratio of about 143 ft^2/capita. Thus 2025 would see a commercial floorspace total of 5.53 billion square feet. Current construction in California is at the rate of 100 million square feet annually. Over fifty years with a complete turnover of existing stock, this would yield about 5 billion square feet. Alternatively, it might be argued that our assumptions concerning economic growth imply a faster construction rate than simple trend extrapolation or population scaling. This argument is particularly plausible for retail stores, offices and banks, which constitute 41 percent of the 1975 stock. If we project these subsectors to grow with our income variable GSP, then they should increase over the per-capita projection by a factor of 1.70. This factor is the ratio of 2025 per-capita GSP to 1975 per-capita GSP. We have adopted this latter method of projection, and we find that total commercial floorspace to be about 7.11 billion square feet under these assumptions. The difference between the two projections is a factor of about 1.29.

There is no clear way to decide which scaling procedure is most reasonable. It might be argued, for example, that much commercial activity will be shifted to electronic communications, thus eliminating the need for additional floorspace. The uncertainties involved in our time scale are enormous. It is important to notice, however, that even

*American Society of Heating and Refrigeration Engineers Standard 90-75

Table VI-4

Commercial Sector Demand

	1975 Average Consumption[1]	1975 Efficiency[1]	End-Use Requirement	2025 Energy Intensity[2] Scenario A	Scenario B
<u>Low Quality Energy</u>					
Heating	22,800 Btu/ft^2	70%	16,000 Btu/ft^2	.54	.70
Cooling					
gas-fired (40%)	25,700 Btu/ft^2	COP = .6	11,000 Btu/ft^2	.54	.70
electric (60%)	3.3 kWh/ft^2				
Hot Water	21,400 Btu/ft^2	70%	15,000 Btu/ft^2	.54	.70
<u>High Quality Energy</u>					
Lighting	9.9 kWh/ft^2	1.0	33,800 Btu/ft^2	.54	.70
Mechanical Equipment	2.4 kWh/ft^2	1.0	8,200 Btu/ft^2	.54	.70
Refrigeration	1.7 kWh/ft^2	1.0	5,800 Btu/ft^2	.54	.70
Miscellaneous	1.0 kWh/ft^2	1.0	3,400 Btu/ft^2	.54	.70
			93,200 Btu/ft^2		

1975 Average Electric Use = 15.7 kWh/ft^2

Converting Gas Air Conditioning to Electric = 17.0 kWh/ft^2

Scenario A Electric Intensity 9.2 $kWh/ft^2/yr$

Scenario B Electric Intensity 11.9 $kWh/ft^2/yr$

<u>2025 Commercial Floorspace</u>

Assumption 1: constant per capita ratio = 143 ft^2/capita
38.6 million people
floorspace = 5,530 million ft^2

Assumption 2: constant per capita ratio for all subsectors except retail stores (24% of 1975 stock) and offices and banks (17% of 1975 stock); see LBL (1976)
scale these to GSP per capita growth (1.70 times 1975 level)
floorspace = 7110 million ft^2 = $(.41 \times 5530 \times 10^6 \times 1.7 + .59 \times 5330 \times 10^6 = 7110 \times 10^6)$

<u>Total Energy Requirements</u> (5,530 million ft^2)

	Scenario A	Scenario B
1. Space and Water Heat	$.132 \times 10^{15}$ Btu	$.171 \times 10^{15}$ Btu
2. Electric Energy		
Btu equivalent	$.174 \times 10^{15}$ Btu	$.225 \times 10^{15}$ Btu
kilowatt-hours	50.9×10^9 kWh	65.8×10^9 kWh

[1] B. Weisenmiller (1975)

[2] National Academy of Sciences (1977)
(Energy requirement per unit output relative to 1975)

using the larger floorspace projection will not have a serious impact on the qualitative nature of our supply/demand balances. The commercial sector in all outcomes will shrink in importance as far as critical limited resources are concerned. In no case will electricity consumption be larger than 20 percent of total demand. The 1975 share for this sector was roughly one third of the electricity demand. This decline in importance is due to our assumptions about the changing nature of industrial demand, its growth and increasing electrification.

A final word about supply mixes for this sector is important. Table VI-4 shows a significant saturation of gas-fired absorption air conditioning. In our energy accounting we have assumed that all of this converts to electricity regardless of the supply assumptions. Thus in our distributed outcome we do not distinguish between solar-driven air conditioners and electric air conditioners driven by solar electricity; both are represented by the same level of energy contribution by solar energy.

Demand management is likely to increase in importance in the commercial sector. Already there are computer systems available to manage loads in larger commercial buildings. These can limit demand by using scheduling techniques, and they provide space conditioning only where required in the building. In the decentralized end states where space and water heating are done with solar energy, there is a potential cloudy day backup problem. This is likely to be less severe than in the residential sector for a variety of reasons. Most important is the range of backup options that are available. These include garbage incineration, the use of heat recovery techniques for auxiliary supplies and installation of large storage tanks.

6.3.3 Industrial Sector

It would seem hopeless to try to predict a mix of industrial activities in the U.S. and in California in 2025. There certainly will be many products not yet even invented that will contribute significantly to the GNP. However, the major energy-consuming industries are generally those that provide basic commodities which have long had widespread and diverse use within the economy. Thus we can gain a useful estimate of the total energy requirements for industry in 2025 by considering only the few industries that are now and probably will continue to be major energy consumers and treating the remainder of the industrial sector as a single undifferentiated unit that will have an energy intensity typical of today's industry but with better energy conservation practices.

We adapt the CONAES assumptions in this sector by limiting attention to only nine basic industries: agriculture, aluminum, cement, chemicals, construction, food, glass, iron and steel, and paper. We use national 2025 production levels and energy intensity estimates that are then scaled to California gross state product. Since GSP will grow faster than GNP, this implies that the share of each California sector will rise in 2025 to about 1.28 times its 1972 share of the total U.S. sector. This factor of 1.28 is just the ratio of GSP increase (3.11 times 1975) to GNP increase (2.43 times 1975 level). Such linear scaling is the best which can be done given our lack of knowledge; it does, however, lead to conclusions that may seem improbable on other grounds, e.g. California's share of high energy-consuming industries, also transport, as compared to the rest of the nation, will increase. In Table VI-5 we derive industrial energy consumption using this method. The method used for allocating GSP is given in Appendix 3. We have deleted from our estimates the energy requirements of present energy-producing sectors such as petroleum refining.

Our next task is to break out these energy requirements into a thermodynamic spectrum characteristic of each sector. This is required for our effort to match energy supply to the specific type of demands we must meet. First, we separate electricity from all other fuels. Then we use data from the Battelle Corporation study on the proportion of the process heat load in each industry in three heat ranges: below 212°F, from 212°F to 350°F, and the high temperature zone beyond that. These data are scaled by the CONAES energy intensity factors. Again we must assume linearity for lack of more detailed information. In Tables VI-6 and VI-7 we present the results of these calculations for each demand level. These data will be used to determine how much solar energy can be used for industrial process and to calculate cogeneration potentials.

Table VI-5

Energy Use Figures for California Industrial Sector

Industrial Sector[1]	U.S. Energy Consumption[2] 1975 (quads)	Production Level 2025 (1975 = 1)[3]	Energy Intensity 2025 (1975 = 1)[4]		U.S. Energy Consumption 2025 (quads)		California Share of Value Added 2025[5]	California Energy Consumption (quads)		
			A	B	A	B		1975	2025 A	2025 B
Agriculture	1.2	2.2	.83	.83	2.20	2.20	12.7%	.12	.12	.28
Aluminum	0.6	3.7 (5.0)[6]	.53	.61	1.20	1.80	nil	nil	nil	nil
Cement	0.5	2.3	.55	.60	.63	.69	14.5%	.06	.09	.10
Chemicals	3.1	3.5	.72	.77	7.80	8.40	6.8%	.16	.53	.57
Construction	0.9	1.4	.50	.60	.63	.76	12.7%	.09	.08	.10
Food	1.1	2.6	.62	.75	1.80	2.20	14.6%	.13	.26	.32
Glass	0.2	2.6	.65	.74	.34	.38	10.8%	.02	.04	.04
Iron and Steel	3.1	2.1	.68	.74	4.40	4.80	3.6%	.09	.16	.17
Paper	2.2	3.7	.53	.63	4.30	5.10	7.0%	.12	.30	.36
Other Manufacturing	5.6	2.6	.52	.73	7.60	10.60	12.7%	.56	.97	1.35
	18.5				30.90			1.35	2.71	3.29

[1] The industrial sectors include the following standard industrial classification (SIC), industries and industry groups:
Agriculture: SIC codes 01-07
Aluminum: Primary aluminum (3334), aluminum sheet, plate and foil (3353), aluminum extruded products (3354), aluminum rolling and drawing, not elsewhere classified (3355)
Cement: Cement, hydraulic (3241)
Construction: This is not a SIC industry. It represents asphalt products supplied to the construction industry (Source: Bureau of Mines)
Food: Food and kindred products (20)
Glass: Flat glass (3211), glass, pressed or blown (322)
Iron and Steel: Blast furnace, basic steel products (331)
Paper: Paper and allied products (26)
Other Manufacturing: (10-39, not included above)

[2] U.S. Energy Consumption in 1972. Source: Outlook for Energy Demand and Conservation: Report of the CONAES Panel of Demand and Conservation (Draft), April 1977, Table IV-S, p. IV-33).

[3] Computed from CONAES Integration Scenarios, Chapter 4, Table A. (Production Levels)

[4] Energy Intensity 2025. Source: (1975-2010) Outlook for Energy Demand and Conservation, April 1977, Table IV-3, p. IV-20.

[5] Computed from 1972 Census of Manufactures, Bureau of Census, 1972.

[6] Aluminum production level is 3.7 in Scenario A; 5.0 in Scenario B.

Table VI-6

Process Heat Requirements for California Industry (10^{12} Btu): Scenario B

Sector	Total Energy Use	Electrical Energy Use	Direct Process Heat (F°)			Hot Water/Steam (F°)			Liquid Fuels
			<212	212-350	>350	<212	212-350	>350	
Agriculture[1]	280	114	13	--	--	--	--	--	153
Cement[2]	100	8	--	--	92	--	--	--	--
Chemicals	570	109	--	99	55	--	307	--	--
Construction (Asphalt)	100	11	--	--	74	--	4	11	--
Food	320	44	4	47	7	31	135	50	--
Glass[4]	40	4	1	2	33	--	--	--	--
Iron and Stell	170	29	--	--	136	--	5	--	--
Paper	360	79	--	--	47	--	234	--	--
Other[5]	1350	232	4	122	368	26	558	40	--

[1] Energy Requirements for Agriculture in California, California Department of Food and Agriculture, January 1974. Diesel fuel use (transport and fiel use) is assigned to liquid fuels; irrigation energy to electricity; fertilizer non-feedstock energy to low temperature direct heat. Total 2025 use is divided among these three sectors in proportion to the data from the California Department of Food and Agriculture, 1974.

[2] SIC 324 Cement, hydraulic

[3] SIC 291 Petroleum refining

[4] SIC 322 Glass, pressed or blown

[5] Total energy use allocated in proportion to the average of non-agricultural industries

Table VI-7

Process Heat Requirements for California Industry (10^{12} Btu): Scenario A

Sector	Total Energy Use	Electrical Energy Use	Direct Process Heat (°F)			Hot Water/Steam (°F)			Liquid Fuels
			<212	212-350	>350	<212	212-350	>350	
Agriculture[1]	280	114	13	--	--	--	--	--	153
Cement[2]	90	7	--	--	83	--	--	--	--
Chemicals	530	101	--	92	51	--	288	--	--
Construction[3] (Asphalt)	80	9	--	--	59	--	3	9	--
Food	260	36	3	38	6	25	110	41	--
Glass[4]	40	4	1	2	33	nil	nil	nil	--
Iron and Steel	160	27	--	--	128	--	5	--	--
Paper	300	66	--	--	39	--	195	--	--
Other[5]	970	166	3	88	264	19	401	29	--

[1] Energy Requirements for Agriculture in California, California Department of Food and Agriculture, January 1974. Diesel fuel use (transport and field use) is assigned to liquid fuels; irrigation energy to electricity; fertilizer non-feedstock energy to low temperature direct heat. Total 2025 use is divided among these three sectors in proportion to the data from the California Department of Food and Agriculture, 1974.

[2] SIC 324 Cement, hydraulic

[3] SIC 291 Petroleum refining

[4] SIC 322 Glass, pressed or blown

[5] Total energy use allocated in proportion to the average of non-agricultural industries

Because industrial demands will turn out to be so critical in our supply matching exercise, it is important to point out limitations in our data. Intertechnology Corporation (197) has also made estimates of the temperature spectrum in industry. For our purposes what really matters is the amount of heat above 350°F for which solar energy is probably not available. On this point ITC does not appear to differ significantly from Battelle. The account which Lovins gives of this area suggests that a greater amount of medium-temperature heat should be ascribed to potential solar applications than Battelle indicates. This point does not affect the high-temperature requirement which will cause an intensive electrification in our decentralized scenarios.

6.3.4 Transportation Sector

California is atypical in its use of energy for transportation. In 1972 California used 1,920 trillion Btu (essentially all in the form of liquid fuels) for transportation. This was 8 percent higher than the U.S. average on a per capita basis (96.3 million Btu per capita versus 89.1 million). The distribution of energy use among modes is also unusual, with California using relatively more energy for autos and air travel and relatively less for trucks than the U.S. as a whole.

We will scale California to the CONAES assumptions preserving these features in our projections. The Transportation Resource Group of the CONAES Demand/Conservation Panel estimated that in the B energy price scenario the total national energy demand for transportation in 2010 would be 16.9 quads. The corresponding estimate for the A energy price scenario is 12.0 quads. These should be compared to the 1975 demand for transportation of 15.9 quads. These estimates are based upon a number of assumptions, primary among them that the time spent per day by persons in autos (now about 54 minutes) remains about the same, and that the 1985 mandated auto mileage efficiency standards are met. In the A energy price scenario it is assumed that air passenger traffic per capita increases about 60 percent by 2010 and in B by 100 percent.

Table VI-8 shows transportation end use in the United States, extrapolated to 2025. The data are CONAES projections extrapolated

Table VI-8

U.S. Transportation Energy Demand, 2025

	Travel Demand (Passenger-Miles or Ton-Miles per Capita)	Load Factor	Vehicle Efficiency	Energy Intensity[1] (Btu's per Ton-Mile or Passenger-Mile)	Energy Use[2] (MBtu's per Capita)	Total Energy Use (quads)
Automobile						
1975	10,500	2.2 PM/VM	14 MPG	4,060	42.60	9.10
Scenario A	12,800*	2.5 PM/VM	37* MPG	1,350	17.40	5.30
Scenario B	14,100*	2.3 PM/VM	31 MPG	1,750	24.30	7.40
Air Transport						
Passenger						
1975	745	52.2%		7,630	5.68	1.20
Scenario A	1,180*	75%		3,180*	3.76*	1.10
Scenario B	1,510*	70%		3,410*	5.14*	1.60
Freight						
1975	18.7	1** TM/VM	1** TM/Btu	15,500	0.29	0.10
Scenario A	84.1	1.35** TM/VM	2.32** TM/Btu	6,600	0.56	0.17
Scenario B	84.1	1.22** TM/VM	1.41** TM/Btu	9,300*	0.78	0.24
Truck (freight)						
1975	2,580	1** TM/VM		5,200	13.40	2.90
Scenario A	3,640	1.15** TM/VM		2,240	8.20	2.50
Scenario B	4,050	1.04** TM/VM		3,690	14.90	4.50
Rail (freight)						
1975	3,560			690	2.46	0.50
Scenario A	5,160			600	3.10	0.92
Scenario B	5,090			660	3.36	1.00
Other (water freight, transit, passenger trucks/vans, misc.)						
1975					8.63	1.80
Scenario A					7.33	2.20
Scenario B					8.31	2.50

*2010 CONAES estimates are assumed unchanged to 2025.
**Load factors and efficiencies expressed as proportions of 1975 values.

[1]Energy Intensity
Automobile = (125,000 Btu/gal)/(load factor)(MPG)
Truck = 1975 intensity/vehicle efficiency
All other modes, assumed directly

[2]Energy use per capita = (energy intensity) x (travel demand)

linearly to 2025 (National Academy of Sciences, 1977). The asterisked numbers are 2010 values. We have not extended these where behavioral limits, such as the 54 minutes per capita per day of auto time or technical limits, were imposed by CONAES.

We factor special California characteristics into our estimates by calculating a California share of U.S. totals that reflects increased propensity to travel. Starting with Hoffman's estimates (1976) of 1975 California travel demand by mode, we get a California share for each mode. These shares must then be adjusted for increased population. Here the factor of 1.28 used in the industrial sector reappears. Thus in 1975 the California share of gasoline for auto travel was 13.6 percent, but by 2025 it is projected up to 17.4 percent due to population increases. Therefore, the CONAES Scenario A automobile energy projections of 6.3 quads nationally translates into .92 = (.174 x (5.3)) quads in California. These calculations and data are summarized in Table VI-9. The results are a virtually unchanged energy consumption in Sceanrio A from 1975 and a 40 percent increase to 2.9 quads in Scenario B. We note that our scaling procedures magnify the large increases in transport previously assumed in the CONAES scenarios.

A final word must be said about mode switching and mass transit. Our projections have not allowed for these alternatives. Opinions differ on the desirability and feasibility of mass transit. Demand for this kind of travel depends upon many factors among which land use patterns and density are significant.

As will be seen in section 6.4 below, availability of liquid fuels appears to necessitate some significant changes in the transportation sector. The approach followed has been to develop here an alternative schedule of energy demands for transportation based on a conversion to electric vehicles for urban transit. The analysis is based upon the work on electric urban transit systems at LBL and at the Stanford Research Institute (SRI, 1977). Electrically-driven personal vehicles are assumed to be utilized for urban automobile transportation, and electric vans for urban truck freight. The analysis together with key assumptions is shown in Tables VI-10 and VI-11. The result of the use of electric drive for these purposes is a reduction in liquid fuel requirements from 2110 and 2910 trillion Btu in the A and B demand levels, respectively, to 870 (A)

Table VI-9

California Energy Use for Transportation (quads)

	1. 1975	2. California Share (percent of total)	3. 2025 A	4. 2025 B
Automobile	1.24	13.6	.92	1.29
Air	.24	18.5	.30	.44
Truck Freight	.26	9.0	.29	.52
Railroad Freight	.08	16.0	.19	.20
Other	.26	14.4	.41	.46
	2.08	13.0 avg.	2.11	2.91

Notes:

1. Column 1 from Hoffman (1976)
2. Column 2 = (1)/U.S. 1975 consumption for that mode
3. Column 3,4 = CONAES (A,B) national total (Table VI-7) x column 2 x 1.28

Table VI-10

California Energy Use for Transportation
(for 1975 and 2025 - demand levels A & B)
(quads)

	1975	Percent of Transportation Sector Energy Use	CENTRALIZED* 2025 (Liquid Fuel Only) A	CENTRALIZED* 2025 (Liquid Fuel Only) B	DISTRIBUTED** 2025 (Electric Urban Transit) A	DISTRIBUTED** 2025 (Electric Urban Transit) B
Automobile	1.24	14	.92	1.29	.55	.70
Urban	(.92)	(10)	(.68)	(.95)	(.31)	(.36)
Rural	(.32)	(4)	(.24)	(.34)	(.24)	(.34)
Air	.24	18	.29	.42	.29	.42
Truck Freight	.26	9	.29	.52	.18	.32
Urban	(.18)	(6)	(.20)	(.32)	(.09)	(.12)
Rural	(.08)	(3)	(.09)	(.20)	(.09)	(.20)
Railroad Freight	.08	16	.19	.20	.19	.20
Other	.26	14	.45	.48	.45	.48
Total	2.08		2.14	2.90	1.66	2.12

*Centralized end states (A & B) assume syncrude from coal is available in sufficient quantities for the transportation sector.

**Distributed system includes vehicles that run on electricity for urban automobile and urban truck freight transportation. The electric car is assumed to use .45 kWh/mile and obtains a greater end-use efficiency than internal combustion engines (ICE). In a recent SRI study (1977) electric car is shown to be 2.7 times more efficient than an ICE power auto which achieves 30 mpg. For demand level A, where ICE cars obtain 37 mpg, the electric car is 2.2 times more efficient than an ICE car. In demand level B, where ICE cars are assumed to obtain 31 mpg, the electric car is 2.63 times more energy-efficient than an ICE car.

Table VI-11

Hydrocarbon Fuel and Electricity Requirements in the Transportation Sector with Electric Urban Transit (2025 - in quads)

	Demand Level A			Demand Level B		
	Hydrocarbon Fuels	Electricity	Total	Hydrocarbon Fuels	Electricity	Total
Automobile	.24	.31	.55	.34	.36	.70
Urban	---	(.31)	(.31)	---	(.36)	(.36)
Rural	(.24)	---	(.24)	(.34)	---	(.34)
Air	.29	---	.29	.42	---	.42
Truck Freight	.09	.09	.18	.20	.12	.32
Urban	---	(.09)	(.09)	---	(.12)	(.12)
Rural	(.09)	---	(.09)	(.20)	---	(.20)
Railroad Freight	---	.19	.19	.27	.20	.20
Other	.25	.20	.45	.48	.21	.48
Total	.87	.79	1.66	1.23	.89	2.12

and 1230 trillion Btu (B) when electric urban transit systems are utilized. Since this shift implies changes in the ease of traveling from the urban to rural regions and vice versa, there is an implied change in amenity level. Note too that there are no major shifts in land use patterns implied by the demand analysis assumptions, and that more compact living patterns offer an alternative means for reducing transportation liquid fuel requirements.

6.3.5 End-Use Summary

Table VI-12 summarizes the data developed in this chapter to this point. Energy use for heat has been aggregated into two temperature categories, those uses below 350°F and high temperature-applications above that value. A summary of total energy is given for conventional automobile transport and electric urban transit. Note that the electrical energy is treated separately. The total energy input to final demand may be found by summing the electric and non-electric components in row f) (without electric urban transit) or row g) (with electric urban transit). The energy input to final demand is then 4772 trillion Btu (1975); 5582 trillion Btu (scenario A, conventional transport); 7094 trillion Btu (scenario B, conventional transport); 5132 trillion Btu (scenario A, electric urban transit); and 6304 trillion Btu (scenario B, electric urban transit).

Primary energy input has some ambiguity associated with it both for renewable energy sources and conventional sources. This comes about because of the conversion efficiencies involved. A guideline comparison with conventional technologies can be obtained by converting all electricity to primary input using a conversion efficiency of 33 percent. Primary equivalent inputs then become: 5784 trillion Btu (1975); 8454 trillion Btu (demand level A, electric urban transit); and 10,160 trillion Btu (demand level B, electric urban transit). Since California presently uses a considerable amount of hydroelectric power for which such an efficiency is not meaningful, the proper method of conversion is unclear even with the present energy system and becomes far more ambiguous with future systems.

Table VI-12

End-Use Energy (2025)
trillion Btu/year

	1975[6]		A				B			
	Electric	Non-Electric	Electric	Heat <350°F	Heat >350°F	Liquids	Electric	Heat <350°F	Heat >350°F	Liquids
a) Agriculture[1]	36	167	114	13	---	153	114	13	---	153
b) Other industry[1]	140	1100	416	1273	742	---	516	1579	913	
(Paper)			(66)	(195)	(39)		(79)	(234)	(47)	
c) Transportation[2]	---	2100	---	---	---	2110	---	---	---	2910
d) Commercial[3]	140	225	174	132	---	---	225	171	---	---
e) Residential[4]	190	675	167	287	---	---	183	317	---	---
f) Total	506	4266	871	1705	742	2264	1038	2080	913	3063
g) Transportation (electric urban transit)[5] (replaces line c)			790			870	890	---	---	1230
Total (all sectors) (with electric urban transit) using line g) instead of line c)			1661	1705	742	1024	1928	2080	913	1383

Note: Petrochemical feedstocks and lubricants are to be provided from heavy oils here.

(1) Table VI-5,6
(2) Table VI-8
(3) Table VI-3
(4) Table VI-2
(5) Table VI-9,10
(6) California Energy Commission (1975)

The equivalent energy inputs may be approximately scaled to the U.S. situation to provide a simple comparison of the U.S. and California numbers. This may be accomplished most easily by scaling the California results by the inverse ratio of the California to the U.S. populations: 38.5/305 = 0.126. The resulting U.S. equivalent primary energies are 67 and 81 quadrillion Btu for the A and B cases, respectively (with electric urban transit), and for the conventional transport cases for the A and B cases, 60.5 and 73 quadrillion Btu, respectively.

6.3.6 Supply/Demand Balance—Distributed Case

In this section the energy supply potentials from renewable resources estimated in Chapter V are combined with the demand estimates made above. The results of such integrations for the A and B distributed cases are shown in Table VI-13. The assumptions of the energy supply are shown in the footnotes to the table. The distribution of energy sources and energy uses is shown in Figure VI-1.

This supply/demand balance was constructed in the following manner. First, direct on-site use of solar heat was assumed for all applications judged feasible within our assumptions. Thus, residential and commercial space and water heating were assumed met by this source. Our analysis indicates that the amounts of other energy required for backup to these systems is minor if appropriate storage is provided (see Chapter V).

Second, solar heat provided through on-site solar cogeneration systems (see Chapter V) was assumed to provide for most industrial process heat. The guideline for on-site solar cogeneration was that this be used for all industrial heat below 350°F and where possible above 350°F. We estimate that roughly 40 percent of the high-temperature heat can be supplied this way. However, glass making, iron and steel, and heat treating of metals are unlikely applications for solar energy. Thus we have assumed electricity will be required for the remaining 60 percent of the industrial high-temperature heat load.

The limited size of the California biomass resource provides a major constraint on liquid fuels. Even using the electric urban transit approach to the transportation sector, it is still necessary to resort to energy

Table VI-13

Supply/Demand Balance Distributed Cases
(trillion Btu)

	A				B			
		Heat				Heat		
	Electricity	<350°F	>350°F	Liquid	Electricity	<350°F	>350°F	Liquid
Biomass[1]								
Waste				480				480
Tree Farm				100				200
Kelp				444				703
On-Site								
Solar Residential/ Commercial/Agricultural		432				501		
Cogeneration[2]								
Conventional	146	195	39		175	234	47	
Geothermal[3]	327				512[4]			
Hydroelectric[5]	136				136			
Wind[6]	666				666			
On-Site								
Solar[7]								
Cogeneration								
High-Temperature	39		259		53		352	
Low-Temperature	162	1078			202	1345		
Solar-Electric[8]	629				700			
Total	2105	1705	298	1024	2442	2080	399	1383

Note: Petrochemical feedstocks and lubricants are obtained from heavy oils and are not included here.

[1] Table V-7

[2] 183 kWh/10^6 Btu heat, see Appendix 4

[3] 13 GW, 85% capacity factor = 96 x 10^9 kWh = 327 trillion Btu

[4] 20 GW, 85% capacity factor = 150 x 10^9 kWh = 512 trillion Btu

[5] 9.2 GW, 50% capacity factor = 40 x 10^9 kWh = 136 trillion Btu

[6] 65 GW, 34% capacity factor = 195 x 10^9 kWh = 666 trillion Btu

[7] Cogeneration sized to meet all low-temperature heat (350°F) and high-temperature (350°F) heat in chemicals, food, asphalt and 40% of other industries. Typical design gives .15 Btu as electricity for each Btu of heat (McDonnell Douglas Corporation, 1977).

[8] 84 GW, 25% capacity factor = 184 x 10^9 kWh = 629 trillion Btu
94 GW, 25% capacity factor - 205 x 10^9 kWh - 700 trillion Btu

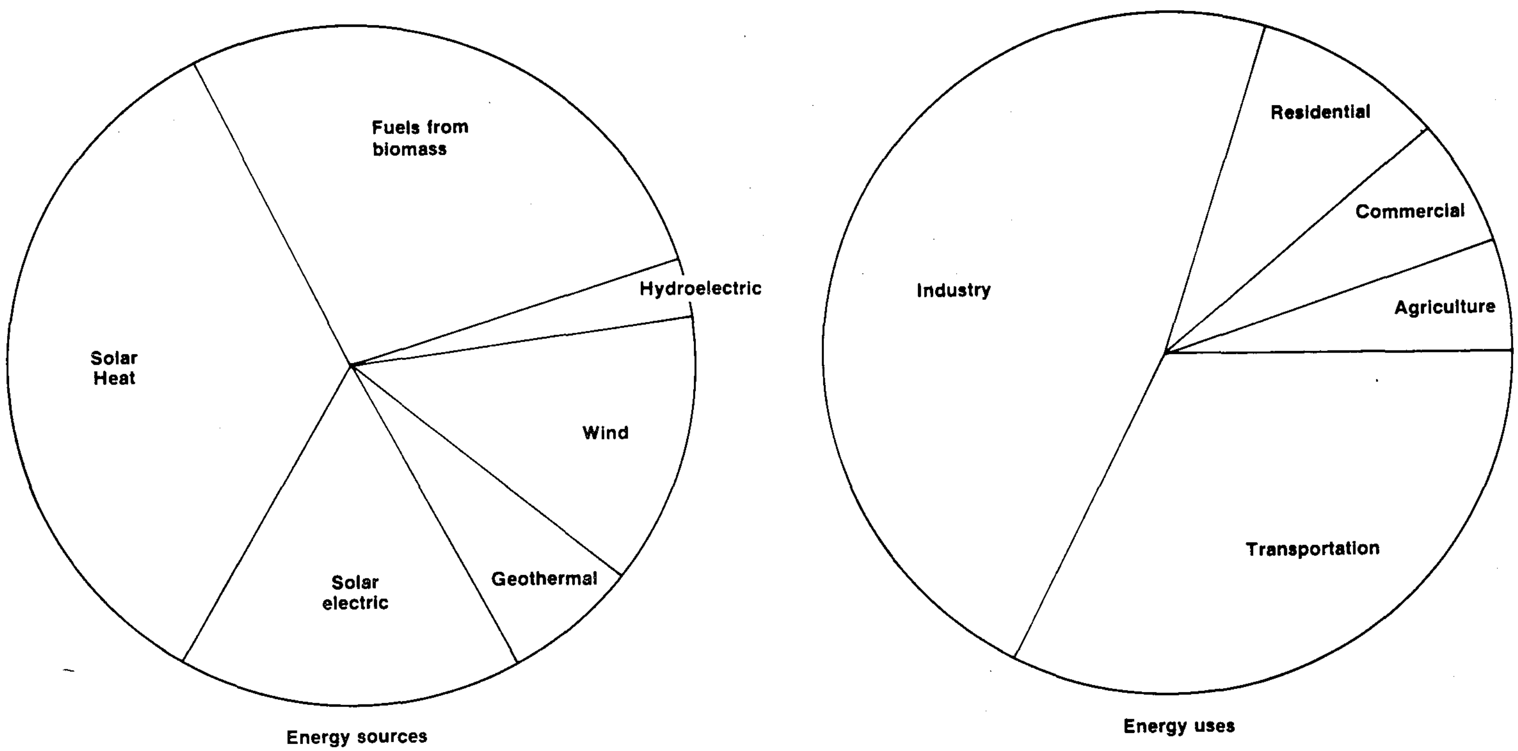


Figure VI-1. Distribution of Energy Sources and Energy Uses, Centralized End State

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from kelp for about half the total liquid fuel requirement. This problem could be eased in a variety of ways. For example, energy imports could be used to lower the stress on California's limited biomass resource base. These imports could be derived either from out of state renewable or fossil energy forms. To replace the kelp use in the A case using methanol from coal produced at 60 percent conversion efficiency would require mining about 30 million tons of coal per year. Oil shale or California heavy oils could also provide this need for many decades.

The geothermal contribution has the problems discussed in Chapter V. There remain substantial technical and environmental problems, as well as a broad spectrum of institutional issues before the geothermal resource can approach the levels used here.

Hydro power is included at roughly present levels and wind at well below 10 percent of the maximum potential specified in Chapter V (there are still quite a few windmills, though—65,000 one-megawatt units).

The remainder of electricity needs were made up using solar technology, either solar thermal plants or photovoltaics. This could be generated on-site or remotely in solar parks. Regardless of whether local or remote siting is used, some means for providing load leveling and continuity of service is required. This can take the form of spatial averaging (large grids) and thermal storage locally.

If the solar electricity systems are located at urban sites, the land use requirements are severe. Indeed, the tradeoff between solar-derived energy and land becomes explicit here. Table VI-14 ranks California cities by population density for the 19 cities in California with populations greater than 100,000 (U.S. Government Printing Office, 1976). These cities contain 35 percent of the 1973 population of the State. The total city area of these nineteen cities is 1580 square miles. This may be compared with the land requirements for the approximately 90,000 megawatts of capacity shown in Table VI-13. Each megawatt of capacity requires roughly 0.01 square mile of land (for collectors, generators, roads and storage). The total land required by 90,000 megawatts is about 900 square miles of land, or over 50 percent of the total present land area of these major cities.

The land use required by the solar units may also be compared with the total urban and industrial area of California. From Table V-5

Table VI-14

California Cities Ranked by Population Density
Cities Greater than 100,000 Population

	Population/ Square Mile	Population (1973) (thousands)	Area (square mile)
San Francisco	16,000	716	45
Berkeley	11,000	117	11
Long Beach	7,400	359	48
Garden Grove	7,000	123	17
Oakland	6,800	362	53
Torrance	6,550	135	21
Los Angeles	6,073	2,816	460
Santa Ana	5,800	157	27
Pasadena	5,000	113	23
Glendale	4,515	133	30
Hungtington Bch	4,360	116	26
Fresno	3.970	166	42
Stockton	3,600	108	30
San Jose	3,273	446	136
Sacramento	2,700	254	94
San Bernardino	2,350	104	44
San Diego	2,200	700	318
Riverside	1,960	140	71
Fremont	1,200	101	84
		7,200 (35% of CA population)	1,580

Cities with more than 100,000 population (U.S. Government Printing Office, 1976). Average density 4500 person/sq mi for these cities.

this amounts to 2.3 million acres, or 3600 square miles. The land required by the solar systems would amount to 25 percent of this area.

Land use thus presents a major potential issue if these units are to be sited in or near large urban areas. Should they be sited remotely the problem may be less severe, for the land requirement of these units is a small fraction of the total land area of the state. We note too that the land use implications of centralized systems are also quite severe, and it remains a subject for investigation to explore how the very different land use requirements of differing energy systems come into conflict with zoning regulations, safety requirements, environmental standards, etc.

By remote siting of either distributed or centralized energy systems the character of the land use issues changes qualitatively, and the siting for solar systems becomes closely akin to problems associated with remote siting of conventional energy conversion systems.

The approach taken here is a macro approach to meeting California's needs with distributed energy systems. We have also explored the same set of issues using a micro approach in which a single prototype city is examined in some detail. This work is described in the paper appearing in Volume 2, "Land Use Configurations and the Utilization of Distributive Energy Technology." The conclusions of the alternative approach are similar to those discussed here. The assumptions made differ in some ways but not enough to significantly affect the major conclusions regarding the complexity of trading off land use against energy. Somewhat higher energy requirements are imposed (less attention to energy conservation), and attention is concentrated upon meeting of peak loads rather than annual average loads as was done here.

The data of Table VI-13 illustrate the feasibility of developing a model—albeit a very incomplete and stylized one—of the California system in 2025 which operates entirely on in-state renewable resources. The picture presented here will be refined and explored in greater depth from a wide variety of perspectives in subsequent work.

6.3.7 Supply/Demand Balance—Centralized Case

In this section we develop one estimate of supply requirements assuming a business as usual approach of large centralized projects. The uncertainties surrounding the large-scale technologies are as great as in the distributed case. There is currently a broad ranging debate in policy-making circles concerning the desirability of synthetic hydrocarbon fuel production, the extent to which large central station electricity generation is feasible in California and the role of coal in the state.

Because the hydrocarbon fuels problem is so severe, it is difficult to devise a future energy system for California without assuming either major shifts in transportation needs or technology or the availability of liquids to meet transportation requirements. Another issue surrounds assumed availability of synthetic gas from coal. This issue is really one half of a coin whose other side is the prospects for large electrical generating plants. For industrial purposes the two are substitutes for one another, albeit imperfect substitutes. If unlimited synthetic gas were available, then no electrification would be necessary in industry. The result would be an electrical requirement roughly 40 percent of that in the distributed cases.

Our assumption is that roughly half the industrial heat load would be supplied by synthetic gas and half by electricity. To fire cogeneration in the chemicals, iron and steel, and paper industries, between 1.1 quads (A demand) and 1.3 quads (B demand) of fuel is required. Considering only fuel chargeable to heat from cogeneration and adding enough additional industrial heat to make up half the total requirement gives us a synthetic gas requirement for heat. To this we add cogeneration fuel chargeable to power to get the total synthetic gas requirement.

Our results are shown in Table VI-15 and Figure VI-2. The notes explain our assumptions about geothermal and hydro supplies. We find that under our assumed supply mix between 54 GW (A demand) and 72 GW (B demand) of large central station plants would be required. This will present severe difficulties with respect to siting due to seismic, air quality and water resource problems.

Table VI-15

Supply/Demand Balance Centralized Cases
(trillion Btu)

	A				B			
	Electricity	Heat <350°F	Heat >350°F	Liquid	Electricity	Heat <350°F	Heat >350°F	Liquid
Synthetic Liquids				2163				3063
Synthetic Gas								
Cogenerated Fuel[1]	534		860		591		453	
Cogenerated Heat			824				883	
Other Industry			147				363	
Geothermal[2]	327				327			
Hydroelectric[3]	136				136			
Central Station	4				5			
Coal or Nuclear	1182		___	___	1490		___	___
Total	2020		1831		2366		2199	3063

[1]See Appendix 4

[2]13 GW, 85% capacity factor = 96 x 10^9 kWh - 327 trillion Btu

[3]9.2 GW, 50% capacity factor = 40 x 10^9 kWh = 136 trillion Btu

[4]62 GW, 65% capacity factor = 353 x 10^9 kWh = 1204 trillion Btu

[5]77 GW, 65% capacity factor = 459 x 10^9 kWh = 1566 trillion Btu

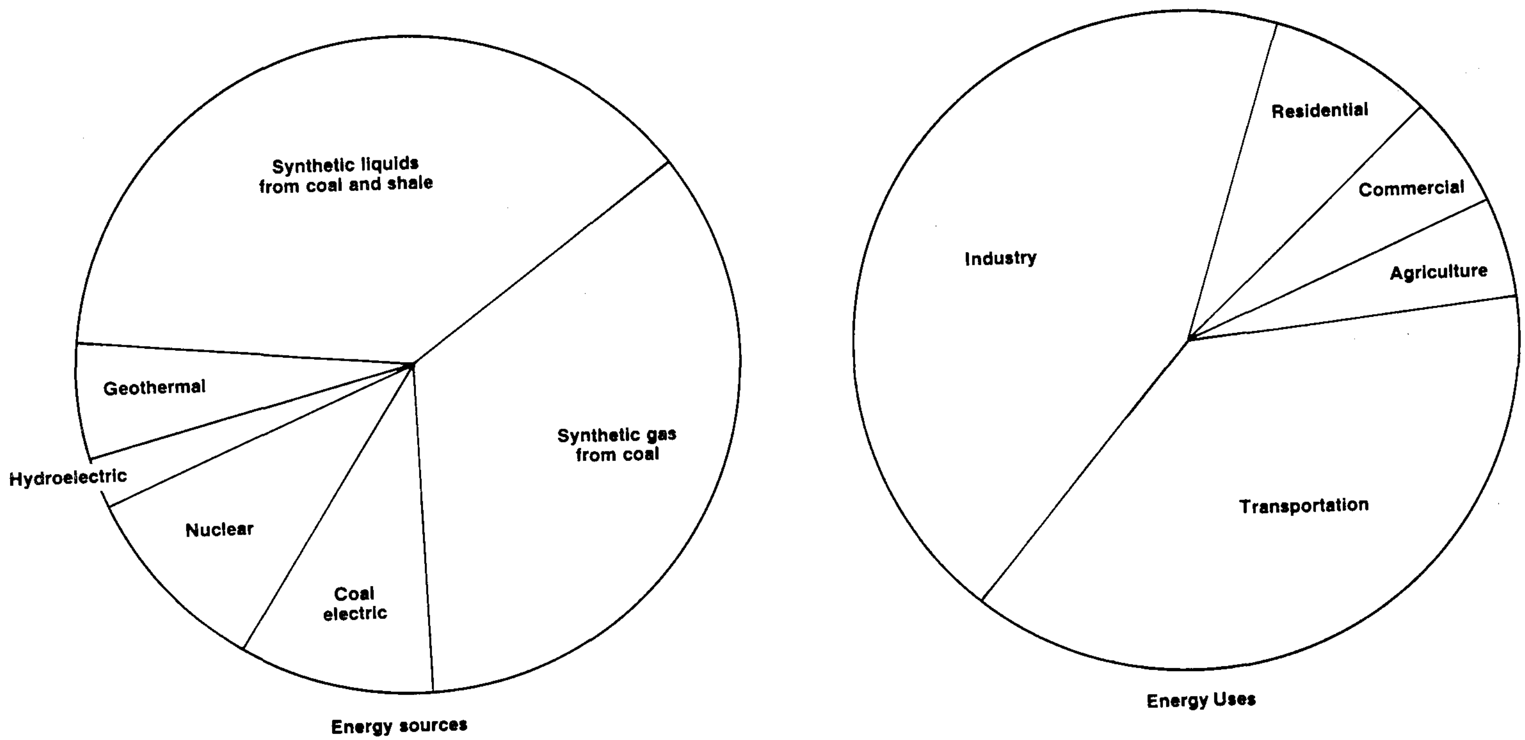

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Figure VI-2. Distribution of Energy Sources and Energy Uses, Centralized End State

In the centralized outcome energy resources are derived largely from nuclear energy, coal and oil shale. There is a considerable degree of flexibility regarding the mix selected. For each of these technologies the conversion system can be located either in California or in some other place. California has essentially no primary resources of uranium, coal or oil shale. Should energy conversion take place at the energy source (the Rocky Mountain states in the case of oil shale and coal), then California will be exporting the pollution, land use and social impacts of these conversion processes, as well as the jobs created through them. There is considerable current interest within California regarding the proper locus for conversion technologies—especially coal-fired electricity generating plants. The issue is central to the development of California energy policy and will be explored more extensively in future work of this project.

Finally, reference must be made to prospects for energy inports from outside the contiguous United States. This approach could play a major role in either a future based upon fossil fuels or one based upon renewable energy resources. Neither of these futures appears to us to be consistent with a "distributed" energy future, however. One approach emphasizing large reactor systems has been developed by Marchetti (IIASA, 1975). This approach would locate many breeder reactors on a remote island and would use hydrogen as a means for transporting energy. A similar approach could be developed making use of solar systems located in tropical regions. These could be either solar thermal or photoelectric type systems or could emphasize biomass. Issues associated with such systems go far beyond the scope of this study.

6.4 CALIFORNIA IN 2025: A QUICK SKETCH OF THE LOW DEMAND, DISTRIBUTED TECHNOLOGIES END STATE

6.4.1 Population

The California population has grown to 38.6 million from 21.2 million in 1975. The fertility rate remains high, and migration into the State continues at 100,000 per year. Thus the age distribution is only slightly different than in 1975, with a median age ust over 32. The regional distribution of population is much as in 1975. Central cities (L.A. and S.F.) have not grown rapidly, but their outlying regions have. Some rural counties have grown more rapidly than the state average, others less rapidly.

6.4.2 The Economy

The Gross State Product has increased to $462 billion (1975 dollars) from $160 billion in 1975. The GSP per capita is $12,000, the same as the U.S. average. This growth in GSP has been achieved with some increase in the amount of leisure time, and with attainment of "full employment" (about 4% unemployed). The increase in labor productivity from 1975 to 2025 has been only about 1.6 percent per year, instead of the 3 to 4 percent typical of the decade prior to 1975. The agricultural sector has grown less rapidly than the rest of the California economy, being limited by water and land availability. The relative sizes of the government and service sectors have increased, but not drastically.

6.4.3 Energy Demand

All new buildings meet tight conservation standards and require only about half the energy for heating and cooling of the 1975 building stock. The buildings remaining from 1975 have been renovated to bring them close to the 2025 standards for thermal performance. Use of appliances in the home has increased, but each device uses only half the energy of the corresponding 1975 device. No new major energy-consuming devices have been introduced in the home. Industries are more energy-efficient and require on the average only about 60 percent as much energy per dollar of output as in 1975. However, industrial output has increased along with the rest of the economy, and thus total industrial energy demand is twice that of 1975. Transportation in urban regions is primarily by private vehicle (mostly electric). The time spent per person in a private car is about the same as in 1975, about 54 minutes per day. The annual miles of air travel per person has doubled since 1975, but planes are more efficient because of improved engines and wing design.

6.4.4 Energy Sources

California runs almost entirely on renewable energy resources, primarily solar energy, hydropower, wind and biomass. Almost all buildings are solar-heated. In low-density areas, buildings use passive solar design for space heating, without backup in the southern part of the state. In solar collector systems are used, with combustion of municipal solid waste as a backup. In northern and mountainous areas large thermal storage is used, but electrical or fuel backup is still required a few times a year. Wind or geothermal energy is used for heat in some regions with such resources. Buildings consume electricity for lighting, appliances, cooking and refrigeration. Cooling is by passive systems where possible, by solar-driven air conditioners in the hottest regions, and by electricity in places that require cooling but infrequently.

Industry makes extensive use of solar heat for process temperatures up to 350°F. Above this temperature, they use electricity. Most industries with large electrical requirements are able to combine solar thermal generation of electricity with use of the waste heat for other applications. Chemical feedstock is obtained primarily from biomass, with only little use of the remaining California oil resource for this purpose.

Biomass-derived fuels provide for air transport and for rural transportation. However the lack of sufficient fuels from biomass has required the widespread use of electric vehicles in the metropolitan areas. The electric vehicles pick up power from freeway roadbeds to extend their range for commuting in the San Francisco Bay and Los Angeles areas. Liquid fuels are used for private vehicles only in the regions outside major cities and their suburbs.

An electrical grid still exists in California, but it is a more dispersed, more redundant and more finely interconnected system than in 1975. Generation is by small units, with solar cogeneration by industries, wind turbines, and hydroelectric facilities providing most of the capacity. These allow each region to provide for its own peak loads.

The most pressing energy problem in the state is the chronic shortage of liquid fuels. These are valuable as chemical feedstock, for energy backup (a small amount of fuel storage replacing a large thermal storage unit), and for transportation. However, the available land and water are fully dedicated to agriculture, forestry and energy farms, and no more can be brought into production without loss of recreational or wilderness areas. This shortage of fuels causes an economic incentive for development of the few remaining wild streams and rivers and wilderness lands for biomass production.

6.4.5 The Environment

Most of the environmental impacts commonly associated with energy reduction and use in 1975 are gone. There is little combustion in the urban air regions, so air quality is back to the levels of the early 20th century. However, the urban and suburban sprawl associated with the use of dispersed (i.e., solar) energy technologies has increased the land consumed by habitation. The large number of wind turbines and pumped hydroelectric storage facilities have destroyed many scenic values. Almost all streams and valleys have some development for the hydroelectric power system. Nuclear power is not used in the state, and no part of the nuclear fuel cycle is present. Geothermal power is used in some regions, with some visual impacts and some air and water pollution. The major environmental impacts of energy are those caused by the construction of wind, solar and hydroelectric facilities.

REFERENCES

J.D. Balcomb, Passive Solar Heating of Buildings, Los Alamos Scientific Laboratory, Report No. LA-UR-77-1162, 1977.

California Department of Finance, Population Projections for California Counties—1975-2020, Report 74 P-2, Sacramento, California, June 1974.

California Energy Commission (CED), Forecast, Volume II (unpublished and Appendices A-G, 197 .

California Energy Commission, Quarterly Fuel and Energy Summary, 2nd Quarter, 1975.

California Energy Commission, Quarterly Fuel and Energy Summary, 4th Quarter, 1975.

Hoffman

International Institute of Applied Systems Analysis (IIASA), Second Status Report of the International Institute of Applied Systems Analysis, Report RR-76-1, Laxenburg, Austria, 1975.

Lawrence Berkeley Laboratory, Electrical Energy Consumption in California: Data Collection and Analysis, UCID 3947, 1976.

Amory Lovins, Soft Energy Paths—Toward a Durable Peace, Ballinger Press, 1977.

National Academy of Sciences, Demand/Conservation Panel Report of the Committee on Nuclear and Alternative Energy Strategies (CONAES), draft report to be released approximately November, 1977. (See also CONAES Resource Group reports.)

McDonnell Douglas, Industrial Applications of Solar Total Energy, Final Report, Volume I, Summary, April 1977.

Stanford Research Institute, Transportation Alternatives for the Automobile, 1977.

U.S. Bureau of the Census, Current Population Reports, Series P-25, Number 381, Population Estimates, December 18, 1967.

U.S. Government Printing Office, Statistical Abstract of the United States, 1976.

B. Weisenmiller, Commercial Consumption in California, Teknekron Inc., (unpublished), 1975.

CHAPTER VII
ISSUES AND PROBLEMS

Chapter VI presents a preliminary technological analysis of some alternative end states. In this section we begin consideration of environmental and social issues in the developmentof alternative energy systems. This chapter draws largely on work presented in greater detail in Volume 2 of this interim report. Those papers for the most part are identification and definition of problems, as seen from various perspectives, and descriptions future work. Chapter VII attempts to bring out salient points made in those papers, to identify relationships between various factors and to begin a process of integration among diverse specialities as the insights they provide bear on problems of policy for development of energy systems.

The investigators upon whose work this section primarily draws are:

University of California:

F.E. Balderston, Business Administration
P. Brown, Business Administration
C.R. Glassey, Industrial Engineering and Operations Research
J.P. Holdren, Energy and Resources Program
I. Hoos, Space Sciences Laboratory
T. LaPorte, Political Science
C.B. McGuire, Public Policy
L. Nader, Anthropology
R. Twiss, Landscape Architecture

University of California, Davis

A. Groth, Political Science
H. Schutz, Consumer Economics

State University of New York, Stonybrook

R. Nathans, W. Averill Harriman School of Urban and Policy Science
O. Carroll, W. Averill Harriman School of Urban and Policy Science

7.1 GENERAL CONSIDERATIONS

The construction and use of energy technologies produce secondary environmental and social consequences that are neither desired nor, for the most part, incorporated in the economic costs charged for the energy supplied. Although it is now essentially universally recognized that these "externalities" or (broadly defined) "social costs" must somehow be taken into account in the processes by which society choose among alternative energy options, it is less likely appreciated that these costs—not resource limits or economics—actually define the energy dilemma in the long term. It is important to try to make clear at the outset why this is so.

The energy problem resides fundamentally in the fact that the relation between energy and well-being is two-sided. The application of energy as a productive input to the economy, yielding desired goods and services, contributes to well-being; the environmental and social costs of getting and using energy subtract from it. At some level of energy use and for a given mix of technologies of energy supply, further increases in energy supply will produce incremental social and environmental costs greater than the incremental benefits to well-being; that is, growth begins to do more harm than good (National Academy of Sciences, 1977).

That such a level, beyond which energy growth no longer pays, exists in principle for any mix of technologies of supply and end use is easily shown from basic economics and physical science; predicting its magnitude exactly is much harder, the more so because social costs even less quantifiable than environmental ones may dominate. Energy policy for the long term should be shaped by awareness that social-environmental costs, not exhaustion of resources, will limit the amount of human well-being derivable from energy. Maximizing this quantity will require striving for technologies of energy supply with low social and environmental costs per unit of energy delivered and fostering patterns and technologies of energy end use that squeeze from each unit of energy used the maximum contribution to human well-being.

This perspective, then, elevates environmental and social characteristics to the top of the list of criteria used to select supply technologies from the menu of genuinely long-term options—fission breeder reactors, fusion, direct and indirect harnessing of solar flows, and possibly some forms of geothermal energy. It rationalizes the possibility that society will choose to pay more (in economic terms) for a more benign energy source than for a less benign one. And it argues for using, as a criterion for selecting short-term and transition energy sources, the extent to which these promote and facilitate the transition to a longer-term energy future built on more benign sources and efficient end use. This perspective places environmental and social impacts at the heart of the energy predicament rather than on the periphery.

The analyses in Chapters V and VI are quantitative in nature and have an air of "necessity" about them in their subservience to "natural law"—given a set of assumptions about society. That air of quantitative "necessity," however, is largely apparent, for "resources" and "energy systems" exist only with respect to society, and society is in a fundamental sense "artificial"—it is as it is only because it has been molded by goals and purposes of people to the environment in which they live. Societies and social phenomena have an air of "contingency" in their malleability by the environment. A major problem of analysis is to show how empirical propositions can be made at all about systems that, given different circumstances, might be quite other than they are. While there can be doubt about the empirical utility of these qualitative considerations, it must be remembered that the "hard" quantitative analyses in preceding chapters have meaning only in terms of propositions about society, and hence can have no more meaning or value than the contingent propositions of this section.

Energy is fundamentally a social economic and political issue. A basic flaw in all energy discussions is that social and cultural context tend to be left implicit. Yet the major choices in energy paths involve profound social and cultural issues that reach to perceptions (and behavior) of individuals, major institutions of society and society as a whole.

All possible paths of development of energy systems will raise difficult social problems, though the different paths raise very different kinds of problems. All possible paths involve substantial social change—changes that may be either painful or unnoticed. Whatever their characteristics may be, transitions are an ever present factor in human life, and most of them occur without the aid of any public policy.

When public planning seeks to influence the course of social change, there readily develops the mistaken belief that changes only happen if they are planned by government. Experience shows, however, that private planning, conscious or unconscious, can and has had a tremendous impact on society—diffusion of the automobile and changes in birth rate being two examples. Public planning must run into difficulties if it does not recognize parallel change in private planning. So in the sections that follow we attempt to begin assessment of factors that may affect private choices as well a public policy.

We begin with the "harder" or more quantitative considerations. But note at each step important qualitative factors must be set aside from the quantitative analysis. Words like "expectation," "taste," "perception" or "role models" are excluded from quantitative aspects of analysis because they are more difficult to handle quantitatively. In the end we must ask the question "Which factors—hard and quantitative or soft and qualitative—are likely to have what effects in shaping development of society generally and the energy system specifically?" That question in turn leads into other thorny issues: "Who analyzes policy and options?" "What kinds of biases are those people likely to have in assessing alternatives?" Those questions lead naturally to discussion of roles of experts, public participation and authority in the functioning of society.

7.2 ENVIRONMENT AND LAND USE

All possible paths of development for energy systems will encounter major problems involving land, air and water. In California major conflicts already occur over siting of facilities, supply of water for energy facilities and emissions to air and water. These conflicts can only increase if the current pattern of development continues. Renewable and distributed sources of energy also will encounter substantial environmental problems, and we begin assessment of those problems and comparison with problem of conventional centralized systems.

Holdren (in Volume 2) develops a comprehensive framework for assessment of environmental impacts of alternative energy systems. He identifies a complete range of questions that have been asked and should be asked as he arranges those into a structure that facilitates comparison among different energy systems. He discusses environmental impacts of various technologies for use of renewable resources and then provides a preliminary tabular comparison of environmental impacts of all the alternatives. From that analysis he derives a "vigorous assertion:" The environmental impacts of certain of the soft technologies—notably increased end-use efficiency, active and passive solar heating and cooling with individual building or neighborhood units, fuel production from biomass in the form of wastes, and dispersed on-site wind generators—will prove markedly smaller than those of the more centralized technologies for harnessing renewables.

Detailed aspects of Holdren's assessment will surely be questioned and modified, but the structure of his argument is such that many details can be modified without negating his central conclusion. That conclusion appears to be robust; it will surely be much debated.

The problems of land use are very different for distributed as compared with centralized energy facilities. With distributed facilities the environmental and social costs are borne at or near the site of end use and benefit. With centralized facilities the costs and benefits occur in very different places. The structure for making decisions and the structure for exercise of political power are very different for those alternatives.

For renewable resources land in effect _is_ energy, for it is land that intercepts the fluxes of energy. In Volume 2 Carroll and Nathans develop an analytic model of a self-sufficient community utilizing distributed technologies for conversion of renewable resources. Their quantitative analysis produces estimates of the quantities of land needed to provide energy in the quantity and quality needed to meet in used. That analysis suggests the very broad dimensions of changes in patterns of land use that would be required by change over to dependence on renewable resources. In such a situation conservation practices can be seen to provide a tradeoff against demands on use of land for supply of energy. They emphasize the need to critically examine the broader institutional, economic, social and political problems that would be involved in such changes.

Twiss and others in Volume 2 review the literature on the relation between land use, transportation and energy consumption and assess institutions and processes involved in making land use decisions. Most land use decisions are made by local institutions, and such decisions are critical for development of energy systems. The local institutions for making land use decisions are old, historic and deeply intrenched; moreover, they developed in response to social needs vastly different from those under discussion here. They can be very resistant to outside pressures. They can also be very responsive to changes of local sentiment.

In a general way distributed technologies leave land use decisions in the hands of the existing authorities, local institutions, which would then be forced to make agonizing decisions, tradeoffs that require significant changes in historic patterns of land use. Centralized systems will require centralized processes for making land use decisions, so that local interests in one place can be over-ridden for the benefit of local interests in another place. Which institutional frame might be expected to produce "better" dicisions? And decisions "better" in what sense(s)? What values, beliefs, expectations of the American people are most fundamentally affected by the alternative institutional arrangements?

7.3 ECONOMICS

Problems of economic and social prediction from an historic base remain very difficult. Economists have developed multi-equation econometric models of the national economy that have yielded useful results, but these models can at best produce predictions that are contingent upon continuation of the economic structure that is incorporated in their equations. The equation system does not account for numerous kinds of changes that will inevitably occur—changes in taste, priorities, technology, political conditions, population or of the environment. In general, of course, the longer the horizon of forecast, the greater is the likelihood that fundamental structural changes of this kind will invalidate predictions, of both numerical projections and qualitative effects of policy change.

A first step in the present study is an investigation of the physical and technological feasibilities of various distributed and renewable energy systems for California in 2025. Economic constraints enter this part of the study implicitly in a number of places (e.g. a known method of producing biomass is ruled out because the resource requirements are thought to be too high or too speculative) and explicitly in a limited number of other places—usually as specific resource limits (e.g., no more than 40,000,000 acre-feet of water per year are available for all agriculture in California; 150,000 acres of land is available for wind mills, etc.). But other than these resources and first-order cost constraints, no attention is given to economic considerations. Relative costs of different energy systems are not studied. The means by which individuals, firms and managers are induced to carry out the roles envisaged for them in the various systems are ignored. Organizational, political and sociological considerations are untouched.

7.3.1 Incentives and Innovations

We assume that the strategy for implementation of any pathway will use a mixture of planning and market tools. Important in the diffusion of any new technology is the economic competitiveness of the technology in the markets, as they exist; consequently analysis of cost and market incentives is an important aspect in the study of pathways. Markets as they exist, however, are not "free" or "natural;" rather they are influenced or biases by a wide variety of non-market circumstances— institutional arrangements, policies, practices of both private enterprise and government. Assessment of the economics of various technologies, therefore, must include clear understanding of existing market and non-market arrangements and the options for modifying those arrangements. More careful examination of cost relationships is an important part of the next phase of this study.

Costs are important not only as comprehensive and aggregate measures of the resource requirements of alternative systems, but also for their role in market incentive systems. If the cost of providing "equal amenities" through a distributed energy system is less than the cost of a "harder," more centralized system, can we then expect that the private enterprise system, without special guidance or interference from government, will take us toward the distributed system? Conversely, if the cost of the centralized system is less, would government interference with market forces be required to move toward the distributed system? How are the decisions of firms to be influenced? The distinction between social and private costs is all important in this investigation.

Firms and households, as energy users, have not in modern times adopted "soft" technologies except in highly unusual, isolated instances. conventional fuels (oil and natural gas) and electrical energy have been cheap and convenient. We intend to study the problem of influencing typical energy-using firms away from the traditional reliance on conventional energy sources and toward "soft" technologies.

Three possible types of actuating forces could cause energy-using firms to contemplate shifts from conventional energy usage to soft technologies. First, some firms might respond to exhortation—appeals for a change out of a sense of social responsibility and to satisfy philosophical commitments to the community. (This sort of impulse toward change has indeed influenced the behavior of some firms in such other contexts as affirmative action and consumer information, but we shall not focus on it in this study.) Second, a significant change in energy prices—bringing about a situation in which conventional energy became much more expensive relative to energy from soft technologies—could actuate change. Third, firms could be subjected to regulatory interventions intended to cause them to shift toward soft technologies.

Balderston, Blattman and Tourinho in Volume 2 begin study of processes producing change in decisions of firms. Brown in Volume 2 describes a plan for study of innovation in small firms.

7.3.2 Demand for Energy

Difficulties, both practical and theoretical, stand in the way of projecting energy demands forward to 2025. If, as expected, relative energy prices rise, the amounts of various energy types demanded by the typical household will contract. Energy consumed directly (e.g. gasoline to run a private automobile, electricity to operate a family dishwasher, etc.)will contract: the effect on this component is the easiest to estimate. Indeed, it is this change which is accounted for in the CONAES projections used in Chapter VI where a fourfold energy price increase is postulated.

The price effect on the demand (the demand elasticity) for indirectly used energy is more difficult to estimate. How much less will be demanded of a product which is more costly to manufacture because the price of its energy inputs has risen? The answer not only requires some knowledge of the price elasticity of demand for the product in question but also information about the manufacturer's ability to substitute other relatively less costly inputs for energy. At present, these more remote effects are not captured in the projections of future energy "requirements." Yet the importance of the effect does not diminish with its causal remoteness: recall that the major uses of energy are not the direct ones. Ultimately the only way to achieve a better understanding of changes in product mixes and hence energy demands in the all-important industrial sector is through development of econometric and technological process analysis techniques which trace back through the causal chain from consumer demand to input factor substitution possibilities in production.

Some more sophisticated economic models (cf. Hudson and Jorgenson, 1976) do attempt to trace through the whole chain of indirect effects indicated. There is a question, however, whether the technology portrayals in such models can be expected to remain valid until 2025.

Even if not much can be learned in micro detail about these effects, it would seem imperative to obtain estimates of aggregate impacts of price changes. It is not especially useful to insist that the world (or the State of California) go on consuming and producing at current levels or trends and in current fashions of production, only then to conclude that the energy system thereby made necessary is insufferably costly.

In keeping with the usual simplifying assumptions of workaday economic analysis, the discussion above takes consumer demand functions (relating prices and amounts demanded) as given—not necessarily constant but at least known by the analyst for the future under study. But tastes and preferences—and therefore demand curves—change over time in ways that we cannot now predict. Governmental policies in a variety of areas surely impact on the development of tastes. Indeed, governmental policies concerning energy doubtless affect the shaping of tastes with respect to goods and services closely allied to energy!

In some of these respects, the end state demand summaries of Chapter VI constitute a particularly harsh test bed for soft technologies—and appropriately so. We want to know the limits, in some sense, of what can be provided, and an attempt to completely meet postualted increases in demand will certainly do this.

In fact, however, a soft energy future would not look like Orange County plus windmills and solar collectors. By postulating a completely soft energy-reliant society without any accompanying social changes, we are led into a situation in which the society is doctrinaire about its energy sources, but uncaring about the social structures which support demand. Both of these assertions are unreasonable. If achieving perfect reliability requires either the damming of every free-running stream in the state or the importation of a small amount of coal, a society concerned enough about the environmental impact of the hard path will clearly choose the coal. Likewise it is highly unlikely that a society which accepted the perhaps higher cost of a soft path would not alter the wasteful structures spawned by hard path technologies (and cheap fossil fuels). Remember that the choice of a soft path <u>in toto</u> is unlikely, but it is no more unlikely to assume that such a decision would not be accompanied by changes in population density, transport, work, conservation-relevant behavior or the type of product demanded from the economic system by the consumer. Any of these changes, much less all, would greatly ease the transition to and the maintenance of a soft-path economy, and obviate the need for carpeting the central valley with windmills or damming every stream in the state.

7.3.3 System Boundaries

For end-state description there should be consistent definition and treatment of the "California system" boundaries. The "centralized system" described in Chapter VI entails direct imports of energy (coal and uranium) because, in the absence of such imports, the 2025 end state would be strictly impossible. The dispersed technology end state, however, involves a) no direct energy imports for any purpose and b) a consequently enormous and artificial reliance on electrification.

Final goods and services are clearly postulated to flow both ways across the "California system" boundary because the high value of real Gross Product per capita requires such interdependencies. We should and must expect that interregional and international trade take place in 2025, and we can reasonably expect that this would be true for direct energy sources as well as for energy-embodying final goods and services produced and used in California and participating in its imports and exports balances.

It would be desirable to analyze the input/output linkages between California and the rest of the world under various end states and to determine how much shift in California's output, consumption, export and import trade could be expected for each category of goods and services according to its energy content relative to physical output and economic value.

In general the energy component of high-value manufactured goods (e.g. electronic products) is a negligible percentage of unit cost, so that even steep increases in prices could not disturb import/export patterns for them. The projected GSP/person in 2025, however, might not be attainable because agricultural exports from California to the U.S. and the rest of the world might be seriously inhibited by: 1) reductions of output on account of energy shortages, 2) reduction of export shipment possibilities because of increases in transport costs and 3) reduction of other regions' effective demands for California's agricultural products because of severe impacts of energy shortages on their real outputs and incomes.

What about systems boundary aspects of the projected California population? In particular, both the total California population and its geographical distribution might be drastically changed by new economic and social constraints, including the energy system.

The amounts of real capital to support the investment requirements of an energy path are sure to be large on a 50-year horizon. Systems boundary aspects of this include:

1) What should be assumed about real capital formation? Would California be considered as an isolated entity, as a potential importer of capita or (in view of its generally affluent character) an exporter of capital to other parts of the nation and the world?
2) Financial/monetary flows in parallel with real capital formation and capital transfers also need a system boundary.

It is not inconsistent that there be interregional capital transfers and financial flows.

7.4 SOCIAL/POLITICAL ISSUES

To this point, discussion has been largely in quantitative terms or around modes of analysis that are in principle quantifiable. That discussion has evoked a number of words that are symbols of ideas that in principle cannot be quantified—institutions, organization, process, perception, purpose, expectation, attitude, etc. In this section we seek to assess how an array of qualitative concepts come to bear on choices for policy with respect to development of the energy system.

7.4.1 Organizations

It is more difficult to assess institutional feasibility than to demonstrate technological consistency or to estimate the magnitude of economic investment that would be required to achieve the indicated state of affairs. We focus attention here on formal organization. Problems of institutional feasibility, however, must extend to include consideration of beliefs, values, expectations, etc. which underly organization and which find expression in formal organizations.

Possibly the most fundamental social change in the western world in this century is the growth and development of large-scale organizations, both private and public. Individuals and groups have become dependent on such large-scale institutions. Both individual and group self-reliance has decreased. The pattern of occupations has become overwhelmingly one of specialization and wage labor.

In the United States these organizations were initially corporations. Corporations in effect set the tone and style for the economy as a whole by setting standards for hours, wages, working conditions, productivity, specialization, departmentalization, etc. Big Labor and Big Government have developed in response to growth of Big Business. Large bureaucratic organizations have become the dominant or representative institutions of Western society in a remarkably short period of time.

The existing energy industry is characterized by such large organizations. Changed conditions and prospects will require adaptation on the part of those organizations and of individuals. The organizational innovations required by transitions will be molded not only by economic but also by social and psychological factors. It is essential to understand the interplay of these factors on the choices and actions of organizations and individuals. There are important questions about the capacity of bureaucratic types of organizations, private and public, to adapt to changed circumstances. An energy policy must have concern for both the private planning of individuals and the characteristics of organizations and individuals which/who play key roles in implementation of policy.

Organizations of all kinds, and especially large organizations, introduce problems of categories, functions, etc. Problems that do not fit categories tend not to be addressed. The problems of categories is not limited just to government, big business, etc. but rather is endemic among interdependent public and private institutions. For example, in California at the present time there is a major debate among contractors on which division should assume the now lucrative market for energy-efficient components. Should it be plumbers, electricians, air conditioners, etc.? This disagreement is a major obstacle to widespread implementation of energy-efficient components. In general at the large, visible organizations in society—government, universities, big business, labor unions—are taking few initiatives to lead the way to conservation and efficient use of energy, to use their power as role models or to lead by demonstration. Much exhortation there is; leadership by demonstration there is not. Nader et al. in Volume 2 suggest "... that we may need a new division of labor in organizations whereby piecework is replaced by the need for whole job responsibility, and we need to do this in the name of efficiency. We have come full circle."

Because technology in fundamental ways is organization, policies on R&D should have explicit concern for organizational options for alternative energy systems. What kinds of people and organizations will use a particular set of equipment, for what purposes and with what consequences? What kinds of people and organizations will produce and distribute equipment and energy, etc.? Focus on hardware alone will obscure fundamental organizational, hence social, implications of alternative energy technologies.

In this section we focus on organization, but social problems cannot be addressed in such terms alone. Society can be considered on three levels:

1) Society as a whole which must be able to function, survive and adapt to changing circumstances
2) Institutions of society which must be able to function, survive and adapt to changing circumstances
3) People whose basic beliefs and expectations must be fulfilled and, if necessary, adapted to changing circumstances.

Problems on these three levels are coordinate and equal; none has priority. The three levels are not independent. Failure to deal effectively with problems on one level will lead inescapably to collapse of the entire structure. Unfortunately the belief is widely held that solution of problems on one level will produce the social panacea.

7.4.2 Organization of Production and Control

Energy systems have two characteristics that can be characterized by their varying degrees of centralization/decentralization. These are the technological properties of the system of production and distribution on the one hand and the managerial/legal control of production and distribution on the other.

Centralized energy technologies imply a few, large-scale production and conversion units. The primary distinguishing features are large capital investments, large plants and large capacities in production and distribution. Centralized technologies require extensive distribution systems because not much consumption takes place near the site of production. Transmission and transportation costs and losses may be significant. Furthermore, the shutdown of a single centralized facility causes the loss of a large fraction of system capacity. A large amount of capital is required to get into the business, so only a very few large corporations or government agencies dominate markets.

By contrast, distributed energy technologies imply small-scale facilities located close to the end user. Transmission and transportation costs are minimized in the first instance. The fluxes of energy, however, are variable, so means must be found to smooth out those variations in order to match supplies to uses. Smoothing can occur by averaging over time or space. Time-averaging means storage, whereas space-averaging requires linkage into a transmission or transportation grid. Economic factors may make linkage into a grid attractive. If that should happen, there then comes the question of how such a grid might be managed, which introduces the question of centralization of control.

Each energy technology has some minimum requisite level of managerial centralization. This level of centralization must be achieved or the technology is ineffective. Thus large-scale technologies that are physically centralized must be managed centrally; the management of a single generating plant cannot be decentralized below the plant level.

For distributed technologies it is at least possible to have more decentralized control. There is, however, no imperative that such decentralization of control occur. The difference between the requisite level of centralization and the actual level of managerial centralization could be thought of as managerial control in excess of that necessary to operate the technology effectively. There is no technological requirement for vertical integration of electrical utilities or oil companies. Market devices could be developed to achieve coordination among production, wholesale distribution and retailing instead of relying on managerial centralization alone. Social factors and dynamics outside of technology contribute to excess managerial centralization; it should be useful to understand the reasons for and consequences of such extrinsic factors.

Finally, it is important to realize that in fundamental ways technology is organization. Hardware without organization is not technology. People organized, without hardware, or with minimum hardware, can constitute powerful technology, e.g. irrigation in ancient Mesopotamia. In assessing alternative "technologies" it is a basic flaw in reasoning to compare only hardware and its effects; organizational characteristics and effects are fundamental attributes. The crucial requirement for harmony among the three levels of society establishes a vital function of leadership—the setting of the frame within which individuals and institutions act. Such harmony is not to be found in nature. It is a creation of society.

Various aspects of organizational problems are treated by preliminary papers in Volume 2: Brown addresses circumstances, characteristics and prospects of small business; Nader and others address attitudes of key actors in implementation.

7.4.3 Expectations, Beliefs, Behavior, Etc.

The ways people behave, what they find acceptable, tolerable, desirable, etc. depends very fundamentally on notions in their minds—expectations, beliefs, concepts, ideas, information, etc. Some kinds of notions are more important than others in affecting behavior. In comparing cultures, anthropologists have long noted that people live by propositions the validity of which is a function of the belief in them. Such propositions about the world are not true or false in any simple sense. Rather, they are more true if people believe in them, less true if people disbelieve.

Notions in people's minds play a powerful role in private planning and choice. The recent best-seller Shardik forcefully played out that theme. Policy analysis that emphasizes quantitative aspects may tend to ignore or slight these powerful factors. We do not attempt here comprehensive assessment of these sticky—for a democracy—issues, but we make some preliminary review of public attitudes and impact of credibility on response of the public to energy problems.

In Volume 2, Schutz and others review results of public opinion polls relating to energy; Nader and others discuss interviews with key actors to assess attitudes in implementation of energy-related policies. As recently as May, 1977, according to one survey, only half the population believed the energy shortage is real—in a very immediate sense, of course, there is no shortage. Some survey data suggests that awareness of genreal energy problems is correlated with conservation behavior.

In all cases it is clear that credibility of the problem is critical to choices made by people and to actions of various key actors in implementation.

Comparison can be made to conservation of water in northern California in 1977. The public conserved beyond all expectations, voluntarily and with good nature. The problem is credible and in a sense, tangible (pictures of empty reservoirs). Among people and institutions models of conserving behavior served to influence actions of others.

Energy problems lack comparable credibility and immediacy. The problem is not immediate and tangible. People do not know what to believe about the nature of the problem. Leading institutions are not playing roles as models for conserving behavior. Testimony of experts conflicts. Institutions adopt self-serving positions. If the behavior of the Bay Area public in conserving water in 1977 provides any insight, it is that the first step toward encouraging development of energy efficiency and conservation is to establish the credibility of the problem.

Credibility and behavior are strongly influenced by world views. In a study of Solar Energy in America's Future (SRI,1977), Harman and others assessed how differing world views lead to very different approaches to energy problems. There are now, among the American public, widely different expectations for the future, and these very different expectations lead to very different choices for action today. Those different perceptions also lead to different expectations of society in general and organized institutions in particular. Policies for development of the energy system will certainly be storngly shaped by such conflicting perceptions and expectations.

7.4.4 Progress

Belief in "progress" is perhaps the most important social force of the present time. The terms in which that belief is cast bring enormous pressures to bear on choices of policy. Belief in progress undergirds at least the rhetorical basis of policies of governments the world around. The idea of "progress" represents a radical departure from beliefs of all great traditional civilizations, in which the notion of progressive change (in contrast to cyclical change of the natural world) was charged with horror and fear and was contrasted with the idea of that which is eternal, which does not change, and which alone, therefore, is of value. The idea of progress crystallized in Europe in the Middle Ages and from there has spread over the globe. Belief in progress is the criterion which distinguishes a "modern" society from a "traditional" society.

The terms in which "progress" is cast guide the direction of development of a society. For many people and institutions in the United States the principal measure of progress seems to be technology. The presence of technology rather than its use or consequence seems to be the measure. Yet improvement in the quality of life, which is the full measure of progress, depends on many factors, of which technology is only one. It is important to be clear at the outset that there is no simple, linear relation between progress of society generally and development of technology in general or patterns of use of energy in particular.

When "Engine Charlie" Wilson in the 1950's said, "What is good for GM is good for the country," he was ridiculed. Much of current debate about energy alternatives has a similar flavor. There is a theme that the good of the nation depends on the continuing development of established trends of technology, including the organizational aspects. That is, what is good for the energy system is good for the country. The argument is seductive because the energy system now includes not only energy corporations, but unions and public bureaucracies that are interdependent with those corporations, as well as universities and departments who train specialists to fill niches in all of those organizations. The development of large organizations has made all highly interdependent. An important problem now is, "What capacity for adaptation does this complex system of large organizations have?" as people, institutions and society at all three levels attempt to stake out directions of development, of progress, under changing circumstances?

7.4.5 Experts

In twentieth century America planning, public or private, requires the use of professional experts. The development and elaboration of expertise and disciplines is not an autonomous function of the professions. Rather it is a synergistic imperative of a society dependent on larger organizations. Large institutions must be organized; that is, tasks or functions must be defined and described, arranged and related to one another such that the flow of work through specialized parts of the organization yields a coherent product or service. Organization has produced a demand for specialization and expertise.

For some problems the narrow range of the expert is productive, even essential. For other problems narrowness is both malproductive and non-adaptive to changing circumstances. Major social problems of today, e.g. food, energy, poverty, equity, have a seamless quality about them that does not recognize the confines of expertise.

Experts tend to have clearly determined "mind-sets," which determine the frame of reference and terms with which they address problems. Officials and professionals, for example, tend to believe that major changes in consumption of energy, toward conservation, must be mandated, coerced or seduced from the public. Economists tend to favor prices. Physical scientists and engineers favor engineering solutions.

In development of energy policy, a important issue is relationship between technical devices that are available to and advocated by various experts, and political roles, leadership if you will, available to politicians.

7.4.6 Participation and Authority

A current political trend is toward greater citizen access to and participation in public decision-making. Note, for example, President Carter's endorsement of the legislation that will give citizens broader standing to initiate lawsuits against the government (Congressional Quarterly, April 9, 1977). Note also the pressure for greater accountability as evidenced in the 1974 amendments to the Freedom of Information Act. Although the Kennedy proposal for funding public participation and the proposal for the Agency for Consumer Protection has been blocked, recent history suggests that the delay is temporary. Particularly pertinent is the proposal called RUCAG (Residential Utility Consumer Action Group), which would allow direct consumer participation in the setting of policy before a state utility commission or state legislature. Such a group would be local and would have considerable power. In four states, Washington, Oregon, California and Ohio, citizens are already beginning to organize in order to put RUCAG on the ballot by initiative. Some 20 other states are studying the concept. What all this suggests is that grassroots participatory democracy is really nascent and, in sum, that distributed energy production is a natural target. On the other hand it does not necessarily follow that more grassroots participation will lead to either more good sense in making decisions or faster and easier change.

These recent developments are current expressions of a very long trend in Western society. In a broad way, since Roman times, the activation of social energy, development of social dynamism, has been stimulated by increases in the kinds and numbers of people who participate in making social decisions. Development of large, hierarchical organizations in the last century, has worked in a counter direction, but there is no sign that the drive toward increased political participation is waning. The populist drive that was born in the 19th century in the United States is now 20th century renaissance.

The other side of the drive to increased participation is the steady decline of respect for authority (here taken to mean freely conceded authority, not naked use of force). In societies led (or driven) by visions of progress, authority justifies itself by benefits that flow to society from its exercise. In "modern" societies the notion of progress is both fundamental and subversive, for nothing that is it as a must be. Authority must continually rejustify itself—the condition of society must always improve; there can never be "enough" progress. So, from the divine rights of kings to executive privilege of the President there has been a progressive decline in free concession of authority—as natural, legitimate or necessary.

The dilemma is that authority in some measure is essential to the functioning of society. Without authority, freely conceded, societies and governments are faced with alternatives of anarchy or coercion.

7.4.7 Social Shocks, Surprises, Crises

Most of the antecedent discussion considers consequences that flow from trends or assumptions. Certainly over the next fifty years events will occur that are in the nature of shocks or surprises that do not flow from starting assumption but nevertheless will have enormous impact on development of energy systems. It is desirable to consider what impacts some such more or less probable events might have on developments of alternative energy systems. In this interim report we do not analyze the impact of such surprises, but rather list some surprises that seem relatively probable and would strongly impact the energy sytems:

- global shortfalls in production of oil and gas
- war in the Middle East—shutoff of Arab oil in next 10 years
- breakdown of international monetary system and international trade, general depression
- long-continued stag-flation
- continued large unemployment leads to major domestic unrest, turmoil, sabotage, bombings, etc.
- Italy dissolves into economic and political chaos
- major worldwide food deficit
- major ecological disaster
- technological crisis (from Kahn, 197) in 1980's

7.4.8 Politics

With the growth of large organizations, economic and political power has aggregated in successively larger units and become increasingly centralized. That trend, in combination with the extension of participation and of egalitarian sentiment, sets the scene for one of the major themes of political tension in the society—the tension and conflict between centralization of power and extension of participation.

Likewise there is a profound tension, indeed an incompatibility, between the decline in free concession of authority and the centralization of power. In addition, whereas in the past these political conflicts have taken place in an arena that seemed to be unconstrained by the natural environment, now environmental constraints are irreversibly moved to the center of the conflict, as argued by Holdren in Volume 2.

Policies for development of alternative energy systems will be developed and implemented in that larger context. The course of transition will be shaped by events along the way. Two principal alternatives for the transition could be formulated in the following, not necessarily mutually exclusive terms:

1) Declining availability of conventional energy resources could have a sobering impact on public consciousness, creating or at least strengthening a conservation ethic throughout the society and promoting a sense of solidarity, unit and a willingness to sacrifice and work together in the face of a common problem. Ideally this would mean that the social climate for behavioral and technological adaptations to declining resources would become more favorable. This social climate could translate itself into grassroots adaptations, social and technologic, throughout society, into public campaigns for more responsible and frugal energy use and for government measures to alleviate general problems.

   With such a sympathetic response from a substantial majority of the public, the energy "crisis" could perhaps be resolved relatively soon.

2) Given—laudably—the relative openness of the U.S. political system, the great diversity of economic, cultural and political interests subsumed in it, and the great skills in lobbying and advocacy among most of them, solutions are likely to be bitterly contested and clearcut policies hard to achieve. In our present and most likely future communication of energy information, we have many conflicting messages. This makes clearcut awareness of the problem and alternatives for its solution unattainable.

> If real or prospective deprivation produces frustration, anger and upheaval, political leaders might view reduction of consumption as unpalatable and seek ways to maintain basically present patterns of energy use.

Unless there develops a profound change of grassroots consciousness and perception of the problems, the cacophony of competing interests will likely prevail. The outlines of the latter course are already apparent. The prospect that energy consumption in this country might decline has already brought about an intense struggle of diverse interests in Congress and elsewhere for an "appropriate" energy policy.

The basic struggle is over the customary issue of who gets what, how and when. If there is no change in grassroots perception, the characteristics of the conflict can be projected into the future from the present. There will be oil companies seeking better exploration incentives, natural gas suppliers pressing for allegedly indispensable deregulation, coal industry and utilities looking for more favorable state and federal regulations and tax incentives, familiar cries of ripoff, conspiracy and windfall profit from consumer groups, labor unions and political organizations, and increased demands for increased federal role to curb monopolistic exploitation of the poor and weak by the rich and powerful.

The problems implicit in the group struggle about energy may differ from other policy struggles in our system in scope and intensity. Inasmuch as everyone has a stake in energy, more interests are likely to actively involve themselves. The possibility of having much to lose or gain by alternative policies is likely to infuse the group struggle with special intensity.

The foregoing is a scenario for a far-ranging free-for-all in the determination of energy policy. Policies that would emerge would probably not reflect any particular, coherent design but rather the sum of various initiatives, counter-initiatives, accommodations, compromises and even stalemates produced by the clash of contending interests. Such problems might not prove fatal or insuperable to the U.S. polity; the "muddle-through" processes of democratic governance have proved adequate on many past occasions. It is true, however, that a great disparity could indeed develop between the resources of the earth and the capacity of technology on the one hand and what people are able to agree on in light of what they subjectively want and believe on the other. International circumstances would not permit the play to be a purely domestic encounter. The pressures for presidential action to direct the economy in the interest of international order would surely become imperative. No policies can be taken in isolation. What packages of policies would be necessary to effect movement in various directions? What are synergistic effects within packages of policies? How do such policies interact with other social forces? With choice or branching points for policy? What choices lie before us now? What are the consequences of those choices in the near term? If those choices lead to systematic developments on an extensive scale, what are the longer-term consequences?

REFERENCES

Richard Adams, Shardik, Avon Books, New York, 1974.

Congressional Quarterly, April 9, 1977, p. 672.

E.A. Hudson and D.W. Jorgenson, "U.S. Energy Policy and Economic Growth," The Bell Journal of Economics and Management Science, Volume 5, Number 2, Autumn 1974.

National Academy of Sciences, Demand/Conservation Panel Report of the Committee on Nuclear and Alterantive Energy Strategies (CONAES), draft report to be released approximately, November 1977.

Stanford Research Institute (SRI), Solar Energy in America's Future, January 1977.

CHAPTER VIII
DIRECTIONS FOR FUTURE WORK

The individual sections of this report allude in many places to the next phase of activities of the Distributed Technologies in California project. Indeed, a number of the reports included in Volume 2 are explicitly intended as problem definition papers and consist primarily of literature surveys and problem identification. The first two-month period of the project was in fact intended primarily as a period of review, prior to the second phase during which the bulk of the research is to take place. Accordingly, in this chapter we do not present a complete agenda for the next phase of the project but rather highlight the key areas in which we expect to place the bulk of our effort.

8.1 OUTCOME ANALYSIS

The work to date has demonstrated that, subject to an extensive set of assumptions, it is possible to run a complex, highly industrialized post-industrial society entirely on renewable resources internal to the state, and that this can occur in the presence of growth in gross state product. In the next phase we will explore sensitivity of supply/demand matching to changes in a variety of assumptions. Specifically, the next phase is intended to:

- Explore substantial shifts in the composition of the output of the industrial sector
- Explore shifts toward a service-oriented economy, including changes in the manufactured bill of goods, changes in longevity of goods, shifts in recreational patterns, etc.
- Analyze land use pattern changes. The first-phase work disclosed the importance of viewing all solar energy systems in terms of land use/energy tradeoffs. In the second phase such changes will be quantified.
- Analyze imports and exports from California in terms of energy implications. Embodied energy analysis was not included in the first phase of the project. California does not manufacture heavy goods, but concentrates on light manufacturing and sophisticated products. The implication of embodied energy must be explored.
- Review the energy implications of California agriculture. The U.S. as a whole is now paying for its oil imports largely through export of agricultural products. To what degree is this likely to occur in California under various assumptions about future energy use?
- Expand the analysis to include economic factors explicitly. These were omitted by design in the first phase.
- Explore the implications of stabilization of output through averaging in space and time. In the first-phase work the role of averaging was noted as a fundamental distinction between

fossil energy forms and renewable energy. Quantitative analysis is required to go further. This work should lead to analytic results and also to specifications on the type of information which might be collected relating to correlations in space between insolation, wind velocity, etc. Storage analysis will be central to this work.

- Relate results on averaging in space and time to requirements on system reliability and amenity level. To what extent can small sacrifices in amenity level replace investments in averaging? What are the consequences of various types of amenity loss? Can strategies be developed to minimize these consequences in new ways (for example, what would it mean to close down industry periodically—once or twice a year—when renewable resources were inadequate to provide process energy? To what extent can certain industries substitute backlogs of output for energy, in order to keep low-energy use industries operating regularly even in the event of power loss?)
- Technical specification of pathways. This analysis will concentrate upon the replacement process by which distributed technologies gradually substitute for existing technologies. The problems of replacement are particularly interesting when major structural changes are required—as for example in a situation where district heating is introduced in an urban area.
- Transportation options will be explored more extensively than was the case in the CONAES work. The assumptions of the work to date are that there are no major changes in land use practice. Significant land use changes can lead to substantial shifts in energy use. Such changes could significantly reduce the demand for urban transit which leads to the use of electrically-powered vehicles in the preliminary analysis.
- Embodied energy in the goods flowing into and out of California has not been considered to date. The problem of relating California to the rest of the nation will be addressed. The approach taken will be to draw upon the national studies

being carried on at Stanford, Argonne and Brookhaven, and to integrate the California study into this national setting. As a part of this analysis, sensitivity of the California future to energy imports from other states or abroad will be further explored.

- o Study of crisis response options will be initiated. A number of studies suggest that the present oversupply of oil will dramatically change to oil shortfall sometime in the decade of the 1980's or early 1990's. Should this occur, there may be incentives for rapid changeover to renewable energy forms. Such a "discontinuity" may prove an effective means for changing the trajectory of the U.S. energy system from a centralized to a distributed path. The analysis will concentrate upon technical means for rapid implementation of distributed technologies in the presence of an atmosphere of extreme national need. These modes will be contrasted with modes which are more suited to gradual transition.
- o The industrial sector is the primary user of energy in the work to date. In the next phase of the study we propose to make substantive shifts in the industrial sector, emphasizing for example an industrial mix based upon long-lived goods. Kenneth Boulding has emphasized the value of stocks of goods rather than flows in contributing to human satisfaction and well-being. Such a shift in emphasis is likely to prove cogenial to a distributed technology future and may ease some of the stressed found in the present work.

8.2 ANALYSIS OF ENVIRONMENTAL AND SOCIAL ISSUES

- Assess environmental imapcts of "soft" technologies
- Analyze regional land use patterns using distributed energy technologies
- Develop materials, formats and procedures for preparing plans for implementation of distributed technologies at local and regional levels
- Analyze impacts of development of distributed energy technologies on land values, socio-economic groups and institutions for making land use decisions
- Further analyze institutions that play roles in energy
- Study behavior and attitudes of people and organizations who play key roles in implementing distributed technologies
- Consider the various possible roles of education in affecting perceptions of energy problems and behavior
- Assess current public attitudes and trends relevant to development of energy policies
- Analyze factors that influence demand for energy and the structure of the economy
- Develop measures of evaluationg tradeoffs among social, environmental and economic impacts of alternative energy systems

8.3 PROJECT COORDINATION

As a concomittant to the various specific research projects which will address the issues identified above, there will be a major process-oriented activity designed to assure the effectivess of interactions of interations among persons in various disciplines. This would take the form of a seminar which will meet regularly and for discussion of key issues. The proposed structure of this seminar is to include in each presentation a physical scientist and a social scientist. Presentations will be made on the specified topic to be followed by discussion from the various points of view represented in the project. This seminar is viewed as a primary vehicle for assuring the cohesion of the project personnel.

In addition, it is our hope that public comments on this Interim Report may help guide our future inquiry. To that end, we intend to hold a public meeting in Fall 1977. A similar public meeting will probably occur in Spring 1978.

APPENDIX 1

RESIDENTIAL HEATING LOADS—1975

To estimate residential space heating requirements in 2025, we have used the CONAES (National Academy of Sciences, 1977) new device efficiencies for scenarios A and B for electrically-heated houses, and an average heating requirement of 9 Btu/ft^2-degree day for housing constructed in 1975 to meet the present building code requirements. This figure is derived from estimates used by the California Energy Commission for heating requirements of electrically-heated houses in 1975, and from computer simulations of housing built to state code in the major climatic zones in the state (LBL, 1976). (Heating requirements differ markedly with climate throughout the state, and much of the existing housing stock is poorly insulated or uninsulated; actual heating requirements of the present housing stock are in excess of these values.)

To estimate heating requirements in 2025, we used the statewide population distribution of the Department of Finances D-100 forecast (1974), assumed that each person required, on the average, about 400 square feet of living space, allocated the county-by-county populations to one of 15 climate zones, and used the CONAES new device efficiencies (5.4 Btu/ft^2-dd for scenario A and 6.75 Btu/ft^2-dd for scenario B) to calculate total heating requirements. (Population distribution within each climate zone is summarized in Table A1-1, and the climate zones are depicted in Figure A1-1.)

Table A1-1

Population by California Weather Zones

Zone/County	Cooling Zone	2025 Population
1 Eureka (454kBtu/ft^2/yr, 4679 dd/yr)		
Del Norte	Cool	15,400
Humboldt	Cool	103,600
Total		119,000
2 Santa Rosa (576kBtu/ft^2/yr, 3065 dd/yr)		
Lake	Cool	24,400
Mendocino	Cool	57,800
Napa	Cool	90,800
Sonoma	Cool	250,200
Total		423,200
3 San Francisco (539kBtu/ft^2/yr, 2909 dd/yr)		
Alameda	Cool	1,103,600
Contra Costa	Cool	602,100
Marin	Cool	217,800
San Francisco	Cool	671,700
San Mateo	Cool	572,000
Santa Cruz	Cool	152,800
Total		3,320,000
4 San Jose (579kBtu/ft^2/yr, 2969 dd/yr)		
Monterey	Cool	271,600
San Benito	Hot	19,600
Santa Clara	Cool	1,213,000
Total		1,504,200
5 Santa Maria (585kBtu/ft^2/yr, 3053 dd/yr)		
San Luis Obispo	Cool	126,400
Santa Barbara	Cool	283,300
Ventura	Cool	446,200
Total		855,900
6 South Coast (559kBtu/ft^2/yr, 1918 dd/yr)		
Los Angeles(50%)*	Temperate	3,462,250
7 San Diego (633kBtu/ft^2/yr, 1507 dd/yr)		
San Diego	Cool	1,573,100
8 Anaheim (549kBtu/ft^2/yr, 1867 dd/yr)		
Orange	Temperate	1,712,000

*

Table A1-1 (continued)

Zone/County	Cooling Zone	2025 Population
9 San Fernando (549kBtu/ft^2/yr, 1245 dd/yr)		
Los Angeles (50%)		3,462,250
10 Riverside (590kBtu/ft^2/yr, 1919 dd/yr)		
Riverside	Very Hot	527,100
11 Red Bluff (581kBtu/ft^2/yr, 2688 dd/yr)		
Butte	Hot	115,900
Colusa	Hot	12,400
Glenn	Hot	18,200
Lassen	Cool	18,800
Modoc	Cool	7,900
Plumas	Cool	32,800
Shasta	Cool	88,200
Siskiyou	Cool	35,700
Sutter	Hot	45,700
Tehama	Hot	32,300
Trinity	Cool	9,200
Yuba	Hot	45,000
Total		462,100
12 Sacramento (581kBtu/ft^2/yr, 2843 dd/yr)		
Alpine	Cool	600
Amador	Cool	15,500
Calaveras	Cool	16,300
El Dorado	Cool	53,900
Nevada	Cool	32,500
Placer	Cool	92,500
Sacramento	Hot	695,900
San Joaquin	Cool	308,600
Sierra	Cool	2,600
Solano	Hot	183,600
Stanislaus	Hot	214,800
Tuolomne	Cool	24,400
Yolo	Cool	104,900
Total		1,746,100
13 San Joaquin (592kBtu/ft^2/yr, 2650 dd/yr)		
Fresno	Hot	447,200
Kern	Very Hot	347,100
Kings	Very Hot	67,300
Madera	Hot	45,400
Mariposa	Cool	7,900
Merced	Hot	115,500
Mouo	Cool	7,600
Tulare	Hot	206,900
Total		1,244,900

Table A1-1 (continued)

Zone/County	Cooling Zone	2025 Population
14 Mojave (662kBtu/ft^2/yr, 2380 dd/yr)		
Inyo	Cool	17,700
San Bernardino	Very Hot	711,000
Total		728,700
15 Imperial Valley (685kBtu/ft^2/yr, 1216 dd/yr)		
Imperial	Cool	80,200

Source: LBL (1977)

REFERENCES

California Department of Finance, Population Projections for California Counties—1975-2020 (D-100 Series), Report No. 74 P-2, June 1974.

National Academy of Sciences, Demand/Conservation Panel Report of the Committee on Nuclear and Alternative Energy Strategies (CONAES), draft report to be released approximately November, 1977.

Lawrence Berkeley Laboratory, Electrical Energy Consumption in California: Data Collection and Analysis, UCID 3847, July 1976.

Lawrence Berkeley Laboratory, California Solar Data Manual, Draft, July 1977.

APPENDIX 2

RESIDENTIAL AIR CONDITIONING

To estimate residential air conditioning requirements in 2025, we use appliance efficiency standards mandated by the California Energy Commission, rather than CONAES new device efficiencies. The former, now law in California, effect greater savings than are estimated by CONAES, and these savings have been incorporated into the detailed forecast of residential energy requirements prepared for the Commission's Biennial Report (ERCDC, 1977).

The ERCDC forecast uses four cooling zones for the State, assumes a population in 1995 of about 28.5 million people, as projected by the Department of Finance's D-100 (1977) population forecast for that year, and a housing stock of about 10 million units. Although air conditioner efficiencies improve, the saturation of air conditioners is also assumed to increase, continuing present trends in new construction. Average unit energy consumption (UEC) for air conditioners in the present stock (1975) and as mandated by the new standards is as follows:

Air Conditioner UEC's (kWh/yr)

	Single-Family		Multi-Family	
	1975	1995	1975	1995
(VH) Very Hot	4100	1980	2050	790
(H) Hot	3300	1460	1650	880
(T) Temperate	800	396	400	160
(C) Cool	530	250	265	150

(ERCDC, 1977)

Cooling zones are identified in Table A1-1.

Total air conditioning requirements estimated in the forecast are:

Central air conditioners (single-family)	2,963,925,760
Central air conditioners (multi-family)	562,965,248
Room air conditioners	1,443,785,220
Total (kWh/yr)	4,970,876,228

(ERCDC, 1977)

To extrapolate to 2025, we assume the 2025 building stock has increased to 16 million units, accommodating a population of 38.5 million persons. Settlement patterns closely follow those in 1995; hence we assume air conditioning requirements are roughly 66 percent greater than those projected for 1995, or about 8×10^9 kWh/yr (about 27×10^{12} Btu/yr).

REFERENCES

California Department of Finance, Population Projections for California Counties—1975-2020 (D-100 Series), Report No. 74 P-2, June 1974.

Energy Resources Conservation and Development Commission, Biennial Report: Toward a California Energy Strategy, Appendix G, 1977.

APPENDIX 3
ALLOCATION OF GROSS STATE PRODUCT

A3.1 INTRODUCTION

We have used the CONAES "2%" (CONAES, 1977) assumption throughout this study. The simplest way to adapt the CONAES assumption to this study is to extend the linear growth in GNP forward from 2010 (the end-point of the CONAES study) to the year 2025 and then allocate to California a fraction of that GNP equal to the fraction of the U.S. population estimated to reside in California by our population assumptions presented above. This leads to an estimate of California GSP to $460 billion in 2025 (expressed in 1975 dollars; see Table VI-1).

The simple technique above does not provide any information on the composition of the GSP or the labor productivity rates that would be associated with this level of GSP. However we can use the following methodology to develop one possible detailed picture of the GSP in 2025 that is consistent with the CONAES assumptions. The results are displayed in Table A3-1 as discussed below.

An important point to draw from Table A3-1 is that the CONAES assumptions (and thus the assumptions used in this study) correspond to a slower rate of increase of worker productivity than that assumed in other projections. For example, worker productivity is assumed by the Bureau of Labor Statistics (U.S. Department of Labor, 1975) to grow at an exponential rate of 2.7 percent in the private non-farm sector and 5.5 percent in the farm sector. The Department of Commerce (1977) has projected a 3 percent exponential growth rate for the private sector. We project this downturn in worker productivity in response to two factors. One, previous increases in worker productivity are partly the result of shifts from agriculture into manufacturing. The movement of labor from agriculture to other sectors is complete and may be reversed in the next fifty years in response to higher fertilizer prices. Second, the movement to a service-based economy will continue with labor accounting for a much larger share of GSP in 2025 than in 1975. These two factors are hypothesized to cause worker produc-

Table A3-1

GSP Projection to 2025
(constant 1975 dollars)

	1975	2025
D-100 Population[a]	21.2×10^6	38.6×10^6
Working Age Population[b]	13.2×10^6	22.0×10^6
Labor Force[c]	9.4×10^6	15.6×10^6
Employed Labor Force[d]	8.5×10^6	15.0×10^6
Private Sector	6.9×10^6	11.1×10^6
Public Sector[e]	1.6×10^6	3.9×10^6
Hours Worked per Man-Year[f]	1947	1664
Gross State Product[g]	$\$166.0 \times 10^9$	$\$462.0 \times 10^9$
Private Sector	$\$141.1 \times 10^9$	$\$365.0 \times 10^9$
Public Sector[h]	$\$\ 24.9 \times 10^9$	$\$\ 97.0 \times 10^9$
Output per Man-Hour[i] (GNP per man-hour)	\$10.03	\$18.51
Private Sector	10.50	19.76
Public Sector	7.99	14.87

[a]Population estimates in 2025 are derived from California Department of Finance (1974) D-100 projections for 2020 extrapolated to 2025.

[b]Working age population in 2025 were obtained from age-specific population estimates of D-100 projections extrapolated to 2025.

[c]Labor force participation rate assumes to be 71 percent in 2025, equal to that in California in 1975. The 1975 Labor Force Participation Rate was obtained from California Department of Finance (1976).

[d]1975 rate of unemployment in California was 9.9 percent (California Department of Finance, 1976). 2025 rate of unemployment is assumed to be 4 percent (full employment assumed).

[e]Public sector employment in California is assumed to increase from 19 percent of total employment in 1975 to 26 percent of total employment in 2025. This assumption is consistent with OBERS (U.S. Department of Commerce, 1972) projections of employment on a national level. OBERS assumes that the government's share of total employment will increase from 15 percent in 1968 to 21 percent in 2020 (or a .65% exponential rate of growth per year of government's share of total employment). The California projection uses the 65 percent growth starting from the 19 percent share in 1975.

Table A3-1 Footnotes (continued)

[f]1975 hours worked per man-year are taken from Williams and Kimbel (1976). They also assume 2025 average work week declines from 37.4 hours per week in 1975 to 32 hours per week in 2025.

[g]Output per man-hour (GSP per worker-hour) in the private sector grows exponentially from 1975 to 2025 at a 1.27 percent growth rate as a consequence of our assumptions. We assume compensation per employee in the public sector grows in line with increases in private sector worker productivity.

Note: Worker productivity is assumed to grow at a much slower annual rate than projected by Kimbell-Williams (1976), 2.47 percent; the U.S. Department of Labor (1975), 2.7 percent private non-farm sector and 5.5 percent farm sector; and OBERS (1972), 3 percent.

tivity to increase at a much slower rate over the next fifty years than past experience would dictate.

A3.1.1 Allocation of GSP by Sector

In Table A3-2 we have allocated GSP by sector according to a simple methodology developed by Kendrick (Kendrick and Jaycox, 1965). Details are provided in Section A3.2.

This GSP allocation assumes that the present trend toward a service-based economy, with the government and service sectors growing in relative size at the expense of other sectors. The size of the agricultural sector was estimated separately based on estimated food requirements in the year 2025 for projected population (U.S. Department of Commerce, 1972).

Our allocation does not consider shifts in most sectors due to resource scarcities or higher energy prices. For instance, the mining sector can be expected to decrease in size considerably over this period as oil and gas resources are depleted. This decline can be expected to cause shifts in other industrial sectors such as petroleum refining and chemicals. Because of the complexity of this issue, we have excluded this important topic from consideration in this preliminary report.

During the coming year, other methods of assessing changes on GSP composition will be studied. For this report, we have used Kendrick's method to provide a rough internal consistency between the sectoral energy demands (industrial and commercial) and the total GSP.

Table A3-2

Composition of GSP in California for 1975 and 2025[a]

Category	1975		2025	
	Value Added (billion $)	Percent of Total GSP[b]	Value Added (billion $)	Percent of Total GSP
Agriculture Forestry, Fisheries	6.64	4.0	8.88	1.9
Mining	1.33	0.8	1.39	0.2
Construction	7.33	4.4	18.90	4.1
Manufacturing	33.53	20.2	85.93	18.6
Transportation, Communication, Utilities	14.77	8.9	31.42	6.8
Wholesale and Retail Trade	29.22	17.6	80.85	17.5
Finance Insurance, Real Estate	25.40	15.3	60.98	13.2
Services	21.91	13.2	77.15	16.7
Government	26.06	15.6	97.00	21.0
TOTAL GSP	166.00	100.0	462.00	100.0

[a]See Section A3.2 for computations and sources.

[b]GSP by sector in 1975 is assumed to be in same proportions as in 1972.

A3.2 A METHODOLOGY FOR ALLOCATING PRIVATE GSP BY SECTOR

A first step in our allocation of private GSP was to determine the size of the public and private sectors. We obtained this breakdown from Table A3-1 in the GSP section. Next, we allocated private GSP by sector according to a simple allocation methodology (Kendrick and Jaycox, 1965) in conjunction with OBERS projections of earnings in California to 2020 (U.S. Department of Commerce, 1972).

A3.2.1 The Allocation Methodology

Kendrick and Jaycox (1965) develop a simple method for estimating GSP by sector from national income accounts data. Basically, the approach utilizes the accounting identity that GNP equals national income plus capital consumption allowances plus indirect business taxes. From national income accounts data, we computed ratios of national income to earnings, capital consumption allowances to national income, and indirect business taxes to national income for each sector. These ratios were assumed to be the same for California as for the nation. Then, using earnings data for California by sector, we estimated California GSP by sector in 1972 (see worksheets A through D). Comparing the GSP estimate from this approach with estimates provided by Security Pacific Bank, we found a close comparability between the two estimates of total GSP and sectoral GSP except for agriculture (see worksheet D). From these estimates, we obtained a ratio of GSP to earnings by sector in 1972 which we assumed would remain constant over the period of 1972 to 2025.

A.3.2.2 Earnings in 2025

To estimate GSP in California for 2025, we first estimated earnings by sector. We projected earnings to 2025 by extrapolating OBERS earning projections for 2020 in California. In projecting earnings to 2020, OBERS assumed a growth in GSP of 4 percent (compared to our linear "2%" growth assumption) and a population growth 30 percent higher than our estimate. Thus, applying the 1972 GSP to earnings ratio to OBERS projected earnings provides an estimate of GSP over $900 billion (compared to our $462 billion estimate). (See worksheet E.)

Estimates of State Income, 1972

Worksheet A

	National Totals ($ billions)			State Totals ($ billions)	
	Earnings (a)	Contribution to National Income (b)	Ratio (b/a) (c)	Earnings (d)	State Income Originating (d x c) (e)
Agriculture, Forestry, Fisheries	24.6	27.3	1.11	2.2	3.89
Mining	7.3	12.6	1.73	.4	.69
Contract Construction	47.0	52.3	1.11	4.6	5.11
Manufacturing	198.6	244.2	1.23	17.6	21.65
Transportation, Communication, Public Utilities	54.2	73.2	1.35	5.9	7.97
Trade	122.6	148.4	1.21	13.6	16.46
Finance, Insurance, Real Estate	40.7	110.9	2.72	4.7	12.78
Services	115.8	122.4	1.06	14.3	15.16
Government	133.3	154.8	1.16	17.1	19.86

[1] U.S. Department of Commerce, 1976.

[2] U.S. Department of Commerce, 1977.

California 1972 Capital Consumption Allowance
Worksheet B

	National Totals ($ billions)		State Totals ($ billions)
	Capital Consumption Allowance[1]	Ratio to National Income (f/b)	Capital Consumption Allowance (g x e)
	(f)	(g)	(h)
Agriculture, Forestry, Fisheries	5.9	.216	.84
Mining	4.7	.373	.26
Contract Construction	3.0	.057	.29
Manufacturing	24.8	.102	2.21
Transportation, Communication, Public Utilities	18.0	.246	1.96
Trade	11.2	.076	1.25
Finance, Insurance, Real Estate	24.9	.225	2.88
Services	8.0	.065	.99
Government	--	--	--

[1] U.S. Department of Commerce, 1977.

California 1972 Indirect Business Tax

Worksheet C

	National Total ($ billions)		State Totals ($ billions)
	Indirect Business[1] Tax	Ratio to National Income (i/b)	Indirect Business Tax (j x e)
	(i)	(j)	(k)
Agriculture, Forestry, Fisheries	2.2	.081	.32
Mining	1.6	.127	.09
Contract Construction	1.3	.025	.13
Manufacturing	19.8	.081	1.75
Transportation, Communication, Public Utilities	12.4	.169	1.35
Trade	41.6	.280	4.61
Finance, Insurance, Real Estate	32.8	.296	3.78
Services	4.1	.034	.52
Government	.1	--	--

[1]U.S. Department of Commerce, 1977.

Comparison of GSP Estimates (1972)

Worksheet D

	GSP from Worksheets[1] (1972 $ billions) (l)	Percent of Total (m)	GSP Estimate from I/O Table[2] (1972 $ billions) (n)	Percent of Total (o)	Percent Difference $(\frac{l-n}{l})$ (p)
Agriculture, Forestry, Fisheries	5.05	4.0	3.78	3.0	25.0
Mining	1.04	.8	1.14	.9	-10.0
Contract Construction	5.53	4.4	5.18	4.1	6.0
Manufacturing	25.61	20.2	29.20	23.0	-14.0
Transportation, Communication, Public Utilities	11.28	8.9	10.79	8.5	4.0
Trade	22.32	17.6	21.64	17.0	3.0
Finance, Insurance, Real Estate	19.44	15.3	19.49	15.3	-.2
Services	16.67	13.2	16.25	12.8	3.0
Government	19.86	15.7	19.71	15.5	1.0
TOTAL	126.80		127.18		

[1] GSP = Net State Income (e) + Capital Consumption Allowance (h) + Indirect Business Tax (k)

[2] Based on data from Security Pacific Bank supplied to Lawrence Berkeley Laboratory, 1976

Projected Earnings and GSP Estimates in 2025
Worksheet E

	Projected Earnings (2025)[1] (q)	Ratio of GSP to Earnings (d/1) (r)	GSP by Sector 2025 ($ billions)			
			OBERS (q) x (v)	Percent of Total	LBL Projection	Percent of Total
Agriculture, Forestry, Fisheries	5.08	2.3	11.68	1.1	8.88	1.9
Mining	1.02	2.6	2.65	.3	1.39	.3
Contract Construction	37.11	1.2	44.53	4.2	19.40	4.1
Manufacturing	132.93	1.5	199.40	18.8	86.86	18.6
Transportation, Communication, Public Utilities	38.49	1.9	73.13	6.9	31.88	6.8
Trade	117.39	1.6	187.82	17.7	81.77	17.5
Finance, Insurance, Real Estate	34.26	4.1	140.47	13.3	61.45	13.2
Services	149.21	1.2	179.05	16.9	78.08	16.7
Government	157.81	1.4	220.94	20.2	96.03	21.0
TOTAL	673.30	1.57	1059.67	100.0	462.00	100.0

[1] U.S. Department of Commerce, 1972.

From this projection of GSP, we obtained approximate weights from which allocations were derived for GSP by sector for all sectors except government and agriculture. In the case of agriculture, OBERS projected its share based upon the food requirements of the projected population. To make their projection of the agricultural sector realistic, OBERS assessed the impact of population growth on the availability of cropland. The availability of cropland was adjusted to take into account removals due to population pressures on existing cropland and additions due to extended land reclamation and irrigation projects. Yields per acre were projected to increase over time according to historical trends in crop yields. From this detailed analysis, OBERS determined the size of the agricultural sector expressed as earnings.

We have taken the estimate of agricultural GSP derived from these OBERS projections (in worksheet E) and scaled the estimate down by a factor of 1.3 to account for the lower estimate of total population in our study (38.6 million people versus 50.5 million people).

At this point in worksheet E we have determined the GSP shares of the public sector and the agricultural sector. The remaining sectoral shares in the private sector were determined from the approximate GSP weights provided in worksheet E from OBERS which we renormalized to account for the different relative sizes of the agricultural and public sectors in our study. We allocated total GSP to these sectors by these renormalized sectoral shares (see worksheet E).

Three major assumptions were made in allocating GSP according to this method. First, we assumed that the ratio of GNP to earnings by sector is equivalent to California's ratio of GNP to earnings by sector. Second, we assumed that the ratio remains constant over the next fifty years. Finally, we assumed that the sectoral ratios of GSP to earnings were relatively stable from year to year; that is, 1972 ratios are as representative of the GSP to earnings ratio as 1969.

The first and second assumptions appear plausible. Given our nation's interdependent integrated economy, we expect that the shares accruing to labor in each sector are roughly equal. It also appears reasonable to assume that the share accruing to labor in each sector will remain constant into the future. However, the third assumption remains speculative at this point. Further analysis will enable us to determine long-term sectoral ratios of GSP to earnings for each sector.

REFERENCES

California Department of Finance, Population Projections for California Counties—1975-2020 (D-100 Series), Report No. 74 P-2, June 1974.

California Department of Finance, California Statistical Abstract, 1976, 1977.

John W. Kendrick and C. Milton Jaycox, "The Concept and Estimation of Gross State Product," Southern Economic Journal, Volume 32, pp. 153-168, October 1965.

National Academy of Sciences, Demand/Conservation Panel Report of the Committee on Nuclear and Alternative Energy Strategies (CONAES), draft report to be released approximately November, 1977.

U.S. Department of Commerce, Bureau of Economic Analysis, Local Area Personal Income, June 1976.

U.S. Department of Commerce, Bureau of Economic Analysis, The National Income and Product Accounts of the U.S., 1929-74, Table 6.1, p. 178, 1977.

U.S. Department of Commerce, Social and Economic Statistics Administration and the U.S. Department of Agriculture, 1972 OBERS Projections, Volume V, prepared for U.S. Water Resources Council, September 1972.

U.S. Department of Labor, Bureau of Labor Statistics, The Structure of the U.S. Economy in 1980 and 1985, Bulletin 1831, 1975.

U.S. Government Printing Office, Statistical Abstract of the United States, 1976.

University of California, Los Angeles, Business Forecasting Project, June 1976.

Williams and Kimbell, 1976.

APPENDIX 4
COGENERATION

The thermodynamic potential for cogeneration in various industries has been estimated by Thermo Electron (1976a). This potential varies as a function of the temperature profile of the industry's process requirement and the power generation technology considered. For our purposes we will consider the gas turbine technology throughout our discussion. Gas turbines produce more electricity per unit of heat requirement than steam turbines, but less than diesels. The diesel technology however, is not well adapted to large industrial facilities because the units do not come in very large sizes. For some applications either steam turbines or diesels may be more appropriate than gas turbines, but relying on the latter for numerical estimates allows us to average out these variations.

Table A4-1 presents the electricity to process heat ratios that have been derived for three major industries. In all cases excess electricity can be produced over and above the requirements for process. This will be available for use by other electricity consumers.

Table A4-1
Cogeneration Potential by Industry

Chemicals[2]	197 kwh/10^6 Btu	produceable
	69 kwh/10^6 Btu	required for process
	128 kwh/10^6 Btu	available for export
Paper and Pulp[2]	183 kwh/10^6 Btu	produceable
	56 kwh/10^6 Btu	required for process
	127 kwh/10^6 Btu	available for export
Iron and Steel[1]	220 kwh/10^6 Btu	produceable
	106 kwh/10^6 Btu	required for process
	114 kwh/10^6 Btu	available for export

[1]For integrated mills only (Thermo Electron, 1976b)
[2]Thermo Electron (1976a)

The ratios in Table A4-2 were applied to estimates of future industrial heat requirements (Tables VI-5 and VI-6) to derive total production and export potentials. Using an 80 percent capacity factor, it is straight forward to convert the electric energy potentials into power capacity potentials.

In the centralized supply cases, all cogeneration is assumed implemented. In the distributed cases only the paper industry is assumed to cogenerate because of the lack of liquid fuels. In the paper industry, 56 percent of the energy used now comes from waste products. This is assumed to be available in the future.

Table A4-2

Cogeneration: Gas Turbine Technology

	Scenario A	Scenario B
Chemical Industry[1]		
Electricity-Generated	84.5×10^{9} kWh	96.8×10^{9} kWh
Available for Export	54.9×10^{9} kWh	59.0×10^{9} kWh
Incremental Fuel for Power (5500 Btu/kWh)	464×10^{12} Btu	499×10^{12} Btu
Fuel for Steam-Associated	429×10^{12} But	461×10^{12} Btu
Paper and Pulp Industry[1]		
Electricity-Generated	42.8×10^{9} kWh	51.4×10^{9} kWh
Available for Export	30.0×10^{9} kWh	36.0×10^{9} kWh
Incremental Fuel for Power	235×10^{13} Btu	283×10^{12} Btu
Fuel for Steam-Associated	234×10^{12} Btu	281×10^{12} Btu
Iron and Steel Industry[2]		
Electricity-Generated	29.2×10^{9} kWh	31.0×10^{9} kWh
Available for Export	15.1×10^{9} kWh	16.0×10^{9} kWh
Incremental Fuel	161×10^{12} Btu	171×10^{12} Btu
Fuel for Steam-Associated	133×10^{12} Btu	141×10^{12} Btu
Totals		
Electricity-Generated	156.6×10^{9} kWh	173.2×10^{9} kWh
Available for Export	101.0×10^{9} kWh	111.3×10^{9} kWh
Incremental Fuel for Power	860×10^{12} Btu	953×10^{12} Btu
Fuel for Steam-Associated	824×10^{12} Btu	883×10^{12} Btu

[1] Thermo Electron (1976a)

[2] Thermo Electron (1976b)

REFERENCES

Thermo-Electron Corporation, A Study of Inplant Electric Power Generation in the Chemical, Petroleum Refining, and Paper and Pulp Industries, FEA Contract CO-04-50224-00, June 1976a.

Thermo-Electron Corporation, Recommendations for Future Government Sponsored Energy Conservation Research and Development in the Paper and Steel Industries, ERDA Contract E (11-1)-2831, August 1976b.

APPENDIX 5

PROJECTION OF TOTAL POPULATION OF CALIFORNIA COUNTIES
D-100 PROJECTION

County	Population 1975	Population 2025	Ratio of 2025 to 1975
Alameda	1,103,600	1,692,000	1.53
Alpine	600	2,800	4.67
Amador	15,500	34,700	2.24
Butte	115,900	267,000	2.30
Claveras	16,300	36,300	2.23
Colusa	12,400	18,900	1.52
Contra Costa	602,100	1,245,000	2.06
Del Norte	15,400	30,900	2.01
El Dorado	53,900	146,000	2.70
Fresno	447,200	830,000	1.86
Glenn	18,200	26,800	1.47
Humboldt	103,600	178,000	1.72
Imperial	80,200	154,000	1.92
Inyo	17,700	37,400	2.11
Kern	347,100	542,000	1.56
Kings	67,300	119,000	1.77
Lake	24,400	51,600	2.11
Lassen	18,800	28,700	1.53
Los Angeles	6,924,500	9,654,000	1.39
Madera	45,400	88,400	1.95
Marin	217,800	362,000	1.66
Mariposa	7,900	18,700	2.37
Mendocino	57,800	116,000	2.01
Merced	115,500	232,000	2.01
Modoc	7,900	11,100	1.41
Mono	7,600	23,900	3.14
Monterey	271,600	602,000	2.22
Napa	90,800	217,000	2.39
Nevada	32,500	70,300	2.16

PROJECTION OF TOTAL POPULATION OF CALIFORNIA COUNTIES
(continued)

County	Population 1975	Population 2025	Ratio of 2025 to 1975
Orange	1,712,000	3,666,000	2.14
Placer	93,500	204,000	2.18
Plumas	13,800	26,500	1.92
Riverside	527,100	1,263,000	2.40
Sacramento	695,900	1,341,000	1.93
San Benito	19,600	40,300	2.06
San Bernardino	711,000	1,546,000	2.17
San Diego	1,573,100	3,935,000	2.50
San Francisco	671,700	702,000	1.04
San Joaquin	308,600	554,000	1.80
San Luis Obispo	126,400	304,000	2.41
San Mateo	572,000	720,000	1.26
Santa Barbara	283,300	564,000	1.99
Santa Clara	1,213,000	2,254,000	1.86
Santa Cruz	152,800	415,000	2.72
Shasta	88,200	164,000	1.86
Sierra	2,600	4,900	1.88
Siskiyou	35,700	56,500	1.58
Solano	183,600	615,000	3.35
Sonoma	250,200	712,000	2.85
Stanislaus	214,800	418,000	1.95
Sutter	45,700	90,700	1.98
Tehema	32,300	48,700	1.51
Trinity	9,200	15,800	1.72
Tulare	206,900	436,000	2.11
Toulumne	27,400	54,000	1.97
Ventura	446,200	1,276,000	2.86
Yolo	104,900	240,000	2.29
Yuba	45,000	82,800	1.84
THE STATE	21,206,000	35,581,000	1.82

APPENDIX 6

THE CALIFORNIA WIND ENERGY RESOURCE

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ABSTRACT

The size of the wind energy resource for California is estimated by several methods and found to be large relative to the current state electrical consumption. Centralized and dispersed systems for utilizing large amounts of wind energy are compared.

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